STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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# Earthquake Hazard Maps for Oregon

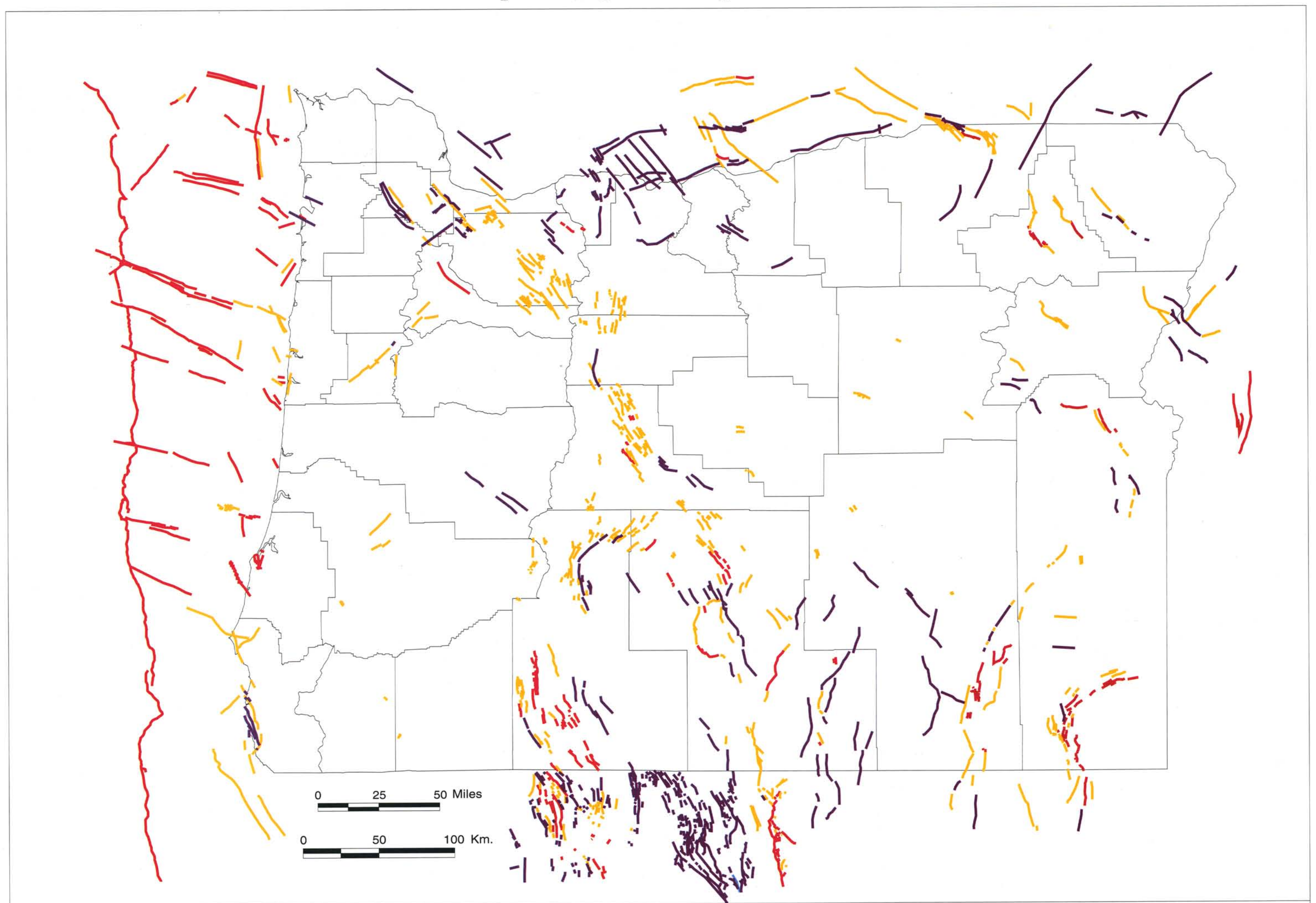
1996

ISSN 0270-952X

## GMS-100

Earthquake Hazard Maps for Oregon
Edited by I.P. Madin and M.A. Mabey

## Map of Oregon Earthquake Faults




Age of most recent faulting

Holocene -late Pleistocene (movement in last 20,000 years) — Late Quaternary (movement in last 780,000 years) — Quaternary (movement in last 1,600,000 years)

**Edited by Ian P. Madin and Matthew M. Mabey**

Based on data from the report *Seismic Design Mapping, State of Oregon*, by Geomatrix Consultants, Inc., to the Oregon Department of Transportation (Geomatrix Consultants, Inc., 1995) and the dissertation *Active faults and earthquake ground motions in Oregon*, by Silvio K. Pezzopane (Pezzopane, 1993).

Until 1993, Oregon enjoyed almost a century without significant recorded earthquake damage, and earthquakes were not considered a significant hazard by most of the residents of the State. However, the Scotts Mills earthquake (M 5.6, March 25, 1993) (Madin and others, 1993) and the Klamath Falls earthquakes (M 5.9, 6.0, September 20, 1993) (Wiley and others, 1993) alerted the people of Oregon to the fact that damaging earthquakes do occur in Oregon and will occur again in the future. Geoscience researchers have been aware for years of the potential for moderate earthquakes in Oregon and during the last decade have demonstrated the likelihood of Oregon's being struck by great earthquakes originating offshore. Many research articles have been written describing the hazard in technical terms, but these reports are generally difficult for the lay reader to understand. This map conveys, in a simplified form, state-of-the-art earthquake hazard information produced by Geomatrix Consultants, Inc., for the Oregon Department of Transportation in 1994 and 1995. This map is designed to provide easy understanding of the general hazard. More specific information is available in the source documents listed in the references, and those documents should be used for siting or design work.

### EARTHQUAKE SOURCES

Earthquakes in Oregon originate from one of three different source areas. *Crustal earthquakes* occur along relatively shallow faults (within about 10 mi of the surface). *Intraplate or Wadati-Benioff* earthquakes occur at greater depths (about 20–40 mi beneath the surface). *Great subduction earthquakes* occur along a great offshore fault that parallels the Oregon and Washington coasts.

*Crustal earthquakes* are the most common in Oregon and include both of the damaging 1993 events. Crustal earthquakes occur along relatively short and shallow faults that are commonly, but not always, visible at the surface. Historically, such earthquakes have barely exceeded magnitude 6, but the historic record is too short to provide a true representation of the earthquake threat. Geoscientists conclude that many faults in Oregon are capable of producing rare earthquakes as large as magnitude 6.5–7. Crustal earthquakes are relatively common in the Portland area and the northern Willamette Valley, off the southern coast of Oregon, in northeastern Oregon, and in scattered areas throughout southeastern Oregon. For most areas east of the Cascades, the majority of the earthquake shaking hazard comes from crustal faults.

*Intraplate or Wadati-Benioff* earthquakes are of the type that severely rocked the Puget Sound region in 1949 and again in 1965. Those who lived in Portland in 1949 may recall that the Portland area suffered some damaging and frightening effects of that earthquake. Intraplate earthquakes occur within the remains of the ocean floor that has been shoved ("subducted") beneath North America. It is now believed that this type of earthquake could occur anywhere beneath the Coast Range or the western Willamette Valley with magnitudes as large as 7–7.5.

*Great subduction earthquakes* occur around the world in subduction zones, where continent-sized pieces of the earth's crust are shoved deep into the body of the earth. These earthquakes consistently are among the most powerful recorded, often having magnitudes of 8–9 on the moment magnitude scale. The Cascadia Subduction Zone, which has long been recognized off the coast of Oregon and Washington, has had no great subduction earthquakes during our short 200-year historical record. However, in the past ten years, a variety of studies have found widespread evidence that these great events have occurred repeatedly in the past, most recently about 300 years ago. The best evidence available suggests that these great earthquakes have occurred, on average, every 350 to 500 years.

### PROBABILISTIC HAZARD MAPS

The probabilistic hazard maps shown in this publication are derived directly from a series of maps produced by Geomatrix Consultants, Inc., for the Oregon Department of Transportation in 1994 and 1995. The purpose of the maps is to provide the best possible up-to-date estimate of the likely strength of future earthquake shaking throughout Oregon. The producers of the maps assembled all existing information about faults, earthquakes, and rates of earth movement and used this information to estimate how often, where, and with what force future earthquakes would strike. All of the information collected by Geomatrix Consultants, Inc., was reviewed by a panel of geoscientists who are experts on Oregon geology and seismology. This information, along with information describing how earthquake shaking travels and diminishes with distance, was modeled with a sophisticated computer system to calculate the probable strength of shaking at any site in Oregon from all earthquake sources combined.

The maps include information about how often an earthquake occurs because, over time, the damage caused by frequent small events may be similar to that caused by much larger but much rarer events. In simple terms, the maps show a level of ground shaking that has a 90-percent chance of not being exceeded in the selected time period (50 years for the 500-year recurrence map, 100 years for the 1,000-year recurrence map, and 250 years for the 2,500-year recurrence map). Another way to look at this is that if you design a building for the level shown on the map, there is only a 10-percent chance that that level will be exceeded during the time period of that map.

Clearly, the level of hazard changes significantly when one changes from the 500-year recurrence map to the 1,000-year recurrence map or to the 2,500-year recurrence map. The time window appropriate to be used for planning will depend on the specific application under consideration. These decisions may be the responsibility of agencies or individuals at various levels of government or private enterprise such as finance or insurance. For example, for extremely important or hazardous facilities, the decision may be to use the 2,500-year maps; for facilities whose failure causes little risk of death or injury, the 500-year map might be appropriate; and for other applications involving life safety, the choice of the 1,000-year map might result.

The original maps produced by Geomatrix Consultants, Inc., showed contours of strength of shaking at increments of one percent of gravity on a 1:500,000-scale base map of Oregon. The maps in this publication were derived from the originals as follows: Digital copies of the contour maps were converted to a raster image with IDRISI (Eastman, 1990), a raster-based GIS (Geographic Information System). The contours were then interpolated to produce a smoothed raster image showing strength of shaking at a resolution of about 2 km². The raster image was then exported into MapInfo™ and combined with geographic data to produce the maps shown here. The relation between color and shaking intensity is the same for all maps, so that the effect of considering the different time periods is apparent.

These maps show the strength of shaking that is likely on the firmest types of geologic material ("bedrock"). Local soft geologic deposits may substantially increase the shaking due to a particular earthquake—beyond the levels shown here.

### EARTHQUAKE FAULT MAP

This map shows all faults in Oregon known or suspected to be capable of producing earthquakes. The faults are divided into three categories based on the age of the most recent activity. The age is determined by estimating the age of the youngest geologic material cut by the fault. As such, the method provides a maximum estimate for the age of activity. It is possible that significant earthquakes might occur along a fault and not break the surface, as was the case with both the Scotts Mills and Klamath Falls earthquakes of 1993. It is also possible that evidence of recent faulting may have been removed or obscured by weathering, erosion, or vegetation. The age categories are as follows:

- Holocene to late Pleistocene, active within the last 20,000 years or so,
- late Quaternary, active within the last 20,000–780,000 years, and
- Quaternary, active within the last 1,600,000 years.

In many areas, particularly western Oregon, it is very difficult to locate faults at the surface, and so it is very difficult to determine where a fault is with respect to a given site. This fault map should not be used to determine the presence or absence of faulting for specific sites. It is also important to note that there is no historical record of an earthquake in the Pacific Northwest that caused visible fault rupture at the ground surface. This includes the north Cascades event in 1872 (M 7.4), the Port Orford earthquake in 1873 (M 6.8), the Portland earthquakes of 1877 (M 5.5) and 1961 (M 5.2), the Milton-Freewater earthquake of 1936 (M 6.1), the Olympia, Washington, earthquake of 1949 (M 7.1), the Seattle, Washington, earthquake of 1965 (M 6.5), the Scotts Mills earthquake of 1993 (M 5.6), and the Klamath Falls earthquakes of 1993 (M 6.0). Clearly, the presence of faults does not necessarily indicate a high degree of hazard, nor does the absence of faults mapped as being active indicate an absence of hazard.

### ACKNOWLEDGMENTS

The editors owe thanks to Geomatrix Consultants, Inc., and the Oregon Department of Transportation for making this information available and permitting its publication. Thanks are also due Bob Youngs of Geomatrix, Linda Noson of Dames and Moore, Seattle, and Silvio Pezzopane of the U.S. Geological Survey for reviewing the maps.

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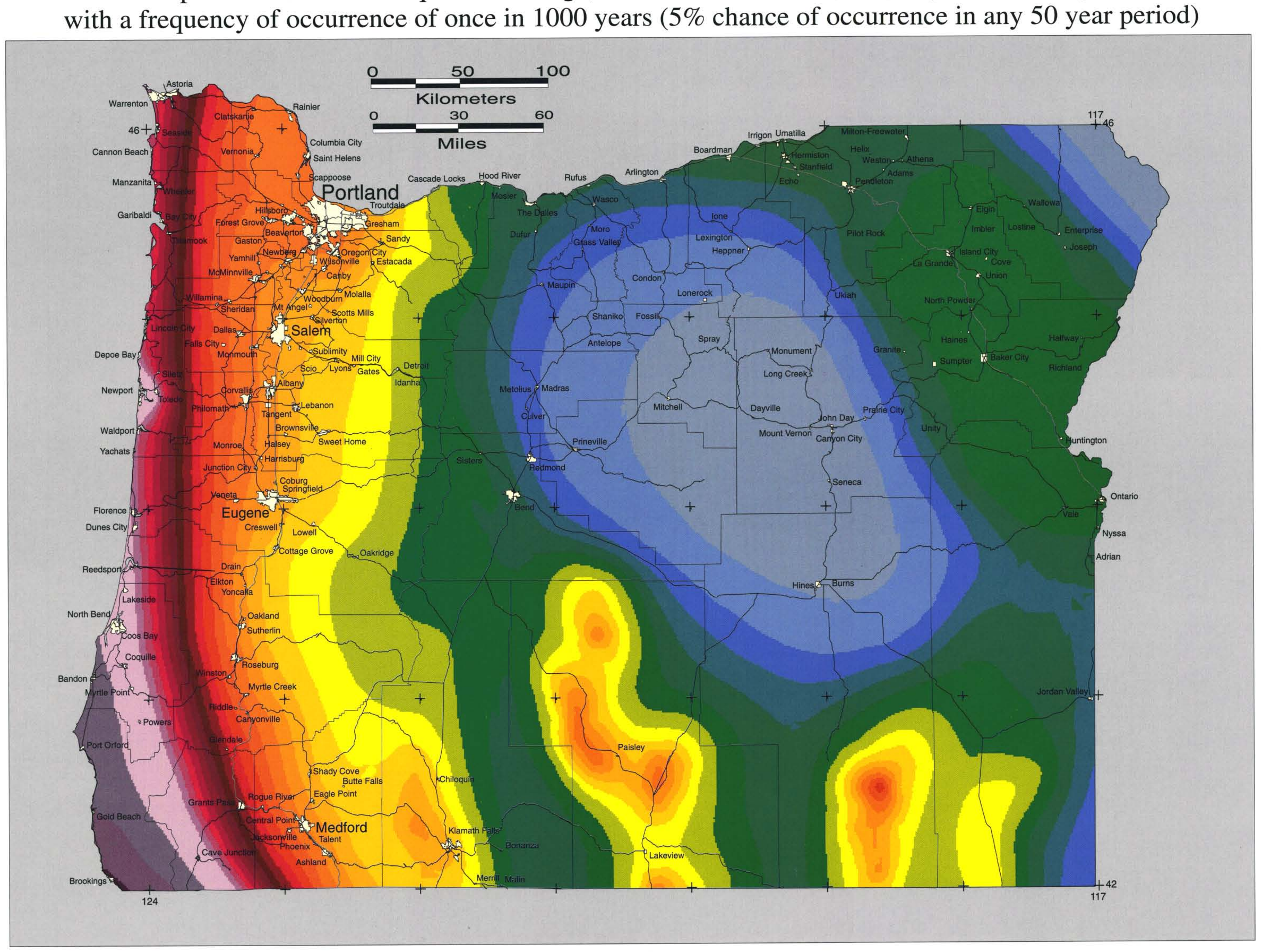
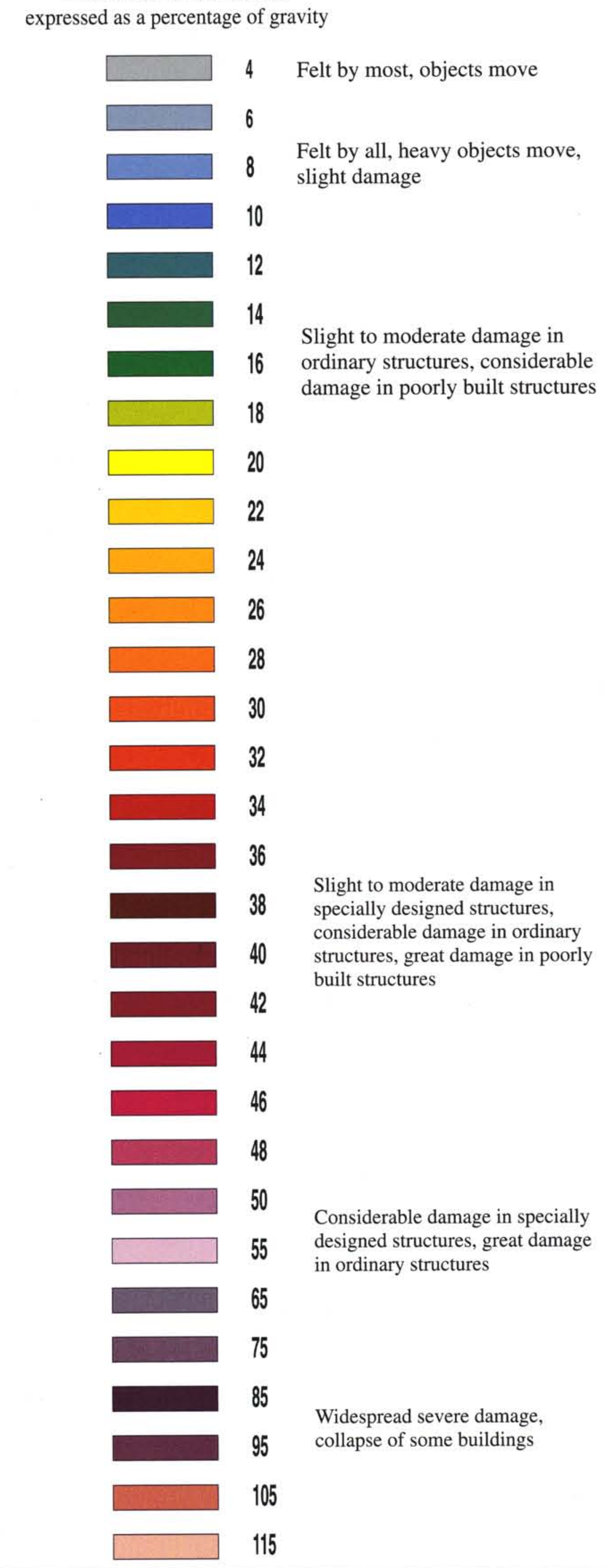
**Table 1.**
**Comparison of peak bedrock acceleration, Uniform Building Code seismic zone factors and modified Mercalli intensity**

| Peak bedrock acceleration (expressed as a percentage of gravity) | Approximate equivalent Uniform Building Code zone(equating the UBC 'Z' factor to acceleration) | Approximate modified Mercalli intensity (after Bolt, 1993) |
|---|---|---|
| 4 | 1 | V |
| 6 | 1 | VI |
| 8 | 1 | VI+ |
| 10 | 2B | VII |
| 12 | 2B | VII |
| 14 | 2B | VII |
| 16 | 2B | VII+ |
| 18 | 2B | VII+ |
| 20 | 2B | VII+ |
| 22 | 3 | VII+ |
| 24 | 3 | VII+ |
| 26 | 3 | VIII |
| 28 | 3 | VIII |
| 30 | 3 | VIII |
| 32 | 4 | VIII+ |
| 34 | 4 | VIII+ |
| 36 | 4 | VIII+ |
| 38 | 4 | VIII+ |
| 40 | 4 | VIII+ |
| 42 | 4+ | VIII+ |
| 44 | 4+ | VIII+ |
| 48 | 4+ | VIII+ |
| 50 | 4+ | IX |
| 55 | 4+ | IX |
| 65 | 4+ | X |
| 75 | 4+ | X |
| 85 | 4+ | X+ |
| 95 | 4+ | X+ |
| 105 | 4+ | X+ |
| 115 | 4+ | X+ |

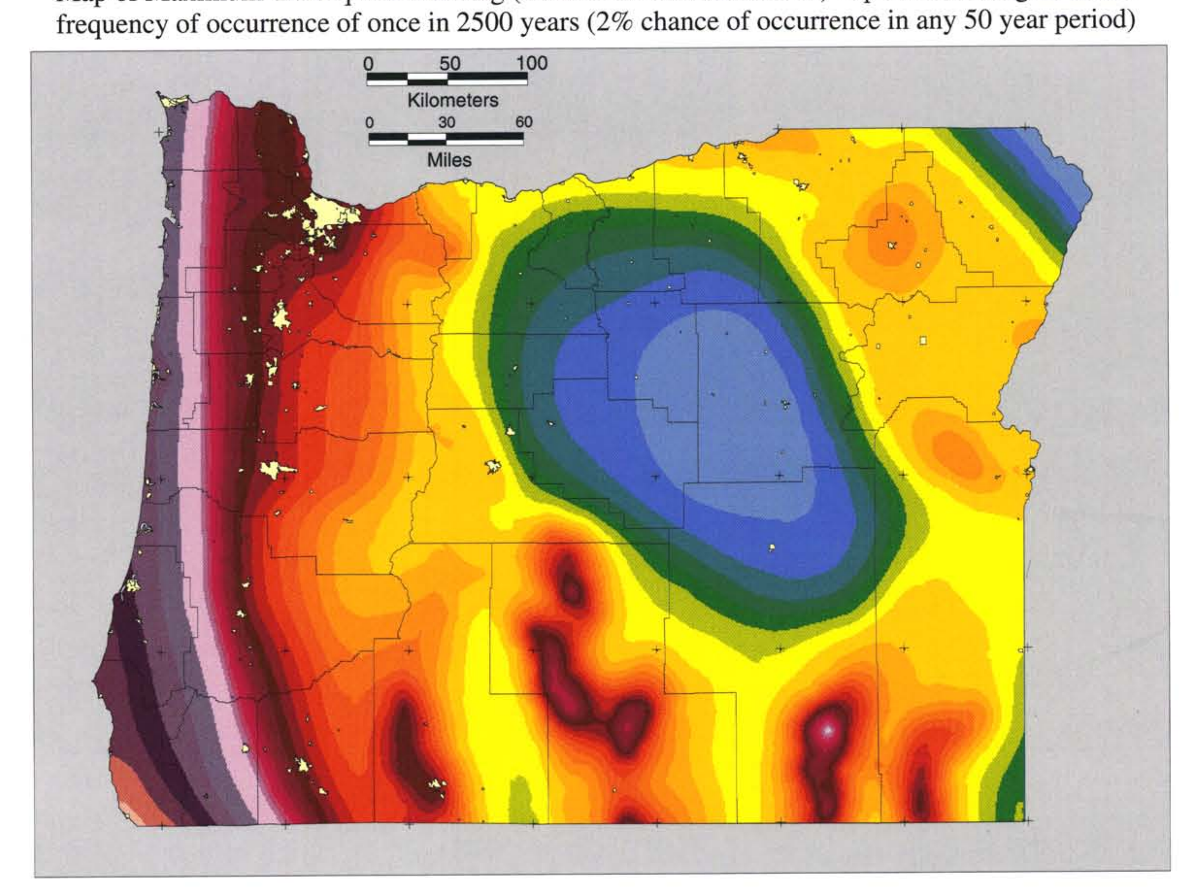
## Map of Maximum Earthquake Shaking (Peak Ground Acceleration) expected in Oregon with a frequency of occurrence of once in 1000 years (5% chance of occurrence in any 50 year period)




## Ground Shaking Explanation for the 500, 1000 and 2500 year recurrence maps




## Map of Maximum Earthquake Shaking (Peak Ground Acceleration) expected in Oregon with a frequency of occurrence of once in 2500 years (2% chance of occurrence in any 50 year period)




## Map of Maximum Earthquake Shaking (Peak Ground Acceleration) expected in Oregon with a frequency of occurrence of once in 500 years (10% chance of occurrence in any 50 year period)