REPORT ON THE "ALISO CANYON FAULT"
AND THE ALLEGED "MOUNTAIN TOP FAULT ZONE"
CAMP PENDLETON, CALIFORNIA

November 25, 1981

SOUTHERN CALIFORNIA EDISON COMPANY AND
SAN DIEGO GAS AND ELECTRIC COMPANY

During the Atomic Safety Licensing Board hearings for San Onofre Nuclear Generating Station Units 2&3, Mr. D. W. Phifer, a retired Marine Corp Colonel, identified what he believed to be six previously undisclosed geologic structures that he alleged were new and could influence the seismic safety of the plant. The Applicants examined his features with Mr. Phifer and then in the field independently and later again with Mr. Phifer and the NRC staff. Documentation in "Report on Limited Appearance of Mr. D. W. Phifer and Alleged Geologic Features" dated July 29, 1981, was then prepared by the Applicants and it discussed in detail each of his alleged new geologic discoveries.

The features discussed and the conclusions reached are:

- "Horno Summit Fault" pp. 4-15
  - Mr. Phifer's suggestion of as much as 20 miles of right lateral displacement is speculative and is contrary to the fact that bedrock formations and contacts are continuous across the hypothesized trend of the fault. It is Applicants opinion that the fault does not exist.
- "Horno Canyon Fault" pp. 16, 17
  - Marine Terraces at elevation 325 project across the fault at Horno Canyon without offset. This surface is 300,000 years old and any fault would be that age or older and not be capable.
- "San Onofre Mountain Fault" pp. 17, 18
  - The inferred "San Onofre Mountain Fault" is not a tectonic feature; but rather a collection of geomorphic and sedimentary feature mis-identified as a fault.
- "Piedre de Lumbre/Las Pulgas Canyon Fault" pp. 15, 16
  - Sediments deposited between these two canyons were layed down as fluvial sediments on a Pleistocene floodplain that is lower in elevation than the adjacent marine terraces. The lower elevation of the fluvial sediments represents a depositional sequence, not faulting.

o "Mateo Canyon Fault" pp. 19-21

- Paired fluvial terrace surfaces can be matched across San Mateo Canyon and the age of these terraces are judged to be 100,000 years old. Thus any faulting, if present, would be at least that old.

o "San Onofre Canyon Fault"

- Vertical offset of 20 feet is unsubstantiated. Stream cutting across resistant San Onofre breccia and eroding soft strata of the Monterey Formation is a normal erosional process and doesn't require faulting to achieve an offset.

The report concludes that these "are not capable faults" and have no significance relative to the seismic design of the San Onofre Units. Further, Mr. T. Cardone, of the NRC Staff in the response to reviewing the field evidence and the Applicants report on the alleged features states that "...I don't see anything in Mr. Phifer's postulated faults or presentation that poses a hazard to the site..." and that he agrees with the evidence and interpretation by the Applicants (Cardone, Tr. 6024:6-18).

On August 17, 1981, Mr. Phifer forwarded to Edison a draft of a letter and supporting maps and photographs he proposed sending to the Nuclear Regulatory Commission. This information was essentially the same as that submitted to the Commission on October 8, 1981. Contrary to the comment by Mr. Phifer on pg. 3, Mr. McNey and Dr. Ehlig were not in agreement with his conclusions regarding the July 17, 1981 field trip. In addition to the features discussed in the limited appearance report described above, Mr. Phifer identified:

o Cristianitos Fault

o Offshore Zone of Deformation

- o Rose Canyon/Newport Inglewood (Fault Zones) which have been analyzed by the Applicants in detail as apart of the licensing proceedings. The Cristianitos fault is not capable, the offshore Zone of Deformation is 5 miles west of the site and the Rose Canyon/Newport Inglewood (Fault Zones) are the south and north ends of the offshore Zone of Deformation. Mr. Phifer agreed on page 5 of his October letter they have been studied.

New concerns raised in the letter of October 8, 1981 were:

- o "Mountain Top Fault Zone"

- o "Aliso Canyon Fault"

These latter two features are discussed in subsequent paragraphs of this report.

A field trip was then hosted by Mr. Phifer on September 19, 1981 and several members of the geologic community as well as consulting firms were invited.

Attendees were:

Mr. Larry Carlson, USMC Natural Resources Office
Mr. M. W. Hart, Geocon Consulting Engineers and Geologists
Mr. G. T. Farrand, Geocon Consulting Engineers and Geologists
Mr. A. E. Farcas, Geocon Consulting Engineers and Geologists

Mr. D. W. Phifer, Coastal and Nearshore Consultant

Mr. J. L. McNey, Southern California Edison

Dr. P. L. Ehlig, Consultant

The trip included revisiting those locations identified in the limited appearance report. They were:

- o Vandergrift Boulevard landslide
- o Piedre de Lumbre/Las Pulgas Canyon fluvial sediments
- o Las Pulgas Ammo Dump area of the Horno Summit Fault
- o Horno Summit Ridge
- o Rifle Range 214 Fault

and

- o Fault F location
- o San Onofre Mountain
- o Horno Canyon landslide at the beach.

The latter three stops were to observe features of the alleged "Mountain Top Fault Zone." While visiting the stops along the "Mountain Top Fault Zone", origin of the tuff bed, minor faulting and conditions leading to the development of the landslide at the mouth of Horno Canyon were described in detail by the Applicants. Dr. Ehlig and Mr. McNey believe that the interpretation of the geology is in error and without technical merit. The Aliso Canyon Fault was not visited.

"Mountain Top Fault Zone"

As described by Mr. Phifer on page 3 of his October 8, 1981, letter to the NRC, the "Mountain Top Fault Zone" (MTFZ) which trends NE-SW, is longer than 3 miles, has a vertical displacement of greater than 600 feet with the east side up, and a width of about 1 1/2 miles. The map signed by David Phifer and dated August 14, 1981 accompanying the subject letter shows the MTFZ bounded by two nearly north-south trending faults. All of the eastern fault and most of the western fault are portrayed on the map by dashed lines which indicates the faults are inferred according to the map legend. Between the bounding faults, the map shows seven short faults with trends ranging from about north 30 degrees west to north 15 degrees east. In pages 4-5 and 4-6 of Enclosure 1, accompnaying the subject letter, Mr. Phifer provides additional information on his MTFZ.

The central part of the fault bounding Mr. Phifer's MTFZ is the same as the F fault which is described along with the E fault (Ehlig, Written Testimony, Contention #3, pp. 1-4; Tr. 2898-2905). The F fault is exposed in a quarry on the northeast side of the old Coast Highway. Here the fault is a discrete nearly planar feature with a strike of about north 15 degrees west and an average dip of 78 degrees to the west. The age of the fault is imprecisely known, but it cuts rocks 14 to 15 million years old and shows no evidence of cutting the coastal terrace. The fault is most likely 4 to 10 million years old. The unconformity (erosional surface) separating the base of the Monterey Formation from the underlying San Onofre breccia is about 25 feet lower in elevation on the west side of the fault than on the east side. Striations produced by fault movement occur in more than one direction on the fault

surface but steeply inclined striations predominate suggesting movement was primarily down the dip of the fault. The age of this fault is uncertain but it was most likely active sometime between ten million years ago and four million years ago based on regional tectonic relationships (Written Testimony, Contention #3, Ehlig, p. 3:21-26; and p. 4:1-2).

The fault shown on the east side of the MTFZ by Mr. Phifer appears to be conjectural. The Applicants know of no mappable faults along the alignment shown on his map. Where his inferred fault crosses the mouth of Horno Canyon, two marine terraces project directly across the canyon with shoreline angles at about 275 feet and 325 feet above sea level. Based on association with the marine isotope chronology (Shlemon, 1978) the 325 foot platform is at least 300,000 years old. Thus, if any fault were present it would be that age or older, and it would not be considered capable according to 10CFR100 Appendix A. On page 4-5 of Enclosure 1 accompanying his letter to the NRC, Mr. Phifer presents reasons for believing significant faulting has occurred within his MTFZ. His principal reasons include:

1. The presence of a tuff bed at an elevation of about 800 feet southwest of San Onofre Mountain which he believes is similar to tuff at an elevation of about 200 feet near the mouth of Horno Canyon.

2. Marine Terraces Qt2, Qt3 and Qt4 (Phifer designations) are continuous across his MTFZ but end abruptly near fault F.

3. There is a zone of extensive landslides along the coastal projection of his MTFZ.

4. Capistrano Formation is exposed at similar elevations as younger San Mateo Formation along the coastal projection of his MTFZ.

5. Offshore bathymetry at depths of 30 and 60 feet appears displaced.

In regard to the tuff bed, it is Applicants' understanding that Mr. Phifer is suggesting that a tuffaceous bed in the San Onofre breccia exposed at an elevation of about 920 feet in the cut along San Onofre Peak trail correlates with a tuff bed which crops out in the breccia a few hundred feet northeast of the old Coast Highway in the area extending from 1/2 miles northwest of Horno Canyon to 2 miles southeast of Horno Canyon. The latter tuff contains pumice lapilli indicating a nearby source and is about 15 feet thick whereas the tuff on San Onofre Mountain is fine-grained and only a few feet thick. The Applicants find no basis for correlating the two tuff beds. Fine-grained tuff beds have a scattered occurrence within the San Onofre breccia. They indicate volcanism was active in the region simultaneous with deposition of the San Onofre breccia.

Mr. Phifer is correct in noting that remnants of marine terraces are aligned across his MTFZ from Horno Canyon to near fault F. There are four terraces in this area, not three as indicated by Mr. Phifer. They have shoreline angles at elevations of about 275, 325, 375 and 450 feet. Terraces are present northwest of fault F and have shoreline angle elevations correlative with those to the southeast of fault F; however, the degree of terrace preservation is less because the area was a headland. The Applicants have observed nothing which would indicate the terraces are offset by faulting.

The extensive landslides along the coast are rotational failures which have occurred where wave erosion has removed lateral support from clay-rich beds in the seaward dipping Monterey Formation. Terrace deposits resting on the Monterey Formation have been extensively deformed within these landslides. However, no deformation or faulting is visible in the in-place terrace deposits exposed in scarps on the landward side of the landslides. The landslides such as that exposed at Horno Canyon are controlled by the lithology and seaward dip of the Monterey Formation and are not a manifestation of a deeper seated deformation as suggested by Mr. Phifer.

Mr. Phifer's suggestion that both the Capistrano and San Mateo Formations are exposed where his MTFZ projects to the coast is based on the mapping of Moyle (1973). Dating by microfossils demonstrates that the Monterey Formation constitutes bedrock beneath the terrace deposits along the entire coast from the Cristianitos Fault to Las Pulgas Canyon (Ehlig, 1977). The exposed part of the Monterey Formation includes lithologies similar to parts of the Capistrano Formation and the San Mateo Formation which is a submarine fan facies of the Capistrano Formation (Ehlig, 1979).

Contrary to Mr. Phifer's belief, the Applicants see no evidence suggesting displacement of offshore bathymetry at depths of 30 and 60 feet.

In conclusion, the Applicants find no evidence for Mr. Phifer's Mountain Top Fault Zone. The F fault which forms the west side of the hypothesized zone was previously mapped and reported. The eastern boundary fault appears to be hypothetical. We find no evidence indicating a through going fault along the

trend shown on Mr. Phifer's map. In particular, the contact between the San Onofre breccia and underlying Eocene sandstone appears to be undisplaced where Mr. Phifer places his inferred fault on the northeast side of San Onofre Mountain. As indicated by Mr. Phifer, minor faults are locally present within the San Onofre breccia; however, the Applicants attribute this to the massive, brittle nature of the breccia and not to the presence of a zone of faulting. We agree with Mr. Phifer's observation that a group of marine terraces remnants extend across his hypothesized Mountain Top Fault Zone in an undisturbed alignment. Because the older terraces are at least 300,000 years old, we find no evidence to support the contention that there are capable faults within the hypothesized Mountain Top Fault Zone nor does the MTFZ intersect the Horno Canyon Fault to form a deformed zone expressed by landsliding. Thus, the alleged structure is not supported by the geologic evidence and is considered speculation.

<u>Aliso Canyon Fault</u>

The feature described as the "Aliso Canyon Fault" by Mr. Phifer has been analyzed by the Applicants using geomorphic expression of the marine terraces and drainage and inspecting aerial photographs. This fault is shown on his map accompanying the October 8, 1981 letter, and shows a dashed line and querries representing an inferred or questionable fault for essentially the length of the feature. Access to Aliso Canyon is limited due to military activities and because the north-east portion is within a Camp Pendleton firing range. The Applicants analysis of the feature determined that marine terrace break-in-slope at the 300, 400 and 500 ft. contours project across Aliso Canyon without deflection. Remnant marine terrace surfaces between

elevation 460 and 520 are about 1,000 feet wide occur east and west of Aliso Canyon, projecting across with no discernable vertical or horizontal separation. The continuity of topographic expression along trend of the terrace break-on-slope surface and the presence of accordant elevations in the uniform soils argues for no major structural deformation since the terrace formation. Terrace surfaces at this elevation north of Las Pulgas were developed over 400,000 years ago (Shlemon, 1978, Figure 12). If the same relationship holds at this location, any faulting along Aliso Canyon would be older.

The Applicants find no evidence for offset bathymetry contours on the offshore axis of Aliso Canyon.

Aliso Canyon is over 9 miles southeast of the site and trends about N40E. If a fault is present, the orientation will not intersect the arc of the 5 mile radius from the site and lies at least 4 miles beyond such a boundary. Geomorphic evidence for significant deformation is absent and even if faulting were present, the Offshore Zone of Deformation 5 miles from the site controls the seismic design. The "Aliso Canyon Fault", if present has no significance to the safety or seimic design of San Onofre Nuclear Generating Station.

The Applicants are not aware of any other geologic disclosures since conclusion of the Atomic Safety and Licensing Board hearings on August 4, 1981.

JLMcNey:npm

RESPONSE TO QUESTIONS

1. How reliable are the locations for the 20 earthquakes?

The reliability of the earthquake hypocentral determinations is a function of the quality of the earth velocity model and the extent and accuracy of the data. The velocity model for the region was constructed on the basis of several refraction profiles recorded from both natural and artificial sources. Station delays appropriate for events located within the dashed box indicated on Figure 1 of the No. 1981 Report were derived from observed delays from quarry and road-cut blasts within the region, the calibration blast discussed by Biehler, and the residuals from very well recorded earthquakes. On the basis of this compilation it was determined that the Caltech model, used throughout the entirety of Southern California, systematically mislocates earthquakes in the region of SONGS about 2 km east of the true locations. It was therefore anticipated that our region specific model would locate the earthquakes westward of the Caltech location. (It should be noted that the very preliminary location provided initially by Caltech, i.e., onshore, was determined by crudely measuring 9 P-wave arrivals from a strip-chart type recording. Such a preliminary location provides a starting point, but it clearly is not a reliable location.)

The number of observations of P- and S-wave arrival times recorded throughout the Southern California array scales with the magnitude of the event. For this reason the larger earthquakes are probably the most accurately located.

The applicants note that the larger events listed in Table 1.1 are all within a few tenths of a kilometer of each other. The largest event (M_L=3) was recorded by over 70 stations. Including P and S data, a total of 111 phase data were located in the location. A good measure of the quality of the model and the location is provided by the root mean square (RMS) and horizontal error estimates of 0.28 sec and 0.4 km respectively. The statistical horizontal error estimate assumes that the velocity model introduces no error into the location. Considering the regional average nature of the velocity model, the true epicenter uncertainty is more likely to be 2 to 3 times larger than the strict statistical estimates shown in Table 1.1 of this response.

Of the three hypocentral parameters, latitude, longitude and depth, the last is the most difficult to determine. Without either several stations located within a source depth of the events or a very localized calibration for station delays, depth estimates are not reliable. The median depth determined in the hypocentral location of this swarm is 14 km. However, based on our previous experience in locating events throughout Southern California, and in consideration of the distance to the seismic stations, the true depth could be located between about 2 and 14 km. The most likely depth is in the range 5-8 km.

The above discussed earthquake locations are each independently determined. Therefore the significance of the location of each separate event must be judged on the basis of the constraining data. The earthquake data can also be analyzed to assess relative locations. The relative spatial dimensions of the sequence are best determined by locating the events relative to

TABLE 1.1. EPICENTRAL LOCATION, MAGNITUDE, RMS AND HORIZONTAL ERROR ESTIMATES (ERH) FOR THE NOV 6-9, 1981 SWARM.

Y M D	H:M	SEC	LAT	LONG	MAG	NO	GAP	RMS	ERH
811106	2037	13.21	33-16.02	117-30.94	1.6	19	166	0.24	0.9
811106	2037	56.85	33-15.95	117-30.30	1.6	19	137	0.23	0.7
811106	2053	19.97	33-16.02	117-31.20	1.6	24	137	0.25	0.8
811106	2055	3.95	33-15.61	117-30.89	1.7	24	138	0.26	0.9
811107	745	36.47	33-16.12	117-31.16	2.4	55	137	0.27	0.5
811107	1140	47.47	33-16.06	117-30.71	2.0	33	137	0.21	0.5
811107	1142	30.07	33-16.07	117-31.55	3.0	111	108	0.29	0.4
811107	1219	57.54	33-16.01	117-31.31	2.3	46	138	0.19	0.4
811107	1219	54.30	33-16.67	117-27.63	1.3	6	212	0.14	2.3
811107	1221	31.97	33-16.24	117-30.66	1.5	17	164	0.21	0.8
811107	1223	1.01	33-16.56	117-30.95	1.2	9	234	0.16	1.5
811107	1223	13.77	33-16.81	117-30.22	1.2	9	161	0.16	1.1
811107	1231	35.63	33-16.18	117-30.71	2.0	35	137	0.19	0.4
811107	1329	6.31	33-16.10	117-31.01	2.3	37	137	0.26	0.7
811107	1330	6.15	33-15.79	117-31.05	1.8	25	140	0.18	0.6
811107	2234	16.96	33-15.97	117-30.59	1.6	23	137	0.19	0.6
811107	2246	48.60	33-15.77	117-30.97	1.6	23	138	0.20	0.6
811108	1450	57.34	33-15.88	117-31.10	2.5	60	138	0.29	0.5
811108	2332	16.09	33-15.71	117-31.07	2.1	33	138	0.29	0.7
811109	047	44.80	33-16.01	117-31.47	2.8	96	138	0.26	0.4

a master event. In the normal process of locating an earthquake (used above) the computer program starts the location beneath the first station that recorded seismic energy. The location is then iteratively refined until the RMS errors of the observed minus the calculated travel-times, to all seismic stations, is minimized. For the present swarm, with a tremendous range in the quality and quantity of phase data from event to event (eg., 111 phase data for the M_L=3.0 and only 6 phase data for the M_L=1.3 event), this procedure will result in a false impression of the true spatial dimensions of the swarm. In a relative location the computer starts the iteration process from a master event (we used the best located event: M_L=3) and determines how far each earthquake must be offset to satisfy the data. Figure 1.1 shows the resulting relative locations. Note that all 20 events are located within about 1 km of the master event.

In conclusion, the swarm surrounds the largest event with a radius of about 1 km. The locaton of the largest event (M_L=3) is:

Lat: $33^{\circ}16.07'$
Long: $117^{\circ}31.55'$

Considerations of the velocity model, the station distribution, the numerous phase data, and the formal statistical error for the largest event, all suggest a horizontal uncertainty of 1 km.

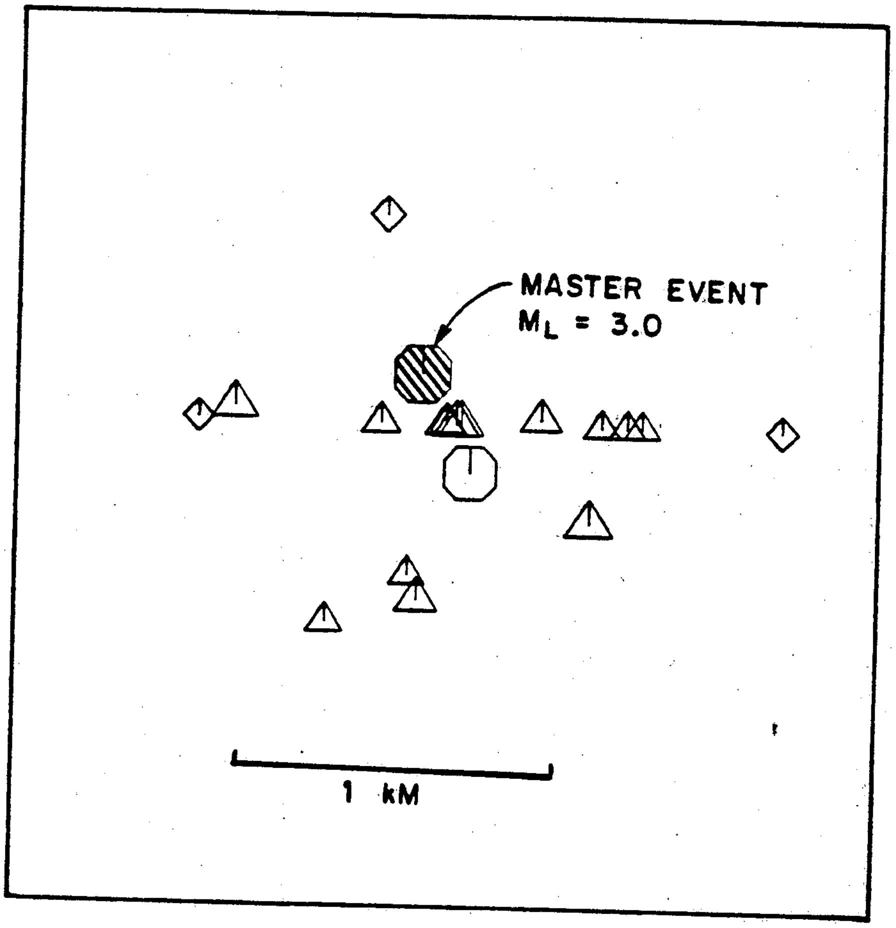


FIGURE 1.1 - Spatial distribution of relative locations. The largest and best located event (M_L=3.0, Nov. 7, 11:42 GMT) was used as the master event.

2. How do the Caltech/USGS locations compare with the Edison locations?

The Caltech/USGS locations are listed in Table 2.1. The epicentral distribution covers an area of 3.5 km in longitude and 2.3 km in latitude. Considering that the Caltech/USGS model is a southern California regional average and that the model does not include station delays, these spatial dimensions are very consistent with the results from the relative locations discussed in the response to Question 1.

Since the swarm centers around the largest event, a direct comparison of the Edison results with the Caltech/USGS results is best obtained by a comparison of the M_L=3 event:

	Lat		Long		ERH
Edison	33	16.07	117	31.55	0.4
Caltech/USGS	33	16.25	117	29.95	2.30

event separation = 2.46 km.

As discussed in the response to Question 1, in this region the Caltech/USGS model consistently mislocates events about 2 km east of the true location.

TABLE 2.1 Caltech locations for the Nov. 6-9, 1981 Earthquake Swarm

DATE	Hr:min	Lat	Long	M_L	ERH
Nov 6	20:37	33 16.03	117 29.23	1.6	0.93
6	20:37	33 16.52	117 28.71	1.6	1.03
6	20.53	33.16.52	117 29.35	1.6	1.11
6	20:55	33 16.38	117 29.62	1.7	1.14
Nov 7	07:45	33 16.07	117 30.14	2.4	0.58
7	11:40	33 16.01	117 29.95	2.0	0.73
7	11:42	22 16.25	117 29.95	3.0	2.30
7	12:19	33 16.18	117 30.00	2.3	0.64
7	12:19	33 15.78	117 30.42	1.3	3.08
7	12:21	33 17.00	117 29.00	1.5	0.91
7	12:23	33 16.75	117 28.20	1.2	1.70
7	12:23	33 16.53	117 29.14	1.2	1.72
7	12:31	33 16.31	117 29.99	2.0	0.70
7	13:29	33 16.12	117 29.20	2.3	2.19
7	13:30	33 16.28	117 29.12	1.8	2.51
7	22:34	33 16.35	117 29.37	1.6	1.00
7	22:46	33 16.04	117 29.80	1.6	0.98
Nov 8	14:50	33 15.74	117 30.11	2.5	0.56
8	23.32	33 15.91	117 30.00	2.1	0.79
Nov 9	00:47	33 16.32	117 29.42	2.8	1.86

3. Describe the first motion data for the five largest events.

All of the first motion data for the five largest events are plotted on Figures 3.1 to 3.5 and tabulated in Tables 3.1 to 3.5. The size of the "C" and "D" symbols on the figures (large and small) correspond to impulsive or emergent arrivals, respectively. The abbreviations over the columns in the tables have the following meanings: STA = station; DIR = compression or dilitation; QUAL = Quality, 2-impulsive, 1-emergent; DIST = distance, km; EVAZ = azimuth from event to station; TOA = take-off angle; X and Y = position in inches from the center of focal plot for plotting station (assumes a 4-inch radius plot).

The best constrained event occurred on Nov 7, 1981 at 11:42 GMT (M_L=3), Figure 3.2. The other 4 events are consistent with this mechanism. However, with the exception of the Nov 9, 00:47 GMT event, Figure 3.5, the mechanisms are not constrained. To evaluate the consistency of the observations, the mechanism from the M_L=3 event has been plotted on all five figures (3.1-3.5). This mechanism is consistent with all of the impulsive (QUAL = 2) arrivals and most of the emergent, or questionable, polarities.

TABLE 3.1 - Focal mechanism data for the Nov. 7, 1981, M_L=2.4 earthquake that occurred 7:45 GMT.

EVENT DATA

0 19811107 7 45 0.0
8.0 33.000 16.12 -117.000 31.16 2.4

AZ1= 136.721
DIP1= 72.428
AZ2= 230.023
DIP2= 79.691

SLIP VECTORS= 140.023 79.691 46.721 72.428

PRIN AXES = 94.336 70.122 2.520 85.013

STA	DIR	QUAL	DIST	EVAZ	TOA	X	Y
SNS	D	2	0.170	351.811	133.360	0.319	-2.217
VST	C	1	0.268	115.941	101.910	-3.204	1.559
OLY	C	2	0.375	63.542	95.745	-3.397	-1.691
PLM	C	2	0.559	80.066	88.384	3.884	0.680
SME	D	1	0.571	13.844	88.174	0.942	3.821
DB2	D	2	0.603	39.177	87.592	2.473	3.035
PEC	D	1	0.691	25.633	86.029	1.669	3.479
GAV	D	1	0.753	0.442	84.918	0.029	3.819
CIS	C	1	0.754	281.408	84.899	-3.743	0.755
HOT	C	1	0.788	85.406	84.302	3.784	0.304
JUL	C	2	0.792	106.066	84.223	3.645	-1.050
KEE	D	1	0.814	62.626	83.841	3.356	1.738
VG2	D	1	0.818	46.273	83.764	2.729	2.610
SYS	D	1	0.858	143.252	83.056	2.244	-3.005
SMO	C	1	0.925	72.766	81.859	3.540	1.098
SS2	C	1	0.938	0.996	81.634	0.064	3.697
SUN	C	1	0.952	351.300	81.383	-0.558	3.646
RAY	C	1	0.968	37.433	81.099	2.235	2.920
YAQ	C	1	0.986	95.891	80.771	3.646	-0.376
COY	C	2	1.018	83.791	80.207	3.623	0.394
BTL	C	1	1.076	23.334	79.167	1.428	3.310
BRG	C	1	1.133	95.197	76.685	3.495	-0.318
BLU	C	1	1.149	351.413	75.682	-0.518	3.431
SIL	C	1	1.222	27.969	71.140	1.543	2.906
MEC	D	1	1.300	73.091	65.332	2.921	0.888

TABLE 3.2 - Focal mechanism data for the November 7, 1981, M_L=3.0 earthquake that occurred at 11:42 GMT.

EVENT DATA

0 19811107 11 42 0.0
8.0 33.000 16.07 -117.000 31.55 3.0

AZ1= 136.721
DIP1= 72.428
AZ2= 230.023
DIP2= 79.691

SLIP VECTORS= 140.023 79.691 46.721 72.428

PRIN AXES = 94.336 70.122 2.520 85.013

STA	DIR	QUAL	DIST	EVAZ	TOA	X	Y
SNS	D	2	0.170	353.656	133.360	0.247	-2.226
VST	C	2	0.273	115.185	101.445	-3.241	1.524
OLY	C	2	0.381	63.814	95.524	-3.412	-1.678
PLM	C	2	0.564	80.447	88.297	3.885	0.654
SME	D	2	0.573	14.352	88.138	0.975	3.812
VPD	D	1	0.582	340.289	87.969	-1.325	3.698
DB2	D	2	0.607	39.539	87.523	2.491	3.017
POB	D	2	0.656	50.029	86.661	2.975	2.494
PEC	D	2	0.694	25.995	85.968	1.690	3.467
CAH	C	2	0.732	70.753	85.294	3.618	1.263
RVR	D	1	0.736	9.805	85.227	0.652	3.774
GAV	D	2	0.754	0.852	84.909	0.057	3.818
CIS	D	1	0.749	281.537	84.992	-3.744	0.764
HOT	C	2	0.793	85.422	84.205	3.781	0.303
JUL	C	2	0.798	105.999	84.126	3.643	-1.045
KEE	C	2	0.819	62.739	83.747	3.356	1.730
VG2	D	2	0.823	46.471	83.679	2.736	2.599
PCF	D	1	0.815	344.350	83.815	-1.019	3.638
CFT	D	1	0.841	24.191	83.360	1.541	3.431
SYS	C	2	0.860	142.908	83.015	2.261	-2.990
CIW	C	1	0.882	283.546	82.623	-3.630	0.875
SMO	C	2	0.930	72.806	81.761	3.537	1.094
BAR	C	2	0.928	129.074	81.806	2.876	-2.335
SCI	C	1	0.904	251.658	82.232	-3.531	-1.171
SS2	D	2	0.938	1.325	81.619	0.085	3.696
MLL	D	1	0.958	30.717	81.273	1.882	3.167
PEM	C	1	0.943	342.401	81.537	-1.117	3.521
PSP	C	1	0.971	56.941	81.042	3.080	2.005
SUN	D	1	0.952	351.628	81.383	-0.537	3.649
RAY	D	1	0.972	37.653	81.027	2.245	2.909
YAQ	C	2	0.992	96.140	80.665	3.640	-0.392
COY	C	2	1.023	83.649	80.104	3.618	0.403
WWR	C	1	1.025	44.865	80.084	2.567	2.579
PAS	D	1	1.031	328.721	79.961	-1.887	3.106
MWC	D	1	1.052	335.202	79.593	-1.519	3.287
BTL	D	2	1.079	23.579	79.115	1.441	3.302

TABLE 3.2 CONT'D

LAQ	C	2	1.103	70.517	78.559	3.376	1.194
BRG	C	2	1.138	95.025	76.363	3.483	-0.306
MRV	C	1	1.140	45.693	76.235	2.499	2.439
CFL	D	1	1.141	338.855	76.214	-1.259	3.256
EWC	C	1	1.167	54.667	74.588	2.796	1.982
BLU	D	2	1.149	351.681	75.703	-0.502	3.435
RDM	D	1	1.165	14.000	74.692	0.830	3.330
MIR	C	1	1.219	82.380	71.320	3.269	0.437
SIL	C	1	1.226	28.166	70.921	1.549	2.893
RMR	D	2	1.232	39.759	70.545	2.089	2.511
JNH	C	1	1.230	343.260	70.644	-0.942	3.132
SAD	D	1	1.249	310.814	69.445	-2.439	2.106
INS	D	1	1.296	58.644	65.645	2.618	1.596
MEC	D	1	1.305	73.129	64.866	2.903	0.880
SBI	C	1	1.276	280.226	67.376	-3.088	0.557
IKP	C	1	1.343	117.063	61.603	2.580	-1.318
LRR	D	1	1.323	341.747	63.351	-0.930	2.821
CRR	D	1	1.363	105.941	59.907	2.716	-0.776
LJB	D	1	1.347	348.621	61.252	-0.569	2.825
SDW	D	1	1.390	15.546	57.553	0.730	2.624
CPM	C	1	1.418	51.017	55.149	2.035	1.647
BAT	D	1	1.424	81.646	54.674	2.570	0.377
RCH	D	1	1.426	43.013	54.437	1.765	1.892
CTW	C	2	1.443	72.903	53.002	2.413	0.742
SBB	D	1	1.439	350.137	53.306	-0.435	2.500
HDG	C	1	1.541	40.901	48.437	1.519	1.754
FRK	D	1	1.587	84.544	46.998	2.245	0.214
SGL	D	1	1.635	111.737	45.972	2.052	-0.818
BC2	C	1	1.769	76.699	45.936	2.148	0.508

TABLE 3.3 - Focal mechanism data for the Nov. 7, 1981, M_L=2.3 earthquake that occurred at 12:20 GMT.

EVENT DATA

0 19811107 12 20 0.0
8.0 33.000 16.01 -117.000 31.31 2.3

AZ1= 136.721
DIP1= 72.428
AZ2= 230.023
DIP2= 79.691

SLIP VECTORS=	140.023	79.691	46.721	72.428
PRIN AXES =	94.336	70.122	2.520	85.013

STA	DIR	QUAL	DIST	EVAZ	TOA	X	Y
SNS	D	1	0.170	352.517	133.360	0.292	-2.220
VST	C	2	0.270	115.561	101.638	-3.224	1.542
OLY	C	2	0.378	63.302	95.612	-3.394	-1.707
PLM	C	2	0.560	80.492	88.359	3.888	0.651
SME	D	1	0.573	14.007	88.138	0.952	3.817
VPD	C	1	0.583	339.987	87.945	-1.344	3.690
DB2	C	1	0.606	39.230	87.546	2.475	3.031
POB	D	1	0.653	49.823	86.704	2.967	2.505
PEC	C	1	0.694	25.688	85.968	1.672	3.476
CAH	D	1	0.730	70.438	85.332	3.612	1.284
JUL	C	2	0.794	106.016	84.188	3.645	-1.046
SYS	C	1	0.857	143.054	83.064	2.254	-2.998
SMO	C	1	0.927	72.694	81.813	3.537	1.102
SS2	D	1	0.939	1.120	81.604	0.072	3.696
PEM	D	1	0.945	342.221	81.508	-1.128	3.516
SUN	D	1	0.953	351.441	81.353	-0.549	3.646
RAY	C	1	0.970	37.459	81.049	2.236	2.918
COY	C	1	1.020	83.682	80.165	3.620	0.401
BRG	D	1	1.135	94.989	76.578	3.492	-0.305
BLU	C	1	1.150	351.527	75.597	-0.511	3.429
INS	D	1	1.294	58.513	65.827	2.621	1.605
MEC	D	1	1.302	73.057	65.125	2.912	0.887

TABLE 3.4 - Focal mechanism data for the Nov. 7, 1981 M_L=2.5 earthquake that occurred at 14:51 GMT.

EVENT DATA

0 19811108 14 51 0.0
8.0 33.000 15.88 -117.000 31.10 2.5

AZ1= 136.721
DIP1= 72.428
AZ2= 230.023
DIP2= 79.691

SLIP VECTORS= 140.023 79.691 46.721 72.428

PRIN AXES = 94.336 70.122 2.520 85.013

STA	DIR	QUAL	DIST	EVAZ	TOA	X	Y
SNS	D	2	0.175	351.745	132.116	0.330	-2.272
VST	C	2	0.265	115.043	102.457	-3.209	1.499
OLY	C	2	0.376	62.941	95.701	-3.381	-1.727
PLM	C	2	0.558	79.974	88.397	3.883	0.687
SME	D	2	0.574	13.673	88.113	0.930	3.822
DB2	D	2	0.606	38.875	87.546	2.456	3.047
POB	D	1	0.653	49.428	86.704	2.950	2.526
GAV	C	1	0.757	0.376	84.844	0.025	3.816
CIS	C	1	0.756	281.665	84.872	-3.738	0.772
HOT	C	1	0.787	85.098	84.311	3.783	0.324
JUL	C	2	0.791	105.914	84.249	3.649	-1.040
KEE	C	1	0.815	62.303	83.815	3.345	1.756
VG2	C	1	0.820	46.014	83.721	2.716	2.622
SYS	C	1	0.854	143.140	83.121	2.251	-3.003
BAR	D	1	0.921	129.147	81.934	2.876	-2.341
SMO	C	1	0.925	72.507	81.851	3.534	1.114
SS2	D	1	0.941	0.941	81.567	0.061	3.695
SUN	C	1	0.956	351.287	81.310	-0.558	3.643
YAQ	C	1	0.985	95.924	80.785	3.646	-0.378
COY	C	2	1.017	83.554	80.213	3.621	0.409
BRG	C	1	1.132	94.893	76.771	3.500	-0.300
BLU	C	1	1.153	351.399	75.449	-0.518	3.422
INS	D	1	1.293	58.376	65.957	2.622	1.615
CRR	D	1	1.356	105.848	60.528	2.743	-0.779

TABLE 3.5 - Focal mechanism data for the Nov. 9, 1981, M_L=2.8 earthquake that occurred at 0:47 GMT.

EVENT DATA

0 19811109 0 47 0.0
8.0 33.000 16.01 -117.000 31.47 2.8

AZ1= 136.721
DIP1= 72.428
AZ2= 230.023
DIP2= 79.691

SLIP VECTORS= 140.023 79.691 46.721 72.428

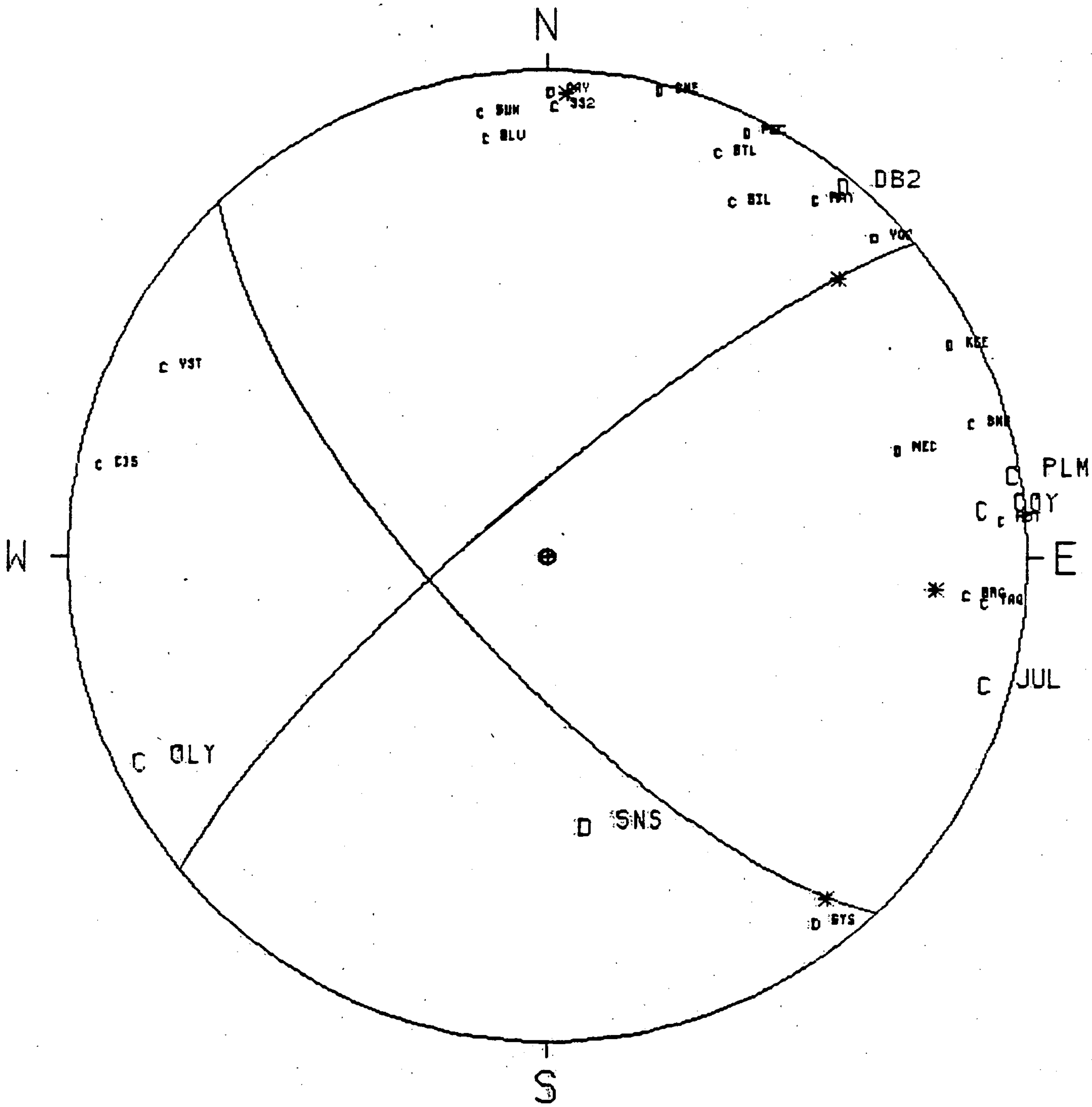
PRIN AXES = 94.336 70.122 2.520 85.013

STA	DIR	QUAL	DIST	EVAZ	TOA	X	Y
SNS	D	2	0.170	353.277	133.360	0.262	-2.224
VST	C	2	0.271	115.096	101.528	-3.240	1.518
OLY	C	2	0.381	63.435	95.524	-3.401	-1.701
PLM	C	2	0.563	80.184	88.310	3.883	0.672
SME	D	2	0.573	14.219	88.126	0.966	3.814
DB2	D	2	0.608	39.353	87.511	2.481	3.025
VPD	D	1	0.583	340.196	87.957	-1.331	3.696
POB	D	2	0.655	49.940	86.672	2.971	2.499
PEC	D	2	0.695	25.870	85.958	1.683	3.470
CAH	C	2	0.732	70.608	85.303	3.615	1.273
GAV	D	2	0.755	0.766	84.881	0.051	3.817
HOT	C	2	0.792	85.299	84.223	3.781	0.311
JUL	C	2	0.796	105.922	84.153	3.645	-1.040
CIS	C	1	0.750	281.500	84.974	-3.744	0.762
KEE	C	1	0.819	62.634	83.755	3.354	1.736
VG2	D	2	0.822	46.393	83.687	2.732	2.603
CFT	D	1	0.842	24.080	83.343	1.535	3.434
SYS	C	1	0.859	142.934	83.040	2.260	-2.992
SMO	C	2	0.930	72.740	81.776	3.536	1.099
BAR	C	1	0.926	129.056	81.836	2.877	-2.334
CIW	C	1	0.883	283.595	82.599	-3.629	0.878
SS2	D	2	0.939	1.256	81.604	0.081	3.696
PEM	D	1	0.944	342.354	81.515	-1.120	3.519
RAY	C	1	0.972	37.570	81.027	2.241	2.913
SUN	D	2	0.953	351.572	81.361	-0.540	3.648
YAQ	C	2	0.991	96.111	80.686	3.641	-0.390
COY	C	2	1.022	83.659	80.124	3.619	0.402
PAS	D	1	1.033	328.700	79.934	-1.888	3.105
MWC	D	1	1.054	335.173	79.567	-1.520	3.285
BTL	D	2	1.080	23.498	79.102	1.436	3.303
LAQ	C	1	1.102	70.500	78.625	3.378	1.196
BRG	C	2	1.137	95.079	76.427	3.486	-0.310
BLU	D	1	1.150	351.638	75.597	-0.504	3.430
RDM	D	1	1.166	13.936	74.650	0.826	3.329
MIR	C	1	1.219	82.210	71.360	3.269	0.447
SIL	D	1	1.226	28.100	70.902	1.545	2.894

TABLE 3.5 CONT'D

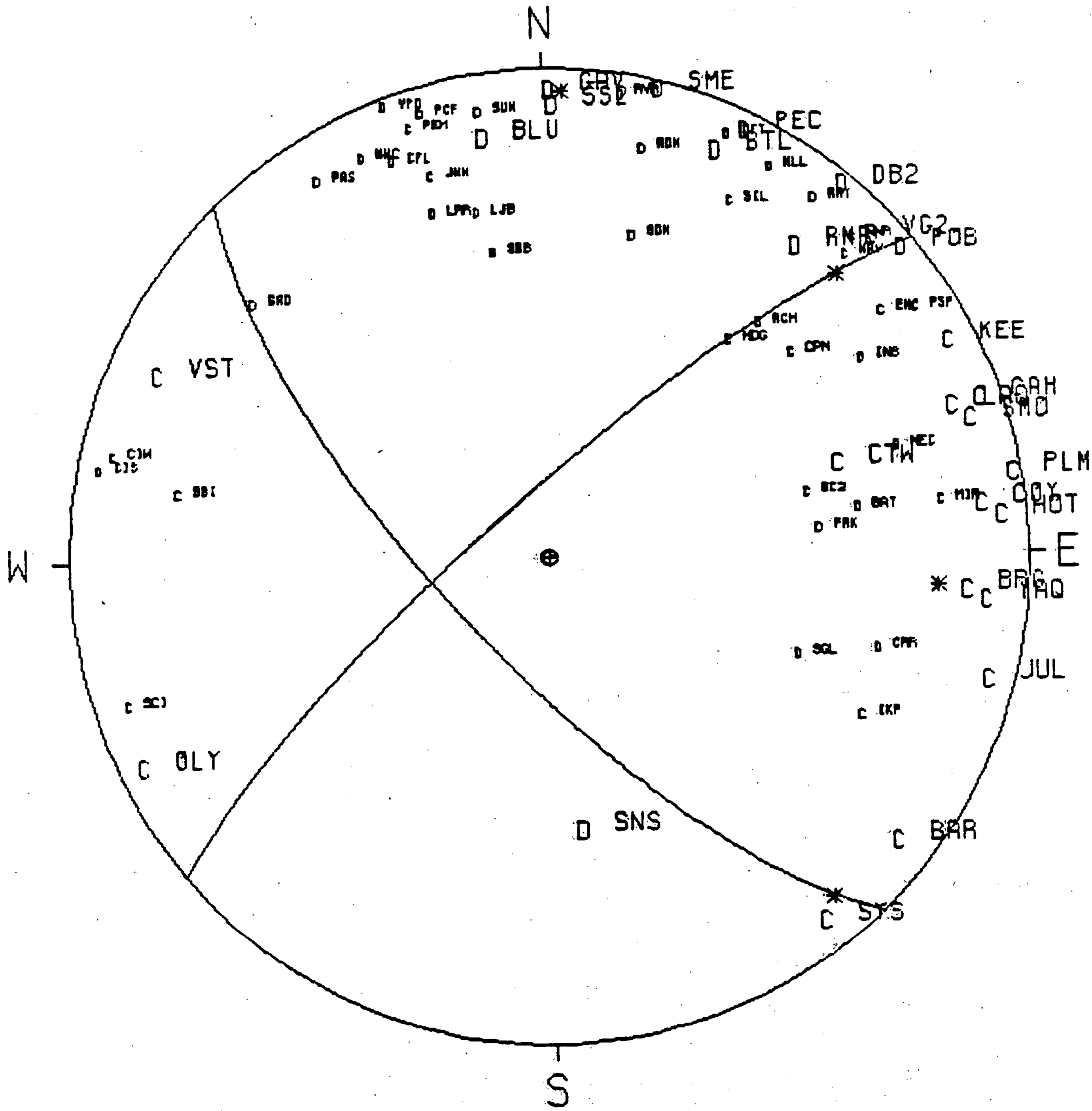
RMR	D	1	1.232	39.692	70.545	2.086	2.514
JNH	C	1	1.232	343.229	70.545	-0.943	3.128
INS	C	1	1.296	58.571	65.671	2.617	1.599
SAD	C	1	1.251	310.836	69.328	-2.434	2.104
MEC	D	1	1.304	73.091	64.944	2.906	0.883
IKP	C	1	1.342	117.047	61.729	2.585	-1.320
LRR	C	1	1.324	341.718	63.223	-0.930	2.815
CRR	D	1	1.361	105.859	60.056	2.723	-0.774
LJB	C	1	1.348	348.583	61.152	-0.570	2.821
CPM	C	1	1.418	50.959	55.173	2.035	1.650
RCH	D	1	1.426	42.952	54.437	1.763	1.894
CTW	C	1	1.442	72.857	53.072	2.415	0.745
KYP	C	1	1.404	306.799	56.345	-2.139	1.600
SUP	D	1	1.462	101.961	51.398	2.400	-0.508
SBB	C	1	1.440	350.098	53.236	-0.436	2.497
HDG	D	1	1.541	40.855	48.445	1.518	1.755

FIGURE 3.1



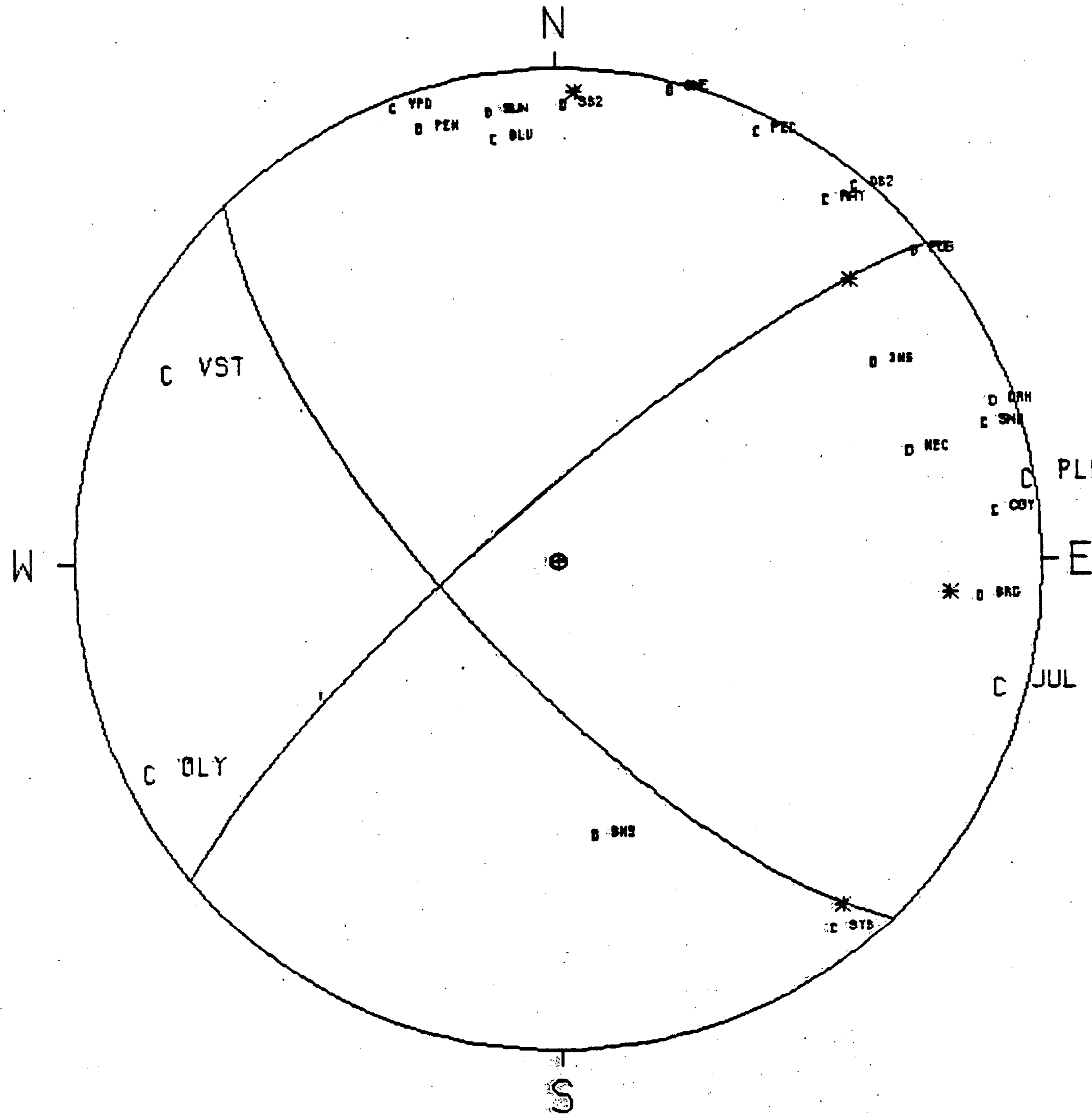
NOV 7, 1981 7:45 GMT MAG=2.4

FIGURE 3.2



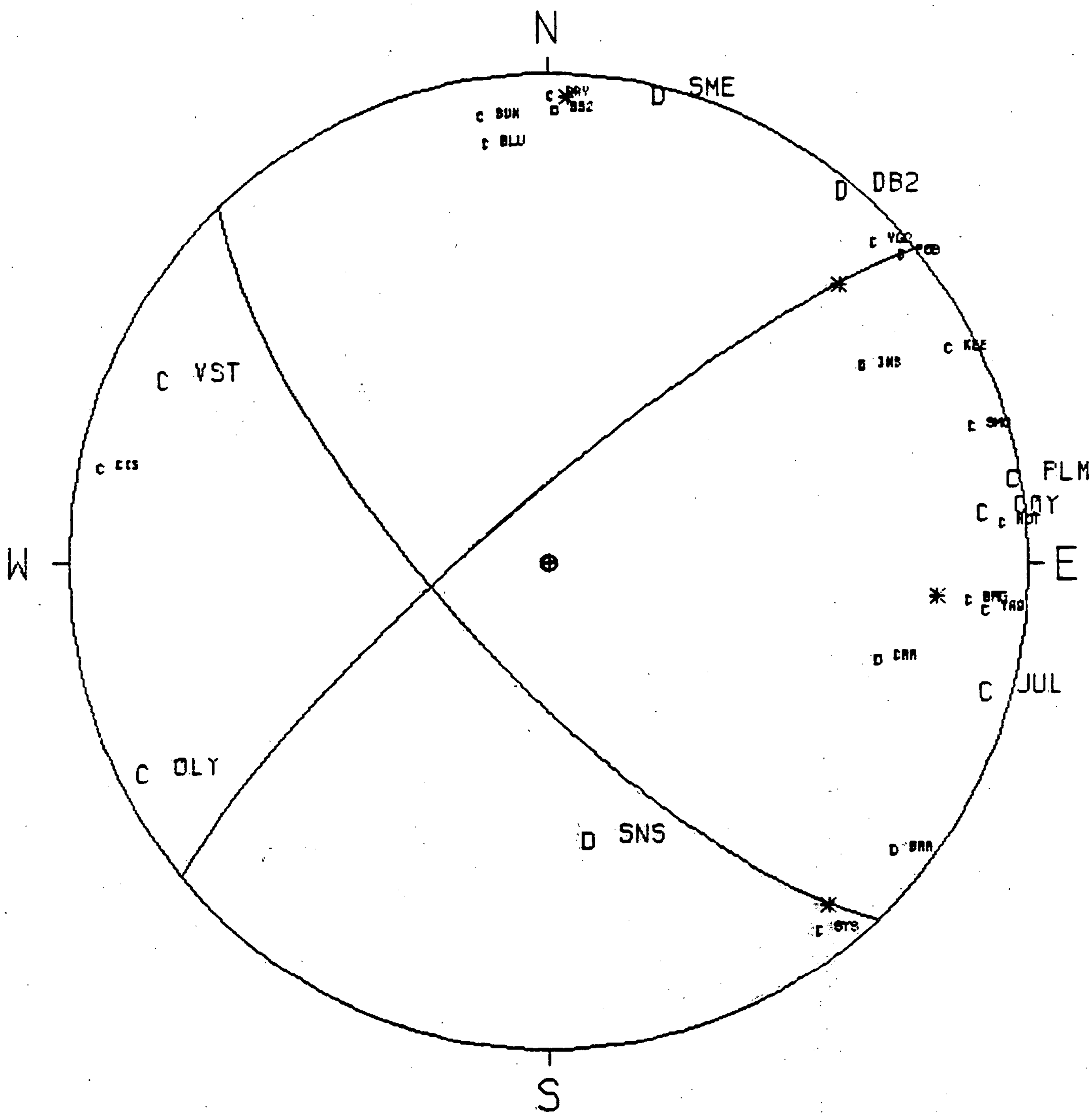
NOV 7, 1981 11:42 GMT MAG=3.0

FIGURE 3.3



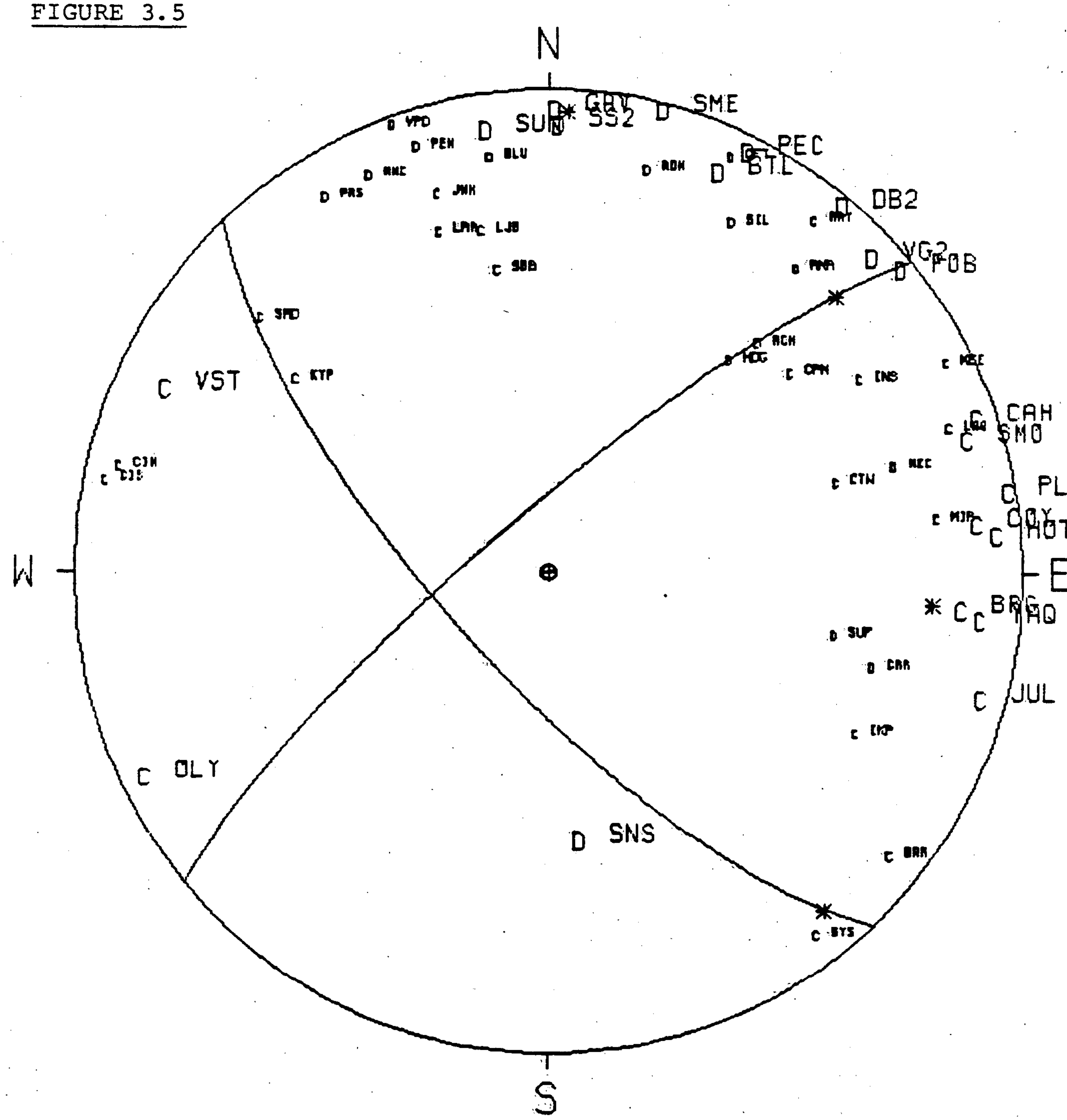
NOV 7, 1981 12:20 GMT MAG=2.3

FIGURE 3.4



NOV 8, 1981 14:51 GMT MAG=2.5

FIGURE 3.5



NOV 9, 1981 00:47 GMT MAG=2.8

4. Quantify the error limits of the strike of the fault planes:

The best fitting focal planes to the first motion data and the estimated uncertainty are:

Strike	Dip
N 43°±10°W	72°±20°SW
N 50°±6°E	80°±20°NW

5. What are the strike of the OZD and CZD in the area of the swarm?

	Location		Trend
OZD:	Sea Floor		N55W to N58W
	Horizon C	-	N42W
CZD:	Sea Floor	-	N18W to N38W

6. How good are the locations of the historic earthquakes?

For consistency, all historic earthquakes discussed in relationship to the Nov 6-9, 1981 swarm have been relocated with the velocity model and station delays briefly discussed in the response to Question 1. Table 6.1 lists the events that occurred in the vicinity of the swarm, along with the RMS and horizontal error estimates.

TABLE 6.1. HISTORIC EARTHQUAKES THAT HAVE OCCURRED IN THE VICINITY OF THE NOV. 6-9, 1981 SWARM.

Y M D	H:M	SEC	LAT	LONG	MAG	NO	GAP	RMS	ERH
341114	2130	49.32	33-14.92	117-29.05	3.5	7	174	0.20	2.8
601125	2230	27.74	33-16.85	117-28.91	3.4	16	172	0.44	2.0
760422	650	13.51	33-15.84	117-28.86	2.0	14	140	0.16	0.6
771229	355	53.81	33-15.42	117-31.47	1.5	9	313	0.22	2.3
781011	2133	21.55	33-13.91	117-31.01	2.6	6	269	1.20	23.9
791111	541	52.80	33-17.73	117-34.04	1.8	31	172	0.40	1.2

7. Dr. D. G. Moore's map does not show the CZD. Why not?

The geologic map offshore and south of San Onofre portrays the geologic structure interpretated by Dr. D. G. Moore. The interpretation of geophysical profiles discusses deformation of the sediments and some intraformational faulting. The folds are generally small, short, and are not seen on adjacent profiles in many locations and as stated by Moore in his written testimony,

> "The use of the term Cristianitos Zone of Deformation (CZD) for the group folds and associated faults that lie approximately on the central San Onofre Shelf, midway between the onshore Cristianitos Fault and a projection of it on the Offshore Zone of Deformation, implies that these structures are somehow related to the Cristianitos Fault. A major conclusion of my study is that the seismic data do not support this implication.... The "CZD" on the central shelf comprises compressional features with broad open folds probably somewhat crenulated at their crusts in places, and with relatively small faults associated with crests and troughs of folds in other places. The faults of this central folded area, furthermore, do not appear to extend to any great depth in the section...."

The deformation associates with these structures is very limited and diminishes in the vicinity of the OZD. As a result of the limited areal extent, the character of the minor faults that do not cut the Pleistocene sea floor nor extend to great depth, and the dissimilarity with the easily recognized OZD, applicants do not identify a structural zone of deformation in the region labeled as the CZD by Greene and Kennedy.

8. What is the distribution of the seismic stations in both distance and azimuth with respect to the earthquakes.

As determined in the master event location analysis (response to Question 1) and supported by the Caltech/USGS results (response to Question 2), within the resolution of the data, the swarm surrounds the largest event. Since the events cluster within about 1 km of this event, the azimuth and distance data do not change significantly from event to event. Table 3.2 lists the seismic stations that recorded the largest event along with the azimuth and distance data.

9. What effect does the station distribution have on these event locations?

The station distribution used to locate earthquakes can bias the locations, particularly if the event is outside of the array and if S-wave data are not available. For the Nov 6-9, 1981 swarm, both offshore seismic stations and an abundance of S-wave data minimize this problem. The epicentral error estimates discussed in the response to Question 1 include station effects.

10. Why is the M_L=1.3 event on Nov 7 at 12:19:54.30 GMT located ~5 km from the largest event?

This earthquake was recorded by only six stations. Because of the larger event (M_L=2.3) that occurred 3.2 sec later, S-wave data are not available for this event. Hence, the location of this earthquake is the least well constrained of the entire sequence. The relative location study discussed in the response to Question 1 and the Caltech locations show that this event was actually located very close to the largest earthquake.

11. What is the consistency of the seismicity in the FSAR and the seismicity plot in the current report?

The seismicity listings and figures in the FSAR are derived from the Caltech catalog. The earthquakes in this catalog have been located with the best velocity models and the best location techniques available when the event occurred. Since the catalog was started nearly 50 years ago, the quality and consistency of the catalog is not uniform; the more recent events are much more accurately located than are the older events. For a strict comparison of the historic locations with the present seismicity, all events must be located with the same procedure. For this reason, we have relocated the historic earthquakes with the velocity model discussed in the response to Question 1. The historic seismicity discussed in this report can therefore be compared directly with the locations of the recent seismicity. This information is shown on Figure 6, 7 and 8 of the November, 1981 report.

12. What is the significance of the event listed in the FSAR, magnitude 5-5.9, that is located in the region of the current swarm?

The seismicity listings and the epicenter map (Figure 2.5-17) in section 2.5 of the FSAR was originally prepared by the National Geophysical and Solar-Terrestrial Data Center of the National Oceanic and Atmospheric Adminstration (NOAA). This seismicity data was superseded by an update constructed from the Caltech catalog, Figure 2.5-17a and Table 2.5-4 (Amendment 23 to the FSAR). The NOAA listing for this event was:

Sept 23, 1963	14:01:17.6	GMT
33.25N	117.516W	
m_b=5.3(CGS)	M_L=2.7 (Pas)	

The corresponding Caltech entries that clarify the record are:

Sept 23, 1963	14:01:17.6	GMT
33.71N	116.93W	
M_L=5.0		

We conclude that the NOAA entry was in error and that none of these events are of interest for evaluating the current swarm.

13. What observations can be made concerning the CZD and the swarm if the Greene and Kennedy map is representative of the geologic conditions?

The interpretation by Greene and Kennedy of the offshore reflection data is limited to a sequence thickness of about 500. The model they propose for the region east of the OZD contains both shallow folding and intraformational faulting. In the evaluation of the current swarm, the significance of these features must be examined in their complete geologic context. As discussed by Dr. Moore (written testimony, p. 45, :15-23), these faults do not appear to extend to great depth and therefore it is unlikely that these features are the seismogenic source of the recent swarm. These minor features are not consistent with a true structural Zone of Deformation (see Response to Question 7).

Dr. Moore discussed old, deeper faults, also located east of the OZD, that lie beneath the Monterey Formation. However, these faults do not break sediments younger than old Monterey (Moore's written testimony, p. 44 :18-25), indicating no connection with the Cristianitos Fault. Further, these structures show down-to-the east motion in contrast with the strike-slip character of the recent swarm.

The fault plane orientation and the location of the recent swarm is shown on Figures 13.1 (Moore) and 13.2 (Greene and Kennedy). The center of the focal mechanism has been plotted at the epicenter of the best located event (M_L=3.0). The horizontal uncertainty for this location is about 1 km. The radius of the mechanism corresponds to the dimensions of the swarm as determined in the relative locaton analysis discussed

in the response to Question 1. The strike of the northwest trending plane ($N43^{O}W$) is nearly parallel to the OZD (Horizon C) and oblique to the general $N18^{O}W$ trend of the Greene and Kennedy CZD.

Greene and Kennedy have presented several line-drawing cross-sections constructed from the numerous reflection profiles from the offshore area. Their profile G-G (SER, Appendix F, p. F20) is the closest profile to the recent swarm. We have projected the epicentral location of the largest event (M_L=3), along the strike of the anticling about 1 km as shown on Plate 1 of Greene and Kennedy, onto this profile, Figure 13.3. As discussed in the response to Question 1, the swarm surrounds this epicentral location with a radius of about 1 km. Considerations of this cross-section strengthens the conclusion that the swarm was associated with the OZD.

On the basis of the spatial association of the swarm with the OZD, the consistency of the determined strike of the focal mechanism with the OZD, and the disagreement of the mechanism with the sense of motion of the old faults located east of the OZD, applicants conclude that the Nov. 6-9- 1981 swarm was associated with the OZD. This location of the swarm and the orientation of the focal mechanism does not conyrovert the extensive geological and seismic investigations of the offshore region.

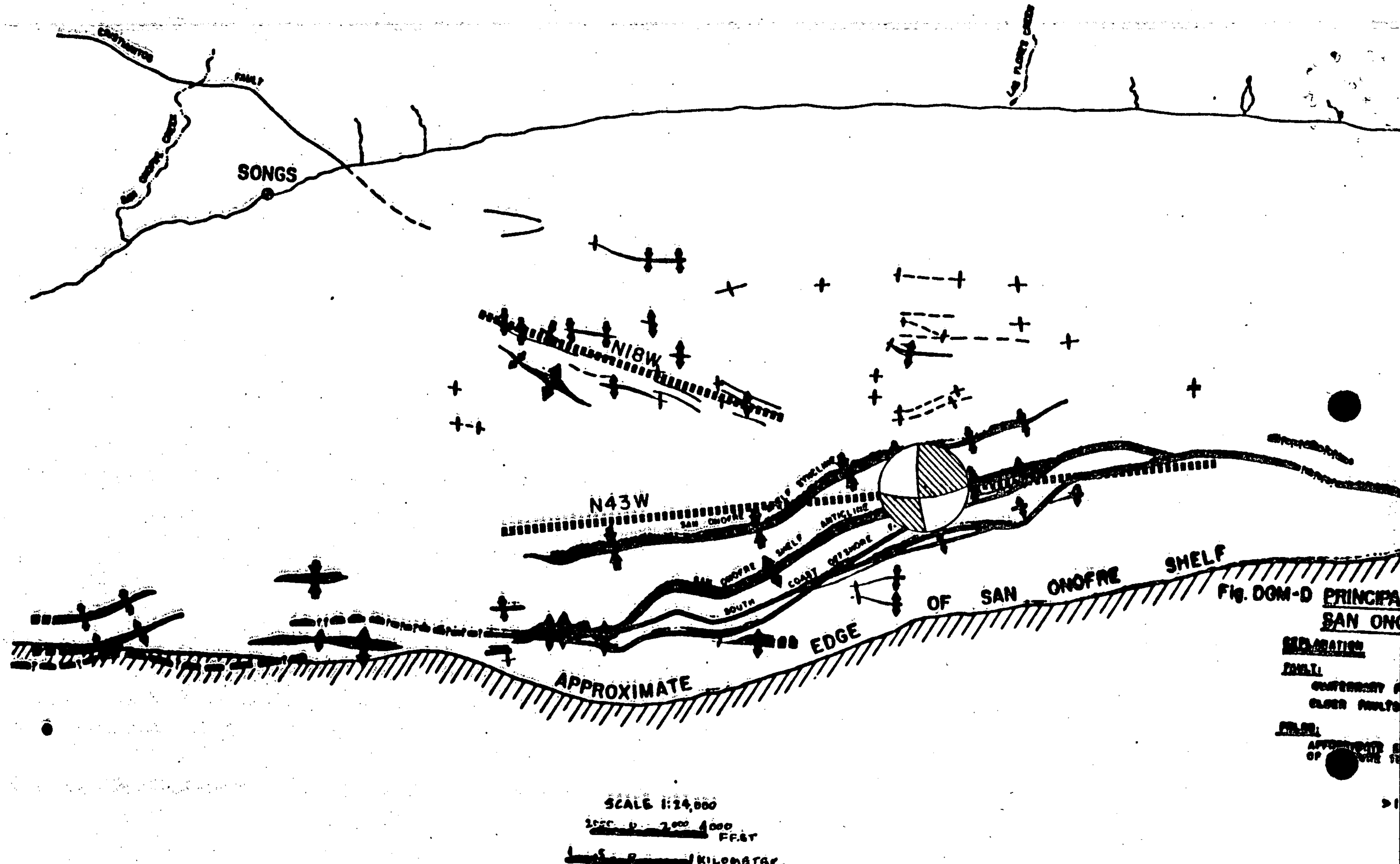


FIGURE 13.1 - Fault plane orientation and location of the Nov. 6-9, 1981 swarm. The base map has been completed by D. Moore (DGM-D). The focal mechanism is centered on the location of the $M_{L=3}$ event. The epicentral uncertainty of this location, as discussed in the response to Question 1, is about 1 km. The radius of the focal mechanism approximately represents the areal distribution of the swarm. The strike of the northwest trending plane is N43W, in good agreement with the strike of the OZD. Both the spatial relationship and the orientation of the strike-slip fault plane strongly suggest that this swarm was associated with the OZD.

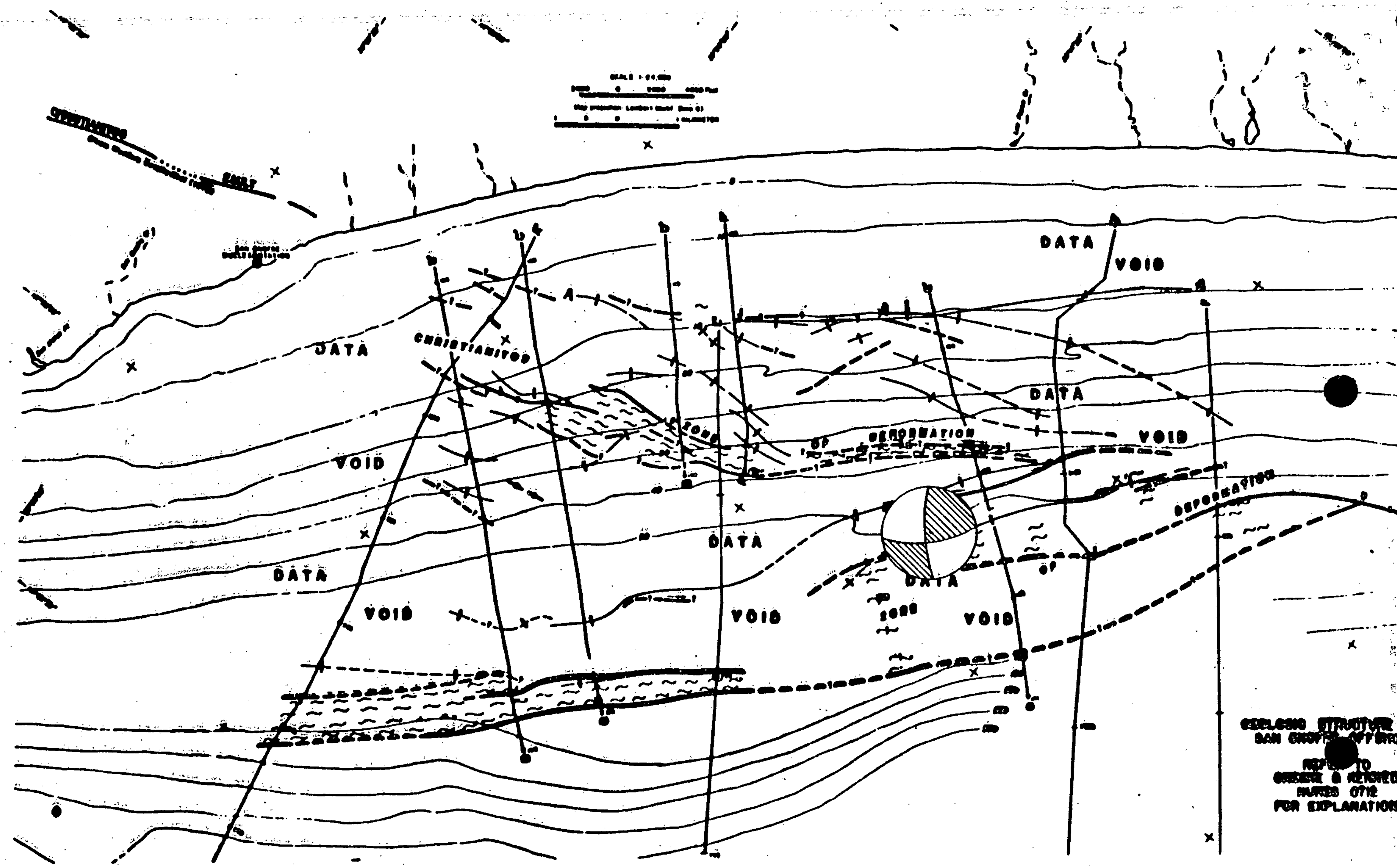


FIGURE 13.2 - Focal mechanism and location of the Nov. 6-9, 1981 swarm. The base map is from Greene and Kennedy, Plate 1, SER.

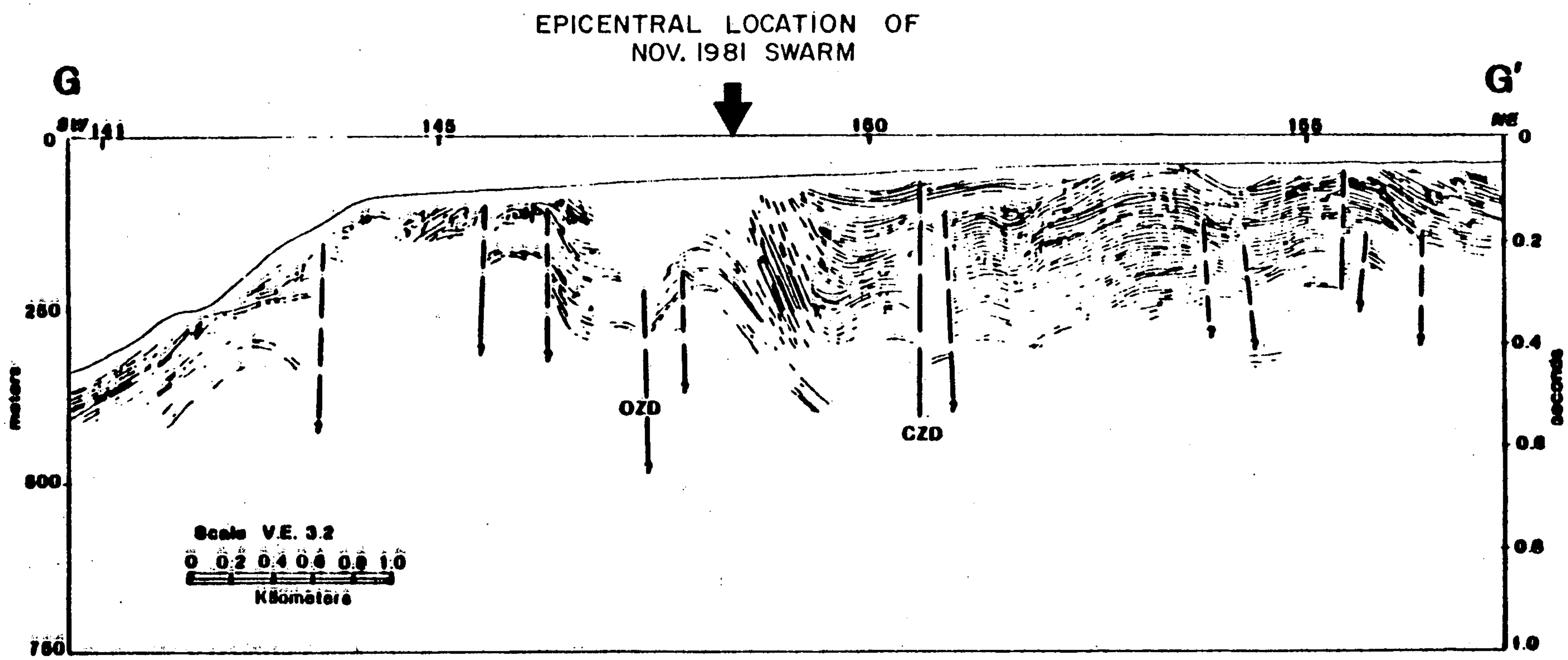


Figure 13.3--Epicenter location of the November 1981 swarm projected onto the reflection profile G-G' of Greene and Kennedy. The arrow indicates the epicenter of the largest event (M_L=3) discussed in the response to question 1. The swarm clusters around this location with a radius of about 1 km.