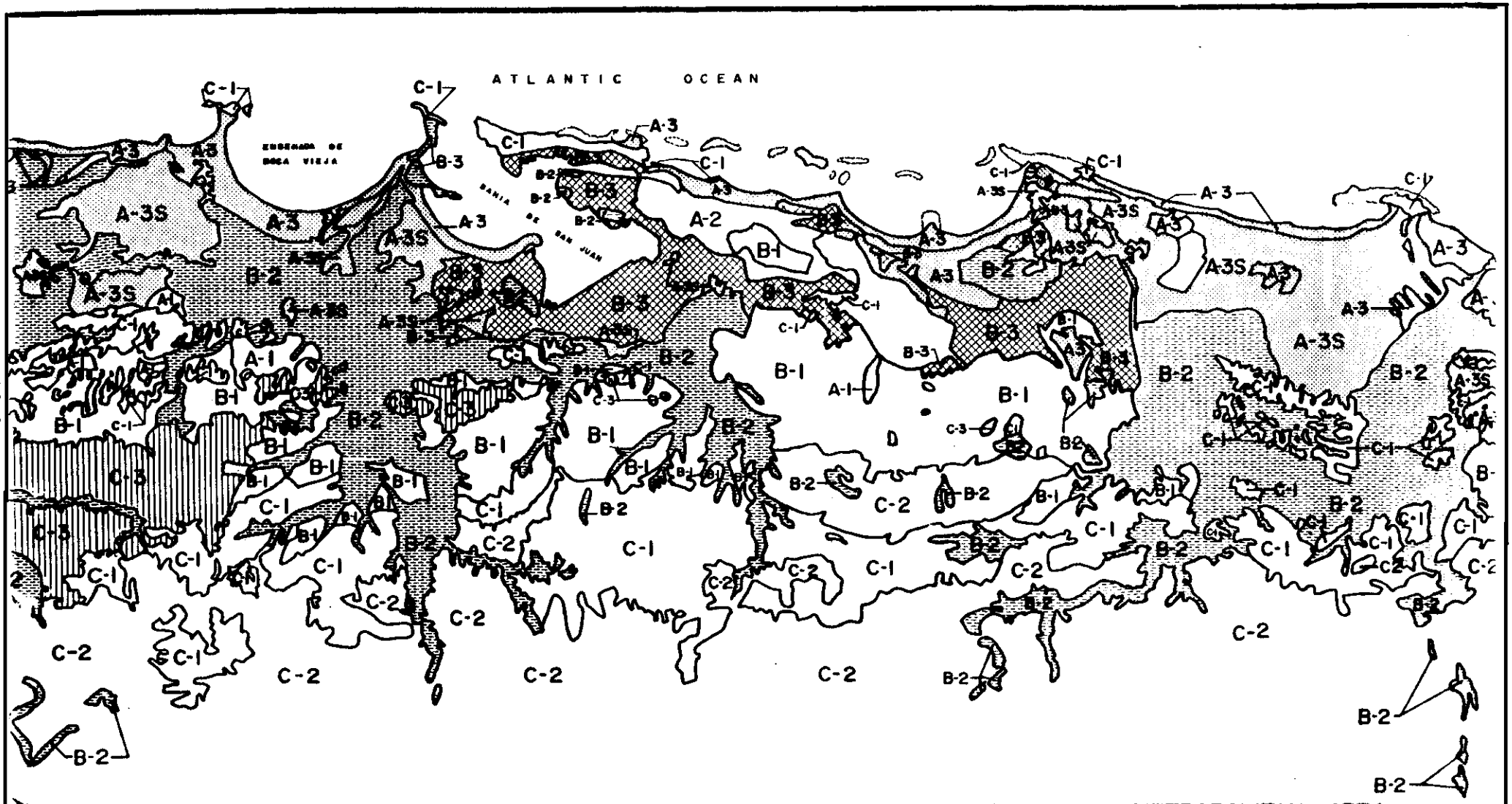
COMMONWEALTH OF PUERTO RICO
DEPARTMENT OF NATURAL RESOURCES

PLANNING RESOURCES AREA

GENERALIZED EARTHQUAKE INDUCED GEOLOGIC HAZARDS MAP FOR THE SAN JUAN METROPOLITAN AREA

	GROUND MOTION AMPLIFICATION	LIQUEFACTION POTENTIAL	GROUND FAILURE POTENTIAL
A - 1	NOT SIGNIFICANT	LOW	VERY LOW
A - 2	NOT SIGNIFICANT	LOW TO MODERATE	LOW
A - 3	NOT SIGNIFICANT TO LOW	MODERATE TO HIGH	HIGH-WHERE THE MATERIALS ARE NOT LATERALLY CONFINED AND MODERATELY SLOPING
A - 3 - S	HIGH	HIGH-IN SAND COVERED LAGOONAL DEPOSITS	HIGH-IN SAND COVERED LAGOONAL DEPOSITS
B - 1	NOT SIGNIFICANT	NONE	VERY LOW
B - 2	MODERATE TO VERY HIGH	HIGH-SPECIALLY WHERE THE MATERIALS ARE NOT LATERALLY CONFINED	HIGH-ALONG RIVER BANKS SLUMP, FLOWS AND LATERAL SPREADS
B - 3	HIGH	HIGH-SPECIALLY IN THE LOOSE SANDS LAGOONAL DEPOSITS	HIGH-SLUMPS-FLOWS AND LATERAL SPREADS
C - 1	NOT SIGNIFICANT	NONE	LOW
C - 2	NOT SIGNIFICANT	NONE	MODERATE TO HIGH
C - 3	NOT SIGNIFICANT	NONE	HIGH

SCALE 1:40,000



GENERALIZED EARTHQUAKE INDUCED GEOLOGIC HAZARDS MAP FOR THE SAN JUAN METROPOLITAN AREA

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DWNG. by VICTOR DAVILA OSORIO

ABSTRACT

GEOLOGIC HAZARDS INDUCED BY EARTHQUAKES IN THE METROPOLITAN AREA OF SAN JUAN, PUERTO RICO

STUDY PREPARED FOR THE RESOURCES PLANNING AREA OF THE DEPARTMENT OF NATURAL RESOURCES OF PUERTO RICO
Consultant José Molinelli PhD

The tectonic setting and regional seismicity of the north-eastern Caribbean expose the island of Puerto Rico to a high seismic hazard. Large magnitude events in 1918 (est. magnitude (7.5), 1787 (est. magnitude 8.-8.25) caused hundred of deaths and millions of dollars in material losses. Similar events will occur in the future. Off-shore faults in the Puerto Rico Trench, Mona Passage-Mona Canyon area, Anegada Passage, and the Muertos Trough are the most important potential earthquake sources in the Puerto Rico area. The Puerto Rico Trench, approximately 60 km. north of the metropolitan area of San Juan, poses the greatest hazard to the study area due to its proximity and high seismic potential (est. magnitude 8.8.25). On the basis of earthquake magnitude and intensity recurrence, regional attenuation and this researcher's judgement, the selected earthquake hazard level (most probable earthquake) for the risk analysis corresponds to a Modified Mercalli intensity VIII. This value isued as the basis for damage estimation.

The geology and geomorphology of the study area were defined as a preliminary step to mapping earthquake-induced geologic hazzards. Three hazards were defined for the study area; ground shaking, landslides, and liquefaction. A map depicting hazards zones was prepared showing three levels of susceptiblity for each hazard. Damage ratio was estimated for each zone adapting the procedures recommended by the Rice Center for earthquake risk analysis. The most important geology hazard in the metropolitan area of sań Juan is ground shaking, liquefaction and landslides. The analysis concludes that the most vulnerable areas are the artificial fills placed over swamp deposits around San Juan Bay, Caño Martín Peña and Laguna San José and the alluvial deposits in the floodplains of Río Grande de Loíza, Río Piedras and Río Bayamón. Both areas

are exposed to a high ground shaking and ground failure hazard. Located in these zones are important lifelines such as the Bahía de Puerto Nuevo thermoelectric plant, transmission lines, electric energy substations, water treatment plants, pumping stations, water mains, docks, airport facilities and vital expressways that link the capital with the rest of the Island.

Moderate to high liquefaction potential is present in the alluvial deposits of the floodplains of Río Grande de Loíza, Río Bayamón and in the loose saturated sands near the coasts. Located in these zones are a large number of high rises and housing units, airport facilities, roads, water mains, pumping stations, and other lifeline.

Moderate to high landslide potential is present in the southern portion of study area. Landslide damage potential in this zone varies with the antecedent moisture conditions of the hillslopes. An earthquake after a protracted period of rains can severely affect lifeline specially roads, where slope excavations, overloading, removal of lateral support, and other similar situations cause potentially unstable slope conditions.

It is recommended that earthquake mitigation strategies focus on high risk zones on the artificial fills surrounding the Bay and lagoons, the floodplains of Río Grande de Loíza, Río Bayamón and Río Piedras, and localized zones near the coast characterized by a moderate to high liquefaction potential. Site specific geotechnical studies should be conducted in areas of greater risk in order to assess the specific vulnerability.

Puerto Rico must prepare for a big earthquake. A significant portion of the residential, commercial and transportation infrastructure are located in hazardous zones. Today the potential damage that will bre created by a large earthquake event is greater than ever before. This study is a step in the efforts to prepare the Island for such event.

PROPOSED EARTHQUAKE HAZARD MITIGATION MEASURES

1.0 ENSURING THE CONSTRUCTION OF EARTHQUAKE-RESISTANT STRUCTURES BY:

- 1.1 Updating, adopting and enforcing antiseismic building codes.
- 1.2 Conducting appropriate engineering, geologic, and seismologic studies.
- 1.3 Investigating and evaluating risk of a proposed site and or structure.
- 1.4 Testing and strengthening, or replacing critical facilities.
- 1.5 Repairing, strenghthening or reconstructing after and earthquake.

2.0 REMOVING OR CONVERTING EXISTING UNSAFE DEVELOPMENT THROUGH:

- 2.1 Removing or converting existing unsafe structures.
- 2.2 Acquiring or exchanging hazardous properties.
- 2.3 Discontinuing uses that do not conform with zoning regulations.
- 2.4 Clearing and redeveloping blighted areas before an earthquake.
- 2.5 Reconstructing damaged area conforming to its natural hazards.

3.0 PROTECTING EXISTING DEVELOPMENT THROUGH:

- 3.1 Securing building contents and nonstructural components.
- 3.2 Stabilizing potential earthquake-triggered landslides.
- 3.3 Strengthening or retrofitting unreinforced masonry buildings.
- 3.4 Operating monitoring, warning and evacuating systems.
- 3.5 Creating improvement districts that assess costs to beneficiaries.

4.0 REGULATING NEW DEVELOPMENT IN HAZARDOUS AREAS BY:

- 4.1 Requiring appropriate land-use zoning districts and regulations.
- 4.2 Creating special hazard-reduction zones and regulations.
- 4.3 Regulating building setbacks from known hazardous areas.
- 4.4 Enacting subdivision ordinances.
- 4.5 Placing moratoriums on rebuilding.

5.0 PROVIDING FINANCIAL INCENTIVES OR DISINCENTIVES BY:

- 5.1 Conditioning insurance rates to hazard level.
- 5.2 Adopting lending policies that reflect risk of loss.
- 5.3 Clarifying the legal liability of property owners.
- 5.4 Conditioning federal and state financial assistance.
- 5.5 Making public capital improvements in low hazard areas.

6.0 DISCOURAGING NEW DEVELOPMENT IN HAZARDOUS AREAS BY:

- 6.1 Informing and educating the public of potential hazards.
- 6.2 Disclosing the hazards to potential buyers.
- 6.3 Enacting gubernatorial executive orders.
- 6.4 Adopting seismic-safety or alternate-land use plans.
- 6.5 Developing public-facility and utility service-area policies.

7.0 OTHER MEASURES

- 7.1 Upgrading the quality and quantity of seismic/ earthquake related information.
- 7.2 Upgrading the monitoring system and analysis knowhow of the personnel of Cayey.
- 7.3 Expand the seismic exposure software presently available in government agencies.
- 7.4 Expanding the Interagency Hazard Mitigation Task Force with the private sector.
- 7.5 Promoting Multiple Hazard Mitigation Management vs. single hazard mitigation.

Natural Hazards Office.
Resources Planning Area.
DEPARTMENT OF NATURAL RESOURCES OF PUERTO RICO.

Generalized Damage Ratio Estimates for the San Juan Metropolitan Area.

Hazard Zone	% Area	Damage Ratio
A-1	2	.35
	98	.05
A-2	5	.35
	95	.05
A-3	10	.35
	90	.07
B-1	100	.05
B-2	90	.15
	10	.35
B-3	20	.35
	80	.20
C-1	2	.10
	98	.05
C-2	5	.10
	95	.05
C-3	15	.10
	85	.05

Hazard zones are shown in the Earthquake-Induced Geologic Hazard Map.

Damage Ratio is the ratio of the cost of repair to the cost of replacement.

$$DR = \frac{\text{Repair Cost}}{\text{Replacement Cost}}$$

APPENDIX I

Magnitude Recurrence For the Puerto Rico Region

Magnitude	100 years probability	One event every
4.0	198.266	
4.1	164.553	
4.2	137.187	
4.3	114.863	once a year
4.4	96.564	
4.5	81.499	
4.6	69.040	
4.7	58.695	
4.8	50.071	2 years
4.9	42.855	
5.0	36.794	
5.1	31.685	
5.2	27.366	
5.3	23.701	
5.4	20.582	5 years
5.5	17.920	
5.6	15.641	
5.7	13.685	
5.8	12.002	
5.9	10.549	10 years
6.0	9.292	
6.1	8.202	

Magnitude	100 years probability	One event every
6.2	7.255	
6.3	6.429	
6.4	5.709	20 years
6.5	5.078	
6.6	4.525	
6.7	4.040	
6.8	3.612	
6.9	3.235	30 years
7.0	2.902	
7.1	2.608	
7.2	2.346	
7.3	2.114	50 years
7.4	1.908	
7.5	1.724	
7.6	1.560	
7.7	1.413	
7.8	1.282	
7.9	1.165	
8.0	1.059	
8.1	.964	100 years
8.2	.879	
8.3	.802	
8.4	.733	
8.5	.670	

APPENDIX II

Earthquakes within 200 miles of Puerto Rico 1915 - 1983

Year	Month	Day	Latitude	Longitude	Magnitude
1946	Aug	04	19.25	69.00	8.1
1943	Jul	29	19.25	67.50	7.9
1918	Oct	11	18.50	67.50	7.5
1916	Apr	24	18.50	68.00	7.2
1917	Jul	27	19.00	67.50	7.0
1946	Oct	04	18.75	68.50	7.0
1915	Oct	11	19.00	67.00	6.8
1920	Feb	10	18.00	67.50	6.5
1927	Aug	02	19.00	64.50	6.5
1943	Jul	30	19.25	67.75	6.5
1919	Sep	06	19.50	64.50	6.3
1922	Dec	18	19.00	67.00	6.3
1930	Jun	25	19.00	64.00	6.3
1961	Nov	16	18.50	68.80	6.0
1964	Dec	22	18.40	68.00	6.0
1933	Jul	21	19.00	68.50	5.8
1955	May	13	19.28	64.38	5.8
1970	Jul	08	18.00	64.60	5.8
1935	Sep	15	19.00	65.00	5.6
1939	Dec	24	18.00	68.00	5.6
1939	Mar	07	18.00	67.00	5.6
1939	Mar	07	18.00	67.00	5.6

Year	Month	Day	Latitude	Longitude	Magnitude
1943	Aug	08	19.00	68.00	5.6
1943	Aug	15	19.00	68.25	5.6
1944	Aug	09	18.50	67.00	5.6
1966	Nov	03	19.20	68.00	5.6
1961	Aug	19	18.00	68.80	5.5
1964	Aug	10	19.10	67.30	5.5
1967	Sep	03	18.64	67.67	5.5
1965	Jun	12	19.20	64.90	5.4
1966	Jan	15	19.30	65.30	5.4
1959	Jul	21	18.87	68.04	5.3
1964	Jan	18	18.80	69.40	5.3
1965	Sep	06	18.60	67.60	5.3
1966	Dec	24	18.69	64.51	5.3
1966	Jan	13	19.00	64.70	5.3
1967	Apr	12	18.00	68.39	5.3
1971	Jun	26	19.02	68.01	5.3
1965	Nov	15	18.24	65.36	5.2
1965	Nov	16	18.73	67.50	5.2
1966	Nov	03	19.10	67.90	5.2
1965	Nov	21	19.30	67.40	5.1
1966	Sep	07	19.01	64.67	5.1
1968	Apr	13	19.00	66.90	5.1
1966	Aug	13	18.01	68.70	5.0

Year	Month	Day	Latitude	Longitude	Magnitud
1966	Dec	07	18.30	68.50	5.0
1966	Sep	08	17.63	65.65	5.0
1969	Aug	01	18.80	64.40	5.0
1971	Jul	08	19.07	68.03	5.0
1971	Jun	12	18.91	64.32	5.0
1974	Aug	23	19.05	68.04	5.0
1976	Dec	28	19.96	65.00	5.0
1943	Jul	31	19.00	67.10	4.9
1944	Feb	15	17.00	67.00	4.9
1945	Jul	13	19.00	64.00	4.9
1945	Nov	08	19.00	68.00	4.9
1945	Sep	26	19.00	65.00	4.9
1949	Dec	21	18.50	67.00	4.9
1949	Feb	08	18.00	68.50	4.9
1949	Jun	04	19.50	67.00	4.9
1949	Jun	12	19.00	69.00	4.9
1949	Jun	22	19.00	69.00	4.9
1949	Mar	23	19.00	68.50	4.9
1950	Jun	15	19.00	69.00	4.9
1951	Feb	21	18.57	69.00	4.9
1951	Jul	11	18.00	69.68	4.9
1963	May	23	19.20	64.50	4.9
1966	Sep	10	19.10	67.20	4.9
1967	Aug	15	19.20	68.50	4.9

Year	Month	Day	Latitude	Longitude	Magnitude
1967	Feb	21	19.14	67.91	4.9
1970	Nov	08	18.60	64.70	4.9
1971	Jun	27	19.07	67.91	4.9
1971	Sep	30	18.06	64.52	4.9
1974	Jun	21	18.94	66.99	4.9
1975	Aug	25	15.97	67.62	4.9
1954	Apr	01	19.38	67.23	4.8
1964	Jul	14	19.00	66.50	4.8
1964	Nov	05	18.20	68.40	4.8
1967	Mar	20	19.31	64.94	4.8
1969	Oct	15	19.28	65.43	4.8
1970	Jun	13	19.25	65.22	4.8
1971	Aug	26	19.01	67.73	4.8
1971	Feb	02	18.19	68.39	4.8
1950	Jan	02	19.03	67.72	4.7
1964	Jun	16	19.60	66.80	4.7
1965	Dec	10	18.50	69.00	4.7
1965	Jun	30	18.50	68.70	4.7
1966	Nov	04	19.20	67.80	4.7
1966	Nov	09	19.20	67.90	4.7
1966	Nov	20	18.20	68.40	4.7
1968	Mar	29	18.80	64.80	4.7
1968	Oct	31	17.92	67.60	4.7
1969	Jan	03	18.50	65.06	4.7

APPENDIX III

MODIFIED MERCALLI INTENSITY SCALE OF 1931
(Unabridged)

[Adapted from Sieberg's Mercalli-Cancani scale, modified and condensed.]

I. a. Not felt - or, except rarely under especially favorable circumstances.
Under certain conditions, at and outside the boundary of the area in which a great shock is felt:
b. Sometimes birds, animals, reported uneasy or disturbed.
c. Sometimes dizziness or nausea experienced.
d. Sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly.

II. a. Felt indoors by few, especially on upper floors, or by sensitive, or nervous persons.
Also, as in grade I, but often more noticeably:
b. Sometimes hanging objects may swing, especially when delicately suspended.
c. Sometimes trees, structures, liquids, bodies of water, may sway, doors may swing, very slowly.
d. Sometimes birds, animals, reported uneasy or disturbed.
e. Sometimes dizziness or nausea experienced.

III. a. Felt indoors by several....
b. Motion usually rapid vibration.
c. Sometimes not recognized to be an earthquake at first.
d. Duration estimated in some cases.
e. Vibration like that due to passing of light, or lightly loaded trucks, or heavy trucks some distance away.
f. Hanging objects may swing slightly.
g. Movements may be appreciable on upper levels of tall structures.
h. Rocked standing motorcars slightly.

IV. a. Felt indoors by many, outdoors by few.
b. Awakened few, especially light sleepers.
c. Frightened no one, unless apprehensive from previous experience.
d. Vibration like that due to passing of heavy, or heavily loaded trucks.

e. Sensation like heavy body striking building, or falling of heavy objects inside.
f. Rattling of dishes, windows, doors; glassware and crockery clink and clash.
g. Creaking of walls, frame, especially in the upper range of this grade.
h. Hanging objects swung, in numerous instances.
i. Disturbed liquids in open vessels slightly.
j. Rocked standing motorcars noticeably.

V. a. Felt indoors by practically all, outdoors by many or most.
b. Outdoors direction estimated.
c. Awakened many, or most.
d. Frightened few--slight excitement, a few ran outdoors.
e. Buildings trembled throughout.
f. Broke dishes, glassware, to some extent.
g. Cracked windows--in some cases, but not generally.
h. Overturned vases, small or unstable objects, in many instances, with occasional fall.
i. Hanging objects, doors, swing generally or considerably.
j. Knocked pictures against walls, or swung them out of place.
k. Opened, or closed, doors, shutters, abruptly.
l. Pendulum clocks stopped, started, or ran fast, or slow.
m. Moved small objects, furnishings, the latter to slight extent.
n. Spilled liquids in small amounts from well-filled open containers.
o. Trees, bushes, shaken slightly.

VI. a. Felt by all, indoors and outdoors.
b. Frightened many, excitement general, some alarm, many ran outdoors.
c. Awakened all.
d. Persons made to move unsteadily.
e. Trees, bushes, shaken slightly to moderately.
f. Liquid set in strong motion.
g. Small bells rang--church, chapel, school, etc.
h. Damage slight in poorly built buildings.
i. Fall of plaster in small amount.
j. Cracked plaster somewhat, especially fine cracks (in) chimneys in some instances.
k. Broke dishes, glassware, in considerable quantity, also some windows.
l. Fall of knickknacks, books, pictures.
m. Overturned furniture in many instances.
n. Moved furnishings of moderately heavy kind.

VII. a. Frightened all--general alarm, all ran outdoors.
b. Some, or many, found it difficult to stand.
c. Noticed by persons driving motorcars.
d. Trees and bushes shaken moderately to strongly.
e. Waves on ponds, lakes, and running water.
f. Water turbid from mud stirred up.
g. Incaving to some extent of sand or gravel stream banks.
h. Rang large church bells, etc.
i. Suspended objects made to quiver.
j. Damage negligible in buildings of good design and construction.
k. (Damage) slight to moderate in well-built ordinary buildings, considerable in poorly built or badly designed buildings, adobe houses, old walls (especially where laid up without mortar), spires, etc.
l. Cracked chimneys to considerable extent, walls to some extent.
m. Fall of plaster in considerable to large amount, also some stucco.
n. Broke numerous windows, furniture to some extent.
o. Shook down loosened brickwork and tiles.
p. Broke weak chimneys at the roofline (sometimes damaging roofs).
q. Fall of cornices from towers and high buildings.
r. Dislodged bricks and stones.
s. Overturned heavy furniture, with damage from breaking.
t. Damage considerable to concrete irrigation ditches.

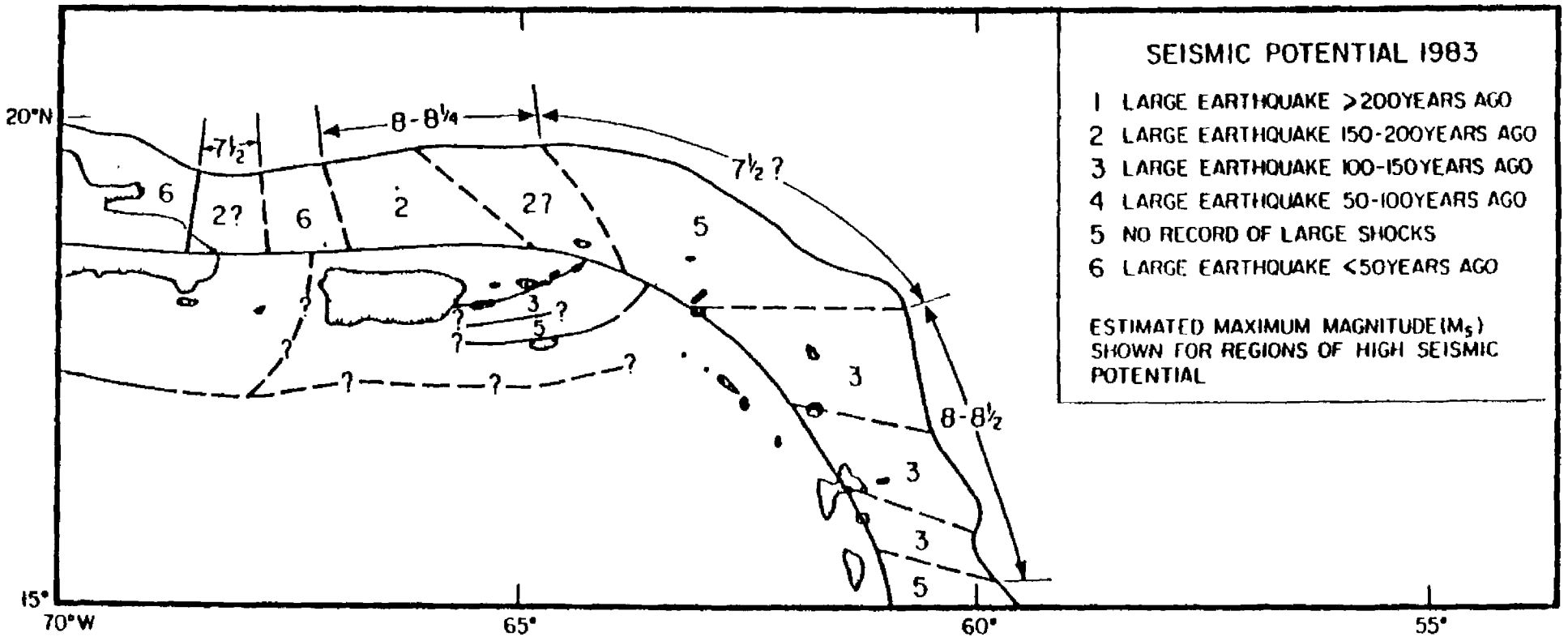
VIII. a. Fright general--alarm approaches panic.
b. Disturbed persons driving motorcars.
c. Trees shaken strongly--branches, trunks, broken off, especially palm trees.
d. Ejected sand and mud in small amounts.
e. Changes: temporary, permanent; in flow of springs and wells; dry wells renewed flow; in temperature of spring and well waters.
f. Damage slight in structures (brick) built especially to withstand earthquakes.
g. (Damage) considerable in ordinary substantial buildings, partial collapse; racked, tumbled down, wooden houses in some cases; threw out panel walls in frame structures, broke off decayed piling.
h. Fall of walls.
i. Cracked, broke, solid stone walls seriously. Wet ground to some extent, also ground on steep slopes.
j. Twisting, fall, of chimneys, columns, monuments, also factory stacks, towers.
k. Moved conspicuously, overturned, very heavy furniture.

IX. a. Panic general
b. Cracked ground conspicuously.
c. Damage considerable in (masonry) structures built especially to withstand earthquakes.
d. Threw out of plumb some wood frame houses built especially to withstand earthquakes.
e. (Damage) great in substantial (masonry) buildings, some collapse in large part; or wholly shifted frame buildings off foundations, racked frames.
f. (Damage) serious to reservoirs.
g. Underground pipes sometimes broken.

X. a. Cracked ground, especially when loose and wet, up to widths of several inches; fissures up to a yard in width ran parallel to canal and stream banks.
b. Landslides considerable from river banks and steep coasts.
c. Shifted sand and mud horizontally on beaches and flat land.
d. Changed level of water in wells.
e. Threw water on banks of canals, lakes, rivers, etc.
f. Damage serious to dams, dikes, embankments.
g. (Damage) severe to well-built wooden structures and bridges, some destroyed.
h. Developed dangerous cracks in excellent brick walls.
i. Destroyed most masonry and frame structures, also their foundations.
j. Bent railroad rails slightly.
k. Tore apart, or crushed endwise, pipelines buried in earth.
l. Open cracks and broad wavy folds in cement pavements and asphalt road surfaces.

XI. a. Disturbances in ground many and widespread, varying with ground material.
b. Broad fissures, earth slumps, and land slips in soft, wet ground.
c. Ejected water in large amounts charged with sand and mud.
d. Caused sea-waves ("tidal" waves) of significant magnitude.
e. Damage severe to wood frame structures, especially near shock centers
f. (Damage) great to dams, dikes, embankments, often for long distances.
g. Few, if any, (masonry) structures remained standing.
h. Destroyed large well-built bridges by the wrecking of supporting piers, or pillars.
i. Affected yielding wooden bridges less.
j. Bent railroad rails greatly, and thrust them endwise.
k. Put pipelines buried in earth completely out of service.

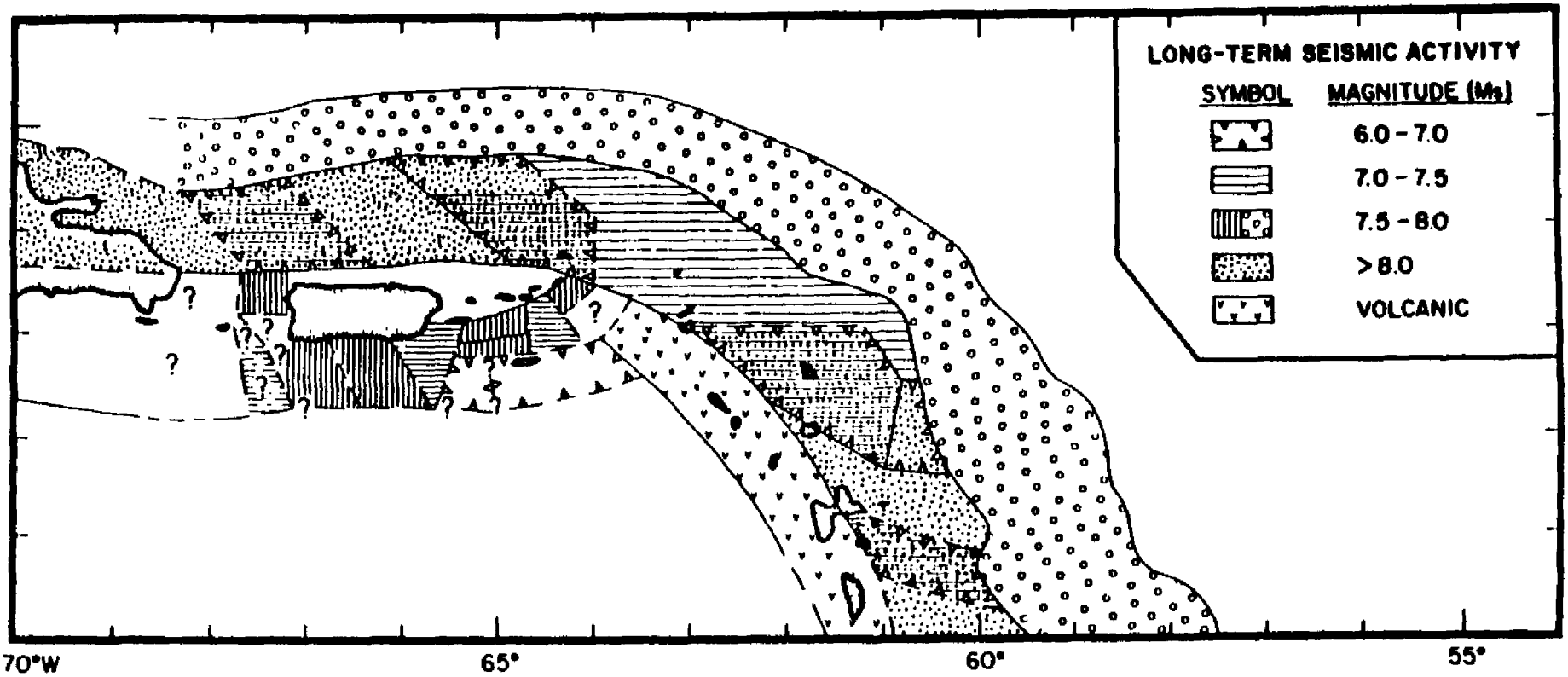
XII. a. Damage total--practically all works of construction damaged greatly or destroyed.
b. Disturbances in ground great and varied, numerous shearing cracks.
c. Landslides, falls of rock of significant character, slumping of river banks, etc., numerous and extensive.
d. Wrenched loose, tore off, large rock masses.
e. Fault slips in firm rock, with notable horizontal and vertical offset displacements.
f. Water channels, surface and underground, disturbed and modified greatly.
g. Dammed lakes, produced waterfalls, deflected rivers, etc.
h. Waves seen on ground surfaces (actually seen, probably, in some cases).
i. Distorted lines of sight and level.
j. Threw objects upward into the air.



Estimate of Seismic Potential for the northeastern Caribbean

From McCann 1984

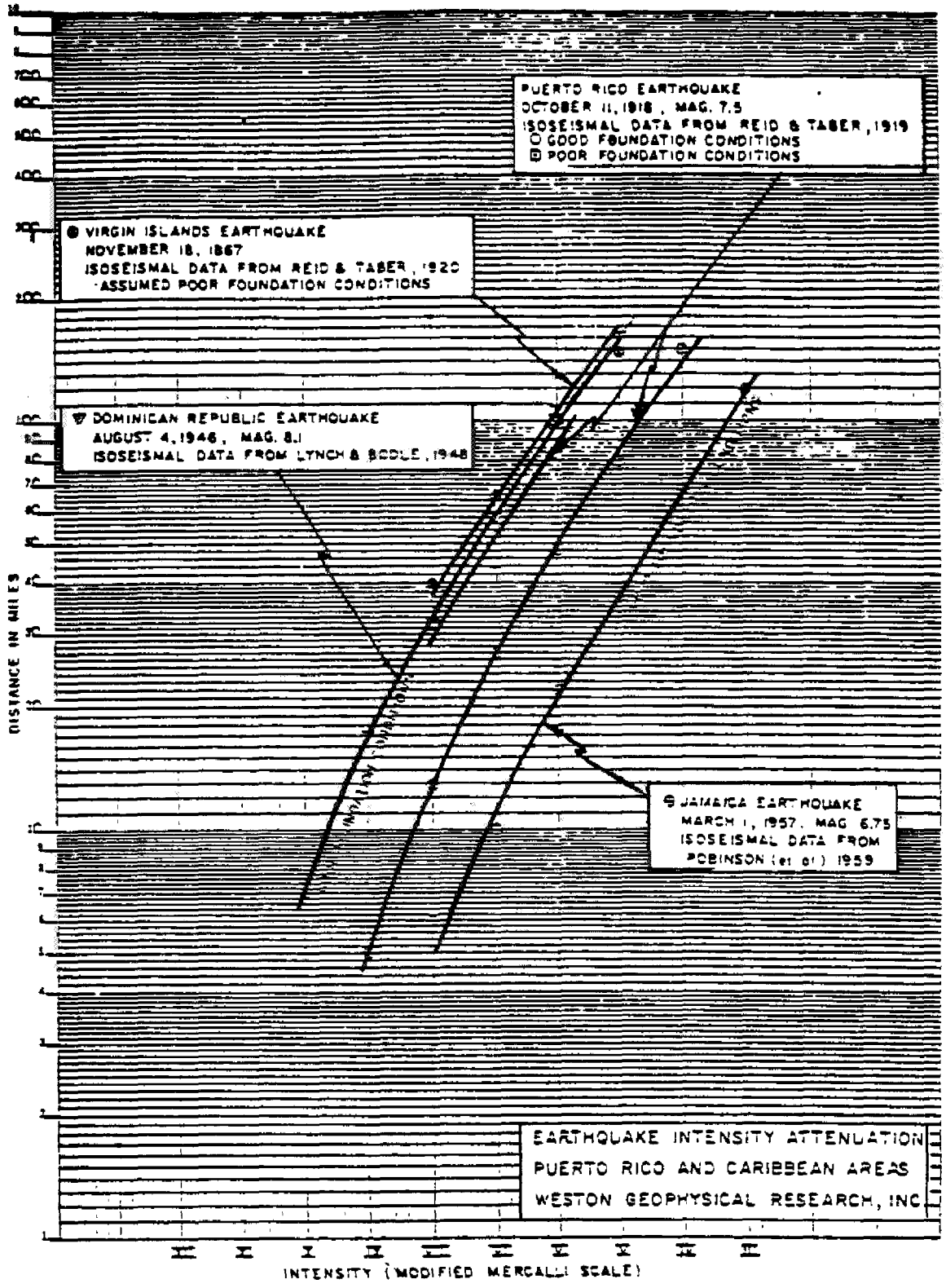
Lamont-Doherty Geological Observatory of
Columbia University



Estimate of long-term activity of shallow focus along the Caribbean - North American plate boundary

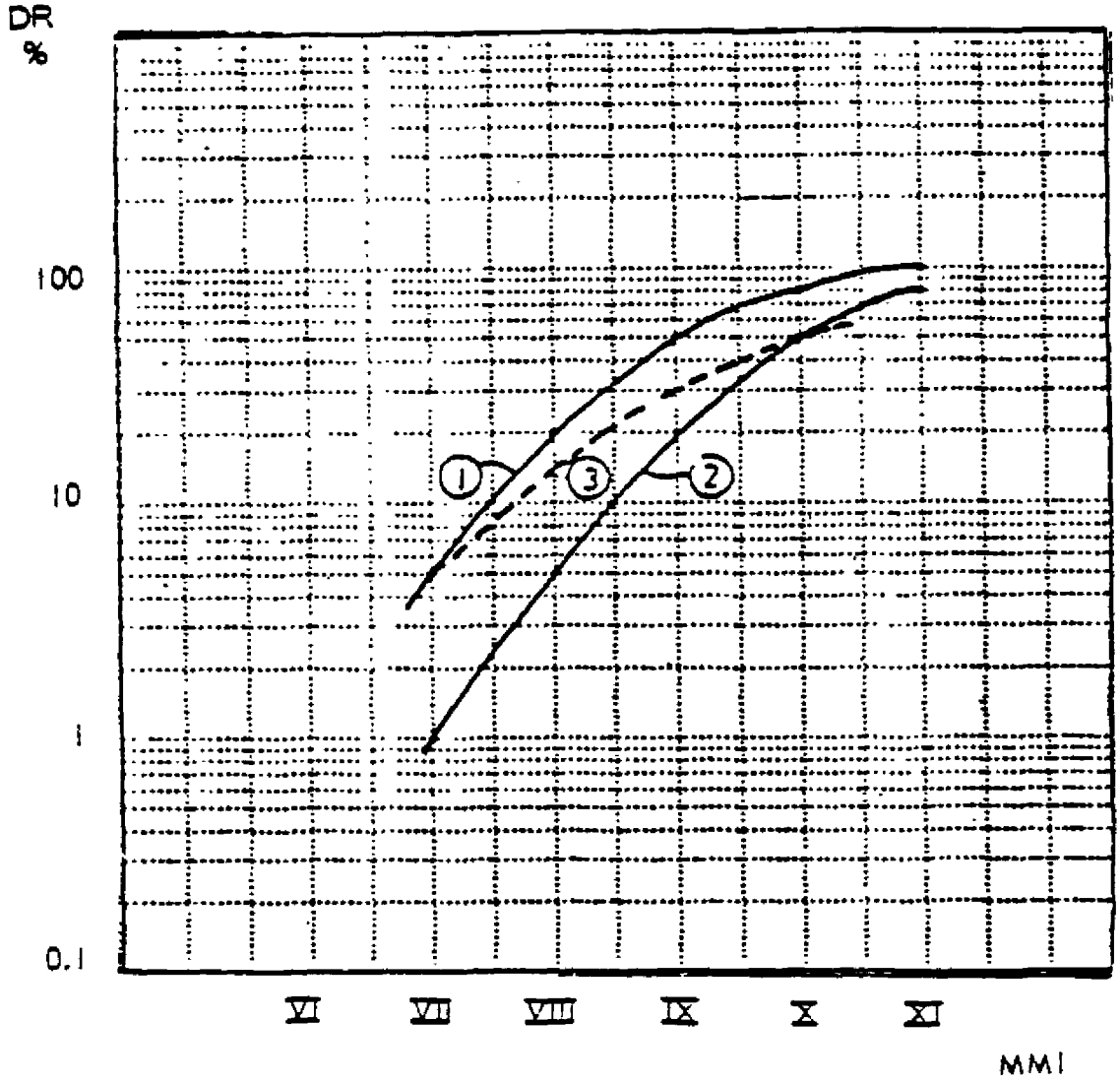
From McCann and Sykes, 1984

Lamont-Doherty Geological Observatory of
Columbia University



Regional earthquake intensity attenuation

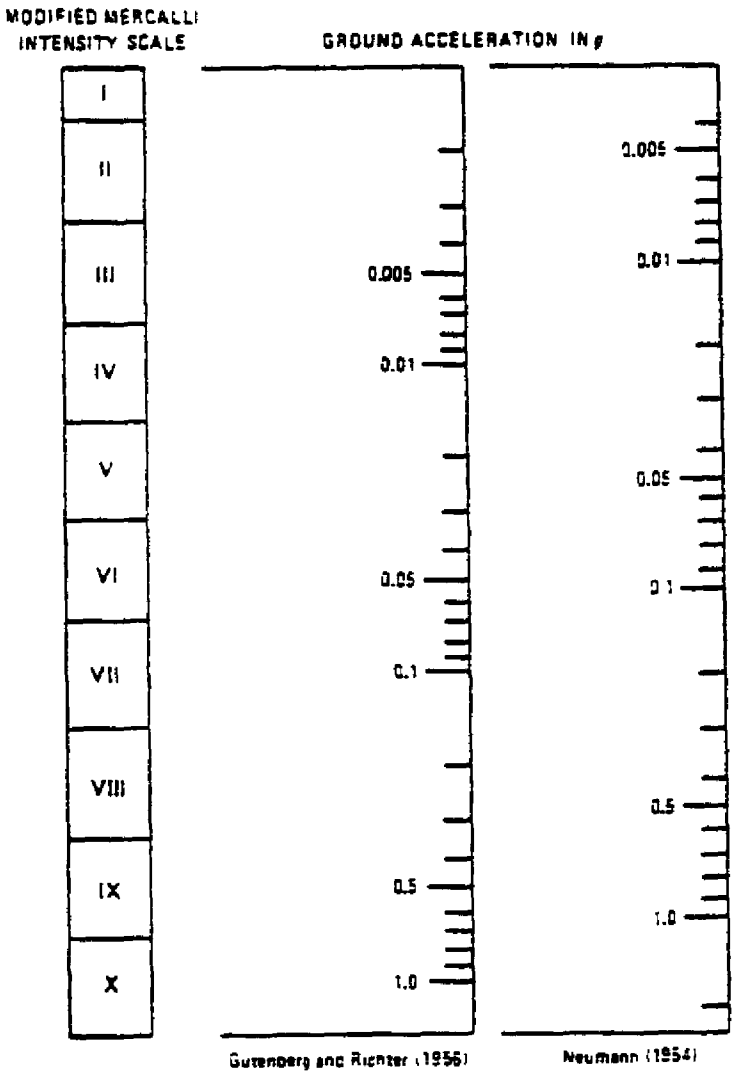
AVERAGE DAMAGEABILITY FOR "MODERN CONSTRUCTION" TAKEN FROM SAUTER AND SHAH, 1978; ORIGINALLY FROM "GUATEMALA 1976-EARTHQUAKE OF THE CARIBBEAN PLANT", MÜNCHENER RÜCKVERSICHERUNGS-GESELLSCHAFT, MUNICH



1 Modern construction. No seismic design

2 Modern construction. Seismic design

3 Average damage ratio used by Münchener Rückversicherungs-Gesellschaft (verbally communicated to Sauter and Shah, 1978)



Intensity and Acceleration Relations Proposed by Neumann, and Gutenberg and Richter

From Hays 1980

MODIFIED MERCALLI SCALE		RICHTER SCALE: MAGNITUDE
INTENSITY	EFFECT	
I	Not felt except by a very few under especially favorable conditions.	1.5
II	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.	2
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.	2.5
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.	3
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.	3.5 4
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.	4.5
VII	Damage negligible in buildings of good design and construction: slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.	5
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.	5.5
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.	6 6.5
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.	7
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.	7.5
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.	8

Comparison of Modified Mercalli Scale and Richter Scale

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