Section 306
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EARTHQUAKE BRACING FOR CENTRAL OFFICE EQUIPMENT

Contents

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in providing earthquake protection for central office switching systems and its associated equipment, including carrier and radio equipment.

1.2 This is the first issue of this section. It is issued for use in preparing plans and specifications for central office switching systems.

1.3 This section describes the effects of earthquakes, the areas where they present risks, and the measures that can be implemented to mitigate the interruption to telephone service. The data presented will also include identification of the various standards applied to structures to resist the forces associated with earthquakes.

1.4 A decision relative to the need for earthquake protection is a part of the preparation of the site requirements in the REA Form 522, "General Specification for Digital, Stored Program Controlled Central Office Equipment," and other equipment specifications.

1.5 The information presented here does not take precedence over the building and safety codes established by the local governing bodies.

1.6 Prediction of an earthquake is an event beyond the scope of this section. The random and unpredictable nature of earthquake motions means that one cannot fully ensure that there will be no loss of life or injury to persons or damage to the equipment.

2. EARTHQUAKE EXPERIENCE

2.1 General

As a starting point, consider the definition supplied by the American Heritage Dictionary.

"An earthquake is the motion of the earth's crust resulting from the sudden relaxation of strains accumulated along geologic faults and by volcanic action resulting in movements in the earth's surface."

These movements of the earth's surface are transmitted to the buildings and their contents within the affected area.

2.2 Movement of the earth's surface can range from minor earth shaking causing slight or no movement of objects upward to violent motion resulting in catastrophic failure of buildings, destruction of equipment in the buildings and ultimately loss of life. The areas likely to experience the most violent earthquakes are well defined as are areas subject to less violent earthquake activity.

2.3 The sudden movement or acceleration of the earth's surface in both the horizontal and vertical directions cause the buildings and their contents to move. The movement of the earth's surface may be a single movement to a new position of rest or it may be a series of smaller movements finally reaching a new position of rest. In both cases, the building and contents begin to vibrate at their natural frequency. The point of consideration here is directed toward individual pieces of the building or equipment such as a beam, a floor slab, an equipment shelf or card. In those cases where these pieces have a natural resonant frequency close to the frequency generated by the earthquake, damage is experienced.

2.4 Damage experienced in buildings includes broken beams and slabs, ceilings falling, etc., and finally collapse. All of this has often been shown in news reports. Central office equipment damage includes batteries falling from their stand or upset of the entire battery rack. In the equipment room switching and transmission equipment and cable racks upset and fall to the floor as a unit or in individual sections. Within the equipment racks card shelves bend, back planes fracture, communication cables disconnect or break and printed circuit boards fracture as a result of the shelf bending or disconnect from the shelf. These are some of the most violent demonstrations of earthquake activity. Less violence is more often the case ranging downward to rattling cups, disturbing the canary, and finally only being measureable on sensitive test instruments.

2.5 Secondary effects of the earthquake include broken cables, mechanical stress and escape of liquids and gases. The broken cables interrupt power distribution and have the potential to start fires. Logic circuits encountering broken or partially broken cables will act erratically or not at all. Mechanical stress in the printed circuit board shelf can cause cracks to break some of the printed wires or their connections in the back plane or in the printed circuit boards.

Leaking water, gas, fuel, etc. from broken piping or loosened joints are sources of damage to the equipment including explosion, fire and water damage.

2.6 The final result is the interruption to telephone service in an area trying to recover from the earthquake. Whether restoration of service can be accomplished in minutes or weeks is dependent on the severity of the damage sustained.

3. BUILDING CODES

3.1 Many government authorities at the local or state level have prescribed building codes which include requirements for consideration of earthquakes. The local authority in most cases uses one of the following codes:

Uniform Building Code
Basic Building Code
Standard Building Code

The Uniform Building Code is in most widespread use. The continued use of the Basic Building Code and Standard Building Code is the result of not modifying the local building code for many years. While they may be out of date, the latter two are still requirements in some communities.

3.2 New building codes are in existence or are being prepared. The American National Standards Institute (ANSI) has issued "Minimum Design Loads for Buildings and Other Structures" (ANSI A58.1, 1982) which includes a section on earthquakes. A later, more comprehensive treatment of earthquakes is in the process of securing national acceptance. The document is currently entitled "Tentative Provisions for the Development of Seismic Regulations for Buildings." It was prepared by the Applied Technology Council in association with the Structural Engineers Association of California under the auspices of the National Science Foundation and National Bureau of Standards. It was first issued in 1978 and amended in 1982.

3.3 While the requirements of the building codes identified in paragraph 3.1 must be met, the information presented in the Applied Technology Council document (see paragraph 3.2) should be reviewed due to its detailed information on seismic risk.

4. MEASUREMENT OF EARTHQUAKES

4.1 General

In order to appreciate the effects of earthquakes, it is useful to use some form of measurement. While the "Richter Scale" is frequently heard in news reports, it is not a good way to describe the resulting damage. The "Modified Mercalli Intensity Scale" more accurately describes the damage that has been experienced.

4.2 The Richter Magnitude Scale is a measure of the amount of energy released by the earthquake as the earth's crust and surface move to a new position of rest. A logarithmic scale is used with no maximum limitation. Up to the present time, no seismic event has been as high as 9 on the Richter Scale.

4.3 The Modified Mercalli Intensity Scale was developed to measure the effect experienced at a particular area. Twelve divisions are used on the scale, each with its unique description. These descriptions were modified in 1931 to include modern features such as tall buildings, cars and underground water pipes. This method gives consideration to the ground and its geological features underlaying the area.

4.4 The relationship between the Richter and Mercalli Scales can be demonstrated by the reports of the same earthquake. Dale City, CA, (south of San Francisco) experienced an earthquake on March 22, 1957. It measured 5.3 on the Richter Scale. Values on the Mercalli Scale ranged from I to VII arranged in roughly circular (isoseismal) areas with the highest values at the center.

4.4.1 Table 1, Relationship Between Magnitude and Intensity, provides a basis for understanding the significance of Richter Scale measurements.

4.4.2 Table 2, Modified Mercalli Scale of Earthquake Shock Intensities, describes the different levels of intensity that may be experienced at a given location. The Modified Mercalli Scale is a basis to begin the selection of design parameters for the earthquake protection for buildings and equipment. As the Tables 1 and 2 demonstrate, there are a wide span of effects resulting from earthquakes. A usable approach has to be selected for evaluating the seismic risk potential for specific areas.

4.4.3 Several maps have been prepared, showing the risk assigned to areas of the country. Figure 1, ESSA/C&GS Seismic Risk Map, was issued in 1969. It identified four levels of risk ranging from none to major destruction. A similar map, Figure 2, Map for Seismic Zones - Contiguous 48 States, and Figure 3, Map for Seismic Zones - Hawaii, Alaska and Puerto Rico, was issued by the American National Standards Institute in ANSI A58.1-1982.

4.4.4 Over the years measurements of earthquakes and analyses of recorded data have been used to develop the mathematical methods for the representation of the earthquake forces. One of the earlier efforts along this line resulted in the U.S. Geological Survey Open File 76-416, "Probablistic Estimate of Maximum Acceleration in Rock," by S. T. Algermissen and D. M. Perkins dated 1976. Based on this and other work, the Applied Technology Council (see paragraph 3.2) issued maps identifying forces to be considered for vertical and horizontal acceleration. The values are assigned on a county basis, including a probability evaluation that these forces may be experienced. This does not mean that a different value wouldn't be appropriate based on better local information. These maps are too big to be included in this document. They are part of National Bureau of Standards Special Publication 510 and may be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

5. EARTHQUAKE BRACING

5.1 General

The material applied and the requirements on the building are chosen in response to the earthquake forces to be handled, the requirements of the local building codes and the value assigned to maintaining telephone service.

5.2 Earthquake bracing is applied in several forms depending on the equipment unit to be secured and the characteristics of the building. It ranges from simply using larger bolts to anchor the equipment cabinets to the floor to elaborate systems of trusses connecting the equipment to the ceiling and walls. In order to allow the use of standard production equipment and cabinets for the switching system, the equipment lineups have additional bracing or frames placed around groups of cabinets (e.g., four cabinets). Card retention equipment is sometimes supplied depending on the card - card cage mechancial interface.

5.3 Battery chargers are supplied in very heavy frames suitable for use in meeting the earthquake bracing requirements. The major difference to be noted is that the chargers are only mounted in the bottom of the equipment rack.

5.4 Battery racks are generally the first item considered for earthquake bracing. The bracing takes the form of side and end racks on each shelf with added retainers between groups of cells or individual cells, hold down devices for the cells, increased anchoring to the floor and heavier iron work used in the battery rack construction. The battery cables from the power board and chargers are normally quite large and rigid. A section of flexible braid of suitable current carrying capacity is sometimes connected between the battery terminals and the battery cables to avoid any stress on the battery.

5.5 Since 1982, some of the small capacity digital switching systems have been supplied in cabinets mounted on wheels. The manufacturer has earthquake bracing for use in this situation. Early installations of this type of equipment should be reviewed to insure that earthquake bracing is supplied where needed. This may involve additional cost on the part of the owner.

5.6 The overall effect of applying earthquake bracing is to increase the floor space required and the design requirements for the floor and walls of the building. The forms of bracing discussed above are applicable only as needed. The COE manufacturer will determine the response needed when earthquake bracing is required by the owner for the equipment being supplied.

6. IMPACT

6.1 General

Earthquake bracing should be specified when new central office switching systems are to be supplied in susceptible areas. Existing systems should be reviewed to ensure the equipment added since initial installation has been installed to meet the earthquake bracing requirements.

6.2 The maps discussed in paragraph 4.4.3 identify seismic risk areas assigning values from 0 to 3 or 0 to 4. It is recommended that any site having a value of 2 or higher, on either Figure 1 or Figure 2, be given consideration for requiring earthquake bracing. The boundaries of the seismic risk zones are not precisely defined. Locations within 50 miles of these boundaries in the 0 and 1 areas should be investigated to determine apparent risk and local practice. More precise boundary definition can be found in the Applied Technology Council document discussed in paragraph 4.4.4. As always, compliance with local building codes must be provided.

6.3 Costs associated with the provision of earthquake bracing can range from less than 1 percent of a large switching system to 5 percent of a small switching system. Building costs are not included since the local building code requirements will generally result in a suitable building.

7. CONCLUSION

7.1 General

The threat of earthquake activity is widespread. Seismic activity resulting in a risk factor of 2 or higher has been assigned to portions or all of 40 states. The areas of seismic activity have been identified. The purpose of this section is to make REA borrowers and their consulting engineers aware of the need to consider earthquake bracing as part of system planning, purchase and installation.

Table 1 - RELATIONSHIPS BETWEEN MAGNITUDE AND INTENSITY

Magnitude (Richter)	Effects (Intensity) (Mod. Mercalli)
1	Only observed instrumentally.
2	Can be barely felt (Intensity II) near epicenter.
4.5	Felt to distances of some 20 miles from the epicenter; may cause slight damage (Intensity VII) in small area.
6+	Moderately destructive.
7+	Major earthquake.
8+	Great earthquake (1857, 1872, 1906).

Table 2 - MODIFIED MERCALLI SCALE OF EARTHQUAKE SHOCK INTENSITIES

I **Not felt by people, except under especially favorable circumstances. However, dizziness or nausea may be experienced.**
Sometimes birds and animals are uneasy or disturbed. Trees, structures, liquids, bodies of water may sway gently, and doors may swing very slowly.

II **Felt indoors by a few people, especially on upper floors of multistory buildings, and by sensitive or nervous persons.**
As in Grade I, birds and animals are disturbed, and trees, structures, liquids and bodies of water may sway. Hanging objects swing, especially if they are delicately suspended.

III **Felt indoors by several people, usually as a rapid vibration that may not be recognized as an earthquake at first. Vibration is similar to that due to passing of a light, or lightly loaded trucks, or heavy trucks some distance away. Duration may be estimated in some cases.**
Movements may be appreciable on upper levels of tall structures. Standing motor cars may rock slightly.

IV **Felt indoors by many, outdoors by few. Awakens a few individuals, particularly light sleepers, but frightens no one except those apprehensive from previous experience. Vibration like that due to passing of heavy, or heavily loaded trucks. Sensation like a heavy body striking building, or the falling of heavy objects inside.**
Dishes, windows and doors rattle; glassware and crockery clink and clash. Walls and house frame creak, especially if intensity is in the upper range of this grade. Hanging objects often swing. Liquids in open vessels are disturbed slightly. Stationary automobiles rock noticeably.

V **Felt indoors by practically everyone, outdoors by most people. Direction can often be estimated by those outdoors. Awakens many, or most sleepers. Frightens a few people, with slight excitement; some persons run outdoors.**

Buildings tremble throughout. Dishes and glassware break to some extent. Windows crack in some cases, but not generally. Vases and small or unstable objects overturn in many instances, and a few fall. Hanging objects and doors swing generally or considerably. Pictures knock against walls, or swing out of place. Doors and shutters open or close abruptly. Pendulum clocks stop, or run fast or slow. Small objects move, and furnishings may shift to a slight extent. Small amounts of liquids spill from well-filled open containers. Trees and bushes shake slightly.

VI **Felt by everyone, indoors and outdoors. Awakens all sleepers. Frightens many people; general excitement, and some persons run outdoors.**
Persons move unsteadily. Trees and bushes shake slightly to moderately. Liquids are set in strong motion. Small bells in churches and schools ring. Poorly built buildings may be damaged. Plaster falls in small amounts. Other plaster cracks somewhat. Many dishes and glasses, and a few windows, break. Knick-knacks, books and pictures fall. Furniture overturns in many instances. Heavy furnishings move.

VII **Frightens everyone. General alarm, and everyone runs outdoors.**
People find it difficult to stand. Persons driving cars notice shaking. Trees and bushes shake moderately to strongly. Waves form on ponds, lakes and streams. Water is muddied. Gravel or sand stream banks cave in. Large church bells ring. Suspended objects quiver. Damage is negligible in buildings of good design and construction; 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. Plaster and some stucco fall. Many windows and some furniture break. Loosened brickwork and tiles shake down. Weak chimneys break at the roofline. Cornices fall from towers and high buildings. Bricks and stones are dislodged. Heavy furniture overturns. Concrete irrigation ditches are considerably damaged.

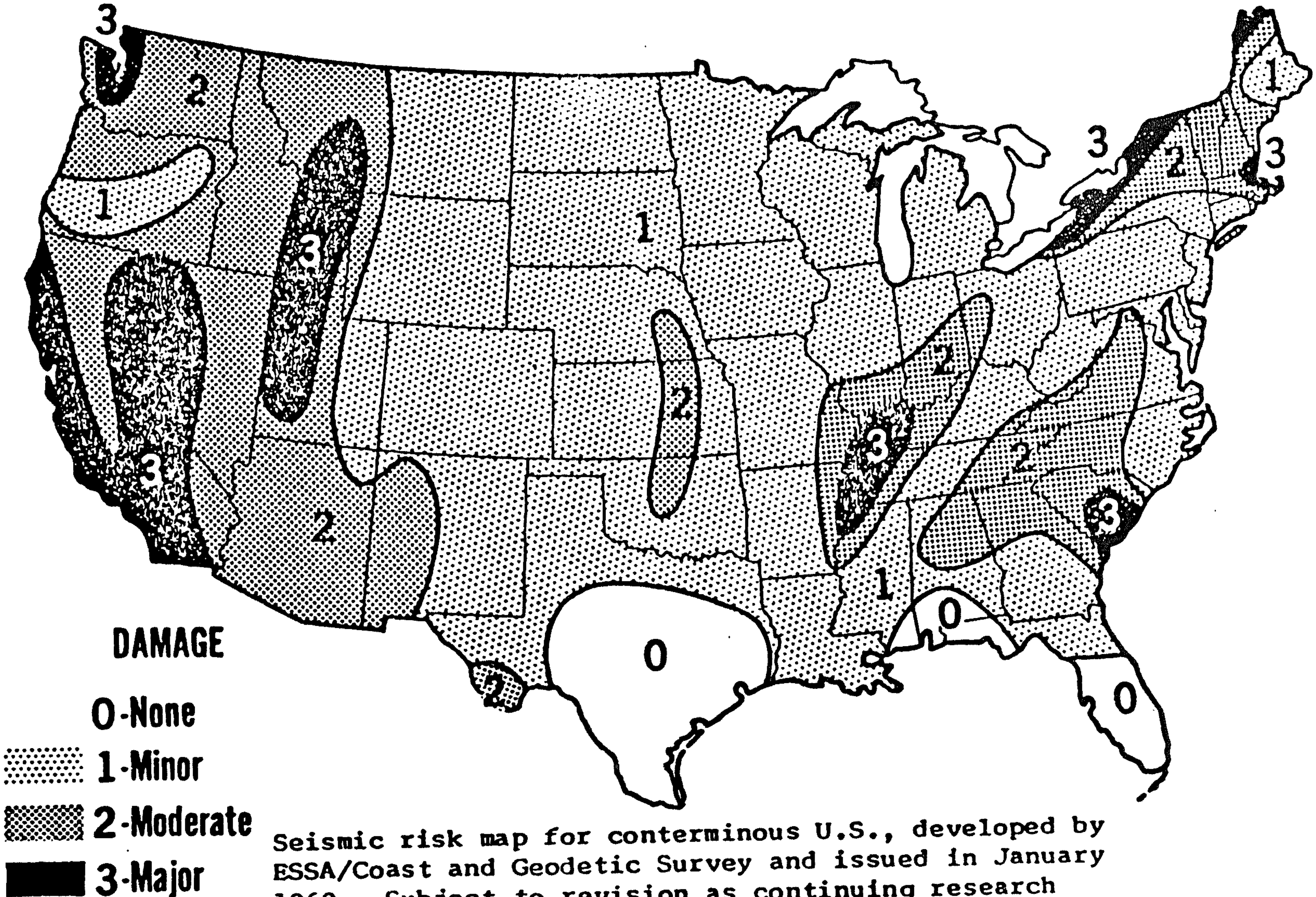
VIII **General fright, and alarm approaches panic.**
Persons driving cars are disturbed. Trees shake strongly, and branches and trunks break off (especially palm trees). Sand and mud erupts in small amounts. Flow of springs and wells is temporarily and sometimes permanently changed. Dry wells renew flow. Temperature of spring and well waters varies. Damage slight in brick structures built especially to withstand earthquakes; considerable in ordinary substantial buildings, with some partial collapse, heavy in some wooden houses, with some tumbling down. Panel walls break away in frame structures. Decayed pilings break off. Walls fall. Solid stone walls crack and break seriously. Wet ground and steep slopes crack to some extent. Chimneys, columns, monuments and factory stacks and towers twist and fall. Very heavy furniture moves conspicuously or overturns.

IX **Panic is general.**
Ground cracks conspicuously. Damage is considerable in masonry structures built especially to withstand earthquakes; great in other masonry buildings—some collapse in large part. Some wood frame houses built especially to withstand earthquakes are thrown out of plumb, others are shifted wholly off foundations. Reservoirs are seriously damaged, and underground pipes sometimes break.

X **Panic is general.**
Ground, especially when loose and wet, cracks up to widths of several inches; fissures up to a yard in width run parallel to canal and stream banks. Landsliding is considerable from river banks and steep coasts. Sand and mud shifts horizontally on beaches and flat land. Water level changes in wells. Water is thrown on banks of canals, lakes, rivers, etc. Dams, dikes, embankments are seriously damaged. Well-built wooden structures and bridges are severely damaged, and some collapse. Dangerous cracks develop in excellent brick walls. Most masonry and frame structures, and their foundations, are destroyed. Railroad rails bend slightly. Pipe lines buried in earth tear apart or are crushed endwise. Open cracks and broad wavy folds open in cement pavements and asphalt road surfaces.

XI **Panic is general.**
Disturbances in ground are many and widespread, varying with the ground material. Broad fissures, earth slumps, and land slips develop in soft, wet ground. Water charged with sand and mud is ejected in large amounts. Sea waves of significant magnitude may develop. Damage is severe to wood frame structures, especially near shock centers; great to dams, dikes and embankments, even at long distances. Few if any masonry structures remain standing. Supporting piers or pillars of large, well-built bridges are wrecked. Wooden bridges that "give" are less affected. Railroad rails bend greatly, and some thrust endwise. Pipe lines buried in earth are put completely out of service.

XII **Panic is general.**
Damage is total, and practically all works of construction are damaged greatly or destroyed. Disturbances in the ground are great and varied, and numerous shearing cracks develop. Landslides, rock falls, and slumps in river banks are numerous and extensive. Large rock masses are wrenched loose and torn off. Fault slips develop in firm rock, and horizontal and vertical offset displacements are notable. Water channels, both surface and underground, are disturbed and modified greatly. Lakes are dammed, new waterfalls are produced, rivers are deflected, etc. Surface waves are seen on ground surfaces. Lines of sight and level are distorted. Objects are thrown upward into the air.



Seismic risk map for conterminous U.S., developed by ESSA/Coast and Geodetic Survey and issued in January 1969. Subject to revision as continuing research warrants, it is an updated edition of the map first published in 1948 and revised in 1951. The map divides the U. S. into four zones: Zone 0, areas with no reasonable expectancy of earthquake damage; Zone 1, expected minor damage; Zone 2, expected moderate damage; and Zone 3, where major destructive earthquakes may occur.

Fig. 1 - ESSA/C&GS Seismic Risk Map

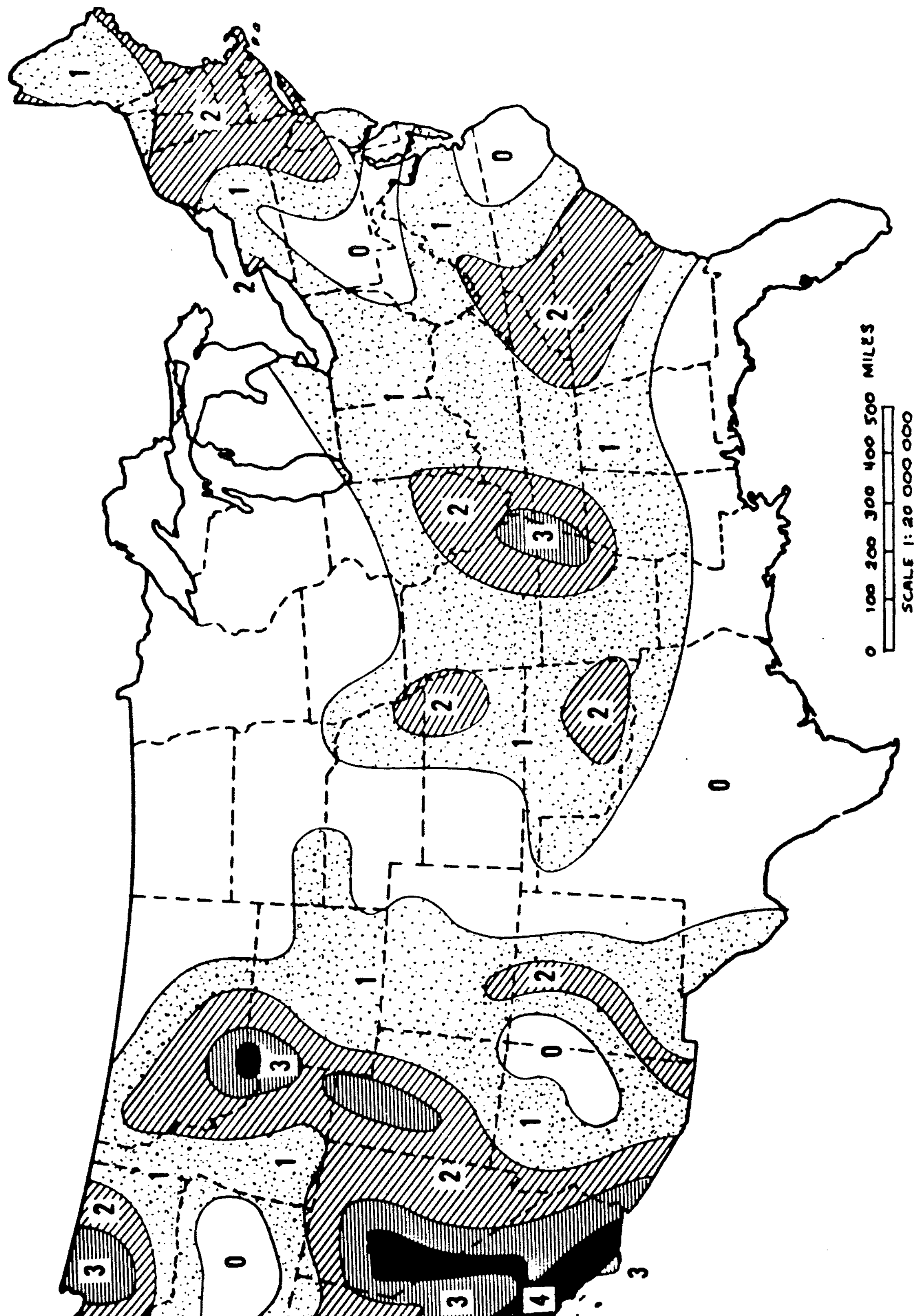


Fig. 2 - Map for Seismic Zones-Contiguous 48 States

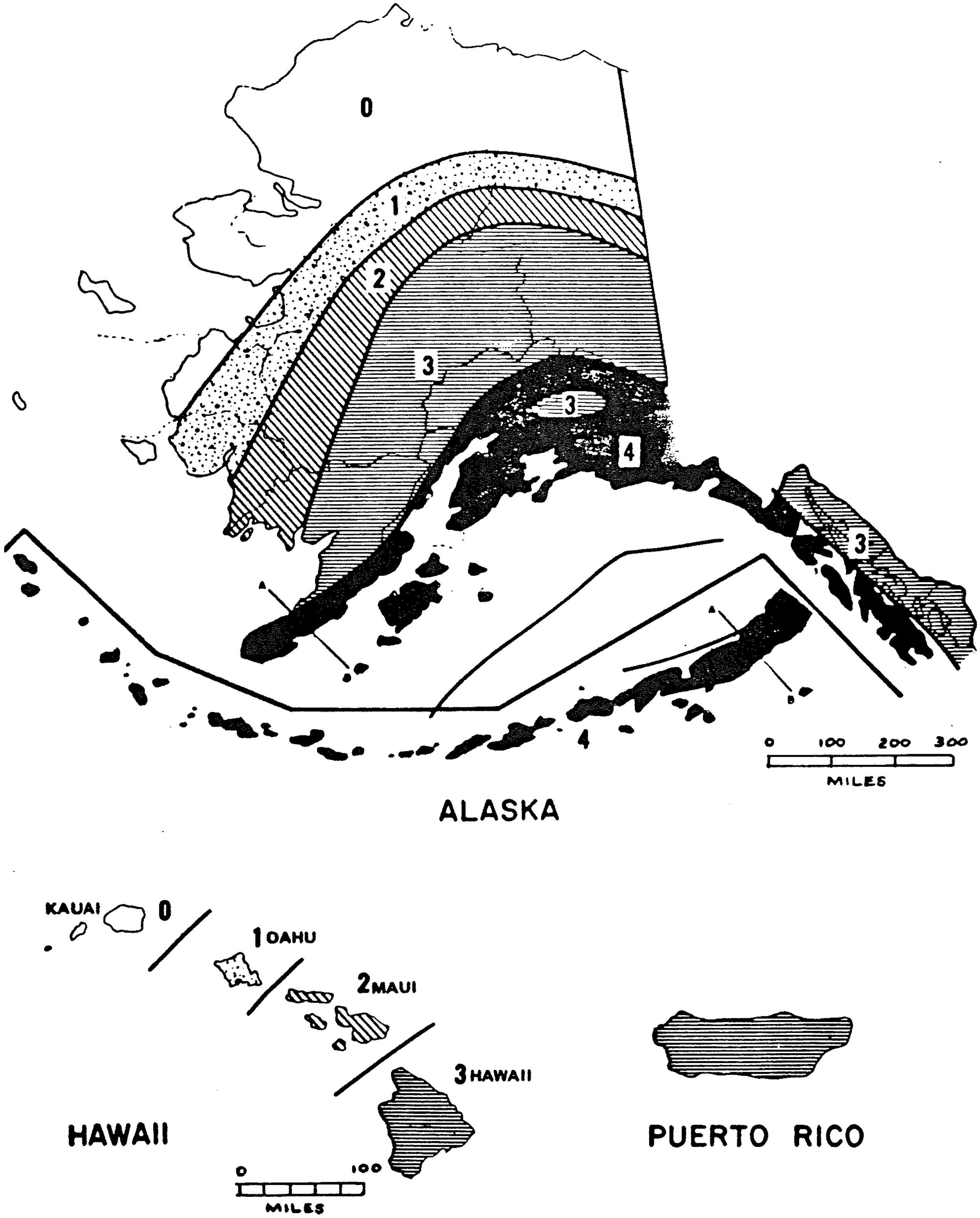


Fig. 3 - Map for Seismic Zones-Hawaii, Alaska, and Puerto Rico

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