Mode of Faulting in the Local Zone of Puerto Rico (LZPR)

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Introduction

The island of Puerto Rico is located at the Northeastern corner of the Caribbean plate which is a transition region from almost normal subduction of the North American plate in the Lesser Antilles, to strike-slip motion west of Hispaniola. Current tectonic models of oblique subduction propose the motion to be partitioned among several fault systems. The main objective pursue in task 1 (part A) of **FEMA PR-0077** was the characterization of the local fault systems using data recorded by the Puerto Rico Seismic Network (PRSN).

Rapid progress in the understanding the geologic and tectonic environment of the Puerto Rico region has been made during de past years (figure 1). Details of the seismogenic zones are being identified, the concept of a **block** for Puerto Rico and the Virgin islands has been established. However, there remain a number of fundamental questions. The two most important ones are the relationship between the seismicity and the geologic structures, and the stress regime in relations to the tectonic process in the Local Zone of Puerto Rico (LZPR). This LZPR has high seismic activity and tsunamis, including large and destructive historic earthquakes of 1867 with M $\sim$ 7.6 in the Virgin Islands and the one in 1918 with M $\sim$ 7.5 located in the Mona Canyon, those earthquakes induced destructive tsunamis in Puerto Rico and Virgin islands as well.

The purpose of this research was to determine a detailed 3-D faulting model from a stress regime and microseismic analysis, which would provide constraints on the geometry and fault length. This goal is also pertinent to tsunami numerical modeling. The basic parameters that control the tsunami tectonic generation are the quake magnitud (M_o), fault dimensions and rupture geometry.

Simple tectonic models suggest that we can explain intrinsic seismicity studying the age of the subducting plate, the rates of convergence and the obliquity. However, heterogeneities within the oceanic plate cause inner structures like the microplates with associate dynamics. In Puerto Rico, the relative motion of the North American Plate (NAP)relative to the Caribbean Plate (CP), creates an E-W striking shear zone. The geometry of surface faulting can be modeled as rigid en echelon blocks rotating or uplifting in response to the large scale shear. An important question in such deformation is whether the blocks are deeply seated or detached at relative shallow depth. A third approach would accommodate all deformation in narrow, boundary-parallel zones, as has been argued for some obliquely convergent subduction zones. In this case, no rotation or uplift is predicted or not distributed shear is observed.

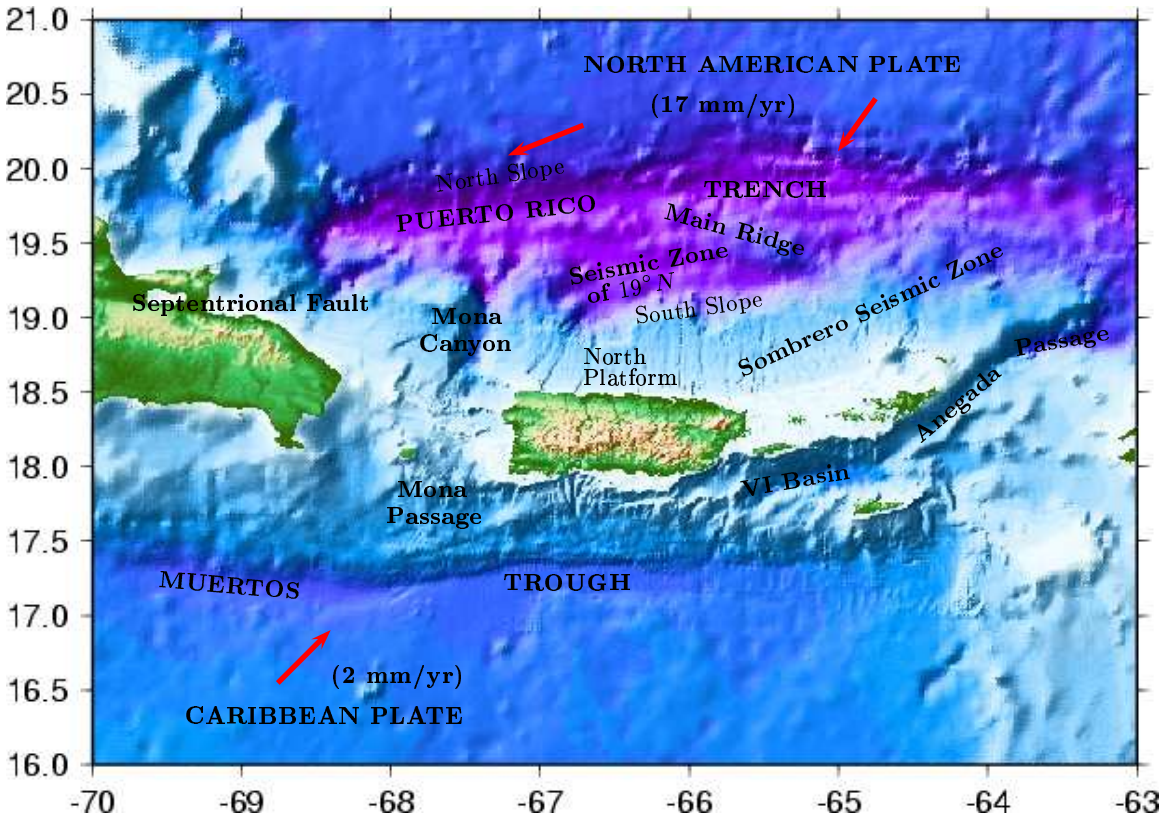

Figure 1. Regional tectonics and major seismic areas in the Local Zone of Puerto Rico (LZPR), vector indicates the relative plate motion (Jansma, et al, 1998).

Regional Tectonics

The LZPR is located in the transition zone between the subduction zone along the Lesser Antilles arc to the left-lateral Cayman transformation fault. Along the Antilles, volcanism occurs at regions where the vector of relative motion is most normal than the arc, and specifically in Puerto Rico, it has been absent during the Neogene. LZPR is best defined as a microplate seated in the convergence zone where the seismic activity defines a Wadatti-Benioff zone dipping at about 50° to the south, which is associate with the well developed trench (Puerto Rico Trench). This configuration suggest subduction of the North American plate with a convergence component north of Puerto Rico. Alternatively, as the structure developed at the Lesser Antilles arc and transported westward by plate motion, the Puerto Rico slab may not require convergence across the present boundary. The geometry of the Cayman trough suggest that the relative motion at Puerto Rico should have an extension component. Accordingly, the Puerto Rico Trench has been interpreted by some as a graben resulting from an extensional allochthon (Speed and Larue, 1991).

The plate motion might not be accommodated completely on the boundary defined by the trench, but also an secondary faults between the trench and the Muertos Trough (MT) just in the fault zones exposed in the figure 1. In hispaniola this is more evident due to the presence of active left-lateral strike slip faults on land, and thrust events near the MT. Thus, a significant component of subduction might persist along PRT, in response to slab pull, or the tendency of the subducting plate to change its geometry towards a vertical dipping plate to reduce the friction along boundary.

Seismicity

In the recent centuries several large earthquakes have occurred in the LZPR (figure 2). They include a M $\sim$ 8 event in 1787 that occurred north of Puerto Rico rupturing probably the main fault along the PRT, and three M $\sim$ 7.5 events during last 150 years scattered along the eastern and western sides of the island (Puerto Rico Seismic Network: Historical Catalogue, 2002). Their mechanisms are unknown, and so their implications in terms of the tectonic process is lacking. Much of what we currently know about the mechanism and

tectonics of the LZPR has been derived from the analysis of seismic data from the Puerto Rico Seismic Network (PRSN).

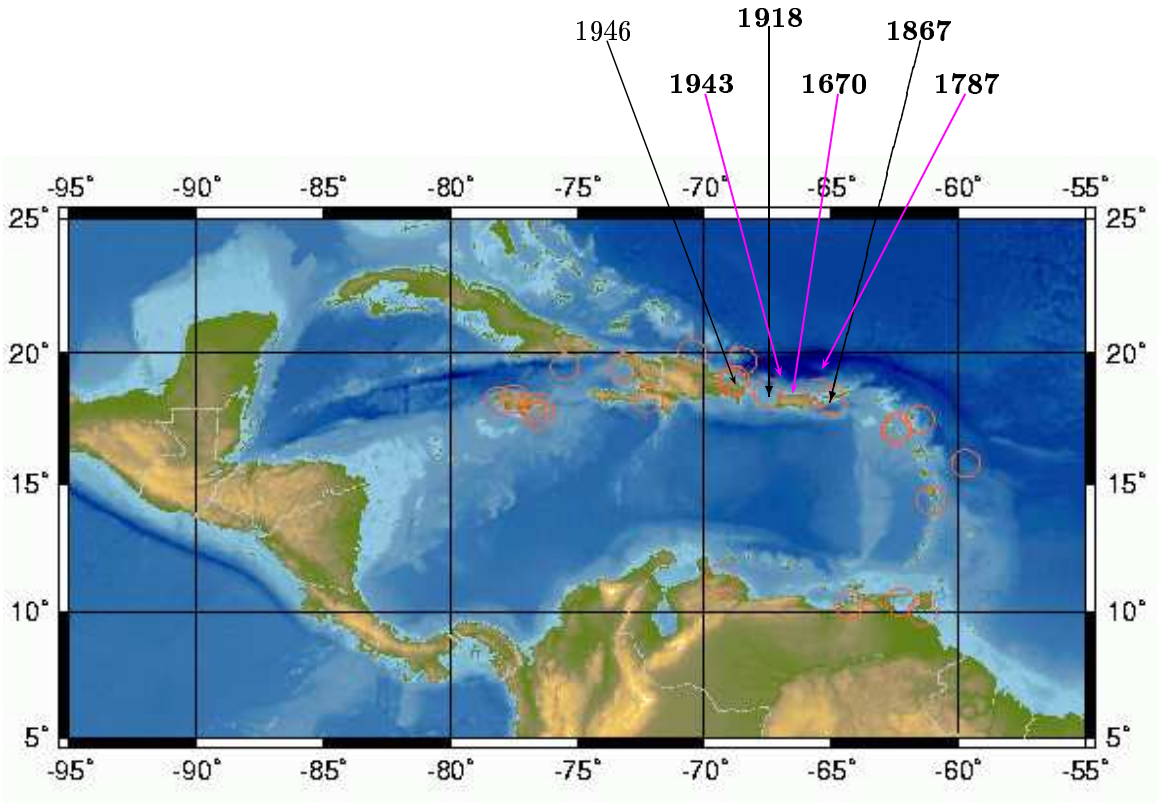

Figure 2. Larger earthquakes and tsunamis in the Caribbean. Circles represent the location of tsunamis (NOAA, catalogue, 2002). Black vectors and dates mark the location of those earthquakes that induced tsunami events and Magenta vectors and dates are for earthquakes without induced tsunami.

Figure 3. shows that he most active regions of microseismicity as evidenced by the last 15 years of data analyzed (1987 to jun 2002) from the local network (PRSN), are at the north of the Virgin Islands (Sombrero Seismic Zone, SSZ), Mona Canyon (MC), the 19°N Fault Zone and the southwestern Puerto Rico. The first two are also regions of macroseismicity as evidenced by the world wide seismic catalogues (Centroid Moment Tensor, CMT, 2002), with events showing a trust mechanism with strike slip component. A better understanding of the deformation regime of the region, is the main core to assess the potential for large events in the future.

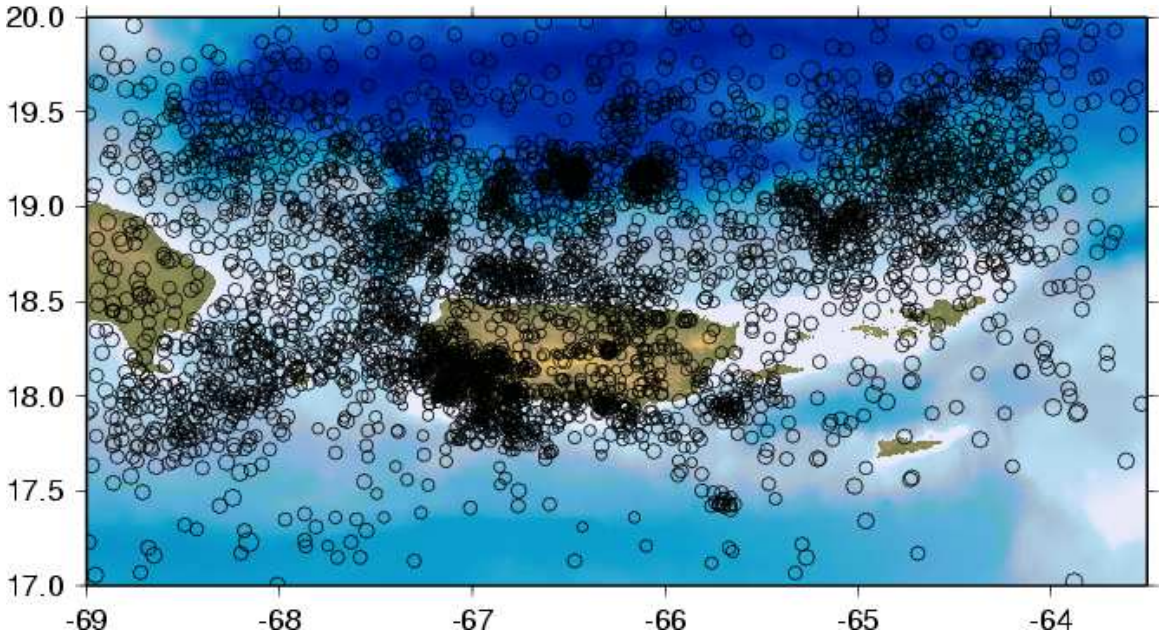

Figure 3. Epicentral map with those earthquakes used in this study. Circles are proportional to the earthquake magnitude.

Puerto Rico Seismic Network

To enhance the understanding of local seismicity, seismic hazard and other related topics, the Puerto Rico Seismic Network (PRSN) of the Dept. of Geology at the Mayagüez Campus of the University of Puerto Rico provides the community a variety of services like near real time waveform and solutions, broadcast and on-line seismic information, preinstrumental and instrumental catalogues, and public education. To monitor the seismicity in the local region of Puerto Rico (17-20◦N and 63.5-69◦W), the PRSN operates a standard 12 short-period L-4 and S-13 sensors and 10 broadband Guralp 40-T, 3-ESP and 3-T seismic stations (figure 4).

In October of 1993, Bataille and von Hillebrandt-Andrade revised the formulas so that the magnitudes calculated by the PRSN would approximate those reported in the PDE's. They use the seismograms of the earthquakes, which occurred between 1981 and 1993 for which the NEIC had calculated a magnitude. The maximum amplitude of the P phase was read for 114 events (3.3 stations/event), the maximum amplitude of the trace was read for 113 events (3.2 stations/event), the F-P CODA was read for 156 events (3.5 stations/event)

and the S-P CODA was read for 97 events (3.1 stations/event). Through a method of "best fit", the constants were calculated according to the following equation:

$$M = a * log(size) + b * log(dist) + c \tag{1}$$

Where:

M	:	calculated magnitude
size	:	amplitude (mm), CODA duration (seconds)
dist	:	epicentral distance
a, b	:	constants for the Puerto Rico Seismic Network
c	:	station correction

They were aware that as new stations will be installed, which can be calibrated, and more data is obtained, the constants and correction factors for the station will change, but it is expected that the differences in magnitude will not exceed 0.3.

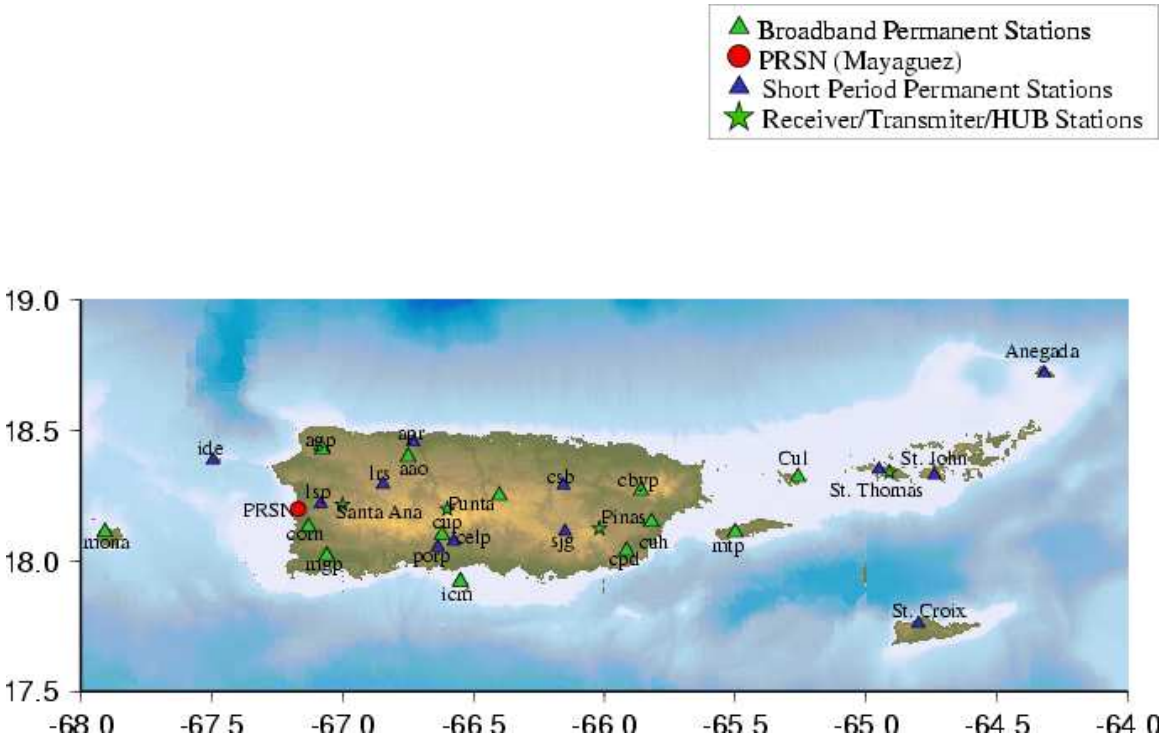

Figure 4. Geographical distribution of seismic stations operated by the PRSN (2002)

Earthquake location programs like PR-HYPO the one used in the PRSN need a realistic crustal model, Huérfano and Bataille (1994) proposed a flat homogeneous P-wave model for Puerto Rico (table 1) and from Wadatti plots the Vp/Vs ratio is 1.74. The complete PRSN seismic catalogue was recompiled with this model so that all solutions are homogeneous in methods. Of course this model need to be improved to include low subsurfaces velocities and lateral heterogeneities which can explain relatively strong velocity contrasts.

Table 1. P-Wave velocity model as used in PR-HYPO (PRSN).

Layer Depth (km)	Vel. - P (km/s)	Vp/Vs
0.0 - 2.81	4.59	1.75
2.81 - 8.86	6.36	1.75
8.86 - 14.74	6.84	1.75
14.74 - 19.18	7.31	1.75
19.18 - 35.0	7.92	1.75

Data Base and Method

During the time period from January 1987 to June 2002, 4422 microseismic records from the PRSN catalogue with quality A, B and C were selected to determine the seismic potential of the LZPR. Each earthquake solution is stamped with a quality factor based on the number of readings, rms, hypocentral errors and azimuthal coverage. This factor allows us to select those reliable solutions inside a specific region. Tables 2a and 2b shows the parameters and scales used to compute quality factors **PQS** and **PQD**; quality value **Q** is the mean of quality factors.

Table 2. Quality criteria defined in the PRSN. (a) quality factors PQS and PQD, and (b) quality value (Q). RMS is the root mean square in seconds, ERH and ERZ are the location errors in km. PS are the readings number and GAP is the azimuthal coverage.

Quality Factors						
PQS	RMS	ERH	ERZ	PS	GAP	PQD
4	<0.15	<5.0	<10.0	>6	<90	4
3	<0.30	<10.0	<20.0	>6	<135	3
2	<0.50	<15.0	<31.6	>6	<180	2
1	↑	↑	↑	↓	↑	1

(a)

Quality Value (PQD/PQS)				
Q	4	3	2	1
4	A	B	B	C
3	B	B	C	C
2	B	C	C	D
1	C	C	D	D

(b)

An additional criteria to determine the data quality is the network stability in terms of methods and instruments during the studied time period. Figure 6. indicates that from 1992 to present the PRSN remain mostly stable as evidenced by the readings. Using that observation, Rivera and Mendoza (2001) proposed that the PRSN completeness is 3.0 for inland events and 3.2 for events located out of the sensor array. Appendix A. present the current network setting that include both broad band and short period instruments around Puerto Rico and nearby Islands of Mona, Desecheo, Vieques, Culebra and the US and British Virgin Islands.

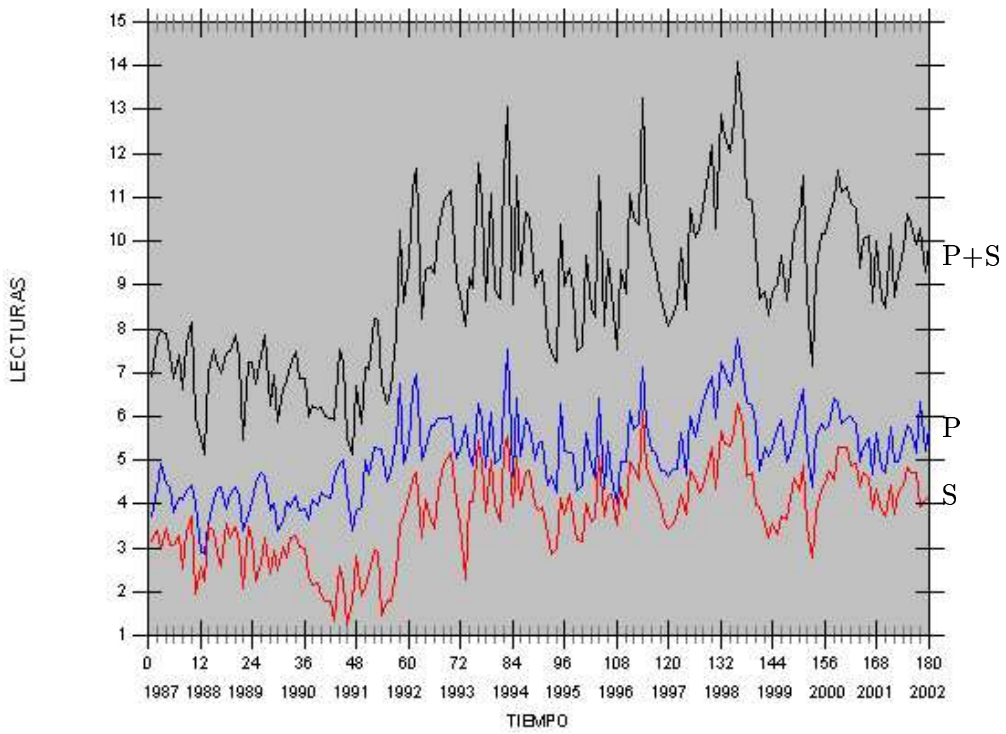

Figure 6. PRSN instrumental time average. Red line is the time sequence of S readings, blue line is the time history of P readings and black line is the history of quake readings.

Based on the offshore seismic distribution of shallow earthquakes (depth less that 50 km) and mapping of known fault systems, we propose 11 subregion each one defined by specific stress parameters as explained by Huérfano (2003). Each region was previously analysed by classic seismological methods like the Gutenberg and Richter b-value relationship and the composite focal mechanism (the code is presented in Appendix B.). Results are presented in the figure 7. and tables 3. where regions names were assigned depending on the predominant fault inside that subregion. The Puerto Rico Trench (PRT) was subdivided in eastern and western section due to intrinsic differences in seismicity and tectonics.

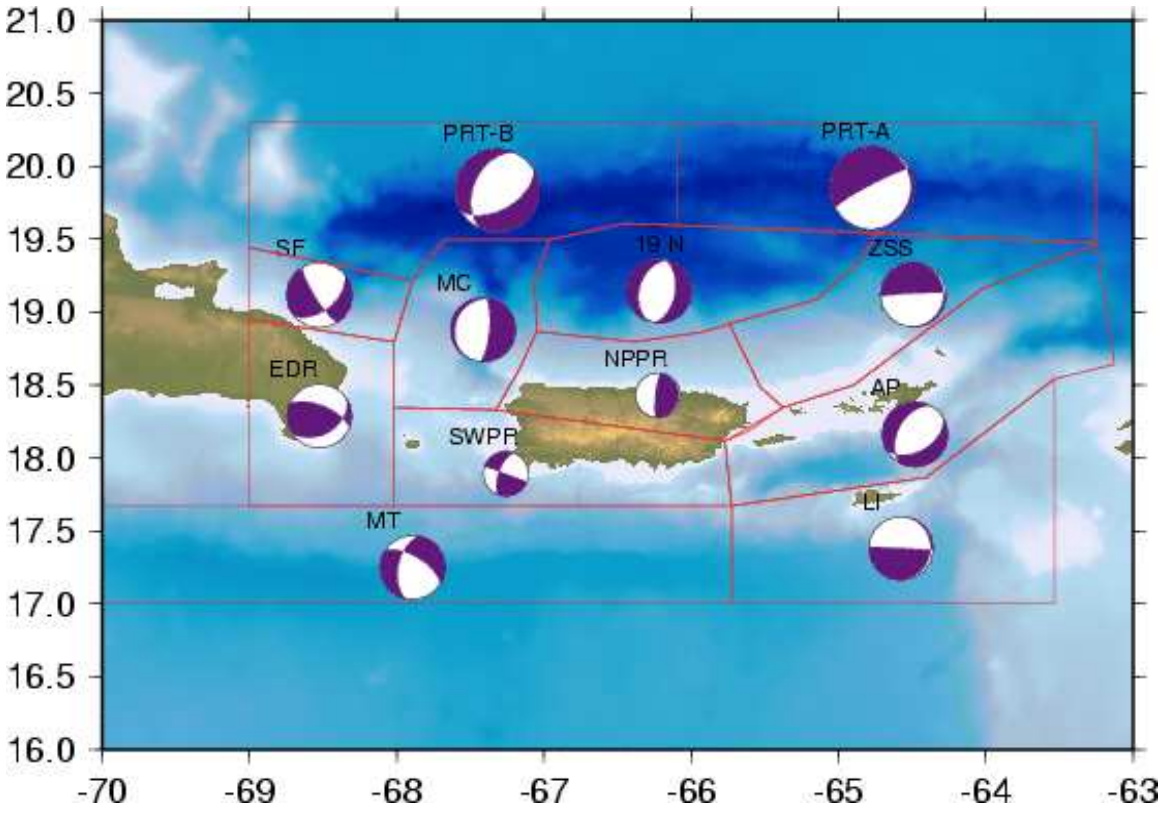

Figure 7. Composite focal mechanism solution for each subregion in the LZPR, the sphere radius is proportional to the maximum expected magnitud. PRT is the Puerto Rico Trench: (A) eastern section and (B) is the western side.

Basic statistic and previous results from other researchers are presented in table 3(a) that states the maximum expected magnitud and recurrence times for equivalent subregions. Using a combination of the Wells and Coppersmith (1994) relationships (equation 2.) with

mean values for a different set of fault systems and geometries we propose a set of maximum Mw for the LZPR, the recurrence time was obtained extracting a specific set of events for a polygon (subregion) and using the b-value relationship (equation 3.).

$$M_w = a^\star + b^\star * log(Variable) \tag{2}$$

where variable may be: SRL, RLD, RW, RA, MD, AD. Constants a* and b* are fault geometry dependant.

$$log(N_{(M)}) = a - b * M \tag{3}$$

where $N_{(M)}$ is the number of earthquakes of magnitud larger that M, a and b are constants.

Table 3.(A) Composite results and previous work. Eve. is the number of events used in the inversion. Lec. is the number of readings per iteration. Mod. is the number of output models and % is the absolute consistency of the best model.

Region	Eve.	Lec.	Mod	%	von Hillebrandt		McCann		Comment
					Mag.	Rec.	Mag.	Rec.	
PRT-A	143	666	1	74	8.1	7620	8.0	3000	Puerto Rico Trench - East
PRT-B	101	481	165	67			8.0	3000	Puerto Rico Trench - West
19°N	237	1362	1	55	7.6	26m	7.5/8.0	350/27m	19°N Fault Zone
ZSS	232	1355	14	64					Sombrero Seismic Zone
MC	148	899	2	65	7.6	3m	7.3	2700	Mona Canyon
AP	119	615	1	62	7.2	1059	7.3	2500	Anegada Passage
SWPR	143	794	2	57	6.5	416	6.5	400	Southwestern PR
NPPR	90	355	19	62	6.5	3090			Puerto Rico north platform
EDR	64	286	2	70					Eastern Dom. Rep.
SF	89	474	41	66	7.8	795	7.8	450	Septentrional Fault Zone
MT	62	308	19	64	7.9	938	7.8	1900	Muertos Trough
LI	62	305	23	65					Leeward Islands, local area

Table 3.(B) Maximum credible earthquake magnitud (Mw), recurrence times, composite focal solutions, historical records and dates.

Region	Mw	Rec.	Regre.		History	Geometry			$\vec{D}$		$\vec{T}$		$\vec{P}$	
	Max.	Time	a	b		λ	δ	φ	Azi.	Pl	Azi.	Tr.	Azi.	Tr.
PRT-A	8.0	3841	6.5	0.9	8.1 (1787?)	9	10	217	152	-5	325	38	161	50
PRT-B	8.0	3841	6.5	0.9		60	52	294	114	-46	133	4	30	70
19°N	7.6	3382	8.3	1.2	7.5 (1943)	10	50	265	107	-49	103	4	245	83
ZSS	7.7	1241	7.7	1.0		10	10	193	177	-2	347	41	187	46
MC	7.5	2083	7.6	1.1	7.3 (1918)	5	75	265	113	-74	99	29	267	59
AP	7.7	3762	7.1	1.0	7.3 (1867)	60	47	293	118	-42	313	1	45	73
SWPR	6.6	1823	8.6	1.4		110	90	335	110	-25	157	17	62	17
NPPR	6.8	2506	6.9	1.1		5	10	89	-84	5	96	55	275	35
EDR	7.2	807	4.7	0.7		58	41	43	22	26	248	58	359	12
SF						50	51	347	58	-10	273	18	16	34
MT	7.6	3092	4.5	0.7	6.7 (1984)	192	54	327	-147	-26	65	5	161	46
LI	7.0	3053	4.1	0.7		5	10	2	3	2	192	44	353	43

The seismicity associated with faults in LZPR are currently located using some form of the Geiger's method, that is a linearization of the travel time equation in a first order Taylor series that relates the difference between the observed and theoretical travel times to **unknown** adjustments in the hypocentral coordinates through the partial derivates of travel time with respect to unknowns. There are some technics to improve the quake locations with the goal of bring structural details such as the location of active planes into well defined focus. But in general all methods show a diffuse picture of seismicity. One very important observation is that the spatial distribution of smaller earthquakes delineates areas in which larger earthquakes are likely to occur (Kafka and Levin, 2000), this need a very carefully and reliable earthquake location to delineate fault systems. Based in the hypothesis that if any quake occur is due to de fracture in a specific fault an that multiple and successive quakes delineates the fault plane, Huérfano (2003) propose a complete set of faultings using two methods. The first is based on the composite focal mechanism analysis while the second is based on geometrical analysis of hypocenters splited by magnitud.

Tsunami warning systems are based on real or near real time capabilities to detect and solve large earthquakes. Tsunami mitigation programs, on the other hand, use the complete scientific knowledge to reduce the effects of this natural phenomena trough education and risk plans. The production of tsunami evacuation maps consists of several stages. First, we need to construct hypothetical tsunami scenarios on the basis of parameters of potential underwater earthquakes. Then we need to perform numerical simulations for each of the earthquake source scenarios. The results must be compared with observations, if such data exits. Finally the worst case scenario must be developed for a tectonically generated tsunami for all the community. In conclusion, the inundations profiles for the worst case becomes a basis for local tsunami hazard planning and to construct the evacuations maps.

Huérfano, (2003), characterized 238 linear potential faults each one generating their hypothetical earthquake. This sources were considered as local and represent the larger faults comparing with non-liner or composite faults. Complete set of parameters are presented in tables 4.

Table 4. Linear fault systems in the LZPR. Name field is used in the software developed to extract fault parameters (Appendix C). Lat and Lon are the geographical coordinates of the pivot for the specific fault. λ, δ and φ are the strike, dip and rake angles

(A). Muertos Trough (MT)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-69.283	17.348	276	40	255	2.1	73.2	31.2	Fault_{01}
-69.269	17.643	274	40	255	2.1	73.2	31.2	Fault_{02}
-68.748	17.221	283	41	272	2.1	73.2	31.2	Fault_{03}
-68.018	17.741	250	21	270	2.1	73.2	31.2	Fault_{04}
-68.060	17.179	274	40	260	2.1	73.2	31.2	Fault_{05}
-67.399	17.544	253	68	265	2.1	73.2	31.2	Fault_{06}
-67.469	17.390	266	65	234	2.1	73.2	31.2	Fault_{07}
-67.385	17.306	259	43	265	2.1	73.2	31.2	Fault_{08}
-67.722	17.334	52	89	242	2.1	73.2	31.2	Fault_{09}
-66.991	17.640	243	56	106	2.1	73.2	31.2	Fault_{10}
-66.949	17.685	157	71	257	2.1	73.2	31.2	Fault_{11}
-66.443	17.334	273	45	240	2.1	73.2	31.2	Fault_{12}
-66.008	17.193	303	48	60	2.1	73.2	31.2	Fault_{13}
-65.993	17.404	317	80	237	2.1	73.2	31.2	Fault_{14}
-66.738	17.292	39	60	243	2.1	73.2	31.2	Fault_{15}
-66.401	17.699	223	39	308	2.1	73.2	31.2	Fault_{16}
-68.538	17.769	237	45	150	2.1	73.2	31.2	Fault_{17}
-68.341	17.25	355	36	330	2.1	73.2	31.2	Fault_{18}
-67.779	17.573	285	80	73	2.1	73.2	31.2	Fault_{19}
-67.469	17.755	208	87	223	2.1	73.2	31.2	Fault_{20}
-67.062	17.432	240	40	240	2.1	73.2	31.2	Fault_{21}
-66.036	17.741	132	84	60	2.1	73.2	31.2	Fault_{22}
-65.895	17.307	22	30	169	2.1	73.2	31.2	Fault_{23}
-67.146	17.741	208	27	70	2.1	73.2	31.2	Fault_{24}

(B). Puerto Rico Trench (PRT)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-64.1244	19.8623	97	45	225	3.2	174.9	50.7	Fault_{25}
-64.616	19.707	94	45	225	3.2	174.9	50.7	Fault_{26}
-64.236	19.553	95	45	225	3.2	174.9	50.7	Fault_{27}
-65.052	19.483	60	5	86	3.2	174.9	50.7	Fault_{28}
-64.124	19.988	244	85	90	3.2	174.9	50.7	Fault_{29}
-64.574	19.328	44	5	86	3.2	174.9	50.7	Fault_{30}
-63.730	20.157	228	85	90	3.2	174.9	50.7	Fault_{31}
-65.277	19.876	91	30	225	3.2	174.9	50.7	Fault_{32}
-65.614	19.721	92	40	215	3.2	174.9	50.7	Fault_{33}
-65.951	20.129	95	40	220	3.2	174.9	50.7	Fault_{34}
-66.963	19.553	80	50	210	3.2	174.9	50.7	Fault_{35}
-66.232	19.862	85	30	225	3.2	174.9	50.7	Fault_{36}
-66.485	19.988	111	40	240	3.2	174.9	50.7	Fault_{37}
-65.030	19.461	315	56	110	3.2	174.9	50.7	Fault_{38}
-67.287	19.764	85	40	225	3.2	174.9	50.7	Fault_{39}
-68.425	19.637	84	45	200	3.2	174.9	50.7	Fault_{40}
-69.662	19.876	104	82	253	3.2	174.9	50.7	Fault_{41}
-67.751	19.511	87	45	225	3.2	174.9	50.7	Fault_{42}
-67.301	20.101	222	63	285	3.2	174.9	50.7	Fault_{43}
-68.115	19.103	30	30	243	3.2	174.9	50.7	Fault_{44}
-68.510	19.117	52	45	200	3.2	174.9	50.7	Fault_{45}
-67.821	20.213	228	45	305	3.2	174.9	50.7	Fault_{46}
-68.608	20.536	200	80	266	3.2	174.9	50.7	Fault_{47}
-67.582	20.129	246	45	325	3.2	174.9	50.7	Fault_{48}
-64.981	20.507	145	45	270	3.2	174.9	50.7	Fault_{49}
-65.706	19.982	111	40	210	3.2	174.9	50.7	Fault_{50}
-67.132	19.946	105	35	220	3.2	174.9	50.7	Fault_{51}

(C). Mona Canyon (MC)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-67.146	19.455	216	60	270	7.3	62.0	37.1	Fault_{52}
-67.512	18.935	36	30	270	7.3	62.0	37.1	Fault_{53}
-67.357	19.764	198	45	315	7.3	62.0	37.1	Fault_{54}
-67.849	19.469	121	45	270	7.3	62.0	37.1	Fault_{55}
-67.413	18.963	283	61	123	7.3	62.0	37.1	Fault_{56}
-67.413	18.823	221	45	270	7.3	62.0	37.1	Fault_{57}
-67.793	18.823	41	45	270	7.3	62.0	37.1	Fault_{58}
-67.371	18.668	221	45	270	7.3	62.0	37.1	Fault_{59}
-67.694	18.289	41	45	270	7.3	62.0	37.1	Fault_{60}
-67.343	19.244	189	45	270	7.3	62.0	37.1	Fault_{61}
-67.427	18.654	9	45	270	7.3	62.0	37.1	Fault_{62}
-67.343	19.146	214	58	279	7.3	62.0	37.1	Fault_{63}
-67.287	18.977	224	60	285	7.3	62.0	37.1	Fault_{64}
-66.963	18.907	281	75	10	7.3	62.0	37.1	Fault_{65}
-67.680	18.935	216	65	230	7.3	62.0	37.1	Fault_{66}
-67.526	19.005	243	60	310	7.3	62.0	37.1	Fault_{67}
-67.518	19.485	224	60	325	7.3	62.0	37.1	Fault_{68}
-67.357	18.991	31	45	260	7.3	62.0	37.1	Fault_{69}
-67.371	18.584	40	15	255	7.3	62.0	37.1	Fault_{70}
-67.188	18.879	321	17	263	7.3	62.0	37.1	Fault_{71}
-67.174	18.626	313	20	250	7.3	62.0	37.1	Fault_{72}
-67.680	18.724	135	48	208	7.3	62.0	37.1	Fault_{73}
-67.483	18.626	321	62	124	2.3	84.7	33.8	Fault_{74}
-67.959	18.453	100	85	345	2.3	84.7	33.8	Fault_{75}

(D). 19°N Falt System (19°N)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-64.785	19.567	230	64	297	2.3	84.7	33.8	Fault_{76}
-65.867	19.033	72	60	225	2.3	84.7	33.8	Fault_{77}
-66.724	18.991	69	75	225	2.3	84.7	33.8	Fault_{78}
-66.289	19.595	238	45	330	2.3	84.7	33.8	Fault_{79}
-66.232	19.483	228	45	330	2.3	84.7	33.8	Fault_{80}
-67.034	19.525	101	45	225	2.3	84.7	33.8	Fault_{81}
-66.373	19.398	91	45	225	2.3	84.7	33.8	Fault_{82}
-65.951	19.746	200	45	320	2.3	84.7	33.8	Fault_{83}
-65.797	19.735	195	45	330	2.3	84.7	33.8	Fault_{84}
-67.034	19.047	66	47	167	2.3	84.7	33.8	Fault_{85}
-65.825	19.117	35	45	155	2.3	84.7	33.8	Fault_{86}
-64.995	19.441	265	60	56	2.3	84.7	33.8	Fault_{87}
-66.696	19.525	206	84	295	2.3	84.7	33.8	Fault_{88}
-67.048	19.342	136	7	285	2.3	84.7	33.8	Fault_{89}
-66.767	19.455	142	10	280	2.3	84.7	33.8	Fault_{90}
-66.064	19.272	111	18	223	2.3	84.7	33.8	Fault_{91}

(E). Sombrero Seismic Zone (ZSS)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-64.405	19.216	73	80	86	2.3	84.7	33.8	Fault_{92}
-63.716	19.426	274	10	111	2.3	84.7	33.8	Fault_{93}
-64.335	19.286	38	80	86	2.3	84.7	33.8	Fault_{94}
-63.969	19.75	239	10	111	2.3	84.7	33.8	Fault_{95}
-64.967	19.356	122	80	90	2.3	84.7	33.8	Fault_{96}
-64.461	19.033	302	10	89	2.3	84.7	33.8	Fault_{97}
-64.714	19.244	28	75	110	2.3	84.7	33.8	Fault_{98}
-65.502	18.794	60	75	270	2.3	84.7	33.8	Fault_{99}
-65.010	19.075	240	15	270	2.3	84.7	33.8	Fault_{100}
-65.740	18.865	124	85	85	2.3	84.7	33.8	Fault_{101}
-65.698	18.963	152	5	315	2.3	84.7	33.8	Fault_{102}
-64.897	18.780	25	80	110	2.3	84.7	33.8	Fault_{103}
-64.504	19.356	182	80	315	2.3	84.7	33.8	Fault_{104}
-64.518	18.851	281	45	194	2.3	84.7	33.8	Fault_{105}
-65.319	18.50	54	60	90	2.3	84.7	33.8	Fault_{106}
-64.883	18.808	234	30	90	2.3	84.7	33.8	Fault_{107}
-65.234	18.977	105	85	200	2.3	84.7	33.8	Fault_{108}
-65.487	18.977	81	18	92	2.3	84.7	33.8	Fault_{109}
-64.672	19.103	263	72	89	2.3	84.7	33.8	Fault_{110}
-65.487	18.987	125	16	23	2.3	84.7	33.8	Fault_{111}
-64.953	19.384	112	45	198	2.3	84.7	33.8	Fault_{112}
-64.151	19.569	226	86	93	2.3	84.7	33.8	Fault_{113}
-64.925	19.300	54	85	87	2.3	84.7	33.8	Fault_{114}
-64.728	19.651	201	76	278	2.3	84.7	33.8	Fault_{115}

(F). Anegada Passage (AP)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-64.349	19.089	107	45	230	2.0	63.0	29.0	Fault_{116}
-63.238	19.103	253	60	276	2.0	63.0	29.0	Fault_{117}
-63.759	18.794	75	30	259	4.8	48.0	32.8	Fault_{118}
-64.236	19.202	184	70	270	2.0	63.0	29.0	Fault_{119}
-64.532	18.921	114	45	230	4.8	48.0	32.8	Fault_{120}
-64.391	18.626	260	60	81	4.8	48.0	32.8	Fault_{121}
-63.941	18.991	226	45	270	4.8	48.0	32.8	Fault_{122}
-64.265	18.457	50	25	200	4.8	48.0	32.8	Fault_{123}
-64.489	18.092	59	15	189	4.8	48.0	32.8	Fault_{124}
-64.644	18.148	275	29	200	4.8	48.0	32.8	Fault_{125}
-64.588	17.839	314	90	5	3.9	84.0	20.6	Fault_{126}
-64.560	18.064	92	90	5	3.9	84.0	20.6	Fault_{127}
-64.827	17.938	90	90	5	3.9	84.0	20.6	Fault_{128}
-65.684	18.064	103	23	186	3.9	84.0	20.6	Fault_{129}
-65.670	17.755	67	65	340	4.8	48.0	32.8	Fault_{130}
-65.180	17.715	25	60	350	4.8	48.0	32.8	Fault_{131}
-64.813	18.022	260	45	95	2.0	63.0	29.0	Fault_{132}
-65.066	17.867	81	15	350	2.0	63.0	29.0	Fault_{133}
-65.192	17.966	276	15	200	2.0	63.0	29.0	Fault_{134}
-64.335	18.359	287	45	85	2.0	63.0	29.0	Fault_{135}
-65.110	18.036	290	70	153	4.8	48.0	32.8	Fault_{136}
-65.403	18.148	217	42	104	2.0	63.0	29.0	Fault_{137}
-64.110	18.359	30	38	312	4.8	48.0	32.8	Fault_{138}
-63.744	18.640	259	89	274	2.0	63.0	29.0	Fault_{139}
-64.711	18.279	295	47	12	4.8	48.0	32.8	Fault_{140}
-65.092	18.493	235	66	288	2.0	63.0	29.0	Fault_{141}
-64.644	18.738	233	79	123	2.0	63.0	29.0	Fault_{142}
-64.433	18.524	8	84	52	2.0	63.0	29.0	Fault_{143}

(G). Leeward Islands, local area. (LI)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-64.236	17.952	40	5	5	1.5	35.4	20.9	Fault_{144}
-63.744	17.966	287	85	94	1.5	35.4	20.9	Fault_{145}
-65.614	17.320	320	84	274	2.1	30.9	23.9	Fault_{146}
-65.839	17.502	113	7	236	2.1	30.9	23.9	Fault_{147}
-65.333	17.081	290	13	241	1.5	35.4	20.9	Fault_{148}
-65.420	17.150	157	85	88	1.5	35.4	20.9	Fault_{149}
-65.347	17.558	44	5	26	1.5	35.4	20.9	Fault_{150}
-64.644	17.460	290	78	248	1.5	35.4	20.9	Fault_{151}
-65.403	17.530	228	56	222	1.5	35.4	20.9	Fault_{152}
-65.361	17.502	290	56	228	1.5	35.4	20.9	Fault_{153}
-65.136	17.755	253	76	91	2.1	30.9	23.9	Fault_{154}

(H). Septentrional Fault (SF)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-68.156	19.312	275	45	200	5.0	77.6	39.8	Fault_{155}
-68.945	19.462	149	65	85	2.6	77.6	39.8	Fault_{156}
-68.407	18.907	310	25	100	2.6	77.6	39.8	Fault_{157}
-68.453	19.328	171	90	105	2.6	77.6	39.8	Fault_{158}
-68.102	19.372	222	45	300	2.6	77.6	39.8	Fault_{159}
-68.453	18.879	5	52	243	2.6	77.6	39.8	Fault_{160}
-68.214	19.286	162	65	272	2.6	77.6	39.8	Fault_{161}
-68.060	18.808	337	25	265	2.6	77.6	39.8	Fault_{162}
-68.819	19.089	68	90	180	2.6	77.6	39.8	Fault_{163}
-68.945	19.230	99	90	180	2.6	77.6	39.8	Fault_{164}
-69.087	19.043	98	30	269	2.6	113.2	39.8	Fault_{165}
-68.850	19.316	118	34	264	2.6	113.2	39.8	Fault_{166}
-68.608	19.384	257	80	270	2.6	77.6	39.8	Fault_{167}
-68.397	19.342	125	49	74	2.6	77.6	39.8	Fault_{168}

(I). Eastern Dominican Republic (EDR)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-67.989	17.980	220	62	89	1.5	35.4	20.9	Fault_{169}
-68.481	18.134	234	85	290	2.1	30.9	23.9	Fault_{170}
-68.074	18.022	262	80	126	1.5	35.4	20.9	Fault_{171}
-68.397	18.162	198	85	95	1.5	35.4	20.9	Fault_{172}
-68.566	18.359	126	20	275	1.5	35.4	20.9	Fault_{173}
-68.088	18.429	302	55	55	1.5	35.4	20.9	Fault_{174}
-68.411	18.823	111	65	277	1.5	35.4	20.9	Fault_{175}
-68.495	17.938	273	19	0	1.5	42.6	17.8	Fault_{176}
-68.299	17.853	246	60	257	1.5	35.4	20.9	Fault_{177}

(J). Southwestern Puerto Rico (SWPR)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-65.825	17.952	244	45	150	1.1	18.0	13.2	Fault_{178}
-66.879	17.797	224	45	160	1.1	18.0	13.2	Fault_{179}
-65.783	17.769	221	60	120	1.1	18.0	13.2	Fault_{180}
-65.937	17.797	226	60	125	1.1	18.0	13.2	Fault_{181}
-66.064	17.825	222	60	120	1.1	18.0	13.2	Fault_{182}
-66.795	17.938	174	80	190	1.1	18.0	13.2	Fault_{183}
-66.275	17.727	246	65	120	1.1	18.0	13.2	Fault_{184}
-66.148	17.924	151	75	150	1.1	18.0	13.2	Fault_{185}
-66.162	17.825	258	70	160	1.1	18.0	13.2	Fault_{186}
-66.753	17.938	126	60	15	1.1	18.0	13.2	Fault_{187}
-67.048	17.867	226	60	155	1.1	18.0	13.2	Fault_{188}
-67.160	17.980	198	65	110	1.1	18.0	13.2	Fault_{189}
-67.863	18.205	105	15	170	1.1	18.0	13.2	Fault_{190}
-67.849	18.317	113	20	170	1.1	18.0	13.2	Fault_{191}
-67.399	18.219	114	60	165	1.1	18.0	13.2	Fault_{192}
-67.554	18.064	110	60	160	1.1	18.0	13.2	Fault_{193}
-67.849	17.938	231	45	120	1.1	18.0	13.2	Fault_{194}
-67.877	17.867	176	60	10	1.1	18.0	13.2	Fault_{195}
-67.905	17.882	116	45	275	1.1	18.0	13.2	Fault_{196}
-66.443	17.783	247	75	170	1.1	18.0	13.2	Fault_{197}
-66.064	17.952	113	50	350	1.1	18.0	13.2	Fault_{198}
-67.483	17.839	130	45	240	1.1	18.0	13.2	Fault_{199}
-67.526	18.359	97	60	15	1.1	18.0	13.2	Fault_{200}
-67.343	17.853	93	45	285	1.1	18.0	13.2	Fault_{201}
-67.849	18.387	95	25	170	1.1	18.0	13.2	Fault_{202}
-67.441	18.162	290	36	314	1.1	18.0	13.2	Fault_{203}
-66.724	17.896	252	51	279	1.1	18.0	13.2	Fault_{204}
-66.939	17.825	5	47	201	1.1	18.0	13.2	Fault_{205}
-67.540	18.072	349	44	307	1.1	18.0	13.2	Fault_{206}
-67.722	18.233	47	60	221	1.1	18.0	13.2	Fault_{207}
-67.568	17.811	310	64	312	1.1	18.0	13.2	Fault_{208}
-65.797	17.839	335	74	355	1.1	18.0	13.2	Fault_{209}
-67.961	17.713	334	6	80	1.1	18.0	13.2	Fault_{210}
-67.779	18.008	307	21	97	1.1	18.0	13.2	Fault_{211}
-67.975	18.148	41	41	38	1.1	18.0	13.2	Fault_{212}
-65.853	17.727	320	34	100	1.1	18.0	13.2	Fault_{213}

(K). Puerto Rico North Platform (NPPR)								
Lat (N)	Lon (W)	λ	δ	φ	$\|\vec{u}\|(m)$	Length (km)	Width (km)	Name
-66.963	18.584	309	30	205	1.1	18.0	13.2	Fault_{214}
-66.682	18.598	277	25	210	1.1	18.0	13.2	Fault_{215}
-66.879	18.879	217	70	100	1.1	18.0	13.2	Fault_{216}
-66.738	18.865	219	70	105	1.1	18.0	13.2	Fault_{217}
-66.921	18.823	136	30	200	1.1	18.0	13.2	Fault_{218}
-66.809	18.851	160	30	205	1.1	18.0	13.2	Fault_{219}
-66.542	18.823	176	80	310	1.1	18.0	13.2	Fault_{220}
-66.204	18.626	313	50	100	1.1	18.0	13.2	Fault_{221}
-66.064	18.724	290	50	105	1.1	18.0	13.2	Fault_{222}
-66.261	18.851	236	80	15	1.1	18.0	13.2	Fault_{223}
-65.941	18.823	215	75	20	1.1	18.0	13.2	Fault_{224}
-66.134	18.542	45	70	280	1.1	18.0	13.2	Fault_{225}
-65.70	18.598	51	25	160	1.1	18.0	13.2	Fault_{226}
-65.60	18.528	300	30	100	1.1	18.0	13.2	Fault_{227}
-65.712	18.598	237	30	45	1.1	18.0	13.2	Fault_{228}
-66.949	18.626	45	71	222	1.1	18.0	13.2	Fault_{229}
-66.809	18.710	136	30	200	1.1	18.0	13.2	Fault_{230}
-66.991	18.738	242	85	267	1.1	18.0	13.2	Fault_{231}
-66.851	18.612	265	25	210	1.1	18.0	13.2	Fault_{232}
-65.839	18.570	21	54	106	1.1	18.0	13.2	Fault_{233}
-65.769	18.879	190	38	69	1.1	18.0	13.2	Fault_{234}
-66.232	18.668	190	40	222	1.1	18.0	13.2	Fault_{235}
-65.923	18.471	55	85	82	1.1	18.0	13.2	Fault_{236}
-65.600	18.514	135	27	76	1.1	18.0	13.2	Fault_{237}
-67.048	18.879	175	85	89	1.1	18.0	13.2	Fault_{238}

Future Prospects

The fault systems in the Local Zone of Puerto Rico (LZPR) creates high tsunami hazard for Puerto Rico and the Virgin islands. This research probe that ocean floor movements induced by underwater earthquakes have the potential for producing vertical sea-floor displacements, which are considered as tsunamigenic. Historic tsunamis in the LZPR that were generated by quakes in the Mona Canyon and the Anegada Passage have resulted in widespread damage and loss of life along the eastern and western coast of Puerto Rico. Large seismic events will occur in some point in any subregion near Puerto Rico with high potential for generating local tsunamis.

Seismic water waves (tsunamis) originated in the LZPR are considerate as local sources that induce near-field hazard for Puerto Rico and Virgin islands and can reach the coasts and communities within few minutes after the earthquake. Therefore, saving lives and property depends on how well are designed the contingency and education plans that in few words means how well the community is prepared.

The characterization of faults in the LZPR need to be improved using new methods of quake locations, quake relocations. As an initial point, a detailed double difference (DD) scheme will be important to delineate the fault geometry in all the LZPR. More robust algorithms like quake cross correlation, 3-D search and pinpoint detector will resolve the quakes blurs into detailed fault lines.

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Appendix A

Broadband (BB) and Short Period (SP) station operated by the Puerto Rico Seismic Network (PRSN); the * indicates those stations out of service and the ⋆ represent the station of IRIS/USGS (IU). Number in the sensor field indicates the number of components.

No	Station	Location	Net.	Sensor	Lat. ($^\circ N$)	Lon. ($^\circ W$)	Elev. (m)
1	MGP	Lajas	PR	SP (1)	18.007	67.089	60
2	*AGP	Aguadilla	PR	SP (1)	18.4075	67.141	220
3	LSP	Mayagüez	PR	SP (1)	18.177	67.086	390
4	IDE	Isla Desecheo	PR	SP (3)	18.3865	67.49616	140
5	LRS	Lares	PR	SP (1)	18.193	66.845	460
6	*CBYP	Canóvanas	PR	SP (1)	18.271	65.856	140
7	*LPR	Canóvanas	PR	SP (1)	18.308	65.869	140
8	APR	Arecibo	PR	SP (1)	18.271	65.856	140
9	*PNP	Peñuelas	PR	SP (1)	18.059	66.766	53
10	PORP	Ponce	PR	SP (1)	18.054	66.637	165
11	CELP	Ponce	PR	SP (1)	18.075	66.576	195
12	*CLLP	Ponce	PR	SP (1)	18.07	66.5755	195
13	CSB	Bayamon	PR	SP (1)	18.289	66.156	430
14	CPD	Yabucoa	PR	SP (1)	18.039	65.915	370
15	SJG	Cayey	PR	SP (3)	18.112	66.150	457
16	*IMO	Isla de Mona	PR	SP (3)	18.1093	67.9076	85
17	*MOCA	Moca	PR	SP (1)	18.4143	67.0775	150
18	*MCP	Moca	PR	SP (1)	18.4188	67.1105	150
19	*CDP	Cerro de Punta	PR	SP (1)	18.175	66.5916	150
20	*RUM	Mayagüez	PR	SP (1)	18.2050	67.1296	100
21	MGP	Lajas	PR	BB (3)	18.007	67.089	60
22	AGP	Aguadilla	PR	BB (3)	18.4075	67.141	220
23	CBYP	Canóvanas	PR	BB (3)	18.271	65.856	140
24	CPD	Yabucoa	PR	BB (3)	18.039	65.915	370
25	*IMO	Isla de Mona	PR	BB (3)	18.1093	67.9076	85
26	MPR	Mayagüez	PR	BB (6)	18.2116	67.1398	100
27	ICM	Caja de Muertos	PR	BB (3)	17.893	66.521	25
28	MTP	Vieques	PR	BB (3)	18.097	65.552	120
29	*CORN	Cabo Rojo	PR	BB (3)	18.1516	67.1688	150
30	HUMP	Humacao	PR	BB (6)	18.1425	65.8497	180
31	*CDP	Cerro de Punta	PR	BB (3)	18.175	66.5916	150
32	⋆ SJG	Cayey	IU	BB (12)	18.112	66.150	457

Appendix B

Composite Focal Mechanism Routines

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! programa para sacar las polaridades de grupos de eventos.
! Victor/Klaus (1995)

parameter ( ndat = 10000 , n_good = 1501)
character line*80, stat(ndat)*4 , pol(ndat)*1
        character ifile*50
real dist(ndat) , azim(ndat), ainc(ndat)
real g_az(n_good),g_di(n_good),g_ra(n_good)
integer g_nok(n_good)
!        integer white,blue,red,yellow,green,brown
        character sel*2
!       character name*10
        common /par/ xla1,xla2,xlo1,xlo2,dep1,dep2,xmag1,xmag2

common /polar/ azim,ainc,pol,np
common /result/ g_az,g_di,g_ra,g_nok
!       common /par/ ixla,ixlo,xla,xlo,xdep
!        common /colores/ white,blue,red,yellow,green,brown

        sel = ' '

print *, '  '
print *, ' ************************ '
print *, ' Programa para obtener la polaridad de las ondas P,'
print *, ' dado un grupo de eventos en una region determinada'
print *, ' ************************ '
print *, '  '

iquake = 0
call seleccion

idat = 1
        print *,'Dame la direccion de los datos'
!       read(5,'(a)'), ifile
read *, ifile
open(1,file =ifile, status = 'old')


1 read(1,'(a)', end = 2) line

  if(line(1:4) .eq. 'Year') then

11         continue
```

```
     read(1,101,end=2) ixla,xla,ixlo,xlo,xdep,xmag1,xmag2

   print *, ixla,xla,ixlo,xlo,xdep,xmag1,xmag2

   xla = ixla + xla / 60.0
   xlo = ixlo + xlo / 60.0
   xmag = amax1 ( xmag1, xmag2 )

! determina si esta entre los limites requeridos:
!    call selecto(xla,xlo,xdep,xmag,isel)
     print *, 'Searching: ',isel,xla, xlo, xdep, xmag1, xmag2

   read(1,'(a)',end=2) line   ! blanco

   print *, isel

          isel = 1
   if ( isel.eq.1 ) then
! seleccionado
      iquake = iquake + 1
      read(1,'(a)',end=2) line
        read(1,'(a)',end=2) line

      do while ( lnblnk(line) .gt. 0 )
                 if (line(21:21) .eq. 'P' ) then
            read(line,31) stat(idat),dist(idat),im,in,pol(idat)
                 elseif(line(25:25) .eq. 'P' ) then
              read(line,100) stat(idat),dist(idat),im,in,pol(idat)
                 endif

                 print *, line

   azim(idat) = im
 ainc(idat) = in

   if( (pol(idat).eq.'U'.or.pol(idat).eq.'D') .and. lnblnk(stat(idat))
                    .ne. 0 ) idat = idat + 1

!  lnblnk(stat(idat)) .ne. 0 ) idat = idat + 1
                 read(1,'(a)',end=2) line
                 if ( line(1:4) .eq. 'Year' ) go to 11
      enddo

else
! lee hasta el proximo evento
read(1,'(a)',end=2) line
do while ( lnblnk(line) .gt. 0 )
read(1,'(a)',end=2) line
enddo
```

```
endif
endif

go to 1

2 close(1)

np = idat - 1

print *, ' En total tenemos : ',np,' Datos'
print *, ' de ',iquake,' eventos:'

call busca(nok)

nokmax = g_nok(1)
m = 1
do while ( g_nok(m) .eq. nokmax .and. m .le. n_good)
m = m + 1
enddo

print *, ' hay ',m-1,' modelos con: '
print *, nok,' consistencias '
print *, ' de un total de ',np
print *, ' y la geometria de:'
print *, ' strike = ',g_az(1)
print *, ' dip =    ',g_di(1)
print *, ' rake =   ',g_ra(1)

31              format(1x,a4,f5.1,1x,i3,1x,i3,3x,a1)
100         format(a4,5x,f5.1,1x,i3,1x,i3,3x,a1)
101         format(22x,i2,1x,f5.2,1x,i3,1x,f5.2,f6.2,23x,f3.1,1x,f3.1)
102         format(2x,a11,f5.1)
end

subroutine busca(nokmax)
! ahora tenemos np polaridades de ondas P.
! y queremos buscar la geometria que produzca el menor
! numero de lecturas inconsistentes.
parameter ( ndat = 10000 , n_good = 1501)
character pol(ndat)*1
real azim(ndat), inc(ndat)
real n(3),u(3),r(3)
real g_az(n_good),g_di(n_good),g_ra(n_good)
integer nsol(ndat), g_nok(n_good)
common /polar/ azim,inc,pol,np
common /result/ g_az,g_di,g_ra,g_nok
common /good/ nsol

do i = 1 , n_good
g_nok(i) = 0
```

```
enddo

! direcciones son: (1) = norte , (2) = oeste , (3) = up

print *, 'enter domain of search:'
print *, ' enter minimum, maximum , step, for strike:'
read *, da1,da2,daz
if(da1.eq.0.0.and.da2.eq.0.0) then
daz = 5.0
da1 = 0.0
da2 = 360.0 - daz
endif
print *, ' enter minimum, maximum , step, for dip:'
read *, di1,di2,ddi
if(di1.eq.0.0.and.di2.eq.0.0) then
ddi = 5.0
di1 = 0.0
di2 = 90.0 - ddi
endif
print *, ' enter minimum, maximum , step, for rake:'
read *, dr1,dr2,dra
if(dr1.eq.0.0.and.dr2.eq.0.0) then
dra = 5.0
dr1 = 0.0
dr2 = 360.0 - dra
endif

  do j = 1 , 2

! nokmax = numero de maximas consistencias
nokmax = 0

do az = da1 , da2  , daz
caz = cosd(az)
saz = sind(az)

do di = di1 , di2 , ddi

cdi = cosd(di)
sdi = sind(di)
n(1) = - sdi * saz
n(2) = - sdi * caz
n(3) = cdi

do ra = dr1 , dr2 , dra

cra = cosd(ra)
sra = sind(ra)

u(1) = cra * caz + sra * cdi * saz
```

```
u(2) = - cra * saz + sra * cdi * caz
u(3) = sra * sdi

! nin = numero de inconsistencias
nin = 0
! nok = numero de consistencias
nok = 0
! ahora calcula la polaridad para cada data
do i = 1 , np

r(1) = sind ( inc(i) ) * cosd ( azim(i) )
r(2) = - sind( inc(i) ) * sind ( azim(i) )
r(3) = - cosd( inc(i) )

ru = r(1)*u(1)+r(2)*u(2)+r(3)*u(3)
rn = r(1)*n(1)+r(2)*n(2)+r(3)*n(3)
res = ru * rn

if( (res.ge.0.0 .and. pol(i).eq.'U') .or.(res.le.0.0 .and. pol(i).eq.'D') ) then
! (res.le.0.0 .and. pol(i).eq.'D') ) then
nok = nok + 1
nsol(i) = 1
else
nin = nin + 1
nsol(i) = 0
endif

enddo

if( nok .gt. nokmax ) then
nokmax = nok
baz = az
bdi = di
bra = ra
write(6,'(2x,i4,2x,3(f5.1,2x))') nokmax,baz,bdi,bra
endif

if(j.eq.2) then
do m = 1 , n_good - 1
if(nok.gt.g_nok(m)) then
do k = n_good , m + 1 , -1
g_nok(k) = g_nok(k-1)
g_az(k) = g_az(k-1)
g_di(k) = g_di(k-1)
g_ra(k) = g_ra(k-1)
enddo
g_nok(m) = nok
g_az(m) = az
g_di(m) = di
g_ra(m) = ra
```

```
nok = -1
endif
enddo
endif

! termina el loop de "az,di,ra"
enddo
enddo
enddo

da1 = baz - 10.0
da2 = baz + 10.0
di1 = bdi - 10.0
di2 = bdi + 10.0
ra1 = bra - 10.0
ra2 = bra + 10.0
daz = 1.0
ddi = 1.0
dra = 1.0
if(da1.lt.0.0) da1 = 0.0
if(da2.gt.360.0) da2 = 360.0
if(di1.lt.0.0) di1 = 0.0
if(di2.gt.90.0) di2 = 90.0
if(ra1.lt.0.0) ra1 = 0.0
if(ra2.gt.360.0) ra2 = 360.0
! termina el loop de "j"
  enddo

print *, ' num cons. , az  , dip , rake: '
do m = 1 , n_good
print *, g_nok(m),g_az(m),g_di(m),g_ra(m)
enddo

return
end

subroutine selecto(x,y,d,g,isel)
common /par/ x1,x2,y1,y2,d1,d2,g1,g2

        print *, x1,x2,y1,y2,d1,d2,g1,g2
print *, x,y,d,g

isel = 0
if(x.ge.x1.and.x.le.x2.and.y.ge.y1.and.y.le.y2.and.d.ge.d1.and.d.le.d2
                .and.g.ge.g1.and.g.le.g2) then
!         .and.d.le.d2.and.g.ge.g1.and.g.le.g2) then
      isel = 1
endif
return
end
```

```
subroutine seleccion
common /par/ xla1,xla2,xlo1,xlo2,dep1,dep2,xmag1,xmag2

print *, ' Establece la region determinada de fuentes de eventos:'
print *, ' Min, Max Latitud:'
read *, xla1,xla2

print *, ' Min, Max Longitud:   (asumiendo todos  W) '
read *, xlo1,xlo2

print *, ' Min, Max Profundidad:'
read *, dep1, dep2

print *, ' Min, Max Magnitud:'
read *, xmag1, xmag2

return
end
```

Appendix C

Fault Parameter Routines, writen in TCL (Tool Command Language)

```
#!/bin/sh
# initial.tcl --
#
# This's the Initial conditions generator for the floodings: PRSN.
# Several variables were defined to work with the package, be carefull in defines.
#
# PFTP (PRSN - FEMA Tsunami Package) @Victor Huerfano(2002)

#exec itkwish "$0" ${1+"$@"}
package require Iwidgets 4.0
package require Efftcl
source /prsn/tcl/emu-graph/graph.tcl

#package require printer
#package require gdi

global xpixel ypixel nwells
set nwells 0
set plotFont -*-Helvetica-Medium-R-Normal--*-180-*-*-*-*-*-*

eval destroy [winfo child .]
wm title . "Initial conditions Generator (VAHM)"
wm iconname . "initial"

#fonts
set font -*-Helvetica-Medium-R-Normal--*-140-*-*-*-*-*-*

#Initial values problem
set x 0
set y 0

#set pixels for maps
#set xpixel 539          #Puerto Rico local Region
#set ypixel 308
set xpixel 498
set ypixel 356
set zooming 0
set 3d      0

#mouse defs
set mouse 0

#Zooming corners and zeroes
```

```
#set mouse 0
set x1 0
set y1 0
set x2 0
set y2 0
set xx1 0
set yy1 0
set xx2 0
set yy2 0
set ival 1

#Faults map coordinates
#set mouse 0
#set zval 1
#set x1 0
#set y1 0
#set x2 0
#set y2 0

#Fault geographical coordinates
set lat1 0
set lon1 0
set lat2 0
set lon2 0

#Multiple faults
set nlines 1

#Images
#set fileIN prico.gif
set fileIN fema.gif
set zoom $fileIN
set aa 537
set ab 5.5
set ba 307
set bb 3
set xi -69
set yi 20

#Grid zeroes
set dx 0
set sizeX 0
set sizeY 0
set gridX1 0
set gridY1 0
set gridX2 0
set gridY2 0
set gridIN none

frame .menus
```

```
pack .menus -side top -fill x

menubutton .menus.help -text Help -menu .menus.help.text \
           -underline 0 -borderwidth 2 -foreground orange4
set m .menus.help.text
menu $m
     $m add command -label "About" -command "aboutBox"
     $m add separator
     $m add command -label "README" -command {view_file README01 readme}

menubutton .menus.file -text "File" -menu .menus.file.files \
          -underline 0 -borderwidth 2 -foreground orange4
set m .menus.file.files
menu $m
     $m add command -label Open -command { } -state disable
     $m add command -label Save -command { } -state disable
     $m add command -label Print -command {
                                          set file tmp.ps
                                          .canvas postscript -height 800 -file $file
                                          DoPrinter_PS $file
                                  } -state disable
     $m add separator
     $m add command -label "Refresh" -command { ZeRoes }
     $m add cascade -label "Zones" -menu .menus.file.files.zones
     $m add cascade -label Faults  -menu .menus.file.files.faults
     $m add separator
     $m add command -label "Quit" -command "destroy ."

#     $m add cascade -label "Single Fault" \
#                           -menu .menus.file.files.single -underline 0
#     $m add command -label "Multiple Segments" -command { }
#     $m add command -label "Slip Region" -command { }

set   m .menus.file.files.faults
menu $m
     $m add command  -label "All Faults"    -command { Plot_Faults }
     $m add command  -label "User Selected" -command { User_Faults }

set   m .menus.file.files.zones
menu $m
     $m add radio -label "Puerto Rico Trench"    -variable fault -value PRTR }
     $m add radio -label "19 N Fault Zone"       -variable fault -value FZ19 }
     $m add radio -label "Mona Canyon"           -variable fault -value MNCY }
     $m add radio -label "Sombrero Seismic Zone" -variable fault -value SOZS }
     $m add radio -label "Anegada Pasage"        -variable fault -value ANPA }
     $m add radio -label "Southwestern PR"       -variable fault -value SWPR }
     $m add radio -label "North Shore Plataform" -variable fault -value NSPF }
     $m add radio -label "Eastern DR"            -variable fault -value EADR }
     $m add radio -label "Septentrional Fault"   -variable fault -value SEFA }
     $m add radio -label "Muertos Trough"        -variable fault -value MUTR }
```

```
     $m add radio -label "Leeward Islands"       -variable fault -value LEIS }
     $m add separator
     $m add radio -label "All Fault Zones"    -variable fault -value ALLFA
     $m add radio -label "Mouse Selected"     -variable fault -value MOUSE

menubutton .menus.map -text "Parameters" -menu .menus.map.maps \
          -underline 0 -borderwidth 2 -foreground orange4
set   m .menus.map.maps
menu $m
     $m add cascade -label Catalogue -menu .menus.map.maps.cata -underline 0
     $m add cascade -label Geometry  -menu .menus.map.maps.geo -underline 0
     $m add command -label "Select Data" -underline 0 -command { Select_Window }
     $m add separator
#    $m add cascade -label Corners -menu .menus.map.maps.reg -underline 0 -command {}
     $m add cascade -label b-value -menu .menus.map.maps.bval -underline 0
     $m add separator
     $m add check -label "Wells & Copersmith" -underline 0 -variable wells
     $m add command -label Constants -underline 0 -command {}
set   m .menus.map.maps.bval
menu $m
     $m add command -label "Recurrency" -command { B_Value_Table }
     $m add command -label "Graph Plot" -command { B_Value_Plot }
set   m .menus.map.maps.geo
menu $m
     $m add command -label CMT
     $m add command -label PRSN           -command { Geometry_PRSN }
     $m add command -label "User Defined" -command { Geometry_Window }
set   m .menus.map.maps.mag
menu $m
     $m add command -label Minimum
     $m add command -label Maximum
set   m .menus.map.maps.cata
menu $m
     $m add radio -label "PRSN" -variable catalog -value prsn
     $m add radio -label "USGS" -variable catalog -value usgs
     $m add command -label "User Defined" -command { }
#set   m .menus.map.maps.quakes
#menu $m
#     $m add radio -label "PRSN" -variable map -command { }
#     $m add radio -label "USGS" -variable map -command { }
#     $m add command -label "User Catalogue" -command { }
#
#    $m add command -label "Refresh" -command { Zeroes }
#     $m invoke 1

#menubutton .menus.model -text "Models" -menu .menus.model.models \
#           -underline 0 -borderwidth 2 -foreground orange4
#set m .menus.model.models
#menu $m
#     $m add radio -label "Manshina & Smile" -variable model -command { Manshina }
```

```
#     $m add radio -label "Okada" -variable model -command { }
#     $m add radio -label "Eric Gueist" -variable model -command { }
#     $m add separator
#     $m add radio -label "Wells & Copersmith" -variable values -command { }
#     $m add radio -label "S. Ward" -variable values -command { }
#     $m add radio -label "V. Hurfano" -variable values -command { }

#menubutton .menus.grid -text "Grids" -menu .menus.grid.grids \
#           -underline 0 -borderwidth 2 -foreground orange4
#set m .menus.grid.grids
#menu $m
#     $m add radio -label "1 Sec Arc" -variable grid -command { }
#     $m add radio -label "3 Sec Arc" -variable grid -command { }
#     $m add radio -label "9 Sec Arc" -variable grid -command { }
#     $m add radio -label "27 Sec Arc" -variable grid -command {
#                                        set dx 812
#                                        set sizeX 667
#                                        set sizeY 700
#                                        set gridX1 -69
#                                        set gridY1 21
#                                        set gridX2 -64
#                                        set gridY2 15.755
#                                        set gridIN grid27.grd
#                                                        }
#     $m add radio -label "81 Sec Arc" -variable grid -command { }
#     $m invoke 4

menubutton .menus.vis -text "Result    " -menu .menus.vis.visual \
          -underline 0 -borderwidth 2 -foreground orange4
set m .menus.vis.visual
menu $m
     $m add command -label "Mansinha & Smyle" -command { mansinha }
     $m add radio -label "Okada"            -command { set result backup  }
     $m add separator
     $m add command -label Display -command { }
#     $m add radio -label "D"  -command { set result display }
#     $m invoke 3

label .menus.text -width 40 -relief groove -anchor c -foreground blue
label .menus.mess -width 20 -relief groove -anchor c -foreground red

pack .menus.file .menus.map  .menus.vis .menus.text .menus.mess -side left
pack .menus.help -side right

. configure -background gray40

#frame for canvas and icons
frame .body
pack .body
```

```
#Canvas frame and scrollbars
set c .body.canvas.c

frame .body.canvas
pack  .body.canvas -side left

frame .body.canvas.grid
scrollbar .body.canvas.hscroll -orient horiz -command "$c xview"
scrollbar .body.canvas.vscroll -command "$c yview"

canvas $c -relief sunken -borderwidth 1 -width  $xpixel -height $ypixel \
          -xscrollcommand ".body.canvas.hscroll set" \
          -yscrollcommand ".body.canvas.vscroll set" \
          -scrollregion {0 0 100c 100c}
pack .body.canvas.grid -expand yes -fill both -padx 1 -pady 1
grid rowconfig    .body.canvas.grid 0 -weight 1 -minsize 0

grid $c -padx 1 -in .body.canvas.grid -pady 1 \
    -row 0 -column 0 -rowspan 1 -columnspan 1 -sticky news
grid .body.canvas.vscroll -in .body.canvas.grid -padx 1 -pady 1 \
    -row 0 -column 1 -rowspan 1 -columnspan 1 -sticky news
grid .body.canvas.hscroll -in .body.canvas.grid -padx 1 -pady 1 \
    -row 1 -column 0 -rowspan 1 -columnspan 1 -sticky news

$c create image 0 0 -anchor nw -tags mapa \
        -image [image create photo image1a -file $fileIN]
$c create rectangle 0 0 0 0  -outline red -tags tzoom
$c lower Image

#Body frame for icons and excutes
frame  .body.icons
pack .body.icons -expand yes -fill both  -side right -padx 1

image create photo zoomreg -file zoom_reg.gif
image create photo zoomin  -file zoom_in.gif
image create photo zoomout -file zoom_out.gif
image create photo zoomfit -file zoom_fit.gif
image create photo 3-D     -file 3-D.gif

checkbutton .body.icons.l1 -image zoomreg -indicatoron 0  -variable zooming
checkbutton .body.icons.l5 -image 3-D     -indicatoron 0  -variable 3d
button .body.icons.l2 -image zoomin   -command { zoomIN in  2 }
button .body.icons.l3 -image zoomout  -command { zoomIN out 2 }
button .body.icons.l4 -image zoomfit  -command { best_fit }

#menubutton .body.icons.l4 -image zoomfit -borderwidth 3
#menu .body.icons.l4.m -tearoff 0
#.body.icons.l4.m  add command -label "zoom 10%"  -command {}
#.body.icons.l4.m  add command -label "zoom 20%"  -command {}
#.body.icons.l4.m  add command -label "zoom 50%"  -command {}
```

```
#.body.icons.l4.m  add command -label "zoom 100%" -command {}
#.body.icons.l4.m  add command -label "zoom 200%" -command {}
#.body.icons.l4.m  add command -label "zoom 500%" -command {}
#.body.icons.l4.m  add command -label "zoom 1000%"   -command {}

balloonhelp_for .body.icons.l1 {region zoom}
balloonhelp_for .body.icons.l2 {double size}
balloonhelp_for .body.icons.l3 {half size}
balloonhelp_for .body.icons.l4 {fit zoom}

pack .body.icons.l1 .body.icons.l2 .body.icons.l3
#bind .header.right.l1 <Button-1> {exec $browser $link01 &}


bind $c <1>               { PlotLineIN  %W %x %y }
bind $c <ButtonRelease-1> { PlotLineOUT %W %x %y }
bind $c <B1-Motion>       { PlotLineMOV %W %x %y }
set plot(lastX) 0
set plot(lastY) 0
set mouseCOORD " "

#button .zoomin -text "Zoom in" -command {
#       error "Victor Huerfano"
#       .canvas scale tzoom 0 0 5 5
#       .canvas configure -scrollregion [.canvas bbox image ]
#       error [.canvas bbox all]
#}
#pack .zoomin -side left -expand yes -padx 4 -pady 4

#Azimuth/dip Selector
proc best_fit { } {
#     global zooming x1 y1 x2 y2
     global points
     global  dipX dipx1 dipy1 dipx2 dipy2

     set dipX 0

     if { [info exist points] == 0 } {
          Error_Def 8
          return
     }
     if { [llength $points] < 12 } {
          Error_Def 7
          return
     }

     set file geometry.dat
     set fileID [open $file w]
     for {set j 5 } {$j  <= [llength $points]} {incr j 6} {
          set entry [ lrange $points [ expr $j-5 ] [ expr $j ] ]
```

```
          puts $fileID  $entry
     }
     close $fileID

     set geometry [ exec quake_geometry $file ]
#
     set npoints  [ lindex $geometry 0 ]
     set lpoints  [ expr $npoints * 2 ]
     set qpoints  [ lrange $geometry 1 $lpoints ]
#
     set geometry [ lrange $geometry [expr $lpoints + 1] end]
     set nregreA  [ lindex $geometry 0 ]
     set lregreA  [ expr $nregreA * 2 ]
     set qregreA  [ lrange $geometry 1 $lregreA ]
#
     set geometry [ lrange $geometry [expr $lregreA + 1] end]
     set azimuth  [ lindex $geometry 0 ]
#
     set geometry [ lrange $geometry 1 end]
     set nhypos   [ lindex $geometry 0 ]
     set lhypos   [ expr $nhypos * 2 ]
     set qhypos   [ lrange $geometry 1 $lhypos ]
#
     set geometry [ lrange $geometry [expr $lhypos + 1] end]
     set nregreB  [ lindex $geometry 0 ]
     set lregreB  [ expr $nregreB * 2 ]
     set qregreB  [ lrange $geometry 1 $lregreB ]
#
     set dip [ lindex $geometry [expr $lregreB+1] ]

     set w .regretion
     catch [destroy $w]
     toplevel $w
     wm title $w "FEMA Regretion Tool"
     wm iconname $w "entry1"

     frame $w.left
     frame $w.right
     pack $w.left $w.right -side left

     set c1 $w.left.canvas
     canvas $c1 -width 300 -height 300
     pack $c1
     emu_graph foo1 -canvas $c1 -width 250 -height 250
     foo1 data d2 -colour blue -points 1 -lines 0 \
 -coords $qpoints
     foo1 data d1 -colour red -points 1 -lines 1 \
 -coords $qregreA
     $c1 create text 25 15 -fill black -anchor w -text "Azimuth: $azimuth"
```

```
     set c2 $w.right.canvas
     canvas $c2 -width 350 -height 300
     pack $c2
     emu_graph foo2 -canvas $c2 -width 250 -height 250
     foo2 data d2 -colour blue -points 1 -lines 0 \
 -coords $qhypos
#     foo2 data d1 -colour red -points 1 -lines 1 \
#  -coords $qregreB
     $c2 create text 25 15 -fill black -anchor w -text "Dip: $dip"

     bind $c2 <1>  { PlotDIP  %W %x %y }
}

proc PlotDIP { w x y } {
     global  dipX dipx1 dipy1 dipx2 dipy2

     set x [expr int( [.regretion.right.canvas canvasx $x] )]
     set y [expr int( [.regretion.right.canvas canvasy $y] )]

     incr  dipX
     if { $dipX == 1 } {
          set dipx1 $x
          set dipy1 $y
     } elseif { $dipX == 2 } {
             set dipx2 $x
             set dipy2 $y
             set deltaY [expr abs(abs($dipy2) - abs($dipy1))]
             set deltaX [expr abs($dipx2 - $dipx1)]
             set radioR [expr sqrt($deltaY*$deltaY + $deltaX*$deltaX)]

             set angle [ expr asin($deltaY/$radioR)*180/3.14159]
#            set slope  [expr tan($deltaY/$deltaX)]

             .regretion.right.canvas create line $dipx1 $dipy1
             .regretion.right.canvas create text $dipx1 $dipy1

#             tk_messageBox -message "dipx1 dipy1 dipx2 dipy2"
             set dipX 0
     } else {
           set dipX 0
     }
}


#Mouse defined zooming, specific region must be selected before
proc Popup { xx2 yy2 } {
           global xx1 yy1
           global zoom image1a image1b

           set w .popup
```

```
            catch [destroy $w]
            toplevel $w
            wm title $w "FEMA popup Tool"
            wm iconname $w "entry1"

           .menus.text configure -text "Zooming tool"

#--- get fault coodinates
            set fault [.body.canvas.c coords fzoom]

#--- maximum and minimum fault points
            if { $xx1 < $xx2 } {
                set minX [expr int($xx1)]
            } else {
                set minX [expr int($xx2)]
            }
            if { $yy1 < $yy2 } {
                set minY [expr int($yy1)]
            } else {
                set minY [expr int($yy2)]
            }

#           set separator "x"
            set xwin [expr int(abs($xx1-$xx2))]
            set ywin [expr int(abs($yy1-$yy2))]
#           set expand "500%"

            image create photo image1b -file zoom.gif
            image1b copy image1a -from $xx1 $yy1 $xx2 $yy2 -zoom 2
            canvas $w.canvas -width [expr 2*$xwin]  -height [expr 2*$ywin]
            pack $w.canvas -expand yes -fill both -padx 2 -pady 2

#            exec /progra~1/ImagiK/convert -crop $xwin$separator$ywin+$minX+$minY
            $w.canvas create image 0 0 -anchor nw -tags zoomin \
                   -image image1b
#           $w.canvas lower Image

#-- include faults if any
            if { [llength $fault] >= 4 } {
                set fx1 [expr ([lindex $fault 0] - $minX)*5]
                set fy1 [expr ([lindex $fault 1] - $minY)*5]
                set fx2 [expr ([lindex $fault 2] - $minX)*5]
                set fy2 [expr ([lindex $fault 3] - $minY)*5]
                $w.canvas create line $fx1 $fy1 $fx2 $fy2 -fill red -tags pfault
            }
}

#Zooming line button <1 press>
proc PlotLineIN {win x y} {
     global zooming x1  y1 xx1 yy1 3d
```

```
     global mouse xpixel ypixel mouseCOORD
     global wells nwells x1wells y1wells x2wells y2wells

     catch [ .body.canvas.c delete tzoom ]
     set mouseCOORD " "

     set x [expr int( [.body.canvas.c canvasx $x] )]
     set y [expr int( [.body.canvas.c canvasy $y] )]

     set x1 [ expr (7.0/$xpixel)*$x - 70 ]
     set y1 [ expr (21 - (5.0/$ypixel)*$y) ]
     set xx1 $x
     set yy1 $y

     if { $wells == 1 } {
          incr nwells
          if { $nwells == 1 } {
             set x1wells $x1
             set y1wells $y1
          } elseif { $nwells == 2 } {
             set x2wells $x1
             set y2wells $y1
             set wells_results [exec wells_copersmith.exe $x1wells
             tk_messageBox -message "$wells_results"
             set nwells 0
          } else {
              set nwells 0
          }
     }

     if { $mouse == 1 || $3d == 1} {
          catch [ .body.canvas.c delete mouse   ]
#         set mouseCOORD [ linsert $mouseCOORD end "$x1 $y1" ]
     }

     if { $zooming == 0 } {
         .menus.text configure -text "LON: $x1 LAT: $y1"
     } else {
         .menus.text configure -text "Zooming activate"
     }
}

#Zooming line button <1 Release>
proc PlotLineOUT {win x y} {
     global zooming x1 y1 xx1 yy1 x2 y2 3d
     global mouse xpixel ypixel mouseCOORD

     set x [expr int( [.body.canvas.c canvasx $x] )]
     set y [expr int( [.body.canvas.c canvasy $y] )]
```

```
     set x2 [ expr (7.0/$xpixel)*$x - 70 ]
     set y2 [ expr (21 - (5.0/$ypixel)*$y) ]
     set xx2 $x
     set yy2 $y

     if { $mouse == 1 } {
#          set mouseCOORD [ linsert $mouseCOORD end "$x2 $y2" ]
          set file mouse.xy
          set fileID [open $file w]
              foreach pair $mouseCOORD {
                      puts $fileID  $pair
              }
          close $fileID
#         tk_messageBox -message  "$mouseCOORD"
     }

     if { $3d == 1 } {
        .body.icons.l5 deselect
        if { $x1 == $x2 || $y1 == $y2 } {
           tk_messageBox -icon error -title "FEMA fatal error"
           return
        }
        tk_messageBox -message "$x1 $y1 $x2 $y2"
     }

     catch [ .body.canvas.c delete tzoom ]

     if { $zooming == 0 } { return }

     .body.icons.l1 deselect
     Popup $xx2 $yy2
}

#Zooming line button <1 Move>
proc PlotLineMOV {win x y} {
     global mouse zooming x1 y1 xx1 yy1 3d
     global mouseCOORD xpixel ypixel

     set x [expr int( [.body.canvas.c canvasx $x] )]
     set y [expr int( [.body.canvas.c canvasy $y] )]

     set x2 [ expr (7.0/$xpixel)*$x - 70 ]
     set y2 [ expr (21 - (5.0/$ypixel)*$y) ]
     set xx2 $x
     set yy2 $y

     if { $mouse == 1 } {
          .body.canvas.c create oval  $x $y $x $y -fill LightPink1
#          set plot(lastX) $x
#          set plot(lastY) $y
```

```
          set mouseCOORD [ linsert $mouseCOORD end "$x2 $y2" ]
     }

     if { $zooming == 1 || $3d == 1 } {
          catch [ .body.canvas.c delete tzoom ]

          .body.canvas.c create rectangle [expr $xx1] [expr $yy1] \
             [expr $xx2] [expr $yy2]  -outline red -tags tzoom
     }

     if { $zooming == 0 } { return }

}

#Display the window with ABOUT information
proc aboutBox {} {
    tk_messageBox -icon info -type ok -title "FEMA Software System" \
    "Desarrollado por Victor Huerfano \n\
    Tarea 1 en Proyecto FEMA \n\
    Copyright (c) Victor \n\
    Version 1.0"
}

#Activates the user defined browser or inner display tool
proc view_file { filename title } {
     set browser netscape
     exec $browser /victor/fema/programs/$filename.html &
#     package require Iwidgets 3.0
#     option add *textBackground seashell


#     set win [iwidgets::hyperhelp .#auto -title "$title" -modality none \
#         -helpdir ""]
#     $win showtopic $filename
#     $win activate

# toplevel .$title
# wm title .$title $title
# wm iconname .$title $title
# text .$title.text -relief raised -bd 2 -yscrollcommand "
# scrollbar .$title.scroll -command ".$title.text yview"
# pack .$title.scroll -side right -fill y
# pack .$title.text -side left
# set f [open $filename ]
# while {![eof $f]} {.$title.text insert end [read $f 1000] }
# close $f
}

#Zooming window
proc zoomIN { do x } {
```

```
     image create photo image1c -file zoom.gif
     if { $do == "in" } {
          image1c copy [ .body.canvas.c itemcget mapa -image ]
     } elseif { $do == "out" } {
          image1c copy [ .body.canvas.c itemcget mapa -image ]
     }
     image1a blank
     image1a copy image1c
     .body.canvas.c itemconfigure mapa -image image1a
}

#mouse fault option
proc add_Fault {win x y} {
     global mouse
     global zval
     global x1
     global y1
     global x2
     global y2
     global lat1
     global lon1
     global lat2
     global lon2

     catch [ destroy .popup ]
     catch [ $win delete tzoom ]

     geoPoints $x $y

     if { $mouse == 1 } {
        if { $zval == 1 } {
            catch [ $win delete izoom ]
            catch [ $win delete fzoom]

            set x1 [$win canvasx $x]
            set y1 [$win canvasy $y]
            set lon1 [ expr (5.5/539)*$x1 - 69 ]
            set lat1 [ expr (20 - (3.0/307)*$y1) ]

            $win create oval [expr $x1] [expr $y1] \
                 [expr $x1+1] [expr $y1+1]  -outline red -tags izoom
            incr zval
        } else {
               set x2 [$win canvasx $x]
               set y2 [$win canvasy $y]
               set lon2 [ expr (5.5/539)*$x2 - 69 ]
               set lat2 [ expr (20 - (3.0/307)*$y2) ]
               set zval 1

               $win create oval [expr $x2] [expr $y2] \
```

```
                    [expr $x2+1] [expr $y2+1] -outline red -tags izoom
               $win create line [expr $x1] [expr $y1] \
                    [expr $x2] [expr $y2]  -fill red -tags fzoom
        }
     } else {
            catch [ $win delete izoom ]
            catch [ $win delete fzoom]
     }
}

#Shows the geographical coordinates in top of main window
proc geoPoints { x y } {
#     global zooming

     set aa1 [ expr (5.5/539)*$x - 69 ]
     set bb1 [ expr (20 - (3.0/307)*$y) ]

     .menus.text configure -text "$x $y $aa1 $bb1"
}

#Refresh the fault variables using the coordinates popup
proc reload { lat1 lon1 lat2 lon2 } {
            global x1
            global y1
            global x2
            global y2

            catch [.canvas delete fault ]
            catch [.canvas delete tzoom]
            catch [.canvas delete izoom]
            catch [.canvas delete fzoom]
            catch [destroy .popup]

                  set a1 [ expr 537/5.5 ]
                  set a2 [ expr -307/3 ]
                  set b1 [ expr 69*$a1 ]
                  set b2 [ expr -$a2*20 ]
                  set x1 [expr ($lon1*$a1 + $b1)]
                  set y1 [expr ($lat1*$a2 + $b2)]
                  set x2 [expr ($lon2*$a1 + $b1)]
                  set y2 [expr ($lat2*$a2 + $b2)]

                  .canvas create line $x1 $y1 $x2 $y2 -fill red -tags fzoom
                  .menus.text configure -text "$lon1 $lat1 $lon2 $lat2"
}

#Child window with entrys for a single fault coordinates
proc Coordinates {} {
                  set w .region
                  catch {destroy $w}
```

```
                    toplevel $w
                    wm title $w "Single fault selector"
                    wm iconname $w "entry1"

                    set font -*-Helvetica-Medium-R-Normal--*-120-*-*-*-*-*-*

                    iwidgets::Labeledframe $w.pr1 -labelpos ne -labeltext
                    set cs1 [$w.pr1 childsite]
                    iwidgets::entryfield $cs1.lat \
                             -highlightthickness 0 \
                             -labelpos w \
                             -labeltext "Latitude  ():" \
                             -width 8 \
                             -textvariable lat1
                    iwidgets::entryfield $cs1.lon \
                             -highlightthickness 0 \
                             -labelpos w \
                             -labeltext "    Longitude  ():" \
                             -width 8 \
                             -textvariable lon1
                    pack $cs1.lat $cs1.lon -side left -fill x -anchor w

                    iwidgets::Labeledframe $w.pr2 -labelpos ne -labeltext
                    set cs2 [$w.pr2 childsite]
                    iwidgets::entryfield $cs2.lat \
                             -highlightthickness 0 \
                             -labelpos w \
                             -labeltext "Latitude  ():" \
                             -width 8 \
                             -textvariable lat2
                    iwidgets::entryfield $cs2.lon \
                             -highlightthickness 0 \
                             -labelpos w \
                             -labeltext "    Longitude  ():" \
                             -width 8 \
                             -textvariable lon2
                    pack $cs2.lat $cs2.lon -side left -fill x -anchor w

                    button $w.go -text Update -relief groove -command

                    pack $w.pr1 -fill both
                    pack $w.pr2 -fill both
                    pack $w.go
}

#Mouse defined zooming, specific region must be selected before
proc XPopup { } {
            global xx1
            global yy1
            global xx2
```

```
             global yy2
             global zoom

            set w .popup
            catch {destroy $w}
            toplevel $w
            wm title $w "FEMA popup Tool"
            wm iconname $w "entry1"

           .menus.text configure -text "Zooming tool"

#--- get fault coodinates
            set fault [.canvas coords fzoom]

#--- maximum and minimum fault points
            if { $xx1 < $xx2 } {
                set minX [expr int($xx1)]
            } else {
                set minX [expr int($xx2)]
            }
            if { $yy1 < $yy2 } {
                set minY [expr int($yy1)]
            } else {
                set minY [expr int($yy2)]
            }

            set separator "x"
            set xwin [expr int(abs($xx1-$xx2))]
            set ywin [expr int(abs($yy1-$yy2))]
            set expand "500%"

            canvas $w.canvas -width [expr 5*$xwin]  -height [expr 5*$ywin]
            pack $w.canvas -expand yes -fill both -padx 4 -pady 4

            exec /progra~1/ImagiK/convert -crop $xwin$separator$ywin+$minX+$minY
            $w.canvas create image 0 0 -anchor nw -tags [list url: alt: Image] \
                   -image [image create photo image1b -file tmp.gif]
            $w.canvas lower Image

#-- include faults if any
            if { [llength $fault] >= 4 } {
                set fx1 [expr ([lindex $fault 0] - $minX)*5]
                set fy1 [expr ([lindex $fault 1] - $minY)*5]
                set fx2 [expr ([lindex $fault 2] - $minX)*5]
                set fy2 [expr ([lindex $fault 3] - $minY)*5]
                $w.canvas create line $fx1 $fy1 $fx2 $fy2 -fill red -tags pfault
            }
}

#Runs the Manshina & Smile model
```

```
proc Manshina {} {
     global lon1
     global lat1
     global lon2
     global lat2

          if { $lon1 == $lon2 && $lat1 == $lat2 } {
              set answer [tk_messageBox -title "PFTP Error" -icon error -type ok
              case $answer { ok return }
          }
          .menus.text configure -text "($lon1,$lat1:$lon2,$lat2)"

          set w .manshina
          catch {destroy $w}
          toplevel $w
          wm title $w "Manshina & Smile Tool"
          wm iconname $w "entry1"

          set font -*-Helvetica-Medium-R-Normal--*-120-*-*-*-*-*-*

          frame $w.fl1 -relief solid -borderwidth 1
          pack $w.fl1

               iwidgets::Labeledframe $w.fl1.pr3 -labelpos ne -labeltext
               set cs3 [$w.fl1.pr3 childsite]
               iwidgets::entryfield $cs3.len \
                           -highlightthickness 0 \
                           -labelpos w \
                           -labeltext "Len.:" \
                           -width 5 \
                           -textvariable len
                  iwidgets::entryfield $cs3.width \
                           -highlightthickness 0 \
                           -labelpos w \
                           -labeltext "Width:" \
                           -width 5 \
                           -textvariable wid
                  iwidgets::entryfield $cs3.depth \
                           -highlightthickness 0 \
                           -labelpos w \
                           -labeltext "Depth:" \
                           -width 5 \
                           -textvariable dep
                  pack $cs3.len $cs3.width $cs3.depth -side left

                  iwidgets::Labeledframe $w.fl1.pr4 -labelpos ne
                  set cs4 [$w.fl1.pr4 childsite]
                  iwidgets::entryfield $cs4.strike \
                           -highlightthickness 0 \
                           -labelpos w \
```

```
                        -labeltext "Strike:" \
                        -width 3 \
                        -textvariable strike
                iwidgets::entryfield $cs4.dip \
                        -highlightthickness 0 \
                        -labelpos w \
                        -labeltext "Dip:" \
                        -width 3 \
                        -textvariable dip
                iwidgets::entryfield $cs4.rake \
                        -highlightthickness 0 \
                        -labelpos w \
                        -labeltext "Rake:" \
                        -width 3 \
                        -textvariable rake
                iwidgets::entryfield $cs4.slip \
                        -highlightthickness 0 \
                        -labelpos w \
                        -labeltext "Slip:" \
                        -width 4 \
                        -textvariable slip
                pack $cs4.strike $cs4.dip $cs4.rake $cs4.slip -side left

        pack $w.fl1.pr4 -fill both
        pack $w.fl1.pr3 -fill both


        button $w.val -text Values -relief groove -command {Show_Values }
        button $w.go -text Launch -relief groove -command { }
        pack $w.val $w.go -expand 1 -side left
}

#Show Values window
proc Show_Values {slip strike dip rake len dep wid} {
     global dx
     tk_messageBox -title "PFTP Parameters" -type ok -icon question -message "\
                   FAULT #1:\n x=y= $dx (m) \n Slip: $slip (m)\n =
}

#Set all variables to initial conditions and clean memory allocations
proc ZeRoes {} {
     global mouse

     ZeRoes unset
}

#Quake Window request
proc Select_Window {} {
     global dat1 tim1 dat2 tim2
     package require Iwidgets 3.0
```

```
     set w .data
     catch [destroy $w]
     toplevel $w
     wm title $w "Catalogue Search Tool"

         frame $w.files  -relief groove -borderwidth 2
         pack  $w.files   -fill both -padx 8

         frame $w.files.dat
         pack  $w.files.dat -side top  -pady 2
         label $w.files.dat.from  -text "Year  From :      "
         label $w.files.dat.to  -text "  To: "
         entry $w.files.dat.vfrom -relief sunken   -textvariable year1
         entry $w.files.dat.vto   -relief sunken   -textvariable year2
         pack $w.files.dat.from $w.files.dat.vfrom \
              $w.files.dat.to $w.files.dat.vto \
              -fill x -side left

         frame $w.files.dep
         pack  $w.files.dep -side top -pady 4
         label $w.files.dep.from  -text "Depth(Z) Down:"
         label $w.files.dep.to    -text " Up : "
         entry $w.files.dep.vfrom -relief sunken -textvariable depth1
         entry $w.files.dep.vto -relief sunken   -textvariable depth2
         pack $w.files.dep.from $w.files.dep.vfrom \
              $w.files.dep.to $w.files.dep.vto \
               -side left -fill x -expand 1

         frame $w.files.mag
         pack  $w.files.mag -side top
         label $w.files.mag.from  -text "Magnitude Min: "
         label $w.files.mag.to    -text "Max: "
         entry $w.files.mag.vfrom -relief sunken -textvariable mag1
         entry $w.files.mag.vto   -relief sunken -textvariable mag2
         pack $w.files.mag.from $w.files.mag.vfrom \
              $w.files.mag.to $w.files.mag.vto \
               -side left -fill x -expand 1

        iwidgets::Labeledframe $w.files.doit -labelpos w -labeltext ""
        set cs3 [$w.files.doit childsite]
        iwidgets::pushbutton $cs3.go -text Plot -defaultring yes
        pack $cs3.go -pady 2
        pack $w.files.doit -fill both -pady 2
}

#Geeometry Window request
proc Geometry_Window {} {
     global dat1 tim1 dat2 tim2
     package require Iwidgets 3.0
```

```
      set w .rtime
      catch [destroy $w]
      toplevel $w
      wm title $w "Catalogue Search Tool"

          frame .rtime.files  -relief groove -borderwidth 2
          pack  .rtime.files   -fill both -padx 8

          frame .rtime.files.dat
          pack  .rtime.files.dat -side top  -pady 2
          label .rtime.files.dat.from  -text "Strike From:"
          label .rtime.files.dat.to  -text  " To : "
          entry .rtime.files.dat.vfrom -relief sunken -textvariable e1
          entry .rtime.files.dat.vto   -relief sunken -textvariable e2
          pack .rtime.files.dat.from .rtime.files.dat.vfrom \
               .rtime.files.dat.to .rtime.files.dat.vto \
               -fill x -side left

          frame .rtime.files.dep
          pack  .rtime.files.dep -side top -pady 4
          label .rtime.files.dep.from  -text "Dip   From: "
          label .rtime.files.dep.to    -text " To : "
          entry .rtime.files.dep.vfrom -relief sunken -textvariable e7
          entry .rtime.files.dep.vto -relief sunken   -textvariable e8
          pack .rtime.files.dep.from .rtime.files.dep.vfrom \
               .rtime.files.dep.to .rtime.files.dep.vto \
                -side left -fill x -expand 1

          frame .rtime.files.mag
          pack  .rtime.files.mag -side top
          label .rtime.files.mag.from  -text "Rake from: "
          label .rtime.files.mag.to    -text " To : "
          entry .rtime.files.mag.vfrom -relief sunken -textvariable e9
          entry .rtime.files.mag.vto -relief sunken   -textvariable e10
          pack .rtime.files.mag.from .rtime.files.mag.vfrom \
               .rtime.files.mag.to .rtime.files.mag.vto \
                -side left -fill x -expand 1

        iwidgets::Labeledframe .rtime.files.doit -labelpos w -labeltext ""
        set cs3 [.rtime.files.doit childsite]
        iwidgets::pushbutton $cs3.go -text "Seismic Lines" -defaultring yes
        pack $cs3.go -side top -pady 2
        pack .rtime.files.doit -fill both -pady 2


}

#Seismic Lines Plotter
proc Seismic_Lines { } {
```

```
     global xpixel ypixel

     set file LSismicas.dat
     set f [open  $file r]
     while {![eof $f]} {set lines [read $f] }
     close $f

     set nlines [lindex $lines 0 ]
     set lines  [ lrange $lines 1 end]

     for {set i 0} {$i < $nlines} {incr i} {
         set puntos  [ lindex $lines 0 ]
         set tag     [ lindex $lines 1 ]
         set entry   [ lrange $lines 4 [expr 2*$puntos + $puntos + 1] ]
         set vals    [ lrange $entry 0 end]
         set lines   [ lrange $lines [ expr [llength $entry] + 4] end]

#        tk_messageBox -message "$entry"

         for {set j 4 } {$j  <= [llength $vals]} {incr j 2} {
             set x1 [lindex $vals [expr $j - 4 ]]
             set y1 [lindex $vals [expr $j - 3 ]]
             set x1 [expr (70 + $x1)*($xpixel)/7]
             set y1 [expr (21 - $y1)*($ypixel)/5  ]
             set x2 [lindex $vals [expr $j - 2 ]]
             set y2 [lindex $vals [expr $j - 1 ]]
             set x2 [expr (70 + $x2)*($xpixel)/7]
             set y2 [expr (21 - $y2)*($ypixel)/5  ]
#             tk_messageBox -message "$x1 $y1  $x2 $y2"
             .body.canvas.c create line $x1 $y1  $x2 $y2 -fill maroon1
          }
          .body.canvas.c bind $tag <Double-Button-1>  "PlotLSismica $tag"
          .body.canvas.c bind $tag <Enter> "PutNameLine $tag"
          .body.canvas.c bind $tag <Leave> "QuitNameLine $tag"
     }
}

proc QuitNameLine { tag } {
.menus.mess config -text " "
}

proc PutNameLine { tag } {
.menus.mess config -text "Line: [file rootname $tag]"
}

proc PlotLSismica { tag } {
     set file LSismicas.dat
     set f [open  $file r]
     while {![eof $f]} {set lines [read $f] }
     close $f
```

```
     set nlines [lindex $lines 0 ]
     set lines  [ lrange $lines 1 end]

     for {set i 0} {$i < $nlines} {incr i} {
         set puntos  [ lindex $lines 0 ]
         set fig     [lindex $lines 1]
         set xpixel  [lindex $lines 2]
         set ypixel  [lindex $lines 3]
         set entry   [ lrange $lines 4 [expr 2*$puntos+ $puntos+1] ]
         set vals    [ lrange $entry 0 end]
         set lines   [ lrange $lines [ expr [llength $entry] + 4] end]
         if { $tag == $fig } {
              set w .lineas
              catch {destroy $w }
              toplevel $w
              wm title $w "PRSN FEMA Seismic Lines Tool"
              wm iconname $w "initial"

              set c $w.canvas
              canvas $c -relief solid -borderwidth 1 -width  $xpixel
              $c create image 0 0 -anchor nw -tags mapa \
                -image [image create photo image1b -file ./LineasSismicas/$fig]
              pack $c -side top -fill x

         }
     }
}

#Load Defaults
proc Defaults { fault } {
     global xpixel ypixel

     catch [ .body.canvas.c delete regions ]

     if { $fault == "MOUSE" } {return}

     set file Regions.dat
     set f [open  $file r]
     while {![eof $f]} {set lines [read $f] }
     close $f

     if { $fault == "ALLFA"  } {
          set allfa "SEFA PRTR FZ19 MNCY SOZS SWPR NSPF EADR LEIS MUTR ANPA"
          foreach fname $allfa {
#                 tk_messageBox -icon info -title "FEMA Fault Zone Tool"
                  set nregion [ lindex $lines 0 ]
                  set lines   [ lrange $lines 1 end]
                  set nlines  [ lindex  $lines [ expr [lsearch -exact
                  set mlines  [ expr 2*$nlines - 1 ]
```

```
                set plines   [ lrange $lines [ expr [lsearch -exact
                set plines   [ lrange $plines 2 [expr $mlines + 2] ]

#               tk_messageBox -message "$plines"

                set vals $plines
                for {set j 4 } {$j  <= [llength $vals]} {incr j 2} {
                    set x1 [lindex $vals [expr $j - 4 ]]
                    set y1 [lindex $vals [expr $j - 3 ]]
                    set x1 [expr (70 + $x1)*($xpixel)/7]
                    set y1 [expr (21 - $y1)*($ypixel)/5  ]
                    set x2 [lindex $vals [expr $j - 2 ]]
                    set y2 [lindex $vals [expr $j - 1 ]]
                    set x2 [expr (70 + $x2)*($xpixel)/7]
                    set y2 [expr (21 - $y2)*($ypixel)/5  ]
                   .body.canvas.c create line $x1 $y1  $x2 $y2 -fill
#                   .menus.mess config -text "Region: $fname"
                }
                .menus.mess config -text "Region: Puerto Rico"
         }
         return
    }

    set nregion [ lindex $lines 0 ]
    set lines   [ lrange $lines 1 end]
    set nlines  [ lindex  $lines [ expr [lsearch -exact $lines $fault] - 1] ]
    set mlines  [ expr 2*$nlines - 1 ]
    set lines   [ lrange $lines [ expr [lsearch -exact $lines $fault] + 1] end]
    set lines   [ lrange $lines 0 $mlines ]

#     error $lines

#     for {set i 0} {$i < $nlines} {incr i} {
#         set puntos  [ lindex $lines 0 ]
#         set entry   [ lrange $lines 1 [expr 2*$puntos] ]
#         set vals    [ lrange $entry 0 end]
#         set lines   [ lrange $lines [ expr [llength $entry] + 1] end]

        set vals $lines
        for {set j 4 } {$j  <= [llength $vals]} {incr j 2} {
            set x1 [lindex $vals [expr $j - 4 ]]
            set y1 [lindex $vals [expr $j - 3 ]]
            set x1 [expr (70 + $x1)*($xpixel)/7]
            set y1 [expr (21 - $y1)*($ypixel)/5  ]
            set x2 [lindex $vals [expr $j - 2 ]]
            set y2 [lindex $vals [expr $j - 1 ]]
            set x2 [expr (70 + $x2)*($xpixel)/7]
            set y2 [expr (21 - $y2)*($ypixel)/5  ]
#            tk_messageBox -message "$x1 $y1  $x2 $y2"
```

```
            .body.canvas.c create line $x1 $y1  $x2 $y2 -fill orange1
          }
          .menus.mess config -text "Region: $fault"
#         .body.canvas.c bind regions <Enter>  "PutNameLine $fault"
#     }
}

#quakes plotter
proc Quakes_Mapper { } {
     global fault year1 year2 depth1 depth2
     global mag1 mag2 catalog mouse
     global xpixel ypixel points

     catch [ .body.canvas.c delete focos ]

     if { $year1 >= $year2 || [llength $year1] == 0 || [llength $year1] == 0 } {
          Error_Def 1
          return
     }
     if { $depth1 <= $depth2 || [llength $depth1] == 0 || [llength $depth2] == 0 } {
          Error_Def 2
          return
     }
     if { $mag1 >= $mag2 || [llength $mag1] == 0 || [llength $mag2] == 0 } {
          Error_Def 3
          return
     }
     if { $catalog != "prsn" && $catalog != "usgs" } {
          Error_Def 5
          return
     }

     if { $mouse == 1 } {
          set fault mouse
     }
     if { [llength $fault] == 0 } {
          Error_Def 6
          return
     }

     if { $catalog == "prsn" } {set program searchPRSN }
     if { $catalog == "usgs" } {set program searchUSGS }

#    error "$program $fault $year1 $year2 $depth1 $depth2 $mag1 $mag2"

     set points [exec $program $fault $year1 $year2 $depth1 $depth2 $mag1 $mag2 ]
     if { $points == 0 } {
          Error_Def 4
          return
     }
```

```
set puntos  [ lindex $points 0 ]
set points  [ lrange $points 1 end ]
set lpuntos [ expr 4*$puntos - 1 ]
set focos   [ lrange $points 0 $lpuntos ]
set points  [ lrange $points  [ expr $lpuntos+1 ] end ]

for {set j 4 } {$j  <= [llength $focos]} {incr j 4} {
     set x [ lindex $focos [expr $j - 4 ] ]
     set y [ lindex $focos [expr $j - 3 ] ]
     set m [ lindex $focos [expr $j - 2 ] ]
     set z [ lindex $focos [expr $j - 1 ] ]

     #Depth Color
     set p $z
     if { $p <= [ expr $depth1/15 ] } {
        set color white
     } elseif { $p <= [ expr $depth1/14 ] } {
        set color LightYellow2
     } elseif { $p <= [ expr $depth1/13 ] } {
        set color LightGoldenrod1
     } elseif { $p <= [ expr $depth1/12 ] } {
        set color yellow
     } elseif { $p <= [ expr $depth1/11 ] } {
        set color yellow2
     } elseif { $p <= [ expr $depth1/10 ] } {
        set color gold1
     } elseif { $p <= [ expr $depth1/9 ] } {
        set color gold2
     } elseif { $p <= [ expr $depth1/8 ] } {
        set color yellow3
     } elseif { $p <= [ expr $depth1/7 ] } {
        set color gold3
     } elseif { $p <= [ expr $depth1/6 ] } {
        set color yellow4
     } elseif { $p <= [ expr $depth1/5 ] } {
        set color gold4
     } elseif { $p <= [ expr $depth1/4 ] } {
        set color gray50
     } elseif { $p <= [ expr $depth1/3 ] } {
        set color gray40
     } elseif { $p <= [ expr $depth1/2 ] } {
        set color gray30
     } elseif { $p <= [ expr $depth1/1 ] } {
        set color gray20
     } else {
       set color black
     }

    #coordenates
```

```
#        set m $mag
         set xval [expr $m/2 + (70+$x)*($xpixel)/7 ]
         set yval [expr $m/2 + (21-$y)*($ypixel)/5 ]
         set dx [expr $xval-2*$m]
         set dy [expr $yval-2*$m]
         .body.canvas.c create oval $xval $yval $dx $dy -width 1.25 -outline

#          error  "$xval $yval $dx $dy"
#          .body.canvas.c create line $x1 $y1  $x2 $y2 -fill orange1
     }
     View_File $points
}

#Error tool
proc Error_Def { mess } {
     if { $mess == 1 } { set mensaje "Bad Years Selected"}
     if { $mess == 2 } { set mensaje "Bad Depths Field"}
     if { $mess == 3 } { set mensaje "Bad Magnitudes Selected" }
     if { $mess == 4 } { set mensaje "No data.. in the Catalogue" }
     if { $mess == 5 } { set mensaje "Select a Specific Catalogue" }
     if { $mess == 6 } { set mensaje "Select a Specific Region" }
     if { $mess == 7 } { set mensaje "Not Enough Data Points" }
     if { $mess == 8 } { set mensaje "Select a Data Base or Region" }

     tk_messageBox -title "FEMA Tool Error" -icon error -message $mensaje
}

#View tool
proc View_File { points } {
        catch [ destroy .code ]
  toplevel .code
        wm title .code "Search Answer"

frame .code.frame
pack  .code.frame -expand yes -fill both -padx 1 -pady 1
listbox .code.text -height 20 -width 40 \
    -xscrollcommand ".code.xscroll set" \
    -yscrollcommand ".code.yscroll set" \
    -setgrid 1 -highlightthickness 0
scrollbar .code.xscroll -command ".code.text xview" \
    -highlightthickness 0 -orient horizontal
scrollbar .code.yscroll -command ".code.text yview" \
    -highlightthickness 0 -orient vertical

grid .code.text -in .code.frame -padx 1 -pady 1 \
    -row 0 -column 0 -rowspan 1 -columnspan 1 -sticky news
grid .code.yscroll -in .code.frame -padx 1 -pady 1 \
    -row 0 -column 1 -rowspan 1 -columnspan 1 -sticky news
  grid rowconfig    .code.frame 0 -weight 1 -minsize 0
grid columnconfig .code.frame 0 -weight 1 -minsize 0
```

```
        for {set j 5 } {$j  <= [llength $points]} {incr j 6} {
                set entry [ lrange $points [ expr $j-5 ] [ expr $j ] ]
#               tk_messageBox -message "[ expr $j ] [ expr $j+5 ] $entry"
                .code.text insert end  $entry
        }
}

#B value estimator
proc B_Value_Table { } {
        global points
        global mag1 mag2
        global fault year1 year2

        if { $year1 >= $year2 || [llength $year1] == 0 || [llength $year1] == 0 } {
            Error_Def 1
            return
        }
        if { $mag1 >= $mag2 || [llength $mag1] == 0 || [llength $mag2] == 0 } {
            Error_Def 3
            return
        }
        if { [llength $points] < 30 } {
             Error_Def 7
             return
        }

        set w .bval
        catch [ destroy $w ]
  toplevel $w
        wm title $w "B Value Results"

frame $w.frame
pack  $w.frame -expand yes -fill both -padx 1 -pady 1
listbox $w.text -height 15 -width 37 \
    -xscrollcommand "$w.xscroll set" \
    -yscrollcommand "$w.yscroll set" \
    -setgrid 1 -highlightthickness 0
scrollbar $w.xscroll -command "$w.text xview" \
    -highlightthickness 0 -orient horizontal
scrollbar $w.yscroll -command "$w.text yview" \
    -highlightthickness 0 -orient vertical

grid $w.text -in $w.frame -padx 1 -pady 1 \
    -row 0 -column 0 -rowspan 1 -columnspan 1 -sticky news
grid $w.yscroll -in $w.frame -padx 1 -pady 1 \
    -row 0 -column 1 -rowspan 1 -columnspan 1 -sticky news
  grid rowconfig    $w.frame 0 -weight 1 -minsize 0
grid columnconfig $w.frame 0 -weight 1 -minsize 0
```

```
        set file B-value.dat
        set fileID [open $file w]
            for {set j 5 } {$j  <= [llength $points]} {incr j 6} {
                 set entry [ lrange $points [ expr $j-5 ] [ expr $j ] ]
                  puts $fileID  $entry
            }
        close $fileID

        set bvalue [ exec B_Value $file $year1 $year2 $mag1 $mag2 table ]

        for {set j 3 } {$j  <= [llength $bvalue]} {incr j 4} {
                set entry [ lrange $bvalue [ expr $j-3 ] [ expr $j ] ]
#               tk_messageBox -message "[ expr $j ] [ expr $j+5 ] $entry"
                .bval.text insert end  $entry
        }

#        file delete $file
}

proc Geometry_PRSN { } {
     global zooming x1 y1 x2 y2
     global points

     if { [info exist points] == 0 } {
          Error_Def 8
          return
     }
     if { [llength $points] < 30 } {
          Error_Def 7
          return
     }

     if { [winfo exist .popup] == 0 } {
          set x1 0
          set y1 0
          set x2 0
          set y2 0
     }

     set file geometry.dat
     set fileID [open $file w]
     for {set j 5 } {$j  <= [llength $points]} {incr j 6} {
          set entry [ lrange $points [ expr $j-5 ] [ expr $j ] ]
          puts $fileID  $entry
     }
     close $fileID

     set geometry [ exec geometryPRSN $file $x1 $y1 $x2 $y2 ]
```

```
     tk_messageBox -message "$geometry" -title "PRSN Geometry Tool"
}

#Routine to plot single or composite fault systems
proc Plot_Faults { } {
     global fault
     global xpixel ypixel

     catch [ .body.canvas.c delete faults ]
     if { $fault == "MOUSE" } {return}

     if { [llength $fault] == 0 } {
          Error_Def 6
          return
     }

     set pi 3.1415927
     set file Faults.dat
     set f [open  $file r]
     while {![eof $f]} {set lines [read $f] }
     close $f

     set nregion [ lindex $lines 0 ]
     set lines   [ lrange $lines 1 end ]
     set faultP  [ lsearch -exact $lines $fault ]
     set faultS  [ lindex $lines [ expr $faultP - 1 ] ]
     set lines   [ lrange $lines [ expr $faultP + 1 ] [ expr $faultP + 9*$faultS ] ]

#     error "$faultP $faultS [ expr $faultP + 1 ] [ expr $faultP + 9*$faultS ]"

#     set mlines  [ expr 2*$nlines - 1 ]
#     set lines   [ lrange $lines [ expr [lsearch -exact $lines $fault] + 1] end]
#     set lines   [ lrange $lines 0 $mlines ]
#     for {set i 0} {$i < $nlines} {incr i} {
#         set puntos  [ lindex $lines 0 ]
#         set entry   [ lrange $lines 1 [expr 2*$puntos] ]
#         set vals    [ lrange $entry 0 end]
#         set lines   [ lrange $lines [ expr [llength $entry] + 1] end]

         set vals $lines
         for {set j 9 } {$j  <= [llength $vals]} {incr j 9} {
             set x1 [ lindex $vals [expr $j - 9 ]]
             set y1 [ lindex $vals [expr $j - 8 ]]
             set az [ lindex $vals [expr $j - 7 ]]
             set lf [ expr [lindex $vals [expr $j - 3 ] ]/111]
             set tg [ lindex $vals [ expr $j - 1 ] ]

             if { $az == 0 } {
                  set y2 [expr $y1 + $lf]
                  set x2 $x1
```

```
            } elseif { $az < 90   } {
                      set az [ expr 90 - $az ]
                      set y2 [ expr $y1 + $lf*sin($az*$pi/180) ]
                      set x2 [ expr $x1 + $lf*cos($az*$pi/180) ]
            } elseif { $az == 90  } {
                      set y2 $y1
                      set x2 [expr $x1 + $lf ]
            } elseif { $az < 180  } {
                      set az [ expr $az -90 ]
                      set y2 [ expr $y1 - $lf*sin($az*$pi/180) ]
                      set x2 [ expr $x1 + $lf*cos($az*$pi/180) ]
            } elseif { $az == 180 } {
                      set y2 [expr $y1 - $lf ]
                      set x2 $x1
            } elseif { $az < 270  } {
                      set az [ expr 270 - $az ]
                      set y2 [ expr $y1 - $lf*sin($az*$pi/180) ]
                      set x2 [ expr $x1 - $lf*cos($az*$pi/180) ]
            } elseif { $az == 270 } {
                      set y2 $y1
                      set x2 [expr $x1 - $lf ]
            } elseif { $az < 360  } {
                      set az [ expr $az - 270 ]
                      set y2 [ expr $y1 + $lf*sin($az*$pi/180) ]
                      set x2 [ expr $x1 - $lf*cos($az*$pi/180) ]
#                     error "Victor $lf [expr sin(6*3.141516/180)]
            } elseif { $az == 360 } {
                      set y2 [expr $y1 + $lf ]
                      set x2 $x1
            }

            set x1 [expr (70 + $x1)*($xpixel)/7]
            set y1 [expr (21 - $y1)*($ypixel)/5 ]
            set x2 [expr (70 + $x2)*($xpixel)/7]
            set y2 [expr (21 - $y2)*($ypixel)/5 ]

#           tk_messageBox -message "$x1 $y1 $x2 $y2 $az "
            .body.canvas.c create line $x1 $y1  $x2 $y2 -fill red
            .body.canvas.c bind $tg <Enter>    "PutNameLine  $tg"
            .body.canvas.c bind $tg <Leave>    "QuitNameLine $tg"
            .body.canvas.c bind $tg <Double-1> "Do_Results   $tg"
        }
#         .menus.mess config -text "Region: $fault"
#         .body.canvas.c bind regions <Enter>  "PutNameLine $fault"
#     }
#     error $faults
}

#Routine to plot  user selected fault systems
proc User_Faults { } {
```

```
global fault listado

catch [ .body.canvas.c delete faults ]
if { $fault == "MOUSE" } {return}

if { [llength $fault] == 0 } {
     Error_Def 6
     return
}

set w .faults
catch {destroy $w }
toplevel $w
wm title $w "FEMA Faults Tool"
wm iconname $w "Time Series"

set font -*-Courier-Medium-R-Normal--*-120-*-*-*-*-*-*
set listado " "

frame $w.files
pack $w.files -expand yes -fill both -padx 2 -pady 2
scrollbar $w.files.sbar -command {.faults.files.list yview}
pack $w.files.sbar -side right -fill y
listbox $w.files.list -selectmode single -background gray80 -font $font \
        -yscrollcommand {.faults.files.sbar set} -height 10 -width 36
pack $w.files.list -side left

set file Faults.dat
set f [open  $file r]
while {![eof $f]} {set lines [read $f] }
close $f

set nregion [ lindex $lines 0 ]
set lines   [ lrange $lines 1 end ]
set faultP  [ lsearch -exact $lines $fault ]
set faultS  [ lindex $lines [ expr $faultP - 1 ] ]
set lines   [ lrange $lines [ expr $faultP + 1 ] [ expr $faultP + 9*$faultS ] ]

set vals $lines
for {set j 9 } {$j  <= [llength $vals]} {incr j 9} {
    set x1 [ lindex $vals [expr $j - 9 ]]
    set y1 [ lindex $vals [expr $j - 8 ]]
    set az [ lindex $vals [expr $j - 7 ]]
    set dp [ lindex $vals [expr $j - 6 ]]
    set rk [ lindex $vals [expr $j - 5 ]]
    set sl [ lindex $vals [expr $j - 4 ]]
    set lf [ lindex $vals [expr $j - 3 ]]
    set wd [ lindex $vals [expr $j - 2 ]]
    set tg [ lindex $vals [expr $j - 1 ]]
```

```
        $w.files.list insert end "$tg $x1 $y1 $az $dp $rk
        set listado [linsert $listado end "$tg $x1 $y1 $az $dp
    }

    bind $w.files.list <Double-1> "Sigle_Fault "
}

#Single Fault Plotter
proc Sigle_Fault { } {
    global listado
    global xpixel ypixel

    set num  [.faults.files.list curselection]
    set info [lindex $listado $num]

    set pi 3.1415927
    set x1 [ lindex $info 1 ]
    set y1 [ lindex $info 2 ]
    set az [ lindex $info 3 ]
    set lf [ expr [lindex $info 7]/111 ]
    set tg [ lindex $info 0 ]

    if { $az == 0 } {
          set y2 [expr $y1 + $lf]
         set x2 $x1
    } elseif { $az < 90   } {
              set az [ expr 90 - $az ]
              set y2 [ expr $y1 + $lf*sin($az*$pi/180) ]
              set x2 [ expr $x1 + $lf*cos($az*$pi/180) ]
    } elseif { $az == 90  } {
              set y2 $y1
              set x2 [expr $x1 + $lf ]
    } elseif { $az < 180  } {
              set az [ expr $az -90 ]
              set y2 [ expr $y1 - $lf*sin($az*$pi/180) ]
              set x2 [ expr $x1 + $lf*cos($az*$pi/180) ]
    } elseif { $az == 180 } {
              set y2 [expr $y1 - $lf ]
              set x2 $x1
    } elseif { $az < 270  } {
              set az [ expr 270 - $az ]
              set y2 [ expr $y1 - $lf*sin($az*$pi/180) ]
              set x2 [ expr $x1 - $lf*cos($az*$pi/180) ]
    } elseif { $az == 270 } {
              set y2 $y1
              set x2 [expr $x1 - $lf ]
    } elseif { $az < 360  } {
              set az [ expr $az - 270 ]
              set y2 [ expr $y1 + $lf*sin($az*$pi/180) ]
              set x2 [ expr $x1 - $lf*cos($az*$pi/180) ]
```

```
     } elseif { $az == 360 } {
               set y2 [expr $y1 + $lf ]
               set x2 $x1
     }

     set x1 [expr (70 + $x1)*($xpixel)/7]
     set y1 [expr (21 - $y1)*($ypixel)/5 ]
     set x2 [expr (70 + $x2)*($xpixel)/7]
     set y2 [expr (21 - $y2)*($ypixel)/5 ]

     .body.canvas.c create line $x1 $y1  $x2 $y2 -fill red  -tags $tg
     .body.canvas.c bind $tg <Enter> "PutNameLine   $tg"
     .body.canvas.c bind $tg <Leave> "QuitNameLine  $tg"
     .body.canvas.c bind $tg <Double-1> "Do_Results $tg"
}

#Fault Solution
proc Do_Results { name } {
     global fault

     if { $fault == "MUTR" } {
        set mag 7.5
     } elseif { $fault == "PRTR" } {
        set mag 8.1
     } elseif { $fault == "MNCY" || $fault == "FZ19" || $fault == "SOZS" } {
        set mag 7.6
     } elseif { $fault == "ANPA" } {
        set mag 7.4
     } elseif { $fault == "LEIS" || $fault == "EADR" } {
        set mag 7.0
     } elseif { $fault == "SEFA" } {
        set mag 7.8
     } elseif { $fault == "SWPR" || $fault == "NSPF" } {
        set mag 6.5
     }


     set file Faults.dat
     set f [open  $file r]
     while {![eof $f]} {set lines [read $f] }
     close $f

     set nregion [ lindex $lines 0 ]
     set lines   [ lrange $lines 1 end ]
     set faultP  [ lsearch -exact $lines $name ]

     set az      [ lindex $lines [expr $faultP - 6 ] ]
     set dp      [ lindex $lines [expr $faultP - 5 ] ]
     set rk      [ lindex $lines [expr $faultP - 4 ] ]
```

```
#     set faultS  [ lindex $lines [ expr $faultP - 1 ] ]
#     set lines   [ lrange $lines [ expr $faultP + 1 ] [  ]

     set solOUT   [ exec dsretc $az $dp $rk ]
     set solOUT02 [ exec wells  $mag        ]
#     set solOUT   [ linsert $solOUT end $solOUT02 ]

     showOUT $solOUT $solOUT02
}

#Routine to display the OUTPUT in the screen
proc showOUT { solOUT solOUT02 } {
        catch {destroy .code }
toplevel .code
        wm title .code "Fault Plane Solution"

        set font -*-Courier-Medium-R-Normal--*-110-*-*-*-*-*-*

frame .code.frame
pack  .code.frame -expand yes -fill both -padx 1 -pady 1
text  .code.text -height 20 -wrap word -font $font\
      -yscrollcommand ".code.yscroll set" \
    -setgrid 1 -highlightthickness 0 -pady 2 -padx 3
  scrollbar .code.yscroll -command ".code.text yview" \
    -highlightthickness 0 -orient vertical

grid .code.text -in .code.frame -padx 1 -pady 1 \
    -row 0 -column 0 -rowspan 1 -columnspan 1 -sticky news
grid .code.yscroll -in .code.frame -padx 1 -pady 1 \
    -row 0 -column 1 -rowspan 1 -columnspan 1 -sticky news
  grid rowconfig    .code.frame 0 -weight 1 -minsize 0
grid columnconfig .code.frame 0 -weight 1 -minsize 0

       .code.text insert 1.0  $solOUT
       .code.text insert end  "\n%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% \n\n"
       .code.text insert end  $solOUT02
}

#B_Value plot graph
proc B_Value_Plot { } {
#    source /prsn/tcl/emu-graph/graph.tcl

     global points
     global mag1 mag2
     global fault year1 year2

     if { $year1 >= $year2 || [llength $year1] == 0 || [llength $year1] == 0 } {
         Error_Def 1
         return
     }
```

```
     if { $mag1 >= $mag2 || [llength $mag1] == 0 || [llength $mag2] == 0 } {
         Error_Def 3
         return
     }
     if { [llength $points] < 60 } {
          Error_Def 7
          return
     }

     set w .bvalue
     catch [destroy $w]
     toplevel $w
     wm title $w "FEMA B_Value Tool"
     wm iconname $w "entry1"

     set file B-value.dat
     set fileID [open $file w]
         for {set j 5 } {$j  <= [llength $points]} {incr j 6} {
              set entry [ lrange $points [ expr $j-5 ] [ expr $j ] ]
               puts $fileID  $entry
         }
     close $fileID

     set bregretion [ exec B_Value $file $year1 $year2 $mag1 $mag2 plotA ]
#     tk_messageBox -message $bregretion

     set bpoints    [ exec B_Value $file $year1 $year2 $mag1 $mag2 plotB ]
#     tk_messageBox -message $bregretion

#     error "Victor Huefano"

#     set testdata(1) {5.2427 1293.93 5.2477 1331.18  }
#     set testdata(2) {5.2427 2155.64 5.2477 2241.15  }

     set c $w.plot
     canvas $c -width 325 -height 325
     pack $c

     emu_graph foo -canvas $c -width 250 -height 250

     foo data d2 -colour blue -points 0 -lines 1 \
 -coords $bregretion
     foo data d1 -colour red -points 1 -lines 0 \
 -coords $bpoints
}

#Programas para generar condiciones iniciales de Mansinhna y Smylie
proc mansinha {} {
     global fault listado
```

```
      source grids.ini

      set num [.faults.files.list curselection]
      if { $num == "" } {
           tk_messageBox -icon error -message "Please select a specific FAULT"
           return
         }
      set forma [lindex $listado $num]

      set pi 3.14159265359

      set mag 0
      if { $fault == "PRTR" } {
         set mag 8.1
      } elseif { $fault == "MUTR" }  {
         set mag 7.6
      } elseif { $fault == "MNCY" }  {
         set mag 7.6
      } elseif { $fault == "FZ19" }  {
         set mag 7.6
      } elseif { $fault == "SOZS" }  {
         set mag 7.7
      } elseif { $fault == "ANPA" }  {
         set mag 7.7
      } elseif { $fault == "LEIS" }  {
         set mag 7.0
      } elseif { $fault == "SEFA" }  {
         set mag 7.8
      } elseif { $fault == "EADR" }  {
         set mag 7.2
      } elseif { $fault == "SWPR" }  {
         set mag 6.6
      } elseif { $fault == "NSPF" }  {
         set mag 6.8
      } else {
         tk_messageBox -title "FEMA Fatal" -icon error -message " "
         return
      }

      set longi  [lindex $forma 1]
      set lati   [lindex $forma 2]
      set strike [lindex $forma 3]
      set dip    [lindex $forma 4]
      set rake   [lindex $forma 5]
      set slip   [lindex $forma 6]
      set largo  [lindex $forma 7]
      set ancho  [lindex $forma 8]
      if { $rake > 180 } { set rake [expr (360 - $rake)] }

#--- Puntos de  la Malla Exterior
```

```
     set diflat [expr ($y2A - $y1A)*3600]
     set diflon [expr (abs($x1A - $x2A))*3600]
     set puntosXA [expr int($diflon/$deltaA)+1]
     set puntosYA [expr int($diflat/$deltaA)+1]

#--- Coordenadas de la Falla en coordenadas geograficas
     if { $strike  <= 90 } {
        set backaz [expr (90 - $strike)*$pi/180]
        set Xlon   [expr $largo*cos($backaz)/110]
        set Ylat   [expr $largo*sin($backaz)/110]
        set longf  [expr $longi + $Xlon]
        set latf   [expr $lati  + $Ylat]

     } elseif { $strike  <= 180 } {
        set backaz [expr ($strike - 90)*$pi/180 ]
        set Xlon   [expr $largo*cos($backaz)/110]
        set Ylat   [expr $largo*sin($backaz)/110]
        set longf  [expr $longi + $Xlon]
        set latf   [expr $lati  - $Ylat]

     } elseif { $strike  <= 270 } {
        set backaz [expr (270 - $strike)*$pi/180 ]
        set Xlon   [expr $largo*cos($backaz)/110]
        set Ylat   [expr $largo*sin($backaz)/110]
        set longf  [expr $longi - $Xlon]
        set latf   [expr $lati  - $Ylat]

     } elseif { $strike  <= 3600 } {
        set backaz [expr ($strike - 270)*$pi/180 ]
        set Xlon   [expr $largo*cos($backaz)/110]
        set Ylat   [expr $largo*sin($backaz)/110]
        set longf  [expr $longi - $Xlon]
        set latf   [expr $lati  + $Ylat]
     }

#--- Coordenadas de la falla en coordenadas de malla
     set fallaY [expr round(($lati - $y1A)*3600/$deltaA)]
     set fallaX [expr round(abs($x1A - $longi)*3600/$deltaA)]

#--- Inital conditions generator
     set file deform.ini
     set fileID [open $file w]
         puts $fileID "# Deform Version 2.1"
         puts $fileID "# Victor Huerfano, @2002"
         puts $fileID "> Condiciones de Malla"
         puts $fileID "$puntosXA $puntosYA
         puts $fileID "$delta
         puts $fileID "1
         puts $fileID "> Begin fault 1"
         puts $fileID "1.
```

```
        puts $fileID "$fallaX $fallaY
        puts $fileID "$slip
        puts $fileID "[expr $largo*1000] [expr $ancho*1000]
        puts $fileID "$strike
        puts $fileID "$dip
        puts $fileID "$rake
        puts $fileID "1000
    close $fileID

#---
    set deform [exec vic_deform $file]
    bell

#--- Propagacion de la condicion incial a las mallas pequenas

}
```