Characterization of Active Submarine Faults Near U.S. Caribbean Territories

Annual Project Summary for 99HQGR0067

William R. McCann
Earth Scientific Consultants
6860 West 99th Avenue, Westminster, CO 80021-5447
Tel: 303.650.5484 Fax: 303.650.5262 e-mail: esc@envisionet.net

Program Element #1 Products for Earthquake Loss Reduction

Keywords: source characteristics, Seismotectonics, Tectonic Structures

99HQGR0067: Characterization of Active Submarine Faults Near U.S. Caribbean Territories

William R. McCann
Earth Scientific Consultants
6860 West 99th Avenue, Westminster, CO 80021-5447
Tel: 303.650.5484 Fax: 303.650.5262 e-mail: esc@envisionet.net

Abstract

The US territories in the Caribbean (Puerto Rico and the U.S. Virgin Islands) lie within an actively deforming plate boundary zone. Proper determination of earthquake hazard for these islands will be based on the identification and characterization of active faults and the determination of the microseismicity associated with them.

One task undertaken in this program was the development of unified catalog of microearthquakes for the region near the U.S. Territories in the Caribbean. By applying newly acquired clock corrections to LDEO network data (from a previous NEHRP proposal) and combining that data with USGS/PR network data, we were able to form the unified catalog. More than 9,000 events have been rescued from 1975-1982 by this effort, covering more than 700 km of the NE Caribbean seismic zone. That new catalog will greatly improve our understanding of the seismotectonics of the NE Caribbean.

Identification of microearthquakes related to specific submarine faults in the Anegada Passage region, and just off the coast, western Puerto Rico is another task. Microearthquakes in the newly formed catalog of the local seismic network have be used to determine the level and 3-D distribution of seismic activity on the most important faults in those areas. For the Anegada Passage region, the best station distribution (even better than today's) is the period from 1975-1978.

Finally, we have constructed 10 composite focal mechanisms by use of P-wave first motions for events in the Anegada Passage region. Those mechanisms have been compared with the 3-D geometry of the seismicity on the fault, as well as the mapped trace of the segments of the fault. Eight of the solutions are normal faulting and the other two are oblique strike-slip with a normal component. These events describe an extensional regime oriented essentially E-W. The data are consistent with regional stresses induced by arc-parallel extension

Investigations Undertaken

One task undertaken in this program was the development of unified catalog of microearthquakes for the region near the U.S. Territories in the Caribbean. By applying newly acquired clock corrections to LDEO network data (from a previous NEHRP proposal) and combining that data with USGS/PR network data, we were able to form the unified catalog. More than 9,000 events have been rescued from 1975-1982 by this effort, covering more than 700 km of the NE Caribbean seismic zone. That new catalog will greatly improve our understanding of the seismotectonics of the NE Caribbean.

Identification of microearthquakes related to specific submarine faults in the Anegada Passage region, and just off the coast of eastern Puerto Rico is another task. Microearthquakes in the newly formed catalog of the local seismic network have be used to determine the level and 3-D distribution of seismic activity on the most important faults in those areas. For the Anegada Passage region, the best station distribution (even better than today's) is the period from 1975-1978.

Finally, we have constructed 10 composite focal mechanisms by use of P-wave first motions for events in the Anegada Passage region. Those mechanisms have been compared with the 3-D geometry of the seismicity on the fault, as well as the mapped trace of the segments of the fault. Eight of the solutions are normal faulting and the other two are oblique strike-slip with a normal component. These events describe an extensional regime oriented essentially E-W. The data are consistent with regional stresses induced by arc-parallel extension

Results- Development of a Unified Catalog of Microearthquakes

We have applied the clock corrections made available under a previous NEHRP program to the LDEO network data and merged with USGS/PR network data to form a unified catalog for the period 1975-1978. LDEO network data spans 1975-1982, the life of the network.. PR network data spans 1975-1978 (Table 1). Therefore, the merged dataset spans 1975-1978. When data from the PR network for the period 1979-1982 becomes available, it will be easily merged with the LDEO network data provided herein. More than 9,000 events have been rescued by this effort. Stations codes have been converted to the 4-letter code format and conflicting codes converted (Table 2). The final bulletin and final catalog were checked for order in time and duplicate events removed. In the pocket in the back of this report are several diskettes containing original network phase data, the clock corrected, as well as the merged data forming the new regional catalog. The readme file describes the contents of the files and the purpose of the FORTRAN programs used to develop the dataset.

Stations on Puerto Rico used the velocity model of Asencio (1980) for locating events. Stations of the NE Caribbean network (LDEO) used the average velocity model developed by Fischer and McCann (1984) to determine locations. Even though some station delays were calculated to the various models developed by them, we did not apply any of them during this phase of the relocation process. Our intent now is merely to develop a unified catalog with basic new, microearthquake locations. The Fischer and McCann model is a calibrated velocity model using multi-ton calibration shots. All events were located using the Y2K compliant version of Hypoellipse.

Coda magnitudes were calculated using the parameters of the NE Caribbean network developed by Frankel (unpubl. Data). Coda corrections developed for that network magnitude scale were not used.

Results- Seismotectonics of the Anegada Passage Region

Another task was the development of fault plane solutions using first motion data, and the identification of microearthquakes related to specific submarine faults in the Anegada Passage region and just off the coast, western Puerto Rico. Microearthquakes in the newly formed catalog of the local seismic network were used to determine the level distribution of seismic activity on the most important faults in the area. Events were chosen based on typical parameters such as gap, distance to closest station and vertical and horizontal errors. For the Anegada Passage region the best station distribution (even better than today's) is the period from 1975-1978. (That good distribution continued until 1982, but the data from the Puerto Rico network for the period 1979-1982 has yet to be analyzed). Of particular interest is the maximum extent of the depth of seismic faulting, and the segmentation of any fault. Knowledge of both of these parameters will have an important impact on the determination of the potential of the fault to generate damaging earthquakes.

First motion data for locally recorded microearthquakes was used to construct fault plane solutions of events in the Anegada Passage region. We defined the region by 17°N-18.75°N and 66.5°W-63°W. Events on or north of the PRVI platform were then excluded. The remaining events were then filtered to exclude those with no S arrival, any error greater then 10 km, a depth greater than 30 km, or less than 6 first motions. The remaining events were checked for to assure a high quality location. Fault plane solutions were then determined using FPFIT. Nearby events with 4 or more first motions, and high quality locations were then added if found to be compatible with the first fault plane solution. A total of 10 composite solutions were developed (Figure 1). Tables 3 and 4 contain the pertinent information about the events used, and the parameters determined for the fault plane solutions.

Eight of the solutions are normal faulting and the other two are oblique strike-slip with a normal component. These events describe an extensional regime oriented essentially E-W. The data are consistent with regional stresses induced by arc-parallel extension (McCann et al., 1996), but are not consistent with present-day counterclockwise rotation of the Puerto Rico microplate about a nearby pole of rotation, or just trench roll-back inducing N-S extension. We find no evidence in the present dataset in support of a N-NE oriented T-axis as suggested in other models based on seismic reflection data (Jany et al., 1987).

Table 3. Parameters for events used in composite fault plane solutions.

mech #	year	mo	da	hr	mi	lon	lat	dep	Npha	gap	rms	azim1	dip1	stderr1	azm2	dip2	stderr2	stderr3	ne
1	1975	12	9	23	5	-66.2680	18.2582	12	10	139	0.31	183	16	1.2	281	26	0.59	2.4	2
1	1976	5	14	22	14	-66.2807	18.1963	10	11	132	0.1	267	15	1.03	169	25	2.55	3.66	1
1	1977	7	21	20	46	-66.2513	18.2857	30	5	195	0.02	239	8	1.38	145	25	3.61	2.16	2
2	1976	12	31	14	1	-66.1913	18.1497	21	7	127	0.04	143	14	2.39	44	33	2.73	7.84	1
2	1977	8	27	0	23	-66.0402	18.2117	6	8	167	0.46	243	6	0.7	337	39	1.22	3.33	3

mech #	year	mo	da	hr	mi	lon	lat	dep	Npha	gap	rms	azim1	dip1	stderr1	azm2	dip2	stderr2	stderr3	ns
2	1985	3	22	22	6	-66.1763	18.1705	8	7	110	0.34	36	13	0.86	302	16	1.05	3.06	2
3	1975	12	17	11	8	-66.2668	17.9002	5	9	210	0.34	155	4	2.11	246	17	0.81	4.03	1
3	1976	9	2	11	48	-66.2738	17.9158	12	8	207	0.07	32	6	7.8	122	8	3.59	2.89	1
4	1975	12	19	21	14	-66.2098	18.0975	1	8	164	0.39	267	21	0.61	12	35	1.02	2.05	2
5	1977	7	15	6	6	-65.6212	18.0397	14	6	311	0.13	160	10	2.75	252	13	2.18	1.37	2
5	1977	8	14	16	14	-65.5505	18.0267	8	9	319	0.1	318	13	1.75	54	23	2.04	1.4	4
5	1981	7	27	18	7	-65.6678	17.9287	11	21	263	0.26	44	16	6.83	307	24	2.02	1.45	8
5	1982	1	25	7	9	-65.6812	17.8622	9	13	271	17	17	16	167	108	5	206	100	6
6	1975	12	24	17	25	-65.4367	18.0077	7	7	322	0.29	51	32	4.15	300	30	2.28	1.58	2
6	1982	1	26	11	49	-65.4060	17.9473	2	11	221	0.07	126	11	1.02	218	11	2.53	6.36	1
6	1980	11	16	9	12	-65.4022	18.0123	16	16	188	8	263	6	192	168	42	1104	720	7
6	1981	4	5	2	51	-65.3710	18.0040	5	11	185	10	249	16	211	344	17	1117	270	3
7	1980	3	8	1	29	-64.9445	18.1173	20	11	137	0.04	243	18	1.39	341	23	4.92	3.89	3
7	1981	3	20	14	4	-64.9562	18.1170	20	16	113	0.08	241	6	1.32	150	11	3.51	17.09	7
8	1980	1	29	3	26	-64.7720	18.1515	11	15	109	0.12	273	19	1.89	175	23	0.93	2.25	6
8	1982	4	13	15	58	-64.7983	18.0997	5	12	121	0.46	319	0	3.97	229	4	5.96	16.72	5
8	1982	5	31	18	55	-64.7395	18.1847	11	10	123	0.25	62	14	1.74	162	34	1.1	2.06	4
9	1982	1	2	2	27	-64.8057	17.9212	0	14	157	0.48	38	9	1.3	305	20	0.83	2.62	4
10	1980	4	2	22	13	-64.0455	18.5460	24	14	176	0.22	105	10	1.03	9	31	4.78	1.93	2
10	1982	8	25	16	47	-64.3270	18.4012	11	12	203	0.42	291	13	2.58	189	42	1.04	1.71	4
10	1982	9	27	17	28	-64.3390	18.3530	10	11	201	0.08	288	18	3.12	187	32	1.09	2.09	5

Note: parameters are standard output from hypoellipse. See documentation of hypoellipse for details.

Table 4. Parameters of composite fault plane solutions from FPFIT

mech #	dip	strike	rake	dip	strike	rake	Fj	nobs	avwt	stdr
1	90	165	-150	60	75	0	0.090	15	0.14	0.61
2	65	0	-80	27	157	-110	0.070	19	0.12	0.65
3	45	215	-150	69	103	-49	0.000	12	0.05	0.56
4	85	120	-160	70	28	-5	0.000	6	0.07	0.6
5	10	230	-70	81	30	-93	0.130	25	0.16	0.67
6	25	180	-100	65	11	-85	0.070	27	0.11	0.57
7	45	260	10	83	163	135	0.000	15	0.05	0.55
8	85	210	-160	70	118	-5	0.100	17	0.15	0.5
9	55	30	-40	58	146	-138	0.000	8	0.06	0.28
10	50	155	-140	61	37	-48	0.080	13	0.12	0.56

Note: Fj, avwt, and stdr are measures of goodness of the solution- see documentation of FPFIT for details; nobs is number of observations.

FPFIT Fault Plane Solutions

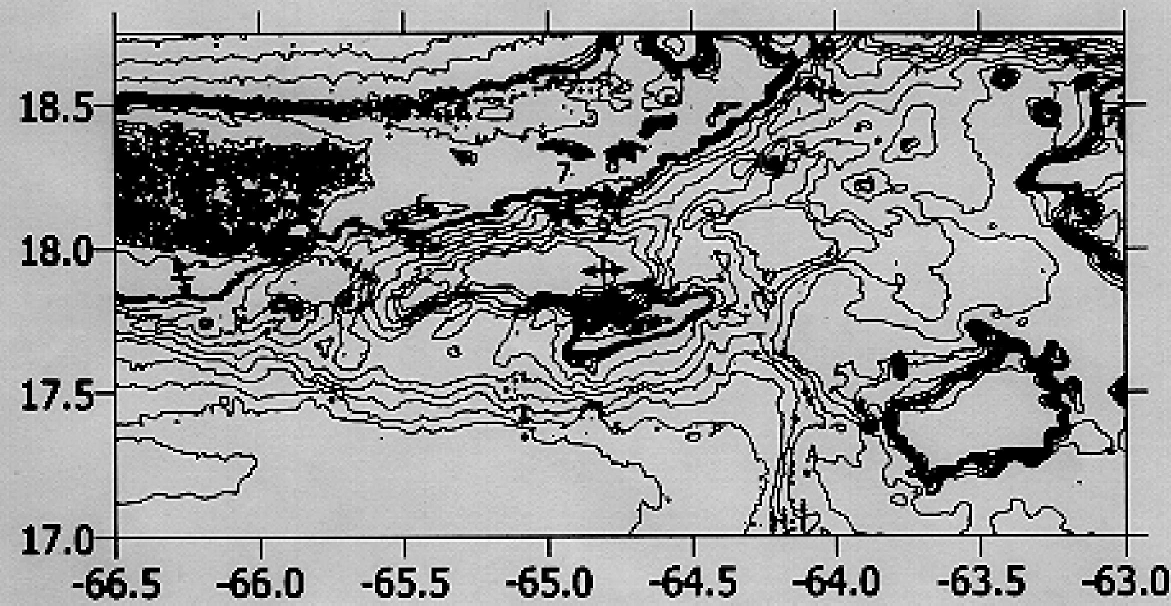

Figure 1. Orientation of two most horizontal stress axes for composite fault plane solutions.

Non-technical Summary

This program has developed a digital catalog of microearthquakes for the US territories in the Caribbean. Data are for the period 1975-1982. More than 9,000 seismic events are to be found in the catalog. Some of this earthquake data was analyzed to determine the style of faulting in the Anegada Passage near Puerto Rico and the US Virgin Islands. We found the regions to be deforming in an extensional manner, with tensional stresses directed East-west.

Final report and Dissemination

Two abstracts and two articles are being submitted for publication. One article is a note describing the newly rescued unified catalog, and another describes the results of the investigation of the Anegada Passage. Unified catalog data and other information are available by sending an e-mail to esc@envisionet.net, attn. W. McCann, data can be sent by e-mail or diskette and are in *.zip compressed format.