Public-data File 86-85

A COMPARISON OF ACCELERATION VALUES DERIVED FROM RECENT SEISMIC HAZARD STUDIES OF THE ANCHORAGE AREA, ALASKA: PART I

By

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September 1986

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TABLE OF CONTENTS

Table of Contents	i
Text	
Introduction	1
Overview of Seismic Hazard Evaluations	2
Characteristics of Seismic Sources	6
Estimating Recurrence Rates	12
Attenuation Relationships	15
Exposure Estimates	17
Discussion	18
Conclusions	20
Acknowledgements	23
References	24
Tables	26
Figures	27

A Comparison of Acceleration Values Derived From Recent Seismic Hazard Studies of the Anchorage Area, Alaska

Lorraine W. Wolf and John N. Davies

Introduction

In recent years, several major seismic hazards studies have been done on Alaska. Of most concern is the southcentral area, particularly Anchorage, since it hosts more than half the state's population. Evaluations of seismic risk affect political and economic decisions made by private industry and government and therefore merit careful attention. We chose to look at a few key studies for the Anchorage area made by various consulting firms and organizations to compare not only the values of expected acceleration but also the major parameters and assumptions which determine the final acceleration values.

The major studies included in our review are the Offshore Alaska Seismic Exposure Study (OASES; Woodward-Clyde, 1978), the Outer Continental Shelf Environmental Assessment Program (OCSEAP; Woodward-Clyde, 1982), Anchorage Office Complex Geotechnical Investigation (Woodward-Clyde,

1982) and the Geological and Geotechnical Considerations for the Knik Arm Crossing, Anchorage (Harding-Lawson, 1984). Other investigations, such as those by Thenhaus (U.S. Geological Survey, 1985), Woodward-Clyde (Susitna Hydroelectric Project, 1982) and the Applied Tech Study (ATC-03, 1978 have been omitted primarily because we lacked complete reports with detailed information on the assumptions, relationships and specific parameters used.

Although complete reports were available for the studies reviewed in our investigation, extracting the actual values used as input into the calculations as well as information on the relationships used and assumptions made was difficult. Individual reports vary substantially with respect to study area and period of interest; results are nonstandardized and therefore difficult to compare. The two main objectives of our investigation were 1) to examine in detail some of the major seismic hazards studies done on the Anchorage area and 2) to standardize the input and the results in such a way that conclusions could be compared.

Overview of Seismic Hazard Evaluations

The basic approach to evaluating seismic hazard involves a well-established 4-step procedure: 1) characterizing seismic sources, 2) estimating recurrence, 3) establishing attenuation relationships and 4) computing the acceleration expected at a specific site (using 1 through 3) during a given period of interest at a specified probability of exceedance.

Characterizing the seismic sources in a particular area of interest involves defining the locations and geometries of the various source zones. These sources can be active faults or tectonic provinces. In our review, we restricted our attention to four sources for comparison: the Castle Mountain Fault, the Border Ranges Fault, the Main Thrust (Interplate or Megathrust) Zone and the Wadati-Benioff (Intraplate) Zone. Each of these constitutes a seismic hazard to the Anchorage area, our particular site of interest. We examined each of the reports to determine how these particular sources were treated. Boundary conditions and fault-length vs. maximum magnitude relationships varied, affecting the maximum magnitudes associated with the sources as well as recurrence estimates.

Estimating the rate of recurrence of earthquakes for a particular source is difficult in Alaska because of the short historical data base. Recorded seismicity alone is generally inadequate for estimating recurrence. Thus reports incorporate geologic information and professional opinion in an attempt to represent earthquake occurrence more accurately. Most studies use a Poisson model to describe earthquake occurrence and a Gutenberg and Richter characterization of the recurrence rate of earthquakes of different magnitudes. The OCSEAP study incorporates a semi-Markov occurrence model for higher magnitudes ($Ms \geq 7.8$). The semi-Markov procedure reflects the assumption that earthquakes involve a gradual accumulation of strain energy which is periodically released. The probability of occurrence for an earthquake characteristic of a particular source is, therefore, not random, but depends upon the time since the last event. Even though the semi-Markov model is particularly applicable to seismic gap environments, we compared reports only on the basis of a Poisson occurrence model.

Each report was examined to determine recurrence rates for earthquakes on individual sources, and where possible, to ascertain the method used to establish these rates. Recurrence rates are presented in Table 1 using the Gutenberg and Richter relation (Richter, 1954:

$$\text{Log } N = A + bMs \quad (1)$$

where N is the cumulative number of earthquakes greater than or equal to a specific magnitude, Ms, per unit time per unit area; *b* is the rate of change of frequency of occurrence with respect to magnitude; and *A* is the y intercept at Ms = 0.

Attenuation relationships presented in the reports were similar, but some reports lacked information as to the actual values used for coefficients. The relationships used in the various studies were recast into the following standardized format (Table 2):

$$a(M,R) = ((b_1 \exp(b_2 M))/ (R+b_3)^{b_4} \quad (2)$$
$$b_3 = C_1 \exp(C_2 M).$$

where *a* , the median horizontal ground acceleration, is a function of magnitude, *m*, and closest distance to rupture, *R*.

Until recently, attenuation relationships based on strong ground motion data from Alaska were not available. Existing reports, therefore, made use of attenuation relationships developed for other areas such as the western U.S. (Joyner and Boore, 1981). Jacob and Mori (1984) concluded that the variance in accelerations for Alaskan earthquakes is the key difference between the limited Alaskan strong motion data set and that of the western U.S. That is, the range of possible peak accelerations at a given distance from an earthquake of specified magnitude is larger for Alaska. Attenuation curves for the Alaskan data set are also flatter than those for the western United States yielding higher peak accelerations at distances >50 km and lower values at shorter distances. Jacob and Mori conclude that attenuation in Alaskan subduction zone environments is not as strong as that in western tectonic provinces and therefore modified attenuation relationships are needed. The implication for seismic hazard analysis in Alaska is that existing relationships for peak horizontal ground accelerations as a function of distance and magnitude may yield estimates of acceleration that are too low, especially if mean values are used.

Finally, values from each report for expected peak horizontal ground accelerations were normalized to a 10% probability of exceedence and a 50-year period of interest for comparison (Table 3). Interest periods for the reports looked at in our study vary from 40 to 50 years, but other studies use periods of up to 100 years (e.g. Woodward Clyde: Susitna Hydroelectric Project).

Characterization of Seismic Sources

The hazard analyses examined in our report vary substantially in their scope and purpose, making it difficult to compare seismic sources. Contributions from a given source or segment of a source may be significant in one analysis and not another. The OCSEAP report is an application of the Woodward-Clyde computer software package, SEISMIC.EXPOSURE, to the Gulf of Alaska region, whereas both the Woodward-Clyde Anchorage Office study and the Harding-Lawson Knik Arm Crossing report focus on engineering and siting considerations for the Anchorage area only. The purpose of the OASES report was to look at nine areas expected to be offered for lease for offshore petroleum exploration and development: Lower Cook Inlet, Kodiak, the Aleutians, the Gulf of Alaska, Bristol Bay, St. George Basin, Norton Basin, Hope Basin and Beaufort Basin. For comparison purposes, we used the Lower Cook Inlet area.

Limiting our investigation to the four seismic sources mentioned earlier, we compared the approaches used in the reports to represent each seismic zone. Seismic sources can be represented as points, lines or planes. The geometry chosen can affect estimates of the transmission path and maximum magnitude associated with the source and therefore may be significant in influencing final exposure estimates. Point sources are easiest to work with but their use tends to result in longer transmission paths (for sites not located close to the source) and possibly lower ground motion values. Use of planar sources distributes seismicity over a larger region, usually resulting in shorter transmission paths to sites and higher ground motion values. Although area sources are more cumbersome in terms of programming, they more closely represent actual source zone geometry.

Castle Mountain Fault. The Castle Mountain Fault is a northeast-southwesterly trending structure located north of Cook Inlet (Fig. 1). Its estimated length is 475 km and, at its closest approach, lies 40 km northwest from Anchorage. Defined as a right-lateral strike slip fault (Detterman and others, 1974, 1976), it shows evidence of Holocene displacement along 80 km of the Susitna segment. At the time of the reports under review, no seismicity had been clearly associated with the Castle Mountain Fault. Recently, however, Lahr and others (1984) showed the 14 August 1984 earthquake to be a right-lateral strike-slip event occurring to the east of the Susitna segment, with aftershocks parallel to the inferred fault plane.

The OCSEAP report models the Castle Mountain Fault as a line source approximately 265 km in length at a 5-km depth. Both the OASES and Anchorage Office studies model the fault as a nearly vertical plane, the former to a depth of 65 km and the latter to a depth of 20 km. The Knik Crossing report (though not explicitly) appears to model the fault as a line source. Although the fault is represented as a plane in source geometry inputs for some reports, all but OASES treat the Castle Mountain Fault as a line in recurrence relationships. Exactly how seismicity is associated with a particular source and projected to a representative line or plane is not clearly presented in any of the reports. Fault-length vs. maximum magnitude relationships used in all reports yield maximum magnitudes of 7.5 Ms for the Castle Mountain Fault. The specific relationship used varies from report to report, some based on only the length of the fault and others on both the length and width.

Border Ranges Fault. The Border Ranges Fault has been mapped as a northward-dipping reverse fault by MacKevett and Plafker (1974) (Fig. 1). It trends northeasterly along the Kenai Penninsula to the northern front of the Chugach Mountains, where it continues in an easterly direction to the St. Elias Mountains. Its estimated length is 1000 km, and at its closest approach, passes through southeast Anchorage. No displacement of Quaternary sediments along the fault trace nor any clear association between microseismicity and the fault have been clearly established (Woodward-Clyde Consultants, 1981), although there is some evidence for motion within the last 4,000 years on the Twin Peaks segment about 60 km to the east of Anchorage (R. Updike, personal communication, 1985).

The OCSEAP report does not include the Border Ranges Fault as a source in their Gulf of Alaska study. The OASES study models the fault as a dipping plane for both source geometry and recurrence. In the Knik Crossing report, the Border Ranges Fault is modelled as a line source. The length of the fault used for constructing the source geometry and for recurrence relationships is not specified in the text. The Anchorage Office study models the fault as a dipping plane and considers two cases, one in which the entire fault length is active (approximately 1000 km) and the other in which only the Twin Peaks segment is active (approximately 20 km). In both cases, the fault is carried to a 20-km depth.

Main Thrust (Interplate or Megathrust) Zone. The main thrust segment of the subduction zone is characterized by the periodic occurrence of great earthquakes. This shallow region of the plate interface extends inland from the Aleutian Trench to approximately 30 km northwest from Anchorage (Fig. 2). The OCSEAP report extends the main thrust zone far east and west beyond our area of concern: the total area attributed to this source in their report extends from Unimak Pass to Sitka. According to the coordinates used as input into the OCSEAP program, the main thrust zone is modelled as a dipping plane beginning at a depth of 20 km and extending to 40 km. The OASES study for the Lower Cook Inlet area divides the subduction zone into three segments: shallow, intermediate and deep. The main thrust zone would correspond to a combination of the shallow and part of the intermediate segments, an area extending from the Trench to Anchorage. Although subdivided differently, the OASES model provides the basic source geometry used in all the reports. Neither the Anchorage Office nor the Knik Crossing reports state the actual coordinates used to define the main thrust zone; however, both reference the OASES study in their source location map.

Wadati-Benioff (Intraplate) Zone. The Wadati-Benioff Zone is defined as the steeply dipping region of the subducting plate which is characterized by deep ($\geq$ 50 km) earthquakes of moderate magnitudes (Fig. 2). The OCSEAP study models the Wadati-Benioff Zone as a dipping plane striking northeasterly from the Lower Cook Inlet to about 50 km northeast of Anchorage. The deep zone is estimated to be approximately 50 km wide in plan view and is represented by a northwest-dipping plane starting at a depth of 63 km and continuing to 90 km. The OASES study models the Wadati-Benioff Zone at the same depths with similar dimensions. The Anchorage Office report models the zone as a series of parallel vertical faults extending through the upper portion of the subducted plate. The actual coordinates used as input are not given in the text, but the average width of the zone, transition area not included, is about 100 km. The Knik Crossing report does not give the coordinates used to describe the Wadati-Benioff Zone; however, it appears its width is similar to that used in the OASES and OCSEAP reports.

Estimating Recurrence Rates

Evaluating earthquake recurrence rates involves establishing a model for the rate of occurrence and for the distribution of earthquake magnitudes. The Poisson model is commonly used to describe earthquake occurrence. It involves two major assumptions: 1) earthquakes are independent events and 2) earthquakes occur randomly in space and time. The Poisson relationship can be written as

$$P_n(t) = (\exp(-\lambda t)\ (\lambda t)^n)\ /n! \qquad t=\geq 0$$
$$n \text{ any integer} \geq 0$$

where $P_n(t)$ is the probability of having n events in time t (Devore, 1982). Although a Poisson model works reasonably well to describe the occurrence of most earthquakes, it does not satisfactorily represent the short term potential for large events occurring in seismic gap environments. To better represent occurrence of earthquakes in these environments, OCSEAP uses a semi-Markov model which carries a time dependence, as discussed earlier.

Empirical information on earthquake recurrence is expressed directly using the Gutenberg and Richter relationship (Eqn. 1). Upper and lower magnitude limits are assigned to each source. When possible, coefficients are derived from historic seismicity data. When historic data are not sufficient for establishing A- and b-values, a subjective evaluation is usually made.

Probabilities of occurrence for specified magnitude ranges are assigned using a Bernoulli or similar model. Given that an event has occurred, the Bernoulli model estimates directly the number of events in each magnitude range. This approach thus assigns a probability of occurrence for a specified magnitude independently of other magnitudes (OASES, 1978).

The various models for occurrence and magnitude distribution are combined to generate a probability distribution of the number of earthquakes of different magnitudes on a given source. Procedures used for estimating earthquake recurrence are outlined fairly well in the OCSEAP and OASES reports. Other reports are not as clear as to the procedures followed or methods used.

Recurrence Parameters. Most reports reviewed assume a Poisson process for representing earthquake occurrence. OCSEAP modifies the Poisson model by introducing a time dependence when calculating the number of earthquakes associated with a particular source. It is unclear whether other reports assume a purely random process or use a modified model. Coefficients for the Gutenberg and Richter relationship, along with upper and lower magnitude limits, are listed in Table 1 for each report. Both OCSEAP and OASES determine the coefficients from historic data and subjective input. It is unclear exactly how coefficients in the Anchorage Office report are determined. The report makes reference to a table of input values for recurrence parameters; however, no such listing is included and appears to be unavailable. Recurrence relationships in the Knik Crossing report are based on 1) historic seismicity within 120 km of Anchorage, 2) seismicity as evaluated for the Gulf of Alaska (OCSEAP) and 3) maximum magnitude and activity rates of individual sources.

Recurrence curves from the reports are presented in standardized form in Figs. 3 a-d. Since the OASES study treats the Castle Mountain and Border Ranges faults as area sources rather than as line sources, a direct comparison with other recurrence curves is not appropriate. Therefore, we converted the OASES curves for these two sources to ones based on a line source by projecting seismicity occurring on a plane to a line. The Knik Crossing report lists the A- and b-values used in that study; however, the values used in other reports are scaled from recurrence curves and are therefore subject to error.

Attenuation Relationships

Attenuation of seismic energy is affected by source conditions, transmission paths and site conditions. Both source and site conditions influence the level and frequency content of seismic energy, while transmission paths determine path length between source and site and the rate of amplitude decay (OASES, 1978). The attenuation model developed in the OASES study defines relationships for two types of sites (rock and stiff) and two types of transmission paths (shallow, $h < 20$ km, and deep, $h > 20$ km). The OASES report incorporates a site classification developed by Seed and others (1976) which defines rock sites as "shale-like or sounder with shear wave velocities > 762 m/s" and stiff sites as "less than 46 m of stiff clay, sand or gravel over rock." These definitions appear to be used in all other reports and are important because of the influence of site conditions on acceleration and velocity predictions. For distances greater than 30 km, maximum horizontal peak ground accelerations are found to be slightly higher for stiff as compared with rock sites, and maximum velocities are found to be significantly higher for stiff as compared with rock sites (OASES, 1978). Values for coefficients used in the reports usually correspond to stiff sites and when explicitly stated, are listed as such in Table 2. Since attenuation is a function of both earthquake magnitude and distance from source, attenuation curves are shown for Ms 5.0 and 7.5. Figures 4 a,b,c,d compare attenuation curves for the reports reviewed as well as curves developed for the Susitna Hydroelectric Project study (Woodward Clyde) and for the western United States (Joyner and Boore, 1981). The OCSEAP study bases their attenuation model on that developed in the OASES report; they use the same attenuation relationship for type A (shallow) transmission paths. A modified relationship, however, is used in OCSEAP for type B paths (deep). Curves for type B paths in OASES and OCSEAP are similar for distances greater than 40 km but diverge for closer distances. Distances used in all reports are defined as the closest distance to the rupture surface. The Anchorage

Office and Knik Crossing report use an attenuation relationship which incorporates strong motion data from the 1979 Imperial Valley, CA, earthquake and from Japan. The site conditions in the Imperial Valley are said to be similar to those in the Anchorage area (Woodward Clyde, 1982). The Anchorage Office and the Knik Crossing reports use only one relationship, making no distinction for transmission paths. The relationships given in the reports are listed in Table 2.

Exposure Estimates

Seismic exposure evaluations are based on three principal elements: characterization of the energy source, transmission of energy and exposure calculations. Final exposure estimates based on the total contribution from all sources in the area are compared for the various reports in Table 3. Also included are estimates from major studies not reveiwed in our analysis. Values for peak horizontal ground acceleration are normalized to a 50-year period of interest and a 10% probability of exceedence. Table 3 also indicates whether a shallow source zone was included in a particular analysis and whether more than one attenuation relationship was used. From the comparison, we note that the U.S.G.S.

study (Thenhaus and others, 1985) predicts the highest acceleration values (480 cm/s/s), while the Anchorage Office study gives the lowest values (147 cm/s/s).

Discussion

Significant variation in peak horizontal ground accelerations exists even among reports from the same consultant. For instance, Woodward Clyde predicts one of the highest accelerations (372 cm/s/s) in their Susitna Dam study (adjusted to Anchorage) and one of the lowest accelerations (147 cm/s/s) in their Anchorage Office study. The key question thus concerns the sensitivity of the final exposure estimates to the individual parameters used in the analysis.

Seismicity in the Anchorage area is clearly dominated by subduction zone sources whose geometry is fairly obvious. Therefore characterizing and defining source zones does not pose a significant problem for this area. Although variations exist in the characterization of individual sources, final exposure estimates do not appear to be particularly sensitive to these differences. For instance, at first glance there seems to be a correlation between acceleration values and the inclusion of a shallow source zone into the exposure calculations: the higher values are associated with reports which include a shallow source zone, whereas lower values are associated with those that do not. However, in their sensitivity analysis, the OASES report concludes that a random source zone does not make a significant difference in final exposure estimates. Furthermore, we note that although the OCSEAP report excludes the Border Ranges Fault as a significant source of seismicity, acceleration values listed in their study are significantly higher than those of the Anchorage Office report, which considers the fault as the second largest contributing source for the area. Therefore, final exposure estimates do not appear to be extremely sensitive to source characterization.

The element of the exposure model which poses the most uncertainty is energy transmission. Final exposure estimates, as seen in Table 3, appear to be most influenced by attenuation relationships. Figure 4d illustrates some significant differences among attenuation relationships by comparing curves for OASES types A and B with the Joyner-Boore curves for the western United States. As is seen from Figure 4d, use of transmission path Type A (shallow source) alone yields acceleration estimates which are quite low in comparison with those from Type B (deep source). As noted earlier, both the Anchorage Office and the Knik Crossing reports use only one attenuation relationship for all depths. Figures 4b and 4c compare values for acceleration versus distance for Ms = 7.5 curves from various reports. The four studies in our review present similar curves for attenuation from shallow sources but significantly different curves for attenuation from deeper sources. Therefore the variation in final acceleration values seen in Table 3 is most likely the result of differences in the treatment of energy transmission from source to site, particularly in the choice of attenuation relationship.

Conclusions

Major seismic hazards analyses for the Anchorage area show significant variation in final exposure estimates. Our comparative review of these reports yield the following conclusions as to the assumptions made and the parameters used in the individual studies:

1) There is a lack of consistency among the reports with respect to source dimensions, geometry and estimates of maximum magnitude.

2) All reports use essentially a Poisson model as a basis for estimating the occurrence rate for earthquakes larger than a specified magnitude threshold. Models for describing the distribution of magnitudes differ and are not explicitly described in every report. Differing values for final recurrence estimates from study to study result primarily from subjective input and are particularly pronounced for higher magnitudes in the main thrust Zone.

3) Attenuation relationships appear to have the most significant influence on final exposure values, thus emphasizing the importance of choosing suitable relationships and coefficients for them. These choices are site specific and the current lack of data on which to base these decisions poses a significant problem for hazards assessment in Alaska. The use of two types of attenuation relationships, which distinguish between energy from shallow and deep events, yields somewhat higher peak horizontal ground acceleration values and may be more appropriate for hazards evaluations.

From the work completed thus far, it is not clear, quantitatively, to what extent variation in values for input parameters influences final exposure estimates. To address this question, we propose in Part II to standardize information presented in the reports reviewed into an appropriate format for input into the OCSEAP program, SEISMIC.EXPOSURE. By using these standardized values in a single exposure program, we hope to more clearly assess the sensitivity of the final exposure estimates to individual parameters and assumptions.

ACKNOWLEDGEMENTS

Lorraine W. Wolf and John N. Davies are cuurently affilliated with the Geophysical Institute, University of Alaska, Fairbanks, Alaska. Support for this study came primarily from the Alaska Division of Geological and Geophysical Surveys. The authors wish to thank Hans Pulpan and Cole Sonafrank, both at the Geophysical Institute, for their invaluable assistance.

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TABLE CAPTIONS

Table 1.	Comparison of A- and b-values and maximum magnitudes used in reports reveiwed.
Table 2.	Comparison of coefficients used in attenuation relationships.
Table 3.	Comparison of normalized acceleration estimates for the Anchorage area.

T. 1

TABLE OF ATTENUATION RELATIONSHIPS

GENERAL RELATIONSHIP:

$$A_{(med)} = ((b_1 \exp(b_2 M)) / (R + b_3)^{b_4}$$

$$b_3 = c_1 \exp(c_2 M) \quad cm/s/s$$

where R is the closest distance to rupture

	b_1	b_2	b_4	c_1	c_2
OCSEAP:					
type A (stiff sites): depth < 6 km	191.0	0.823	1.560	0.864	0.463
type B (stiff sites): depth > 6 km	210.0	0.500	0.850	0.864	0.463
OASES:					
type A (stiff sites): depth < 20 km	191.0	0.823	1.560	0.864	0.463
type B (stiff sites): depth > 20 km	284.0	0.587	1.050	0.864	0.463
ANCHORAGE OFFICE:	80.14	1.100	1.750	0.316	0.629
KNIK CROSSING:	80.14	1.100	1.750	0.316	0.629
SUSITNA HYDROELECTRIC PROJECT:					
type A: ($M_S \le 6.0$)	173.7	1.240	2.100	0.853	0.500
($M_S > 6.0$)	403.5	1.100	2.100	0.853	0.500
type B:	278.0	0.587	1.050	0.853	0.600

TABLE OF A AND B VALUES AND MAXIMUM MAGNITUDES

	A(Ms-5.0)	B	MAX MAG
CASTLE MTN FAULT			
OCSEAP	2.6	0.76 5<Ms<6.5	7.5 Ms
OASES	0.7	0.4	7.25 Ms
W-C ANCH OFFICE	4.2	0.9	7.5 Ms
KNIK CROSSING	3.3	0.76	7.5 Ms
BORDER RANGES FAULT			
OCSEAP	--	--	
OASES	1.4	0.7	6.75 Ms
W-C ANCH OFFICE	3.9	0.9	7.5 Ms
KNIK CROSSING	3.0	0.76	7.5 Ms
MAIN THRUST (INTERPLATE)			
OCSEAP	2.0	0.8 3<Ms<7 3.0 7<Ms<7.8	8.9 Mw
OASES	2.0	0.8 3<Ms<7 3.0 7<Ms<7.8	8.25 Ms
W-C ANCH OFFICE	1.8	0.7	8.6, 9.5 Ms (2 cases)
KNIK CROSSING	2.0	0.8	9.5 Ms
WADATI-BENIOFF (INTRAPLATE)			
OCSEAP	0.6	0.5 3<Ms<7 6.0 7<Ms<7.5	7.5 Ms
OASES	0.6	0.5 5<Ms<7 3.3 7<Ms<7.8	6.5 Ms 7.5 Ms
W-C ANCH OFFICE	3.1	0.9	7.5 Ms
KNIK CROSSING	0.8	0.6	7.5 Ms

NOTE: A AND B VALUES FOR KNIK CROSSING ARE GIVEN; A AND B VALUES LISTED FOR OTHER REPORTS ARE ESTIMATED FROM RECURRENCE CURVES. CURVES ARE NORMALIZED TO THE CUMMULATIVE NUMBER OF EVENTS PER YEAR PER 1000KM (LINE SOURCES) OR PER $1000KM^2$ (AREA SOURCES), m>M.

T-2

TABLE 3

STUDY	ACCELERATION (CM/SEC/SEC)	EXCEEDENCE PROBABILITY	PERIOD (YR)	SHALLOW ZONE?
Anch. Office Bldg Woodward-Clyde	147-274	10%	50	No
Knik Crossing Harding-Lawson	274	10%	50	No
OASES Woodward-Clyde	323 (353)[1]	10%	40 (50)[1]	Yes
OCSEAP Woodward-Clyde	323 (382)[1]	10%	40 (50)[1]	Yes
ATC-03 Applied Tech. Council	353	(10%)[2]	(50)[2]	(Yes)[2]
USGS Thenhaus <u>et al</u>.(1985)	480	10%	50	Yes
Susitna Dam Woodward-Clyde	402 (372)[3]	10%	100 (50)[1]	Yes

<u>Notes:</u>

1. Normalized to 50 year periods of interest using

$$a_1 / a_2 = (T_1 / T_2)^{.43}$$

2. These values only true in that ATC-03 followed Algermissen <u>et al</u>.(1976).

3. Normalized as in 1 for period of interest and adjusted to Anchorage using Figure 6 in Thenhaus <u>et al</u>.(1985).

FIGURE CAPTIONS

Figure 1. Location of line sources in the Anchorage vicinity.

Figure 2. Cross section showing location of subduction zone sources.

Figure 3.

a) Recurrence estimates for the Castle Mountain Fault.

b) Recurrence estimates for the Border Ranges Fault.

c) Recurrence estimates for the Main Thrust (Interplate) Zone.

d) Recurrence estimates for the Wadati-Benioff (Intraplate) Zone.

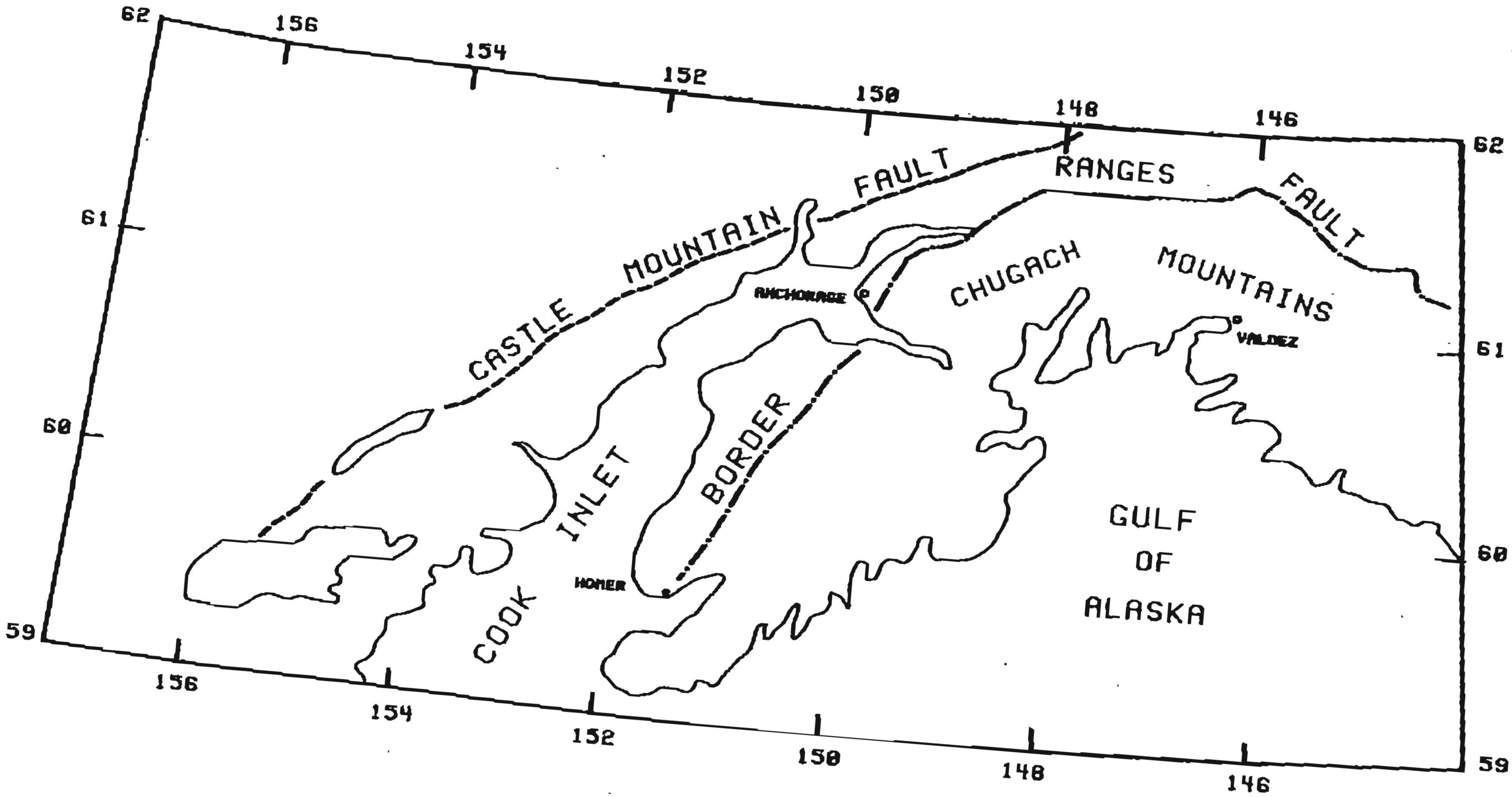
Figure 4.

a) Attenuation Curves (Type A relationships) for magnitude 5.5 events. Median acceleration values are used.

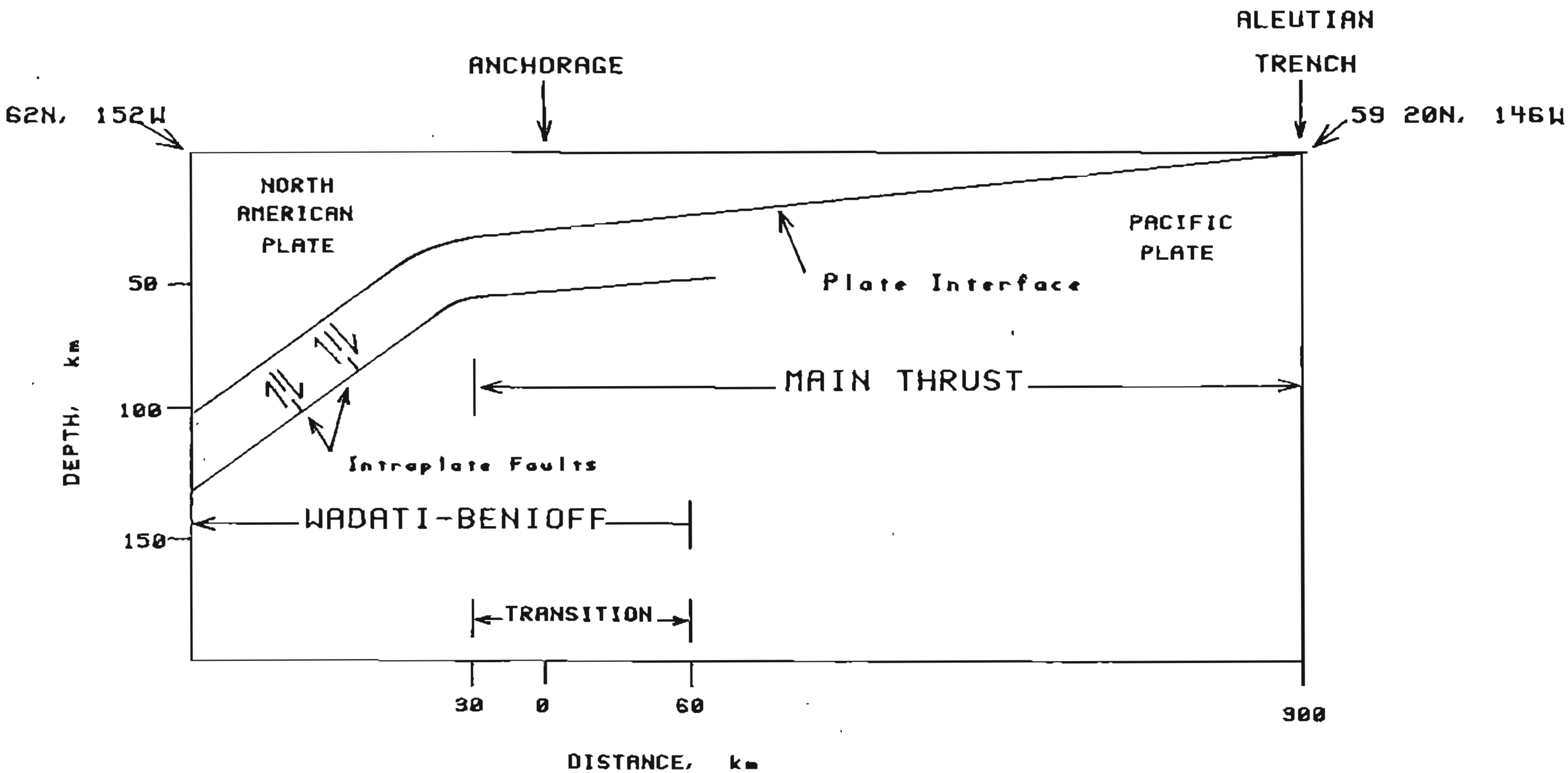
b) Attenuation curves (Type A relationships) for magnitude 7.5 events. Median acceleration values are used.

c) Attenuation curves (Type B relationships) for magnitude 7.5 events. Median acceleration values are used.

d) Comparison of type A and B attenuation curves with Joyner and Boore curve for magnitude 7.5 events.

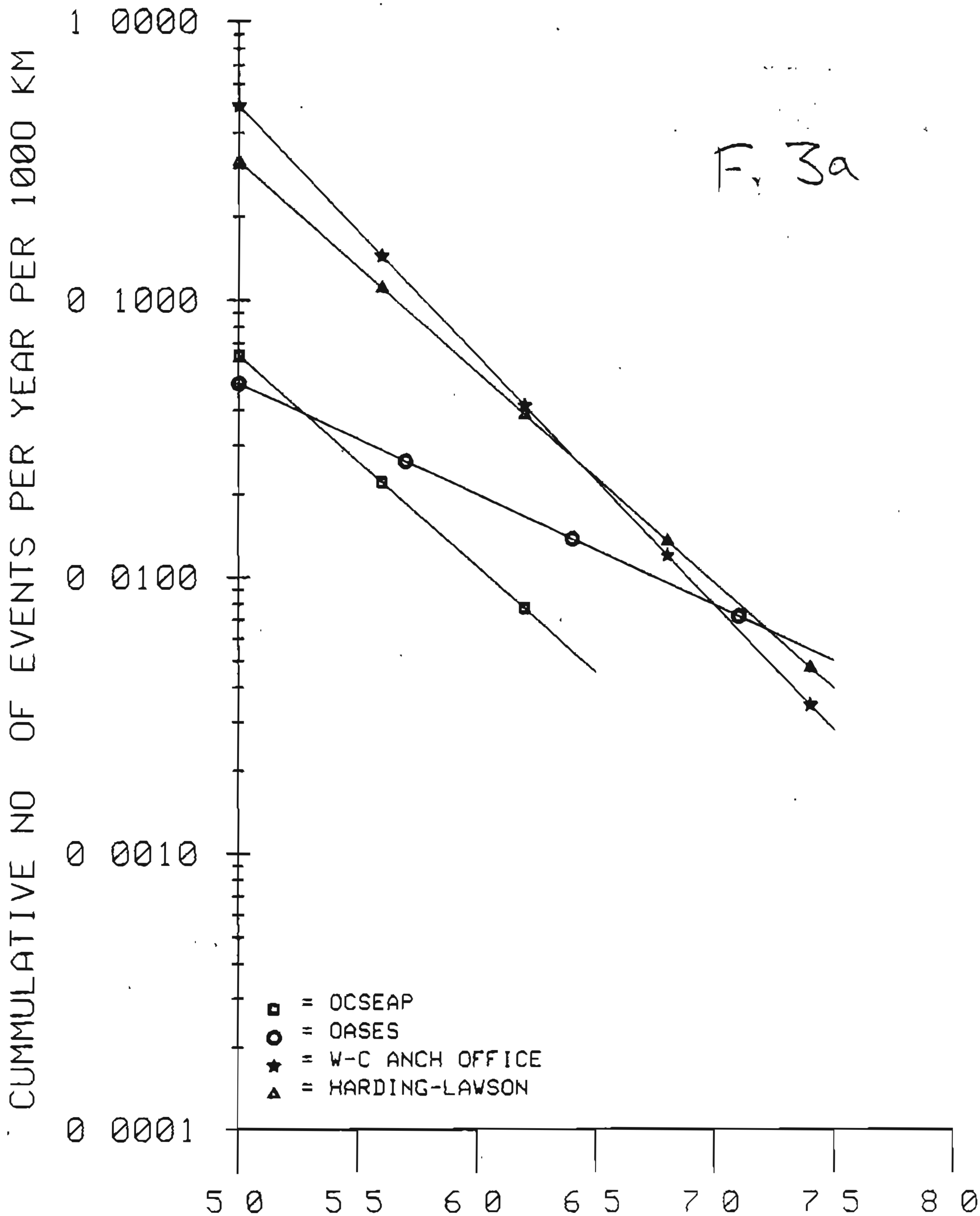

CASTLE MOUNTAIN FAULT
BORDER RANGES FAULT
CHUGACH MOUNTAINS
ANCHORAGE
VALDEZ
HOMER
COOK INLET
GULF OF ALASKA
62
61
60
59
156
154
152
150
148
146

F 1


ALEUTIAN TRENCH
ANCHORAGE
62N, 152W
59 20N, 146W
NORTH AMERICAN PLATE
PACIFIC PLATE
Plate Interface
MAIN THRUST
Intraplate Faults
WADATI-BENIOFF
TRANSITION
DEPTH, km
50
100
150
30
0
60
900
DISTANCE, km

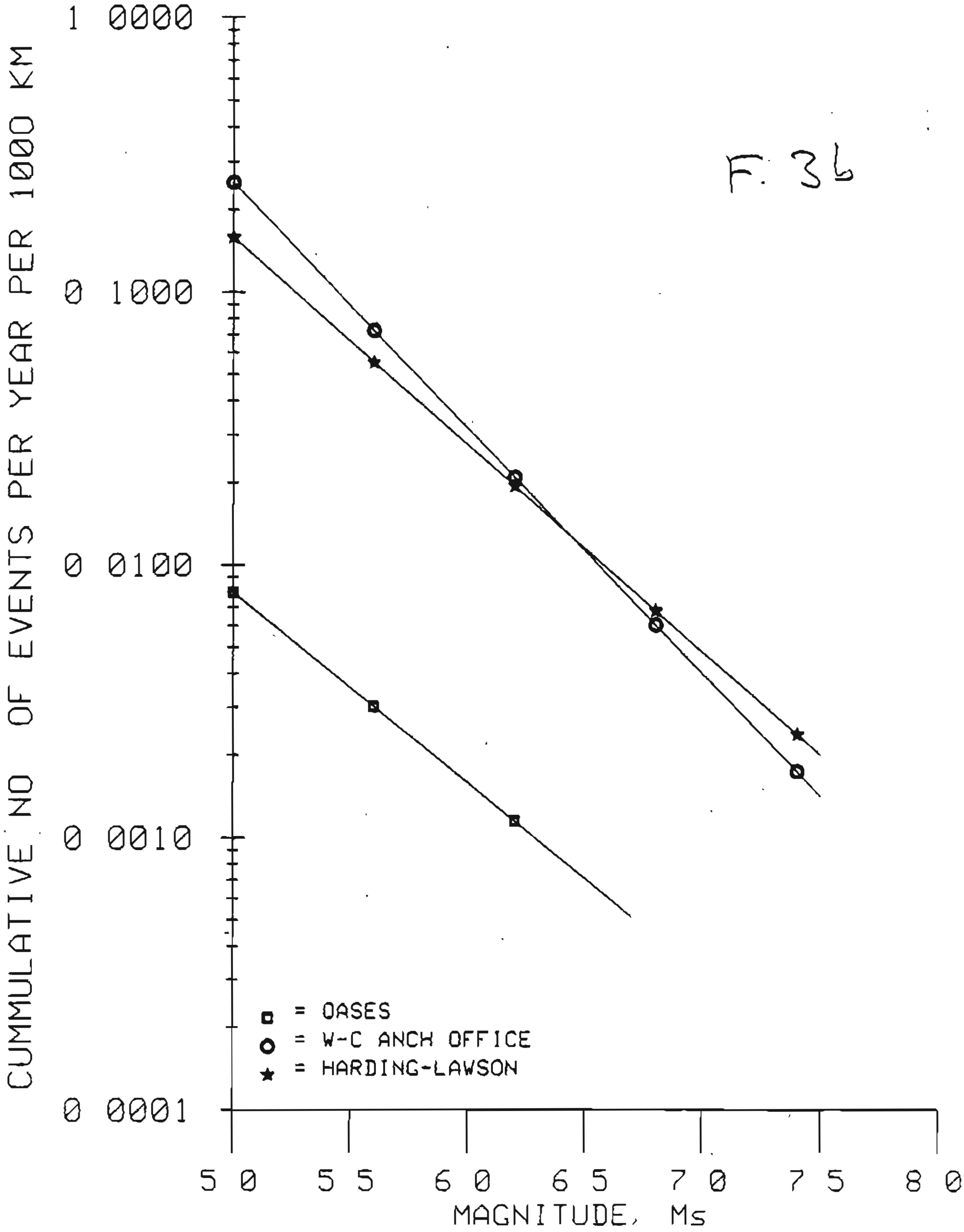
F. 2

CASTLE MOUNTAIN FAULT RECURRENCE ESTIMATES

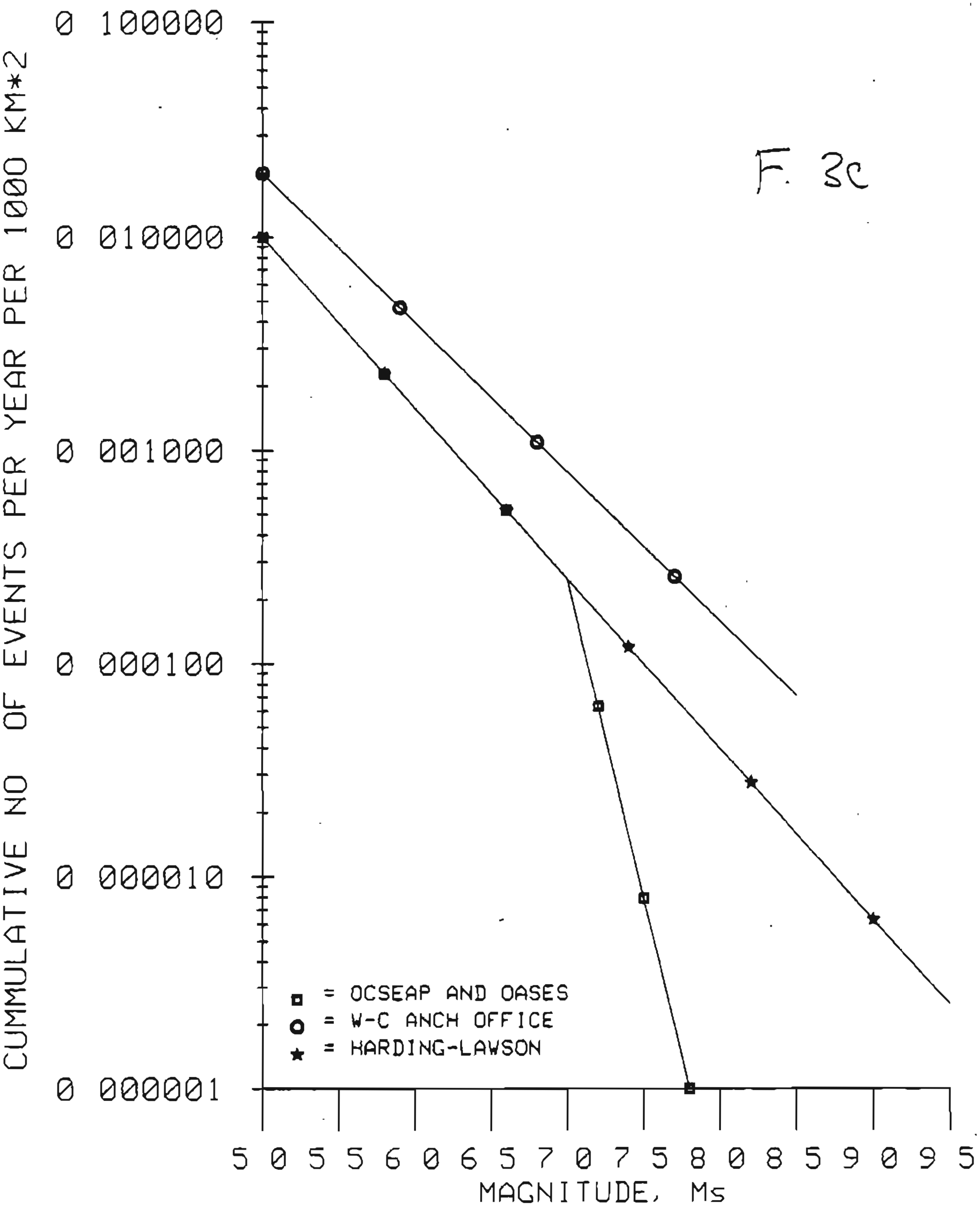


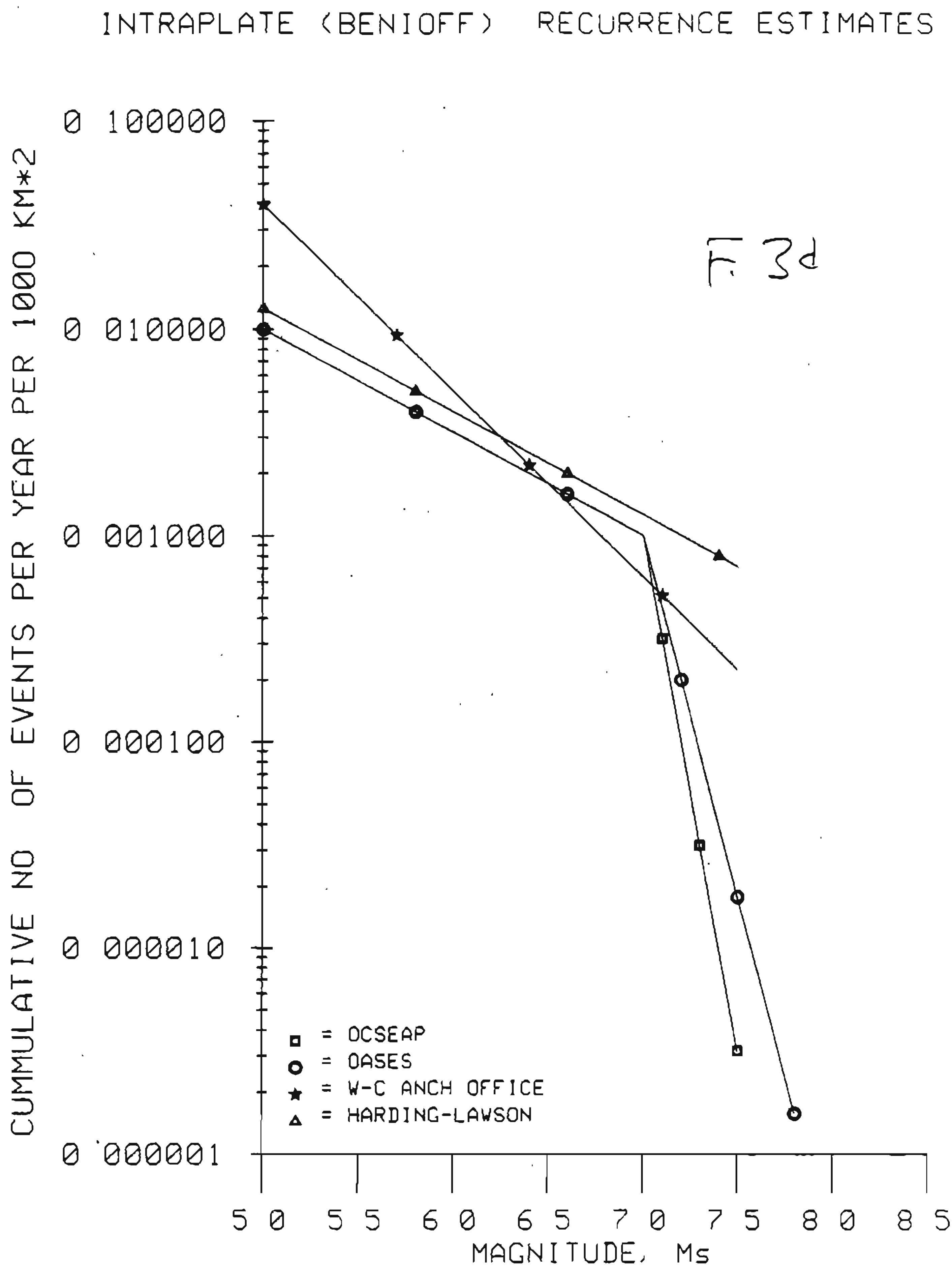
BORDER RANGES FAULT RECURRENCE ESTIMATES

F. 36



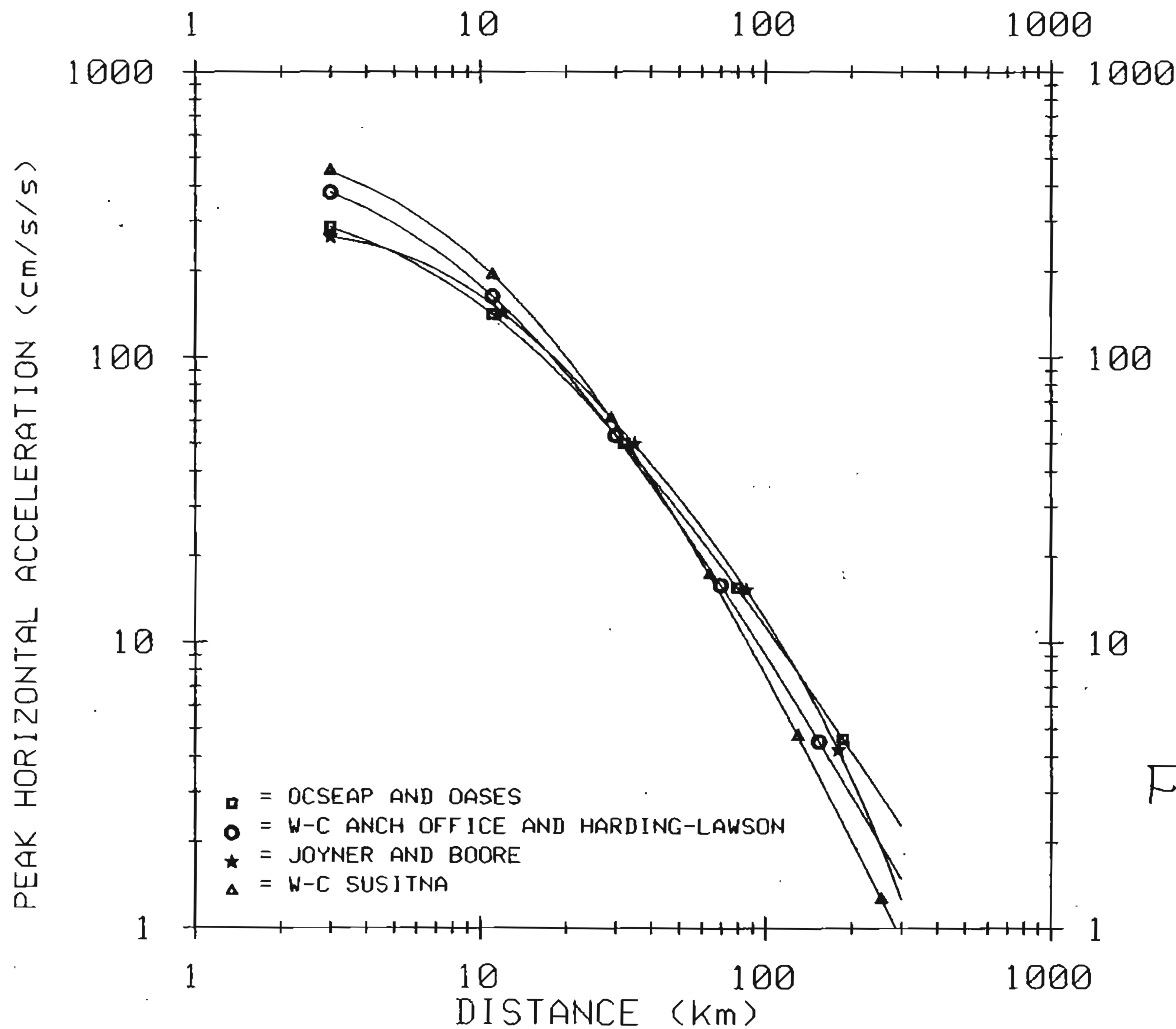
INTERPLATE (MAINTHRUST) RECURRENCE ESTIMATES





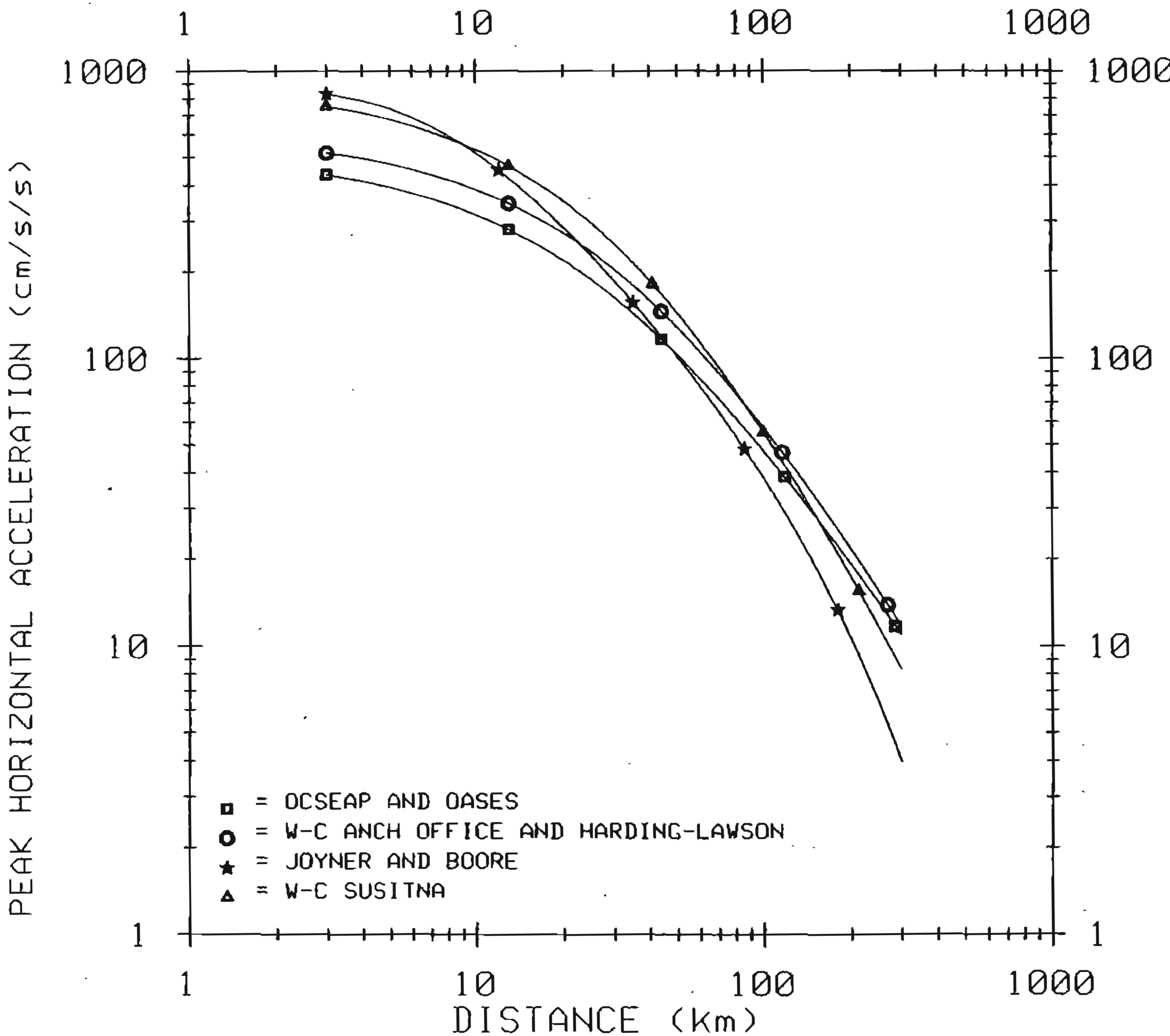
INTRAPLATE (BENIOFF) RECURRENCE ESTIMATES
F. 3d
0 100000
0 010000
0 001000
0 000100
0 000010
0 000001
CUMMULATIVE NO OF EVENTS PER YEAR PER 1000 KM*2
= OCSEAP
= OASES
= W-C ANCH OFFICE
= HARDING-LAWSON
5 0
5 5
6 0
6 5
7 0
7 5
8 0
8 5
MAGNITUDE, Ms

ATTENUATION CURVES FOR Ms = 5 5 TYPE A

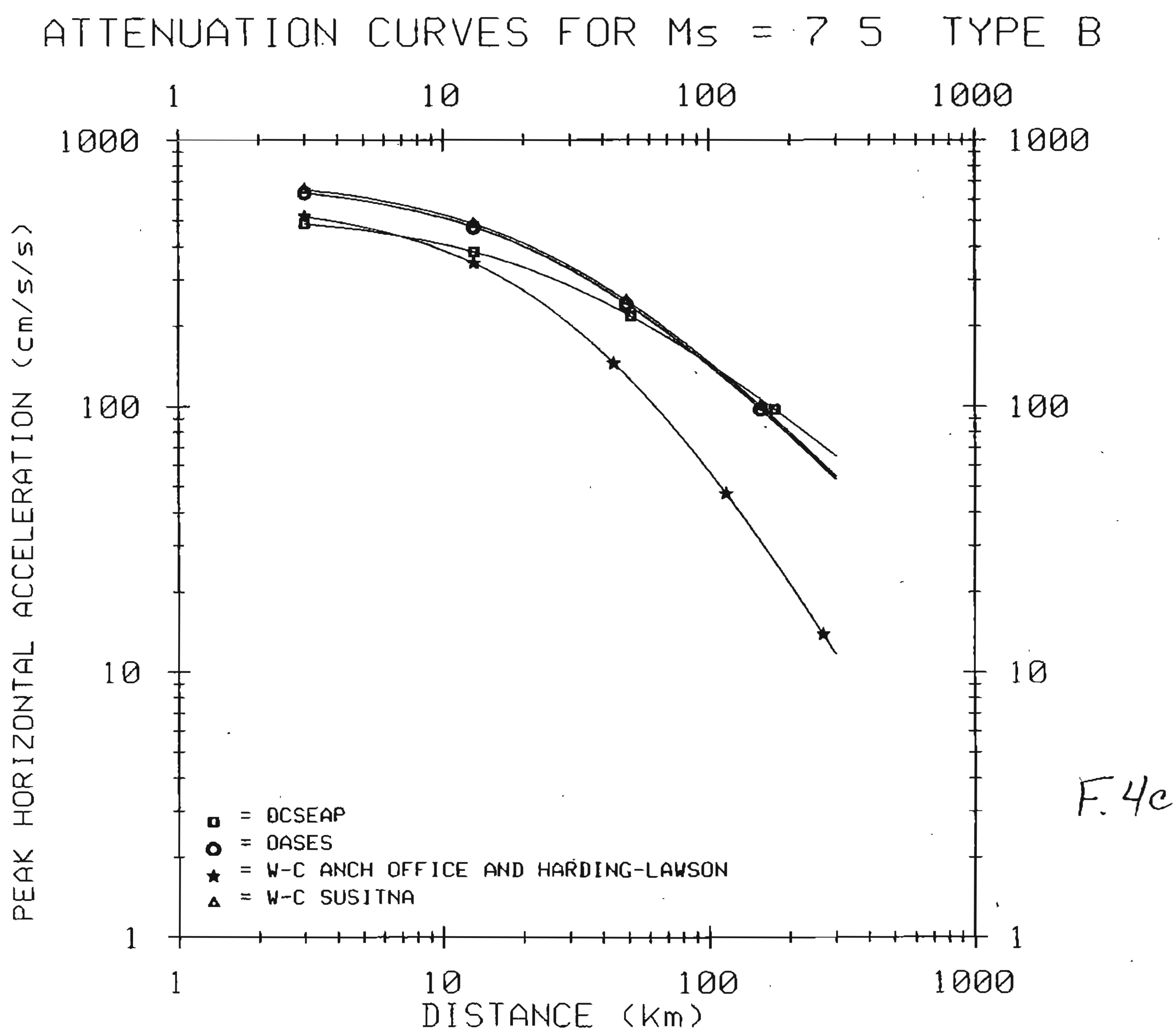


F. 4a

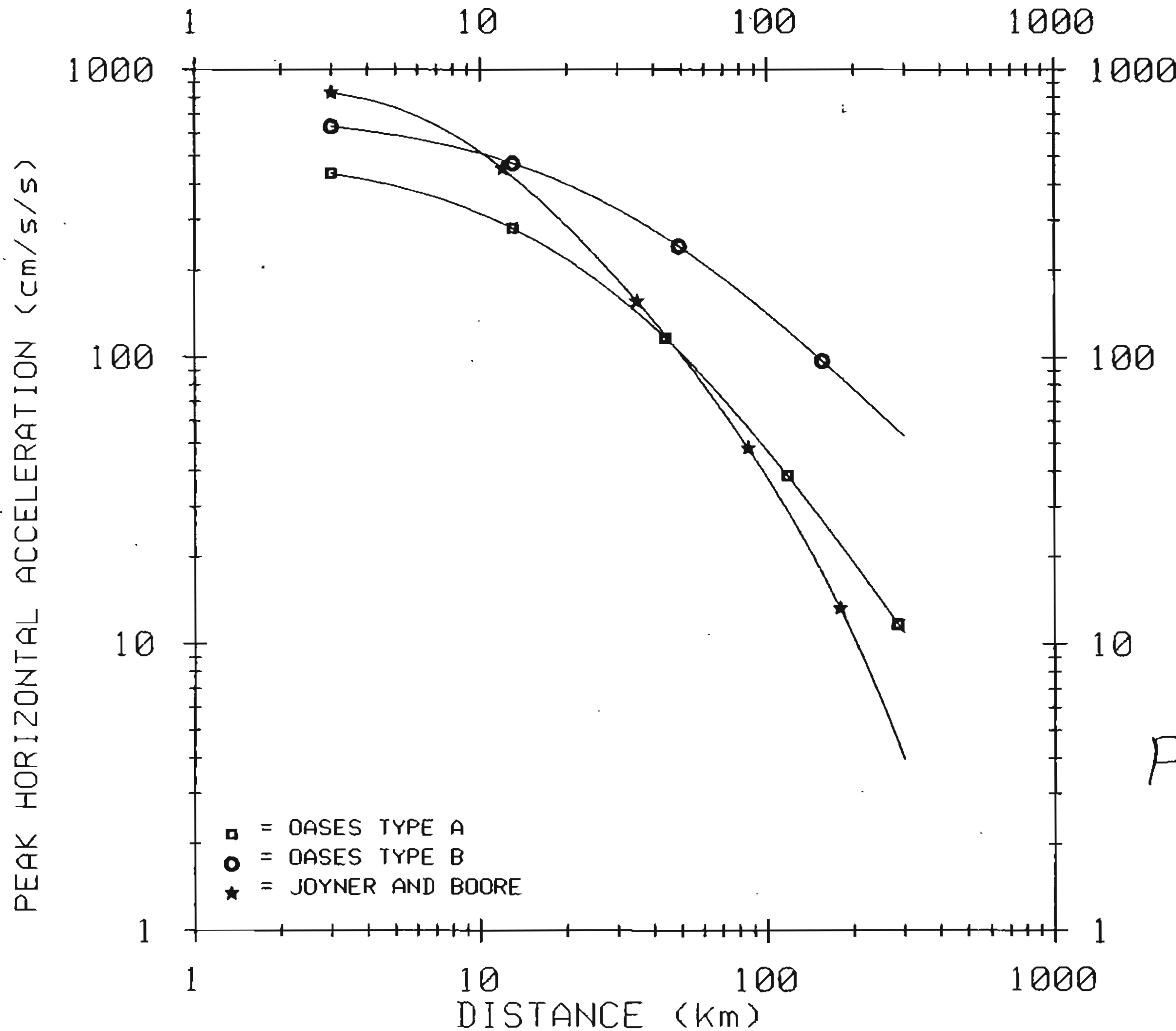
ATTENUATION CURVES FOR Ms = 7 5 TYPE A



F. 4b


ATTENUATION CURVES FOR Ms = 7 5 TYPE B
1
10
100
1000
PEAK HORIZONTAL ACCELERATION (cm/s/s)
DISTANCE (Km)
= OCSEAP
= OASES
= W-C ANCH OFFICE AND HARDING-LAWSON
= W-C SUSITNA
F. 4c

ATTENUATION CURVES FOR Ms = 7 5



F. 4d