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Oregon Department of Geology and Mineral Industries
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IN THIS ISSUE:

Scenario ground-motion maps, western Oregon, Seaside and Portland

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Released December 4, 2001:

Reconnaissance geologic map of the La Grande 30'x 60' quadrangle, Baker, Grant, Umatilla, and Union Counties, Oregon, by M.L. Ferns and I.P. Madin, Oregon Department of Geology and Mineral Industries, and W.H. Taubeneck, Professor Emeritus, Oregon State University. Reconnaissance Map Series map RMS–1, scale 1:100,000; 1 CD, $10. Printed color copies of the map are available on request for $15.

The La Grande quadrangle map covers 1,680 mi^2 (4,350 km^2) in four counties of eastern Oregon. This geologic map with its 77 identified rock units presents a new, more detailed and yet more unified view of the complex nature of this region's complex stratigraphy.

Among the significant advances in understanding the geologic evolution of the area, the following are most noteworthy: (1) The recognition that the unusually high grade metamorphic rocks exposed south of Pendleton cannot be correlated with any of the previously identified pre-Tertiary terranes of northeastern Oregon but are distinctive enough to warrant grouping together as the Mountain Home metamorphic complex. (2) The discovery of the Tower Mountain caldera, a large rhyolite eruptive center of late Oligocene age. This caldera, like most of the quadrangle, was partially buried by the Miocene flood lavas that make up the Columbia River Basalt Group. (3) The recognition that the dacite, andesite, and olivine basalt flows exposed at the top of the section near La Grande are not part of the Columbia River Basalt Group but instead form part of the Powder River Volcanic Field

The accompanying 54-page text highlights the geologic history of the area, water and mineral resources, semiprecious gemstones, geothermal energy, and fossil fuels. It also points out the earthquake and landslide hazards that are most evident along the active margins of the Grande Ronde Valley. For the hurried or less technically interested user, this report has been summarized on a separate two-page sheet.

RMS–1 is being released on one CD-ROM which contains not only GIS data files that make up the map and can be used in various mapping software pro-

(Continued on page 124)

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Cover photos

Oregon Sunstone—proclaimed State Gemstone by Governor Neil Goldschmidt in August 1987—still attracts mining interests to remote areas of the state (article in *Oregon Geology*, February 1987).

The photos on the cover show (from the top) a mine location in southeast Harney County, one of only three known areas in Oregon where sunstone occurs; the raw gemstones; and a characteristic outcrop. The photos were provided by mine owners Larry and Virginia Kribs who operate Desert Dog Mines, Inc., in Bend, Oregon.

Scenario ground-motion maps for western Oregon and comparison of scenario, probabilistic, and design response spectra for Seaside and Portland, Oregon

by Kenneth W. Campbell, EQE International, Inc., 1030 NW 161st Place, Beaverton, Oregon 97006, and Zhenming Wang, Oregon Department of Geology and Mineral Industries*

INTRODUCTION

Earthquake hazards have been recognized as one of the major natural hazards in Oregon since the 1980s. Scientists have revealed that Oregon has experienced many damaging earthquakes in the past (Atwater, 1987; Heaton and Hartzell, 1987; Weaver and Shedlock, 1989; Atwater and others, 1995). Great Cascadia Subduction Zone earthquakes have occurred many times in the past along the northwest Pacific coast, most recently on January 26, 1700 (e.g., Clague and others, 2000). Shallow crustal earthquakes like the magnitude 5.6 Scotts Mills earthquake in 1993 (Madin and others, 1993) and the magnitude 5.9 and 6.0 Klamath Falls earthquakes in 1993 (Wiley and others, 1993), which caused more than $30 million and $10 million of damage, respectively, also threaten communities in Oregon.

This new information has dramatically changed the ground motion estimates and the building seismic design practice in Oregon. In 1990, the U.S. Geological Survey (USGS) estimated the peak ground acceleration (PGA) with a 475-year return period (i.e., a 10-percent probability of exceedance in 50 years) to be between 0.05 and 0.10 *g* (Building Seismic Safety Council, 1994). In 1995, Geomatrix Consultants (1995), using new scientific information, revised this estimate to range up to 0.60 *g*. In a major revision to the national seismic hazard maps in 1996, the USGS (Frankel and others, 1996, 2000) confirmed the increased hazard proposed by Geomatrix Consultants, which was later adopted by the Building Seismic Safety Council (1997) and the International Building Code (International Code Council, 2000). This significant increase in seismic hazard has resulted in a substantial change in the building seismic design code in Oregon, which is based on the Uniform Building Code, from UBC Zone 2 in 1988 to UBC Zones 2B, 3, and 4 in 1998 (International Council of Building Officials, 1988, 1998). A more recent estimate of ground motion in the Portland area by Wong and others (2000) is higher still.

All of the above ground motion hazard estimates were derived from probabilistic seismic hazard analysis (PSHA) based on available geologic and seismologic data. However, the geology and seismology of Oregon are still relatively poorly understood. This can lead to large uncertainty in the probabilistic hazard derived from PSHA. In this paper, we use deterministic seismic hazard analysis (DSHA) as an alternative to PSHA to develop scenario ground-motion maps for four hypothetical earthquakes in western Oregon and scenario response spectra for the Oregon cities of Seaside and Portland. The first two scenarios were moment magnitude (M_W) 8.5 and 9.0 earthquakes on the Cascadia Subduction Zone. The second pair of scenarios were M_W 6.5 and 7.0 earthquakes on the Portland Hills fault, which crops out along the eastern side of the Portland Hills within the city. The resulting scenario maps can be used for policy development, for seismic risk assessment, for emergency and response planning, and to compare scenario response spectra with available probabilistic and design response spectra for communities in western Oregon.

SCENARIO GROUND-MOTION ESTIMATES

We assumed rupture along the entire length and width of the faults in each of the hypothesized scenarios. While the entire fault is not expected to rupture during the smaller scenarios, we made this assumption in order to represent a worst-case scenario at a given location, whereby the earthquake is assumed to occur anywhere along the fault. We created ground-motion scenarios for the median estimate of the average horizontal components of PGA and 5-percent-damped pseudo-acceleration response spectra (PSA) for natural periods of 0.2 s and 1.0 s. We produced median ground-motion maps for a grid of sites in western Oregon spaced at intervals of 0.1° between lat 42.0° and 46.3°N. and long 121.0° and 124.6°W. We also produced scenario response spectra for natural periods ranging from 0.03 s to 2.0 s for the cities of Seaside and Portland.

We defined local site conditions as the boundary of site classes B and C (the B-C boundary). B and C refer to the site classes defined in the 1997 edition of the *Uniform Building Code* (International Council of Building Officials, 1998), the 1997 edition of the NEHRP *Recommended*

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Provisions for Seismic Regulations for New Buildings and other Structures (Building Seismic Safety Council, 1997), and the 2000 edition of the *International Building Code* (International Code Council, 2000), to which we will refer as UBC-1997, NEHRP-1997, and IBC-2000, respectively. The B-C boundary represents a site profile with an average shear-wave velocity in the top 30 m of 760 m/s. This site condition is consistent with the probabilistic seismic hazard maps developed by the USGS (Frankel and others, 1996; 2000); however, this same level of ground motion was conservatively assigned to site class B in the seismic design procedures used in NEHRP-1997 and IBC-2000 (e.g., Leyendecker and others, 2000). These seismic design maps are formally referred to as Maximum Considered Earthquake (MCE) ground-motion maps.

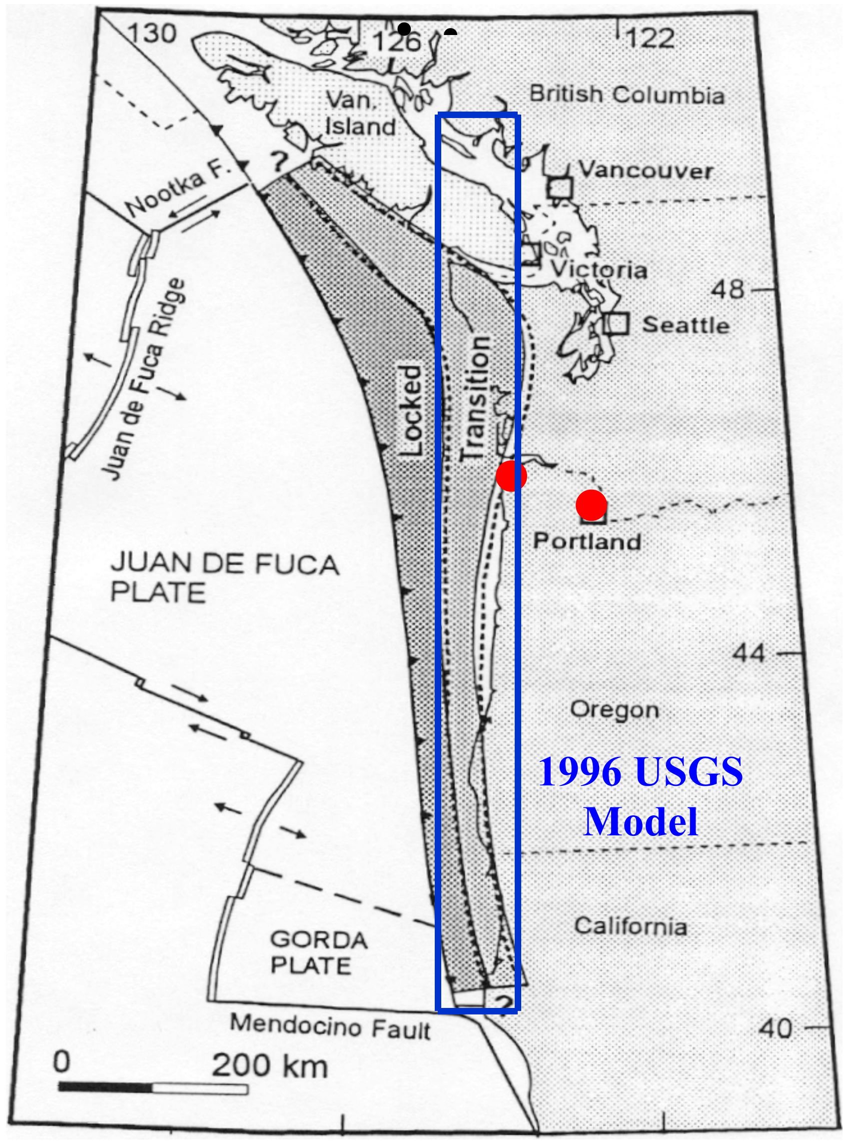

Figure 1. Location of the Cascadia Subduction Zone plate interface proposed by Flück and others (1997), superimposed on the 1996 USGS source zone model of Frankel and others (1996, 2000). The seismogenic zone used in this study included the locked zone and the adjacent (upper) half of the transition zone. The solid red circles are the locations of the cities of Seaside (left) and Portland (right).

CASCADIA SUBDUCTION ZONE SCENARIOS

The assumed rupture surface for the earthquake scenarios on the Cascadia Subduction Zone are shown in Figure 1. Seismologists commonly believe that the entire locked zone, as defined in this study by the model given by Flück and others (1997), will rupture seismogenically during a great earthquake. However, there is disagreement regarding how much of the transition zone might support seismogenic rupture. Flück and others (1997) assume that coseismic displacement will decrease linearly, from a maximum in the locked zone to zero at the lower (eastern) boundary of the transition zone, without specifying whether this displacement will be seismogenic. For purposes of this study, we assumed that seismogenic rupture would extend halfway into the transition zone during both the M_W 8.5 and M_W 9.0 scenarios.

Also shown in Figure 1 is the source zone for the Cascadia Subduction Zone used by Frankel and others (1996, 2000) in the generation of the USGS probabilistic seismic hazard maps. The assumed location of the simple rectangular USGS zone is located farther east than that estimated by Flück and others (1997), who used a three-dimensional analysis of geodetic and geothermal data. In fact, the USGS location puts this source zone on land, whereas the more realistic downdip extent of the seismogenic part of the subduction zone assumed in this study lies totally off the Oregon coast. The depth to the top of the Cascadia Subduction Zone interpreted by Flück and others (1997) is shown in Figure 2. These contours indicate that the rupture surface assumed in this study dips to the east at a relatively shallow angle from a depth of about 5 km at the deformation front to a depth of about 15 km halfway down the transition zone. The bottom of the transition zone occurs at a depth of around 20 km.

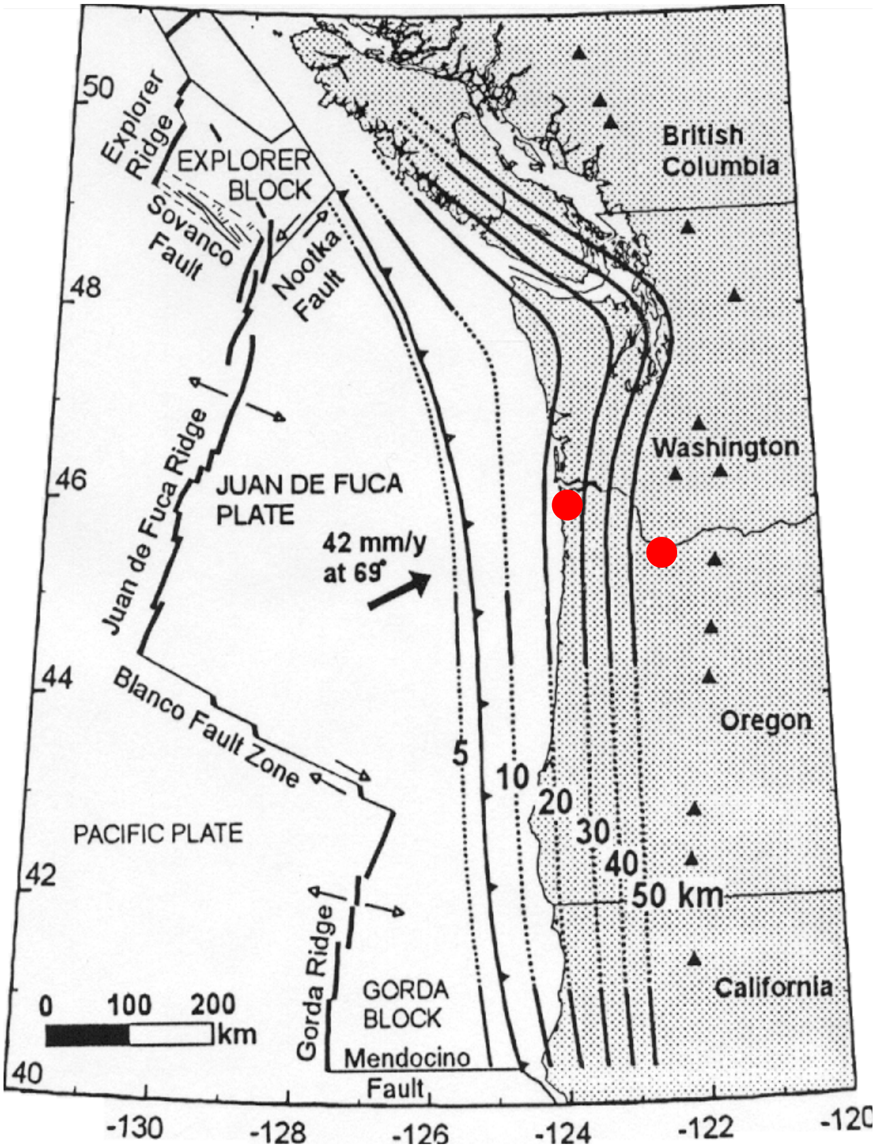

Figure 2. Contours showing the depth to the top of the Cascadia Subduction Zone plate interface (after Flück and others, 1997). The solid red circles are the locations of the cities of Seaside (left) and Portland (right).

We used the attenuation relationship of Youngs and others (1997) to estimate ground motions at each of the grid sites from the two Cascadia Subduction Zone scenario earthquakes. This relationship was developed from strong-motion recordings of subduction-zone earthquakes located throughout the world and currently represents the state of the art for estimating ground motions on rock sites. This is a departure from the model used by Frankel and others (1996, 2000) for their smaller magnitude scenario on the Cascadia Subduction Zone. For their M_W 8.3 scenario, they used both the Youngs and others (1997) relationship and a shallow crustal attenuation relationship developed by Sadigh and others (1997), and they averaged the ground motions predicted from each. For their M_W 9.0 scenario, they used only the Youngs and others (1997) relationship, since the Sadigh and others (1997) relationship is not valid for such a large magnitude. We used only the Youngs and others (1997) attenuation relationship even for the smaller magnitude scenario because, in our opinion, the shallow crustal relationship attenuates much too rapidly and would result in unconservative ground-motion estimates in Portland and other areas located relatively distant from the subduction zone. The crustal attenuation relationship will produce higher ground motions at short distances; however, for the earthquake scenarios used in this study, this affects only a few sites located primarily along the southern Oregon coast.

The median PGA map for the M_W 8.5 Cascadia Subduction Zone scenario is shown in Figure 3. Similar scenario maps for the 0.2-s and 1.0-s values of the 5-percent-damped PSA response spectra are shown in Figures 4 and 5. Median PGA and PSA maps for the M_W 9.0 scenario are shown in Figures 6–8. Estimated 5-percent-damped PSA response spectra for the city of Seaside, which is located approximately 37 km from the hypothesized rupture surface, are compared in Figure 9. Also shown on this figure are the uniform hazard response spectra (UHS) with return periods of 475 years (10-percent probability of exceedance in 50 years) and 2,500 years (2-percent probability of exceedance in 50 years) from Frankel and Leyendecker (2001), the recommended IBC-2000 design response spectrum (International Code Council, 2000; Leyendecker and others, 2001), and the recommended UBC-1997 design response spectrum (International Council of Building Officials, 1998). Seaside currently uses the UBC-1997 Zone 3 seismic provisions for its building design.

PORTLAND HILLS FAULT SCENARIOS

We took the geometry and rupture mechanism of the Portland Hills fault from the USGS seismic hazard study (Frankel and others, 1996, 2000), with one exception. We found that the trace of the Portland

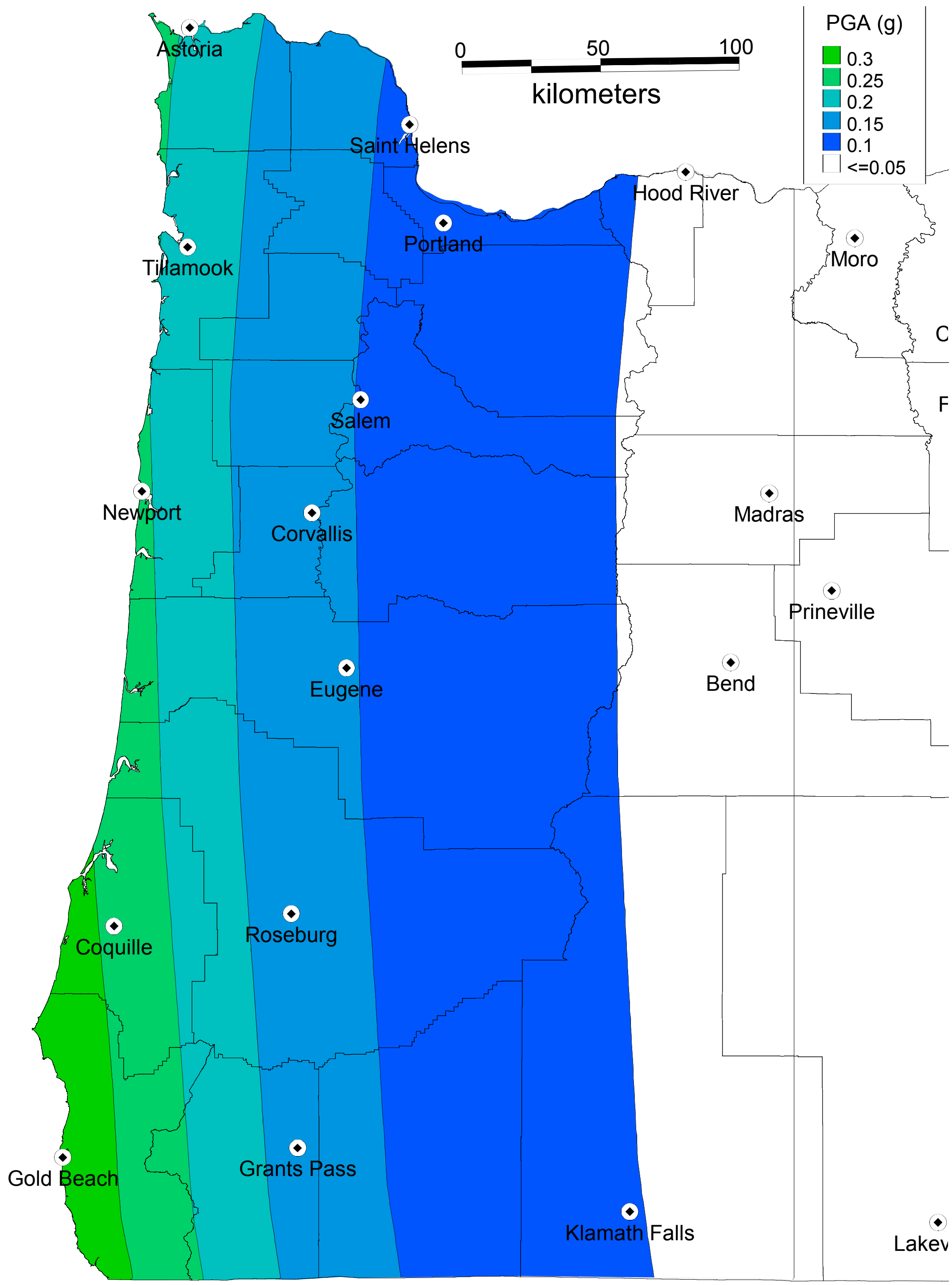

Figure 3. Map of median peak ground acceleration (PGA in *g*) on firm rock (B-C boundary) for a M_W 8.5 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

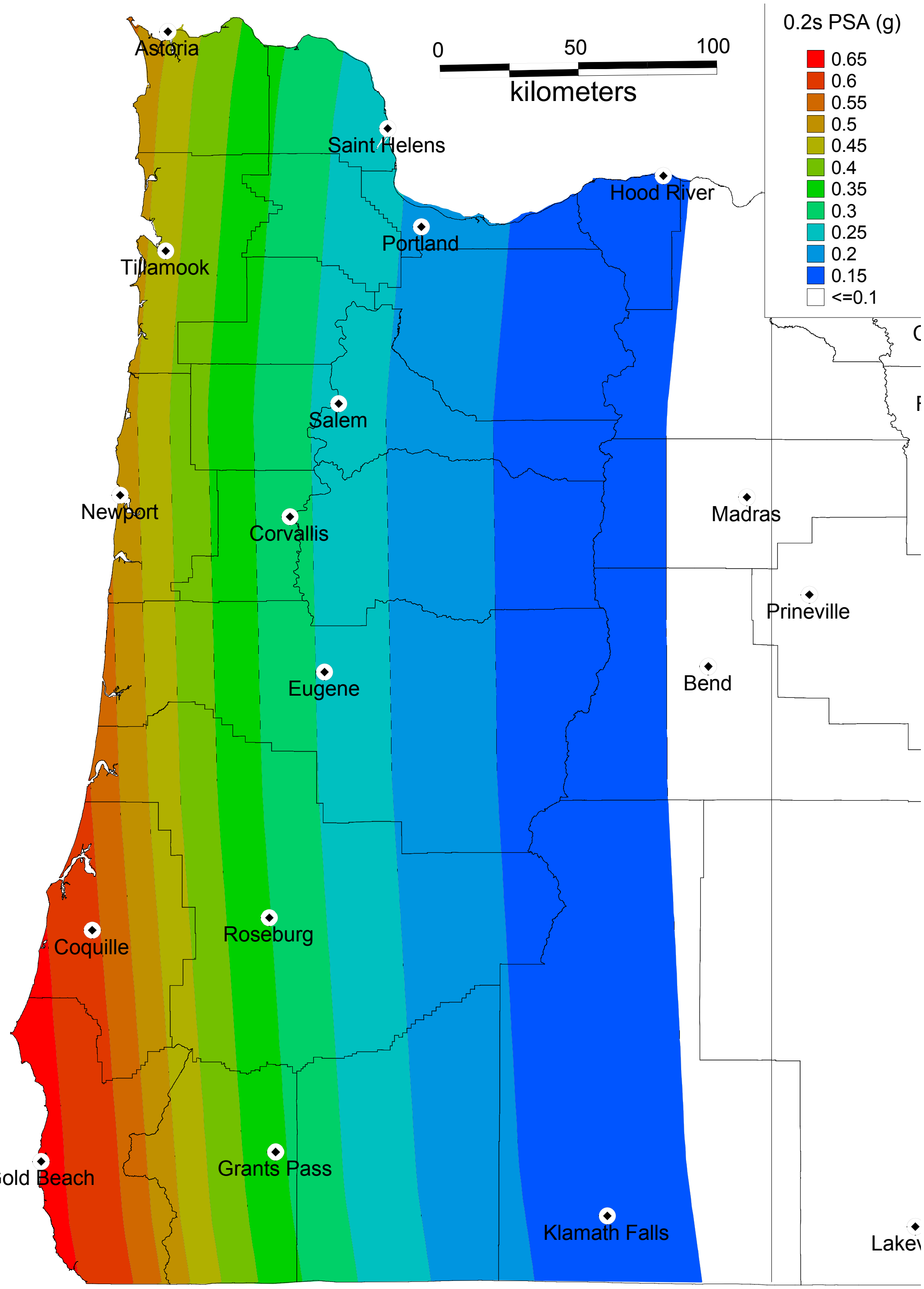

Figure 4. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 0.2-s period on firm rock (B-C boundary) for a M_W 8.5 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

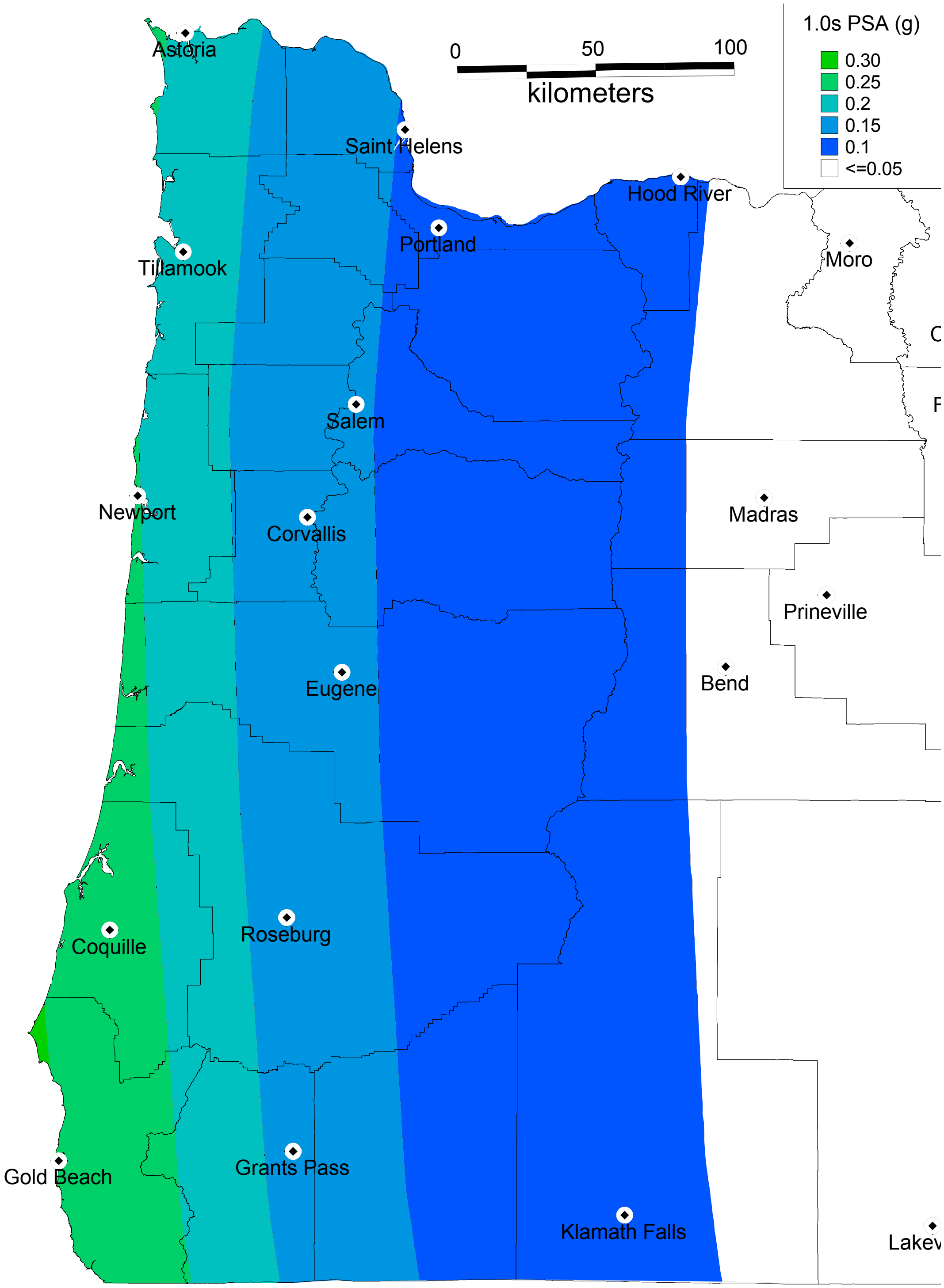

Figure 5. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 1.0-s period on firm rock (B-C boundary) for a M_W 8.5 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

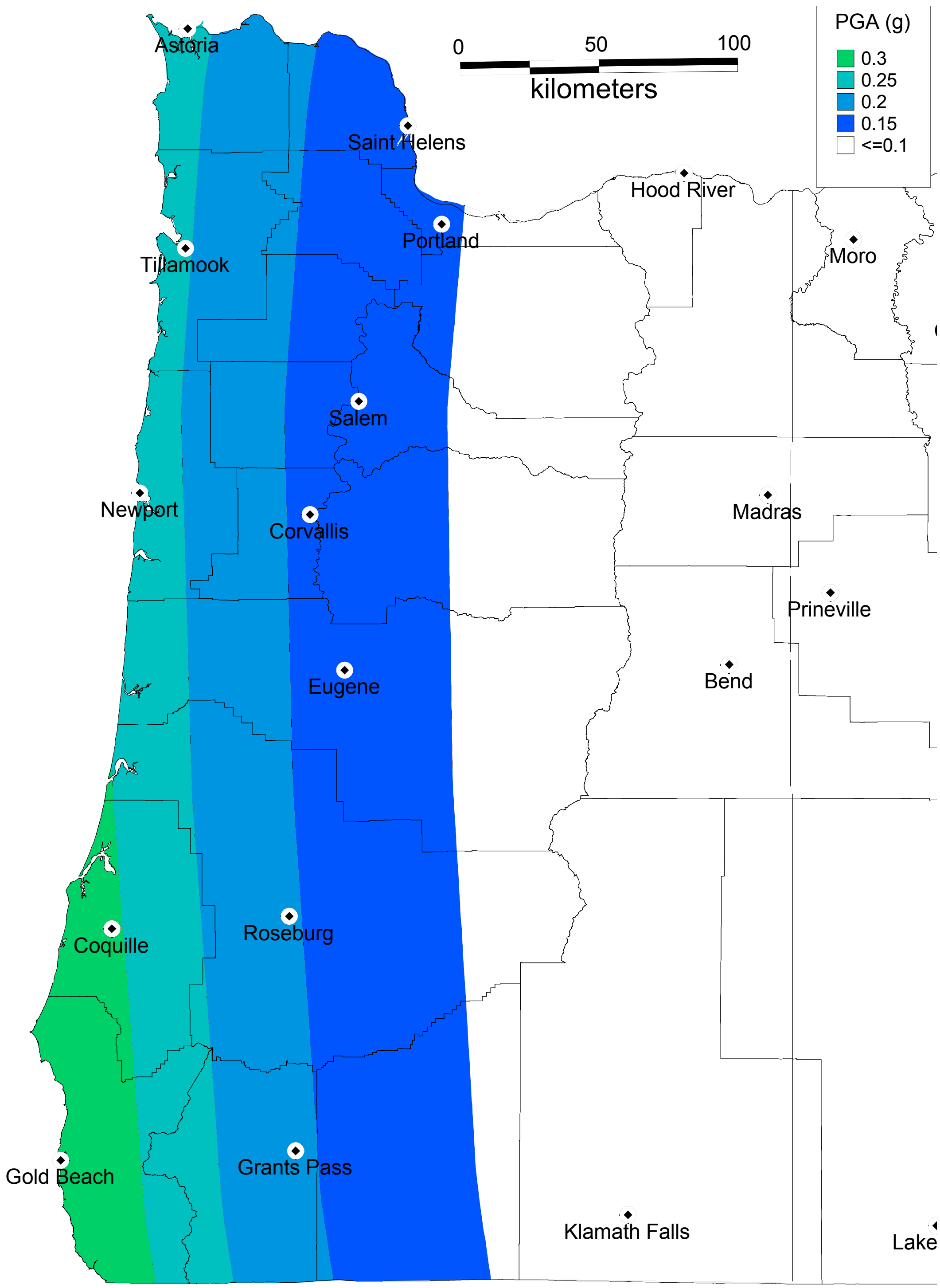

Figure 6. Map of median peak ground acceleration (PGA in *g*) on firm rock (B-C boundary) for a M_W 9.0 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

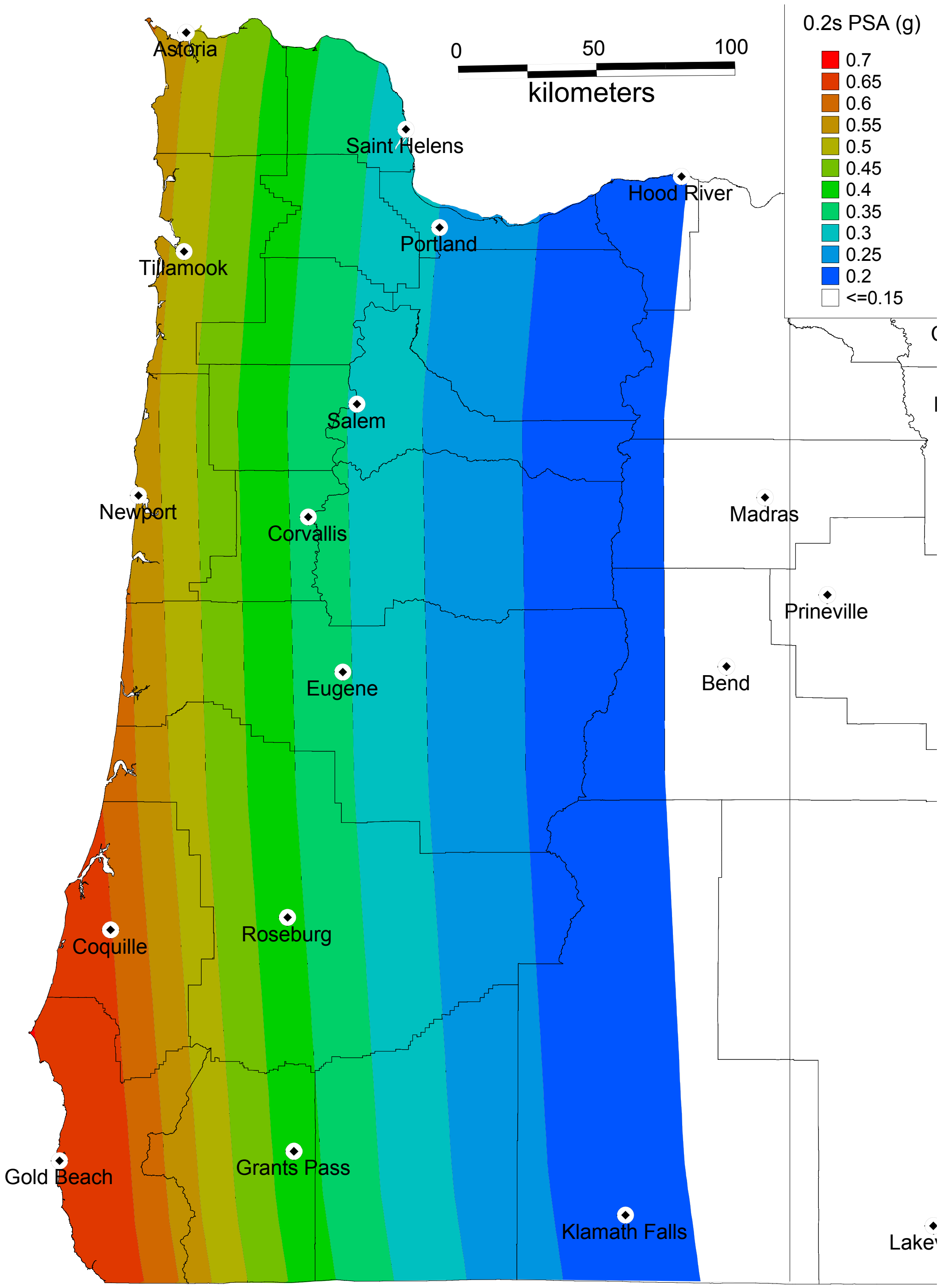

Figure 7. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 0.2-s period on firm rock (B-C boundary) for a M_W 9.0 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

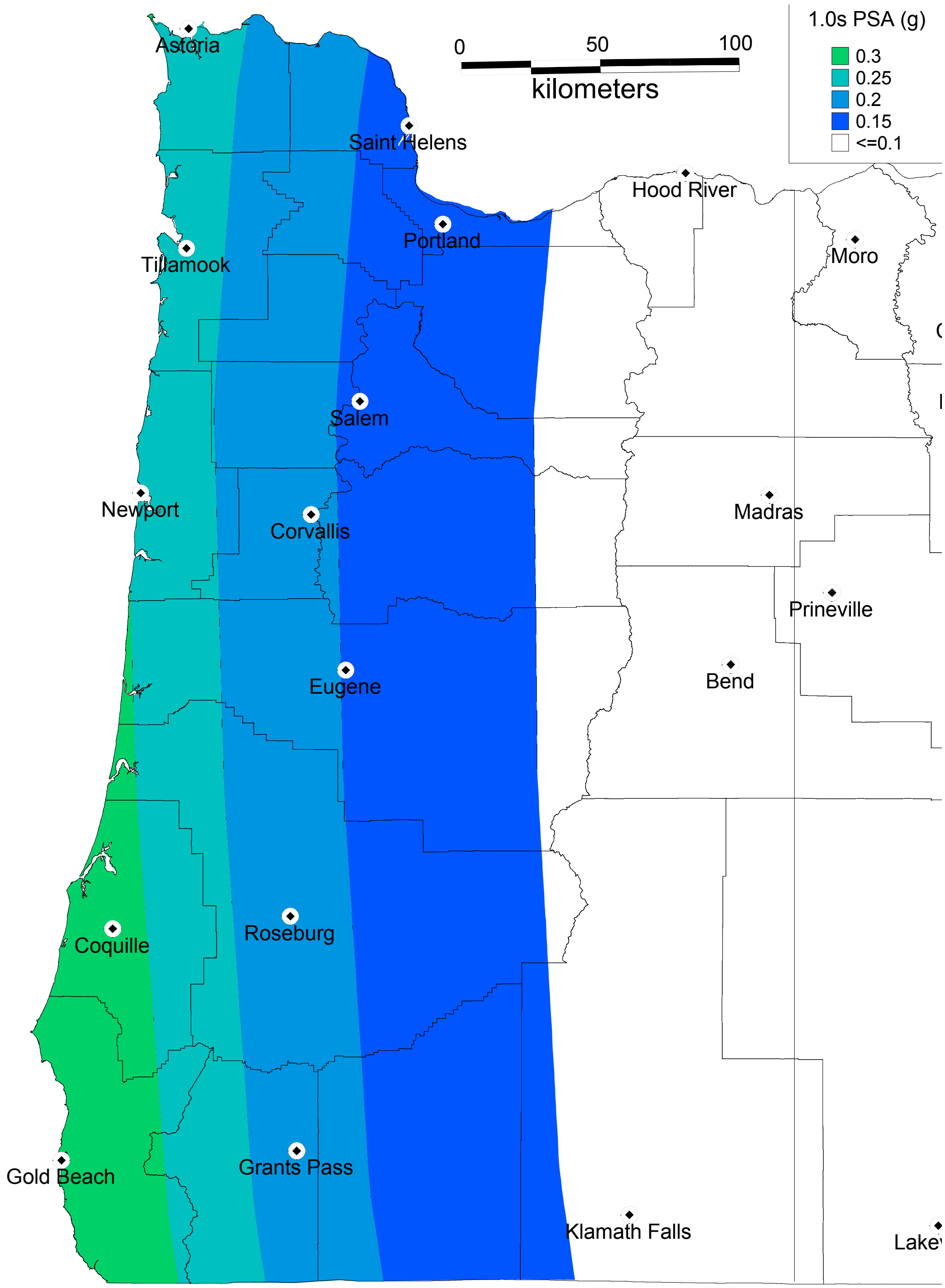

Figure 8. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 1.0-s period on firm rock (B-C boundary) for a M_W 9.0 earthquake located anywhere along the Cascadia Subduction Zone plate interface.

Hills fault determined from the coordinates provided by the USGS was located on the western side instead of the eastern side of the Portland Hills. Ted Barnhard (personal communication, 2001), an EQE staff member who developed the Oregon fault database while employed by the USGS, believes that this mislocation is due to a registration error during the creation of the GIS database. Therefore, we have relocated the fault to lie along the eastern side of the Portland Hills as confirmed from geologic studies. According to the USGS, this 47-km-long, steeply dipping strike-slip fault extends from the ground surface to a depth of 15 km and has a maximum magnitude of 7.0.

We used the attenuation relationships of Abrahamson and Silva (1997), Boore and others (1997), Campbell (1997), and Sadigh and others (1997) to estimate median ground motions at each of the grid sites from the M_w 6.5 and 7.0 scenario earthquakes on the Portland Hills fault. We used the geometric mean (average of the logarithms) of these four estimates as the mapped ground-motion value. We evaluated these relationships for local site conditions that we believed were most consistent with the B-C boundary. As a result, we evaluated the relationships of Abrahamson and Silva (1997) and Sadigh and others (1997) for generic rock, the relationship of Boore and others (1997) for $V_S = 760$ m/s, and the relationship of Campbell (1997) for $S_{SR} = 1$, $S_{HR} = 0$, and $D = 1$ km, values recommended by Campbell (2000) for generic rock. This is a departure from the USGS study, which used only the relationships of Boore and others (1997), Campbell (1997), and Sadigh and others (1997) for the PGA estimates and only the relationships of Boore and others (1997) and Sadigh and others (1997) for the PSA estimates. Our use of the four relationships is more consistent with the current state of the practice.

The median PGA map for the M_w 6.5 scenario is shown in Figure 10. Similar scenario maps for the 0.2-s and 1.0-s values of the 5-percent-damped PSA response spectra are shown in Figures 11 and 12. Median PGA and PSA maps for the M_w 7.0 scenario are shown in Figures 13–15. The scenario 5-percent-damped PSA response spectra for downtown Portland, which is located approximately 1.6 km from the hypothesized rupture surface, are compared in Figure 16. Also shown on this figure are the 475-year and 2,500-year UHS (Frankel and Leyendecker, 2001), the recommended IBC-2000 design response spectrum (International Code Council, 2000; Leyendecker and others, 2001), and the UBC-1997 design response spectrum (International Council of Building Officials, 1998). Portland currently uses the UBC-1997 Zone 3 seismic provisions for its building design.

We should caution the reader that the scenario ground-motion maps provided in this study represent a site on firm rock, defined as the B-C boundary on the USGS seismic hazard maps and site class B in the recent building codes. So the ground motions represented by these maps are not those that would be expected at an actual site with different site conditions. In general, the local site conditions will be softer than those represented by the B-C boundary. Actual ground motions could be as much as two to three times higher on soft soils typical of coastal estuaries and river flood plains. In order to modify the ground motions on firm rock for other types of soil conditions, one would need to determine the soil conditions for the sites of interest, classify these conditions according to a soil-classification system, and apply an appropriate site factor consistent with this classification. Dobry and others (2000) describe the site classes and site factors used in the recent building code provisions. Wong and others (2000) developed a more comprehensive and region-specific set of site classes and site factors which they then used to develop earthquake scenario and probabilistic ground shaking maps for the Portland metropolitan area. Either of these approaches could be used to modify the earthquake scenario maps developed in this study for local site conditions.

DISCUSSION

City of Seaside

Inspection of the Seaside response spectra in Figure 9 indicates that the 475-year and 2,500-year UHS and the recommended IBC-2000 and UBC-1997 design spectra are all higher than our deterministic median response spectrum for the M_w 9.0 earthquake scenario on the Cascadia Subduction Zone. This unusual result is caused, we believe, by three conservative assumptions in the USGS model: (1) the location of the Cascadia Subduction Zone well inland, which places it directly beneath the city of Seaside and other coastal communities; (2) the two-thirds weight given to the more frequent M_w 8.3 earthquake scenario, which results in an average recurrence interval of only 240 years for a great Cascadia Subduction Zone event; and (3) the use of the shallow crustal attenuation relationship of Sadigh and others (1997) as an alternative ground-motion model for the more highly weighted and more frequently occurring M_w 8.3 scenario, which predicts significantly higher ground motions for the relatively short distances to the Cascadia Subduction Zone implied by the USGS location.

At a USGS seismic hazard workshop held April 30, 2001, at Portland State University, Art Frankel indicated that he would likely make several changes to the Cascadia Subduction Zone model in the next revision of the USGS seismic hazard maps—changes that would probably reduce the calculated seismic hazard along the Oregon coast: (1) use only

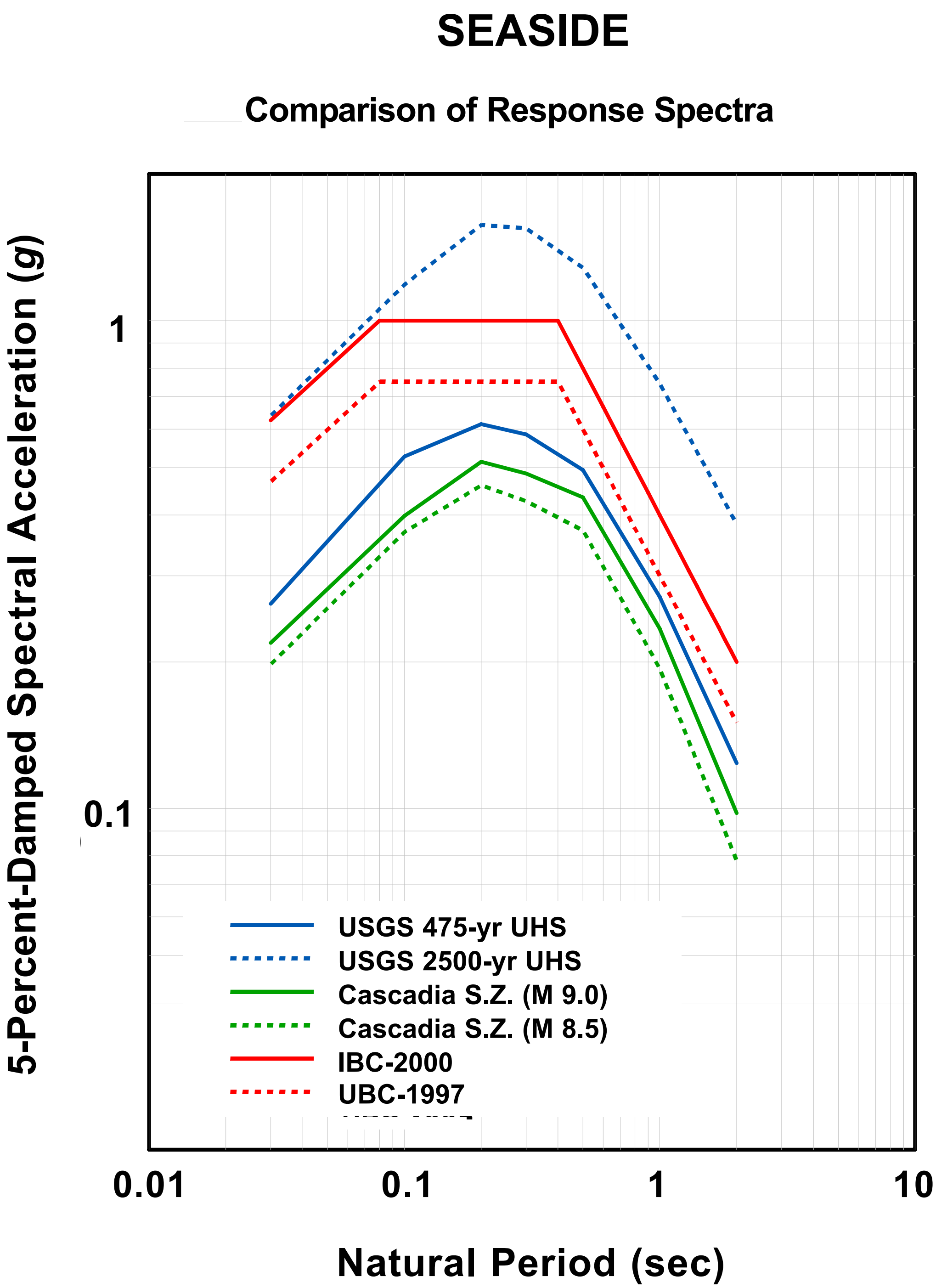

Figure 9. Comparison of response spectra on firm rock (B-C boundary) for the city of Seaside showing: in blue, the 1996 USGS 475-year and 2,500-year uniform hazard spectra; in red, the IBC-2000 and UBC-1997 design response spectra; and in green, the median response spectra for the M_W 8.5 and 9.0 scenario earthquakes on the Cascadia Subduction Zone plate interface.

subduction zone attenuation relationships for all subduction zone scenarios, (2) give equal or greater weight to the less frequent M_w 9.0 earthquake scenario, and (3) revise the location of the Cascadia Subduction Zone to be more consistent with that proposed by Flück and others (1997). However, he is also planning to incorporate uncertainty in the location, magnitudes, and recurrence intervals of his modeled Cascadia Subduction Zone events that can be expected to offset somewhat the anticipated decrease in UHS. For example, he will consider seismogenic rupture of both the locked and transition zones as one possible scenario. Nonetheless, the proposed changes will likely lower the UHS at Seaside and other locations along the Oregon coast. E.V. Leyendecker, a research engineer with the USGS, who also spoke at the Portland State workshop, expressed considerable doubt that the IBC-2000 seismic design parameter maps would be changed based on the upcoming revision, unless the differences are deemed to be important politically.

Frankel and others (1996, 2000) currently assume a recurrence interval of 500 years for a M_w 9.0 scenario and 110 years for a M_w 8.3 scenario in the 1996 USGS hazard model. Since they weight the latter by two-thirds, the average recurrence interval is 240 years, as noted above. While a mean recurrence interval of 110 years cannot be ruled out, a time-dependent probability analysis using an average recurrence interval of 550 years and a standard deviation (natural log) of 0.5 derived from geophysical, paleoseismological, and turbidite data, suggests that such a short recurrence interval is unlikely and should be given smaller weight (Campbell and others, 2001). The USGS model also assumes that great Cascadia Subduction Zone earthquakes can be treated as Poissonian (time-independent) events, even though it is generally accepted that the last great earthquake occurred about 300 years ago during the winter of 1700 (Satake and others, 1996) and strain has been building up ever since. Frankel showed at the Portland State University workshop that, since the Cascadia Subduction Zone is still relatively early in its seismic cycle, the seismic hazard is similar—whether time-dependent or Poissonian behavior is assumed. Cramer and others (2000) came to a similar conclusion based on a time-dependent probabilistic seismic hazard analysis for California.

Several observations regarding the design response spectra in Figure 9 are worth noting. First, the IBC-2000 design spectrum is much higher than the UBC-1997 design spectrum. This we attribute to the conservatism in the USGS seismic hazard maps that are the basis for the IBC-2000 design provisions. The IBC-2000 spectrum is consistent with UBC-1997 Zone 4 but might eventually be lowered, once this conservatism is reduced in the next revision of the USGS seismic hazard maps. Second, the IBC-2000 design spectrum is significantly higher than the 475-year UHS. The 475-year hazard is the nominal basis for the UBC-1997 seismic zone map, although each zone is conservatively defined by a seismic zone factor that represents the upper boundary of the range of ground motions used to define the zone. The IBC-2000 design provisions represent a return period that ranges from around 1,000 years at long periods to nearly 2,500 years at short periods. This is typical of areas outside coastal California, where the IBC-2000 design spectrum more closely corresponds to the 475-year UHS.

One factor that is not effectively dealt with in the building codes is the duration of strong ground shaking. While there are provisions for nonlinear time-history analysis in the codes, these provisions are usually used only for high-rise buildings and other important structures where time-history analysis is warranted. Otherwise a static analysis, an elastic response-spectrum analysis, or an elastic time-history analysis is used without consideration of duration effects. Great earthquakes on the Cascadia Subduction Zone will cause significant ground shaking over a period of minutes rather than seconds or tens of seconds as is typical during smaller magnitude earthquakes. Such a long duration, even at moderate levels of shaking, can cause structures that would ordinarily be left standing during events of normal duration to degrade structurally to the point of collapse. How many times have we heard a structural engineer say that had the earthquake lasted only a few seconds longer that a particular structure would have collapsed? How about minutes longer? One simple remedy is to require additional detailing and strength in the design. This can be done by increasing the UBC-1997 zone factor along the Oregon coast for low-rise buildings and further inland for high-rise buildings to Zone 4, regardless of the current zone, or by adopting the more conservative IBC-2000 design provisions along the coast. Other methods that have been proposed to account for long-duration shaking in design are to decrease the R-factor—the numerical coefficient used to reduce the design forces to account for the inherent overstrength and global ductility capacity of lateral force-resisting systems—or to modify the design elastic response spectrum to account for the inelastic demand of long-duration shaking (e.g., Tremblay, 1998; Tremblay and Atkinson, 2001).

City of Portland

Inspection of the downtown Portland response spectra in Figure 16 shows a complete reversal in the relative amplitudes of the UHS and deterministic response spectra for the M_w 6.5 and 7.0 scenario earthquakes on the Portland Hills fault. In this case, the scenario response spectra envelop the 2,500-year UHS. This result is typical of an assumed large-magnitude earthquake

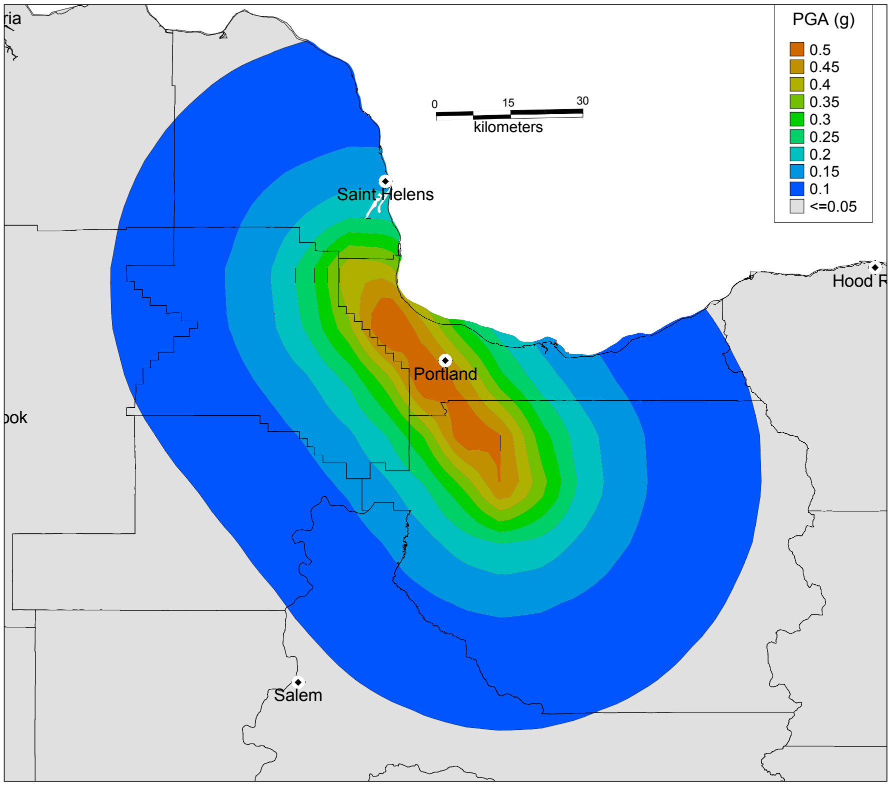

Figure 10. Map of median peak ground acceleration (PGA in *g*) on firm rock (B-C boundary) for a M_W 6.5 earthquake located anywhere along the Portland Hills fault.

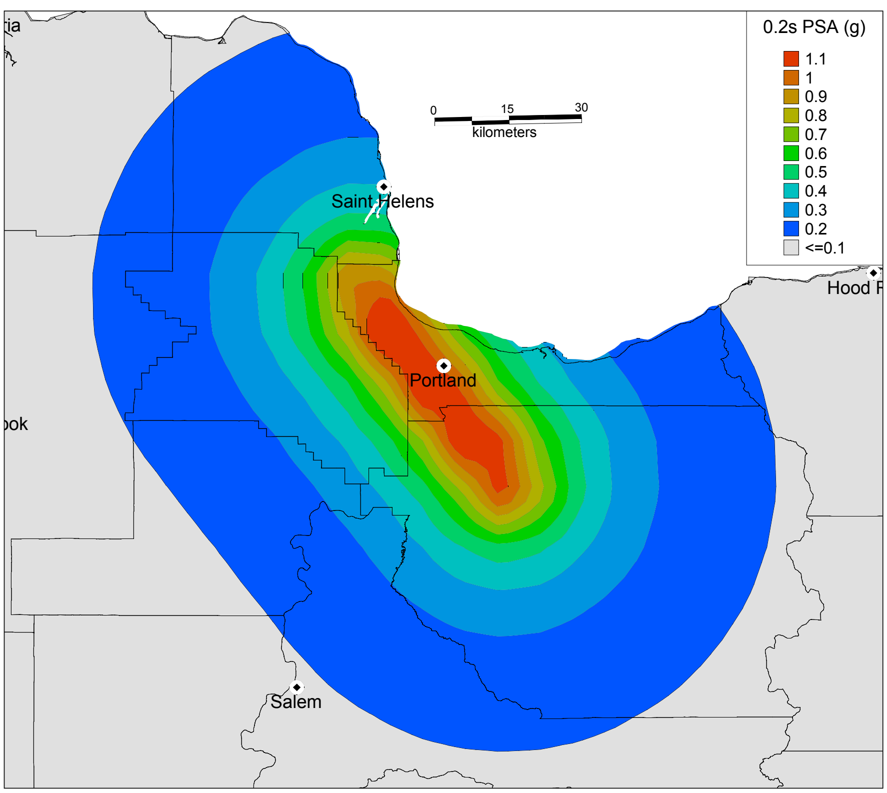

Figure 11. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 0.2-s period on firm rock (B-C boundary) for a M_W 6.5 earthquake located anywhere along the Portland Hills fault.

on a low-slip-rate fault. Frankel and others (1996, 2000) use a 0.1 mm/yr slip rate for the Portland Hills fault, which corresponds to a recurrence interval of about 17,000 years for their assumed M_W 7.0 characteristic earthquake on this fault. Even their more conservative Gutenberg-Richter recurrence model, which is given 50 percent weight in their seismic hazard model, implies a recurrence interval of about 6,000 years for earthquakes of M_W 6.5–7.0. The Portland Hills fault is the only major fault in the 1996 USGS model that impacts the downtown Portland area.

Such relatively long recurrence intervals for the Portland Hills fault suggest that the seismic hazard in downtown Portland based on the USGS model, even for the 2,500-year return period, is dominated by background seismicity (random earthquakes) and great earthquakes on the Cascadia Subduction Zone and not by events on the Portland Hills fault. Frankel indicated at the Portland State University workshop that he will likely decrease the weight of the Gutenberg-Richter recurrence model on Type B faults, such as the Portland Hills fault, in the next revision of the USGS seismic hazard maps. If so, this will shift more weight to the less frequent characteristic event and lower the seismic hazard contribution from this fault even more. However, it will probably have little impact on the UHS because of the already relatively large recurrence intervals on the Portland Hills fault. Frankel also mentioned at the workshop that he is considering including other faults identified by Wong and others (2000) in the downtown Portland area, which might increase the contribution of individual faults to the hazard.

The relatively long recurrence intervals for the Portland Hills fault assumed in the USGS model should not be construed to imply similarly long recurrence intervals for moderate to large earthquakes in the Portland region in general. For example, an analysis of historical seismicity by Bott and Wong (1993) indicates that magnitude 6.0 earthquakes can be expected to occur in the Portland area on average every 300 to 350 years and magnitude 6.5 earthquakes every 800 to 900 years. Wong and others (2000) estimated 500-year peak ground accelerations in the Portland metropolitan area that are 50 percent higher than those estimated by Frankel and others (1996, 2000). They attribute this result to three factors that were not considered in the latter study: (1) the inclusion of the Oatfield, East Bank, and Mollala-Canby faults, (2) the use of a two-times-higher slip rate on the Portland Hills fault, and (3) the assignment of a higher weight to the occurrence of a M_W 9.0 Cascadia Subduction Zone earthquake.

We can see that the IBC-2000 and UBC-1997 design response spectra are more alike for Portland than they are for Seaside. In this case, the UBC-1997 spectrum is actually more conservative, at least at moderate to long periods. However, note again that both design spectra correspond to return periods that are significantly higher than 475 years. Effective return periods for the IBC-2000 spectrum range from around 1,000 years at long periods to over 2,500 years at short periods.

CONCLUSIONS

In summary, we offer the following conclusions based on our study of deterministic median ground motions from scenario earthquakes on the Cascadia Subduction Zone and the Portland Hills fault:

1. Scenario ground-motion maps similar to those developed in this study for western Oregon can be used for seismic risk assessment, mitigation policy development, emergency and response planning, and communication of earthquake hazards to the public.

2. The 1996 USGS seismic hazard maps and the design parameters in the IBC-2000, which are based on these maps, are possibly overestimated for sites located along the Oregon coast due to several conservative assumptions in the modeling of the Cascadia Subduction

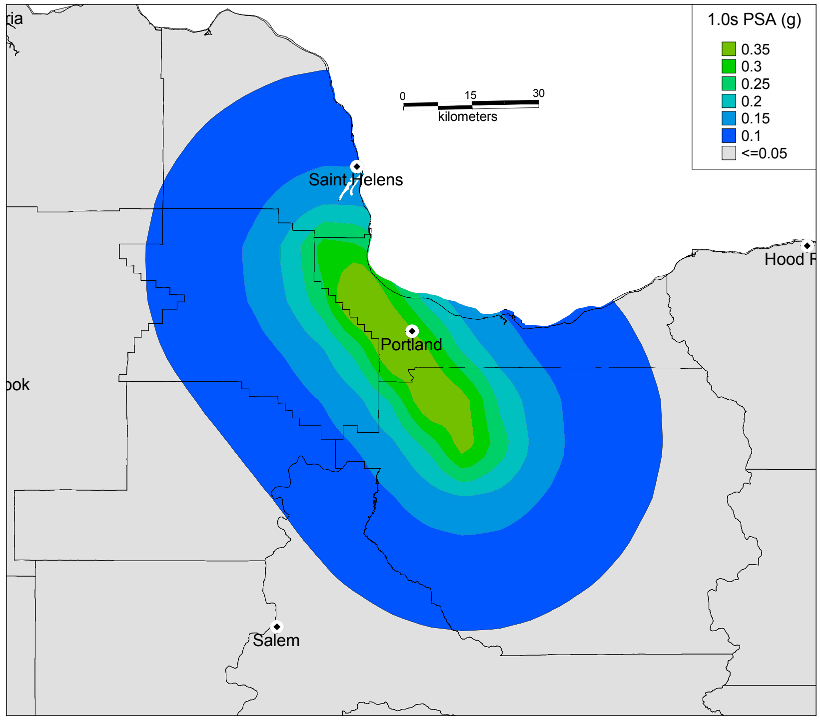

Figure 12. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 1.0-s period on firm rock (B-C boundary) for a M_W 6.5 earthquake located anywhere along the Portland Hills fault.

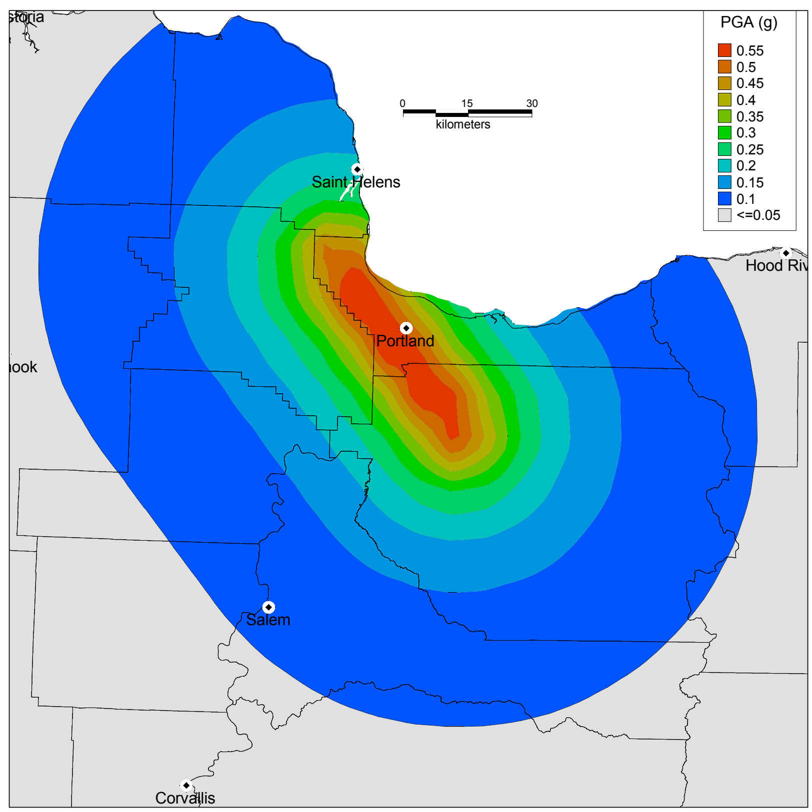

Figure 13. Map of median peak ground acceleration (PGA in *g*) on firm rock (B-C boundary) for a M_W 7.0 earthquake located anywhere along the Portland Hills fault.

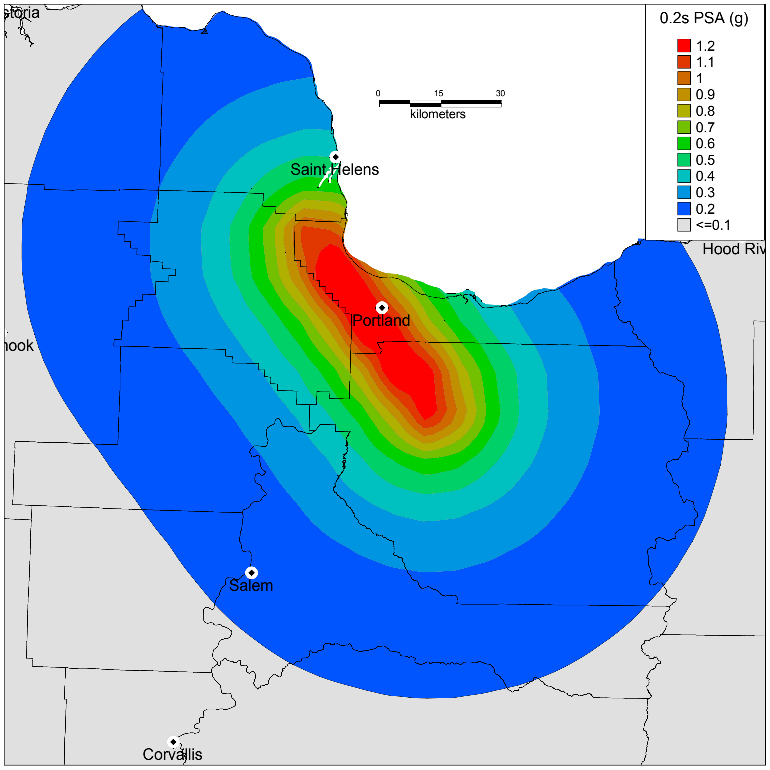

Figure 14. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 0.2-s period on firm rock (B-C boundary) for a M_W 7.0 earthquake located anywhere along the Portland Hills fault.

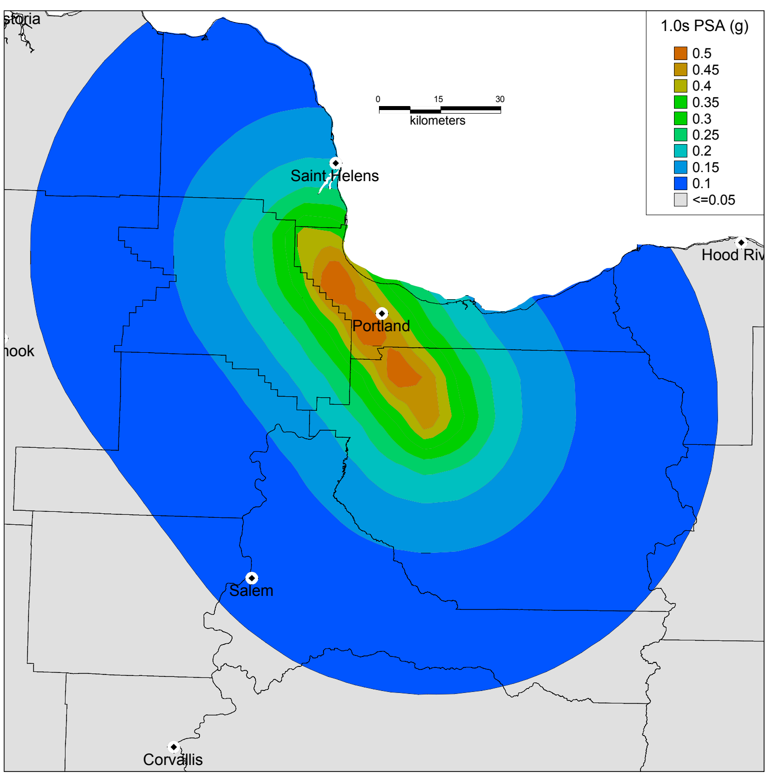

Figure 15. Map of median 5-percent-damped pseudoacceleration (PSA in *g*) at 1.0-s period on firm rock (B-C boundary) for a M_W 7.0 earthquake located anywhere along the Portland Hills fault.

Zone by Frankel and others (1996, 2000). For this reason, the scenario response spectra for the city of Seaside fall well below the 475-year uniform hazard spectrum and the IBC-2000 and UBC-1997 design response spectra. The USGS is expected to apply less conservative assumptions in the next revision of the maps, which should reduce the seismic hazard along the coast (however, see item 6).

3. The 1996 USGS seismic hazard maps and the design parameters in the IBC-2000, which are based on these maps, are dominated by background earthquakes and events on the Cascadia Subduction Zone in the Portland area because of the relatively long recurrence intervals on the Portland Hills fault. For this reason, the scenario response spectra for the downtown Portland area rise above the 2,500-year uniform hazard response spectrum and the IBC-2000 and UBC-1997 design response spectra.

4. The IBC-2000 design response spectrum exceeds the UBC-1997 design response spectrum for the city of Seaside. The reverse is true for downtown Portland. The higher IBC-2000 spectrum in Seaside is due in part to the conservative nature of the USGS seismic hazard maps in that region (see item 2).

5. The IBC-2000 and UBC-1997 design response spectra for both Seaside and downtown Portland correspond to return periods in excess of 475 years. The IBC-2000 spectra are consistent with return periods ranging from about 1,000 years at long periods to 2,500 years at short periods. The UBC-1997 spectra are associated with somewhat shorter return periods in Seaside and longer return periods in Portland.

6. The duration of strong shaking from great earthquakes on the Cascadia Subduction Zone will last several minutes, causing many structures to collapse that would otherwise be left standing after an earthquake of shorter, more normal duration. Since duration is not effectively dealt with in the building codes, one means of protecting against such long-duration ground motion is to increase the required detailing and strength of all buildings along the Oregon coast and high-rise buildings further inland by increasing the design provisions (for example, to UBC-1997 Zone 4 or to the more conservative IBC-2000 design provisions along the coast). Alternatively, modifications could be made to the elastic design spectra

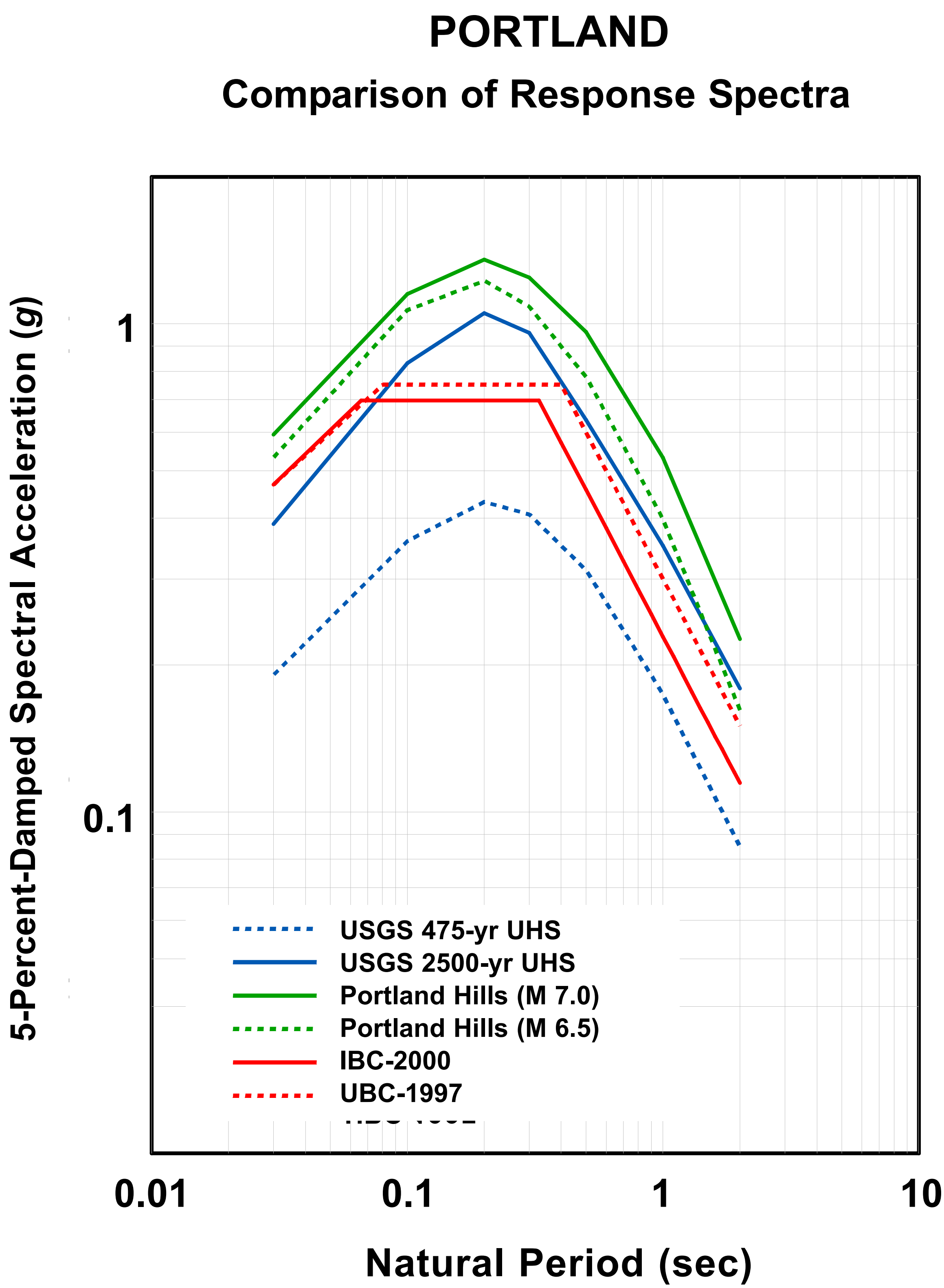

Figure 16. Comparison of response spectra on firm rock (B-C boundary) or downtown Portland showing: in blue, the 1996 USGS 475-year and 2,500-year uniform hazard spectra; in red, the IBC-2000 and UBC-1997 design response spectra; and in green, the median response spectra for the M_W 6.5 and 7.0 scenario earthquakes on the Portland Hills fault.

or to the R-factors used to incorporate inelastic demand.

ACKNOWLEDGMENTS

This work was funded in part by the Oregon Department of Geology and Mineral Industries (DOGAMI) and by EQE International Inc., an ABS Group Company based in Oakland, California. We appreciate many valuable comments from John D. Beaulieu, Oregon State Geologist and Director of DOGAMI, and George R. Priest, Coastal Program Director at DOGAMI. The views and conclusions contained in this paper are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the State of Oregon.

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(Continued from page 106)

grams, but also a printable, full-size (36"x60") color map in PDF form, as well as the above-mentioned text and a complete list of DOGAMI publications. A PDF viewer (Adobe Acrobat Reader) to open and view the map and the text files is available free online from Adobe Systems, Inc., at the following internet address, which is also given in the README file on the CD: http://www.adobe.com/products/acrobat/readstep2.html.

Map RMS-1 represents the culmination of a three-year geologic mapping program partially funded under the U.S. Geological Survey (USGS) National Cooperative Geologic Mapping program. Geologic data were compiled at a scale of 1:24,000 from a combination of new mapping and published and unpublished data. Compilation of the map used air photos, orthophoto quads, Side Looking Airborne Radar, and digital shaded relief images derived from USGS grids. Mapping was supplemented with numerous X-ray fluorescence geochemical and limited argon radiometric age determinations.

Contact persons for the La Grande Quadrangle map are Mark Ferns, Regional Geologist, Baker City field office, at (541) 523-3133 or mark.ferns@dogami.state.or.us; Ian Madin, Geologic Mapping Director, Portland office, at (503) 731-4100 x241 or ian.madin@dogami.state.or.us, and James Roddey, Community Education Coordinator, Portland office, at (503) 731-4100 x242 or james.roddey@dogami.state.or.us.

Released December 27, 2001:

Evaluation of coastal erosion hazard zones along dune- and bluff-backed shorelines in Tillamook County, Oregon: Cascade Head to Cape Falcon. Preliminary technical report to Tillamook County, by J.C. Allan and G.R. Priest, Oregon Department of Geology and Mineral Industries. Open-File Report O-01-03, 1 CD, $10.

Coastal erosion hazard zones along the Clatsop Plains, Oregon: Gearhart to Fort Stevens. Preliminary technical report to Tillamook County, by J.C. Allan and G.R. Priest, Oregon Department of Geology and Mineral Industries. Open-File Report O-01-04, 1 CD, $10.

Preliminary earthquake hazard and risk assessment and water-induced landslide hazard in Benton County, Oregon, by Z. Wang, G.B. Graham, and I.P. Madin, Oregon Department of Geology and Mineral Industries. Open-File Report O-01-05, 1 CD, $10

Preliminary seismic hazard and risk assessments in Tillamook County, Oregon, by Z. Wang, C.S. Hasenberg, G.B. Graham, and F.N. Rad. Open-File Report O-01-06, 1 CD, $10

These four reports have been released for timely information by the Oregon Department of Geology and Mineral Industries upon conclusion of the respective studies. Final reports for these projects are expected to be released in 2002.

The reports are intended mainly for planners, emergency managers, and other technical users who work with geographic information systems (GIS). Each report consists of map data, metadata, and an explanatory PDF text. Each is available only on CD and can be purchased for $10.

For more information, contact James Roddey at 800 NE Oregon St., #28, Portland, OR 97232, (503) 731-4100, ext. 242 (james.roddey@state.or.us). For purchases, **click here**, look for "Store-Maps and Reports" on the naturenw.org web page and search for "O-01-". □

For those who do not have the time or opportunity . . .

Geologic notes — Gleanings from recent publications that may be of interest

by Lou Clark, Oregon Department of Geology and Mineral Industries

Geology, September

"Volcano collapse promoted by hydrothermal alteration and edifice shape, Mount Rainier, Washington," by Mark Reid, Thomas Sisson, Dianne Brien

Using a new three-dimensional slope analysis technique, researchers have determined that Mount Rainier's upper west slope is the part of the volcano with walls substantially weakened from hydrothermal alteration. This technique may be used on other peaks to produce quick and relatively cheap volcanic hazard assessments.

October

"Flood enhancement through flood control," by Robert Criss and Everett Shock

The net effect of the attempt to control floods on the Mississippi River has been to increase the frequency of flooding and increase the potential energy of individual floods. Wing dams and levees created more severe effects than locks and dams.

November

"Historical science, experimental science, and the scientific method," by Carol Cleland

An editor of Nature claimed that all hypotheses about the remote past are unscientific because they cannot be tested by experiment. The implications for geology are obvious. Cleland compares the traditional scientific method with historical science and finds that claims for experimental methods are sometimes overvalued, and problems with historical science are sometimes over-emphasized. The result is that the classic scientific method is not inherently superior to historical science in testing hypotheses.

Nature, October 11

"US lays out bare bones of fossil protection package"

The Paleontological Resources Preservation Act was introduced in Congress on October 2. It has the support of the Society of Vertebrate Paleontology. The Act would increase criminal penalties for stealing fossils from federal land among other things. It is based on the 1979 Archeological Resources Protection Act which was designed to control looting of Native American sites.

"Volunteers flock to donate computer time"

SETI@home distributes packets of data to volunteers who use their idle computer time to analyze the data. The project examines radio telescope data for signs of extraterrestrial life. It has more volunteers than data, so the scope of research may be expanded.

Another project is run by the National foundation for Cancer Research. Since it began in April, a million volunteers have tested 3.5 billion molecules to determine their importance in cancer development.

October 18

"Lessons for the future of journals"

This issue contains an entire section devoted to new journals, including a discussion of electronic publishing. Almost two-thirds of scientific journals are available both in print and on-line, and there are more than 1,000 electronic-only peer-reviewed journals.

A survey showed that about a third of readings are now from electronic sources, scientists rely more on on-line search tools to find articles, and there is more reading from copies of individual articles than whole issues of journals.

"The Earth cubed"

Geochemistry, Geophysics, Geosystems (G^3): an Electronic Journal of the Earth Sciences is an open-access electronic publication of the American Geophysical Union. It emphasizes cross-disciplinary approaches to understanding the Earth as a system. Because of the electronic format, one goal is to offer authors unique publishing opportunities: large databases, virtual-reality images, and movies.

Science, September 7

"Networking to beat the shakes"

The Network for Earthquake Engineering Simulation will give earthquake engineers access to data and software and also allow experiments to be operated over the Internet. Cyberspace shake tables may help in the design of better earthquake-resistant structures. The network will begin operation in the fall of 2004.

September 14

"Top down tectonics?" by Don Anderson

How does mantle convection relate to plate tectonics? The conventional wisdom is that the lithosphere simply reacts to mantle convection. New research suggests that plate tectonics actually organize mantle convection. Subducting slabs cool the mantle and create the gradients needed for convection. In this model, the plates control the thermal evolution of the mantle, rather than being controlled by a dissipative mantle convection system.

September 21

"Peer review and quality: A dubious connection?"

A meta-anaylsis presented at a September conference of editors of medical journals and academics found little evidence that the quality of scientific papers is improved by peer review. Most people, however, agree that the peer review process should continue. Some disagreed that the importance of peer review could be measured in a quantitative way. One participant said, "I could name scores of scientists who have had their reputations saved by peer review."

"Changes in seismic anisotrophy after volcanic eruptions: Evidence from Mount Ruapehu," by Vicki Miller and Martha Savage

It is difficult, but extremely important, to predict volcanic eruptions. Mount Ruapehu is an andesitic volcano in New Zealand that erupted in 1988 and 1995/96. Researchers found changes in shear-wave polarization that could be caused by increased magmatic pressure. They suggest that abrupt changes in shear-wave splitting polarizations may be indicators of volcanic activity and an important tool in the future to forecast eruptions.

October 12

"From Earth's core to African oil"

Africa hasn't moved much for 200 million years. Geologist Kevin Burke argues that plate tectonics is less important to the development of that continent than lava plumes coming from the mantle or even the core. The African plate is pushed by mid-ocean ridges almost all around it. Because it has no cold, subducting slabs around it, the mantle underneath it is heating. That provides the energy for long-lived plumes that raised what is now Ethopia. Erosion of these uplifts produced sediments that were carried offshore and deposited in organic-rich sediments produced from a previous plume. That process created the oil found in the Niger delta and the Congo deep-sea fan.

November 23

"Under the surface"

The Digital Earth project of Cornell University in Ithaca, New York ("Building the Digital Earth") has gathered about 100 geology, geography, and geophysics data sets. You can use an Interactive Mapping Tool to create custom multi-layered maps and cross-sections on line — at atlas.geo.cornell.edu. □

THESIS ABSTRACTS

The Department maintains a collection of theses and dissertations on Oregon geology. From time to time, we print abstracts of new acquisitions that in our opinion are of general interest to our readers.

While reserving the right to determine the desirability of each acquisition, the Department is interested in purchasing two copies of each accepted master's thesis or doctoral dissertation, bound, and complete, for the amount of $150 or $200, respectively, if such a thesis or dissertation concerns the geology of Oregon. Part of the acquisition will be the right to publish the abstract in Oregon Geology.

Alkaline and peraluminous intrusives in the Clarno Formation around Mitchell, Oregon: Ramifications on magma genesis and subduction tectonics, by Michael Appel, (M.S., Oregon State University, 2001), 222 p.

The Clarno Formation is a series of volcanic, volcaniclastic, and related intrusive rocks located in central Oregon. It is the westernmost extent of a broader Eocene magmatic belt that covers much of the western United States. The magmatic belt stretches eastward from Oregon to western South Dakota, and from the Canadian Yukon to northern Nevada. While the creation of the belt was once attributed to subduction of the Farallon Plate under North America, more recent work suggests that a more complex tectonic regime involving extension was in place during the early Cenozoic.

In the vicinity of Mitchell, Oregon, the Clarno Formation is well represented along with Mesozoic metamorphic and sedimentary units and younger Tertiary volcanic and volcaniclastic units. In this area, Clarno volcanic activity occurred from ~52–42 Ma, producing mostly andesites and related volcaniclastic rocks. The Mitchell area is also underlain by related intrusive bodies ranging from basalt to rhyolite in composition. The Clarno was most active at ~49 Ma, and is dominantly calc-alkaline. In addition, there are several coeval alkaline and peraluminous intrusives also scattered throughout the Clarno Formation. While these suites are less voluminous than the calc-alkaline magmatism, they offer insight into the tectonic and magmatic processes at work in this area during the Eocene.

Whereas silicic intrusions are common in the Clarno, the high-silica rhyolite dike on the south face of Scott Butte is unusual due to its large garnet phenocrysts. The existence of primary garnet in rhyolitic magmas precludes middle to upper crustal genesis, a common source for silicic magmas. $^{40}Ar/^{39}Ar$ age determinations of the biotite indicate an age of ~51 Ma. This is after andesitic volcanism had commenced but prior to the most active period of extrusion. The presence of the almandine garnet indicates that the dike represents partial melting of lower (18–25 km) crustal material. The presence of a high field strength element (HFSE) depletion commonly associated with subduction arc magmatism indicates that either the source material had previously been metaso-

matised or that some subduction melts/fluids (heat source) mixed with the crustal melt.

Two alkaline suites, a high-K calc-alkaline basanite (Marshall and Corporate Buttes) and alkaline minette/kersantite lamprophyres (near Black Butte and Mud Creek), were emplaced at ~49 Ma, during the height of calc-alkaline activity. The basanite lacks the HFSE depletion common in the other Clarno rocks. Instead it has a HIMU-type (e.g., St. Helena) ocean-island basalt affinity, resulting from partial melting of enriched asthenospheric mantle. In contrast, the lamprophyres represent hydrous partial melts of metasomatized lithospheric mantle veins and bodies.

Alkaline magmatism was not limited to the most active periods of calc-alkaline activity. The emplacement of an alkali basalt (Hudspeth Mill intrusion) at ~45 Ma occurred four million years after the largest pulse of volcanism, but still during calc-alkaline activity. This alkali basalt represents partial melting of metasomatized lithospheric mantle.

The occurrence of these alkaline suites coeval with the calc-alkaline activity is significant in that it disputes prior subduction theories for the broader Eocene magmatism that are based on spatial and temporal variations from calc-alkaline to alkaline magmatism. These suites also give further insight into the complex tectonic regime that existed in Oregon during the Eocene. The occurrence of asthenospheric melts not caused by fluid fluxing and the accompanying lower lithospheric alkaline melts are normally associated with extension. Extension provides these magmas with both the mechanism for melting, and the ability to reach shallow crust with little or no contamination. Extension is in agreement both with the 1992 interpretation of White and Robinson (Sedimentary Geology, v. 80, p. 89–114) —that most Clarno Formation deposition occurred in extensional basins —and with other provinces in the broader Eocene magmatic belt.

Distribution of heavy metals and trace elements in soils of southwest Oregon, by R.A. Khandoker (M.S., Portland State University, 1997), 281 p.

Soil samples from 118 sites on 71 geologic units in southwest Oregon were collected and analyzed to determine the background concentrations of metals in soils of the region. Sites were chosen in areas that were relatively undisturbed by human activities. The U.S. Environmental Protection Agency-approved total-recoverable method was used to recover metals from samples for analysis. The 26 metals analyzed were: Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, La, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Tl, V, and Zn.

The Klamath Mountains, followed by the Coast Range, contain the highest soil concentrations of Al, Ca, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Ni, V, and Zn. Soils of the Coastal Plain and High Lava Plains contain the lowest concentrations of these metals. Unusually high soil As concentrations are found at two sites in the Klamath Mountains. All Be and Cd values above laboratory's reporting limits are also from the Klamath Mountains and Coast Range. Concentrations of soil Ba and La are fairly uniform throughout the region. Soil Pb levels are generally low with a few exceptions in the Klamath Mountains and Coast and Cascade Ranges. The region west of the Cascade Range has higher soil Hg contents than in the east.

Soil metal concentrations are generally much higher in the region west of the Cascade Range, excluding the Coastal Plain, than in the east, with the exception of Na because of more ultramafic rocks and a wetter climate. Soil metal concentrations are directly related to soil development, with the highest concentrations being found in well-developed Alfisols and Ultisols and the lowest concentrations in poorly developed Entisols. Most metals have similar averages and ranges of concentration compared to the rest of the United States. Metals with high values compared to the rest of the U.S. are Cr, Co, Cu, Mn, and Ni.

In general, Al, Co, Cr, Cu, Fe, La, Li, Mg, Na, Ni, and V are concentrated in the B horizon, while Ba, Ca, Hg, K, Mn, Pb, and Zn are concentrated in the A horizon.

Relationships between landscape stability, clay mineralogy, and stream turbidity in the South Santiam watershed, Western Cascades, Oregon, by John M. Pearch (M.S., Oregon State University, 2000), 199 p.

The clay mineralogy of suspended sediments (SS), recent sediments (RS), and soils was studied to understand the relationships between stream and reservoir turbidity and sediment delivery processes in the South Santiam watershed of the Western Cascades. Smectite is the most abundant clay mineral in SS and is the primary cause of persistent turbidity in municipal water treatment plants in the watershed. Smectite is common in many unstable soils of the watershed and is the dominant clay component in (1) deep-seated earthflows, (2) low-elevation or poorly drained (older alluvium) soils, and (3) altered volcanic host rocks of the Western Cascades. Smectite was less abundant in soils of older, stable geomorphic surfaces of the Willamette Valley (i.e., late Pleistocene Missoula flood deposits) that also included mixed proportions of chlorite, illite, and vermiculite. Pedogenic alteration was the source of smectite in (Pleistocene) terrace deposits. Advanced pedogenic alteration was common in older glacial soils containing abundant gibbsite, chloritic integrades, and kaolinite, where smectite was completely absent. Thus, clay mineralogy shows a strong relationship to geomorphology and landscape stability in the Western Cascades.

Suspended sediments were also sampled for clay mineral analysis during several peak flow periods of the winter 1998-1999 rainy season. Sample sites included inflowing tributaries to and outflow from Green Peter and Foster Reservoirs, as well as below-dam tributaries of the South Santiam River. Most importantly, the clay mineralogy of most sampled tributaries contained dominant smectite and included minor amounts of chlorite, illite, kaolinite, and zeolite (heulandite). Smectite in the SS of major inflowing tributaries and Foster outflow was derived mostly from active unstable, deep-seated earthflows present in the upper South and Middle Santiam sub-watersheds. The minor chlorite, kaolinite, and illite components in the Middle Santiam River represent widespread propylitic alteration of the volcanic host rocks, commonly eroded by debris flows and debris avalanches. Below-dam tributaries flowing into the lower South Santiam River were also dominated by smectite with minor amounts of kaolinite. These clays reflected continuous bank erosion of poorly drained soils.

The SS clay mineralogy of the Foster outflow of Foster Reservoir is generally enriched in smectite relative to the SS of inflowing streams. This indicates that coarse clay particles (kaolinite, illite, chlorite, and zeolite) tend to settle from suspension during water storage in the reservoir. Dam outflow differs in mineralogy from below-dam streams (enriched in kaolinite and halloysite relative to Foster outflow), and is considerably different from sediment derived from Missoula flood deposits (illite, chlorite, and vermiculite).

Source area and storm intensity affect relationships between turbidity and SS clay mineralogy in water treatment plants of the South Santiam municipal watershed. The clay minerals present in each water treatment plant correspond to different sources: (1) chronic long-term earthflow movement, (2) episodic short-term debris flow activation, (3) reservoir release periods, (4) chronic bank erosion of poorly drained soils, or (5) bank slump of Missoula flood deposits. Even though the clay mineralogy of suspended sediments may vary spatially or temporally for a given storm event, erosion of active, deep-seated earthflows is by far the dominant controlling mechanism on suspended sediment regimes throughout the watershed. ☐

EDITOR'S CORNER

Birth pangs

The start of the department's latest map series, **Reconnaissance Maps**, on December 4, 2001, completes our triad of geologic map offerings — the "Geologic Map Series" (GMS), "Interpretive Map Series" (IMS), and "**Reconnaissance Map Series**" (RMS).

However, it did not come without a few painful slips for which this editor asks your forgiveness. In particular, the erroneous affiliation – on the title page! — of coauthor W.H. Taubeneck with the University of Oregon instead of Oregon State University is reason for much contrition. Apologies, Professor Taubeneck!

Corrections have been made by now, but **if you obtained an uncorrected copy of RMS-1**, please do not hesitate to contact this editor or the Nature of the Northwest Information Center to request a corrected version.

Reminders and news

The **Oregon Academy of Science** will hold its annual **meeting for 2002** on February 23 at Pacific University in Forest Grove—the westernmost part of the Portland Metropolitan Area. Chair of the Geology Section is Charles Lane of Southern Oregon University, who can be reached at the following e-mail address: lane@sou.edu or by phone at (541) 552-6479.

One week earlier, on February 16, 2002, the **Oregon Junior Academy of Science** will meet at Western Oregon University. Contact person is Adele Schepige at schepia@wou.edu or (503) 838-8485.

Basalt is in many photos by **Terry Toedtemeier**, curator of photography at the Portland Art Museum. We were fortunate to get to print one picture on the cover of the September 1995 issue of *Oregon Geology*. Now Terry is one of the three Oregonians who were selected for **Flintridge Foundation 2001/2002 Awards for Visual Artists**, each carrying an unrestricted grant of $25,000. Congratulations! More information can be found at www.FlintridgeFoundation.org.

The Oregon State Office of the **U.S. Bureau of Land Management** announces a **change of address**: The new address is 333 SW First Avenue, Portland, OR 97204. (The mailing address is unchanged: BLM, Oregon State Office, P.O. Box 2965, Portland, OR 97208.) The **telephone prefix** for all BLM numbers has also changed, to (503) **808**-XXXX (last four digits unchanged).

In its new location, the Robert Duncan Plaza, the BLM is joining the USDA Forest Service Regional Office. Maps, mining records, and official public land records can be obtained from the BLM Land Office located on the first floor of the Robert Duncan Plaza.

At home

If you wish to find DOGAMI publications on the **DOGAMI home page**, best use the publication lists. Searching is possible but calls for patience. If you wish to purchase publications, go to the address of the Nature of the Northwest and look under Store-Maps and Reports, which covers all DOGAMI serial publications. ☐

Index to OREGON GEOLOGY, volume 63, 2001

Numbers refer to issue and first page of entry. Most subject entries cross-referenced to authors (in parentheses).

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Second Edition of Atlas of Oregon

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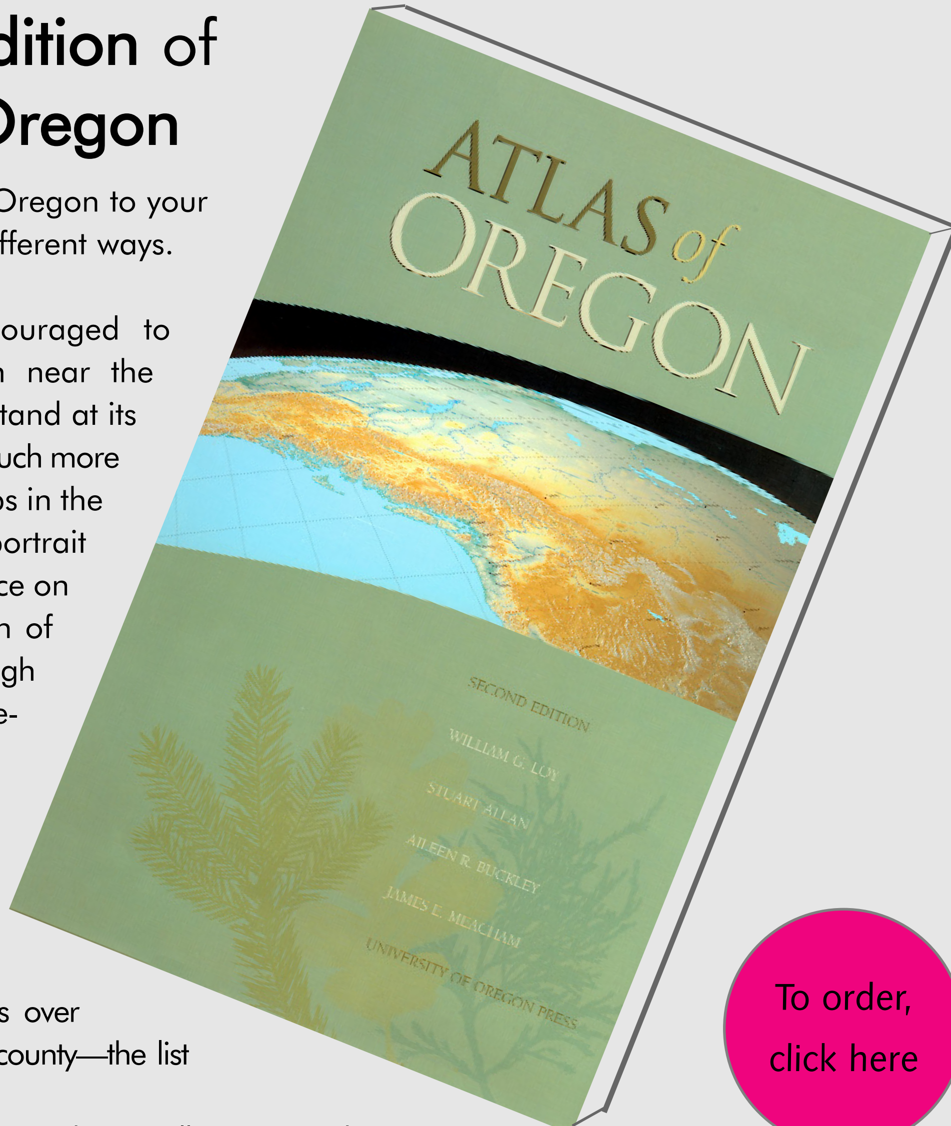

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"The reader is encouraged to browse," this invitation near the end of the book could stand at its beginning: The *Atlas* is much more than a collection of maps in the common sense: It is a portrait of the state, from its place on our globe to the growth of downtown Portland through time, from its geologic beginnings hundreds of millions of years ago to currently protected wild and scenic areas, from the earliest traces of human habitation to the ratio of males to females over 60 years of age in each county—the list could go on and on.

It is obvious that the main authors, William Loy and Stuart Allen, who already produced the first edition 25 years ago, did mean it when they concluded their introduction with the statement: "The *Atlas* . . . is also the authors' tribute to this wonderful state."

Since the time of the first edition, computer technology has made the creation of images much easier, and so most of the information in this edition is visual, with just enough text to make the many kinds of images easy to understand. Interspersed short essays help to keep the detail information in perspective.

The *Atlas of Oregon* is available in both hardcover ($100) and softcover ($60) editions. It has 301 pages and is approximately 10x14 inches in size. Look for "Books" on the naturenw.org web page.

Publication of *Oregon Geology* will continue!

Budget cutbacks and changing technology require that we make changes to the magazine, but we are fully committed to keeping it alive.

Over the timespan of (so far) sixty-three years, the appearance, the subject emphasis, even the name have undergone changes, reflecting the changes of the times in which we live, the changes of the Department's role in them, and the changes of the role of the earth sciences for the welfare of Oregon. What has not changed is the need for the services the magazine has provided-and will not stop providing.

We are now implementing another major change—we hope it will be the last one for a while: Increased demand for the talents of our staff editor, and a reduction in resources mean that we can no longer publish four edited issues a year. One possibility was that we would have to stop production of *Oregon Geology*, which we are not willing to do. Instead, we will now publish two issues a year as a journal on our website.

We will also predominantly compile rather than extensively edit the material submitted. Consequently, we are now asking that material be submitted to us in production-ready quality. For details and the new publication schedule, see "Information for Contributors" below.

We believe *Oregon Geology* is an important publication, offering a unique and suitable place to share information about Oregon that is useful for the geoscience community and ultimately for all Oregonians. Please help us by continuing to read the journal *Oregon Geology* and submit articles.

Information for Contributors

Oregon Geology is designed to reach a wide spectrum of readers in the geoscience community who are interested in all aspects of the geology of Oregon and its applications. Informative papers and notes, particularly research results are welcome, as are letters or notes in response to materials published in the journal.

Two copies of the manuscript should be submitted, one paper copy and one digital copy. While the paper copy should document the author's intent as to unified layout and appearance, all digital elements of the manuscript, such as text, figures, and tables should be submitted as separate files. Hard-copy graphics should be camera ready; photographs should be glossies. Figure captions should be placed together at the end of the text.

Style is generally that of U.S. Geological Survey publications. (See USGS *Suggestions to Authors*, 7th ed., 1991, or recent issues of *Oregon Geology*.) References are limited to those cited. Pre-submission reviewers should be included in the acknowledgments. In view of increasing restrictions on editing time, adherence to such style will be required more strictly than in the past.

For the foreseeable future and beginning with volume 64 for the year 2002, *Oregon Geology* will be published twice annually on the Department web site http://www.oregongeology.com, a spring issue on or shortly after March 15 and a fall issue on or shortly after October 1. Deadline for submission of scientific or technical articles will be January 31 and August 15, respectively. Such papers will be subjected to outside reviews as the Department will see appropriate.

Conclusions and opinions presented in articles are those of the authors and are not necessarily endorsed by the Oregon Department of Geology and Mineral Industries.

Authors will receive a complimentary CD with a PDF version of the issue containing their contribution.

Manuscripts, letters, notices, and photographs should be sent to Klaus Neuendorf, Editor, *Oregon Geology*, 800 NE Oregon Street, Portland, OR 97232-2162, e-mail contact klaus.neuendorf@dogami.state.or.us.

Please send us your photos

Since we have started printing color pictures in *Oregon Geology*, we are finding ourselves woefully short of good color photographs showing geologic motifs in Oregon. That is why we invite your contributions.

Good glossy prints or transparencies will be the best "hard copy," while digital versions are best in TIFF or EPS format, on the PC or Mac platform.

If you have any photos you would like to share with other readers, please send them to us (Editor, *Oregon Geology*, 800 NE Oregon Street, Portland, OR 97232-2162, # 28; e-mail klaus.neuendorf@dogami.state.or.us.) with information for a caption. If they are used, publication and credit to you is all the compensation we can offer. If you wish to have us return your materials, please include a self-addressed envelope.

Places to see—Recommended by the Oregon Department of Geology and Mineral Industries:

Mitchell area, Wheeler County, land of Oregon's geologic roots.

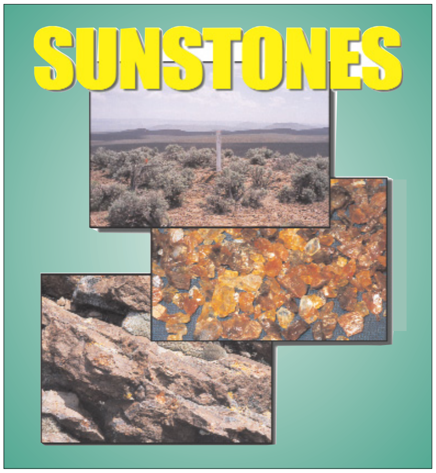
The picture, taken from a point near the junction of State Highway 207 with U.S. Highway 26 just west of Mitchell, offers a view to the southwest toward Bailey Butte in the foreground, White Butte behind it, and the north flank of the Ochoco Mountains in the background.

Here we are on the southwestern edge of the Blue Mountains province and in a region whose underpinnings contain some of the oldest rocks and fossils of the state. These basement rocks are considered to be part of the Baker terrane—fragments of 250-million-year-old oceanic islands that wandered a long way across the ancestral Pacific Ocean before crunching into the North American landmass near the Oregon-Idaho border. Thus began the process that extended the continent farther and farther to the west and created most of the land on which we live today.

Much of this area is underlain by Cretaceous marine sediments that were deposited in 100-million-year-old offshore basins The buttes seen in the photo mark the deeply eroded roots of 40- to 50-million-year-old volcanoes. Folding, faulting, continental volcanism, uplift, and erosion over the last 50 million years have combined to produce an extremely complex and interesting geologic province. (Photo contributed by one of our readers: Jamie Sands of Pendleton)

Access: Mitchell is situated about 50 mi east from Prineville on U.S. Highway 26, which crosses the entire state, from the northern coast near Seaside to the Idaho border at Ontario. From Mitchell, one can easily reach the three units of the John Day Fossil Beds National Monument: the Painted Hills Unit to the northwest, the Sheep Rock Unit (headquarters) to the east near Picture Gorge, and, a little farther, the Clarno Unit to the north. Useful, if somewhat outdated guides, maps, pictures (great aerial view of Mitchell!), and exploration hints, can be found in an unpretentious booklet produced by the Geological Society of the Oregon Country for its President's Campout in 1969 ($1 at the Nature of the Northwest Information Center).

Color reference for illustrations, *Oregon Geology*, volume 63, number 4 (2001)



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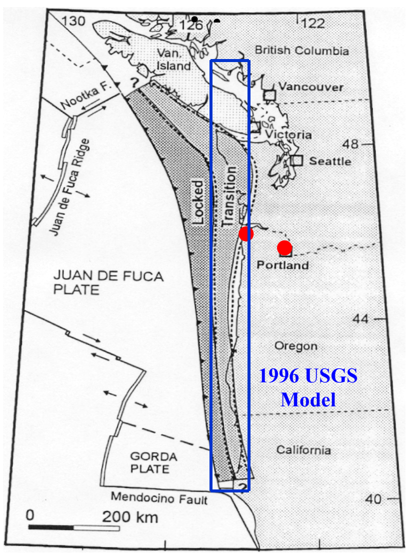

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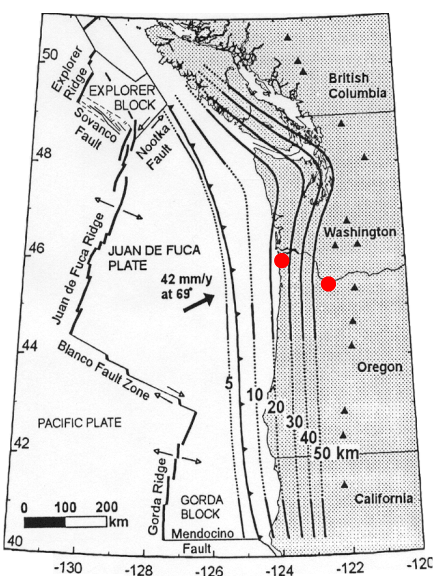

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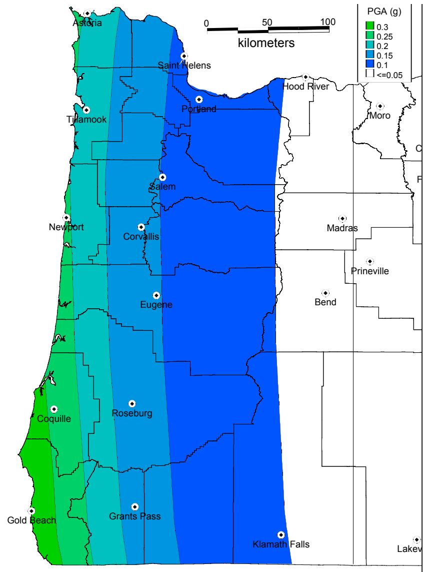

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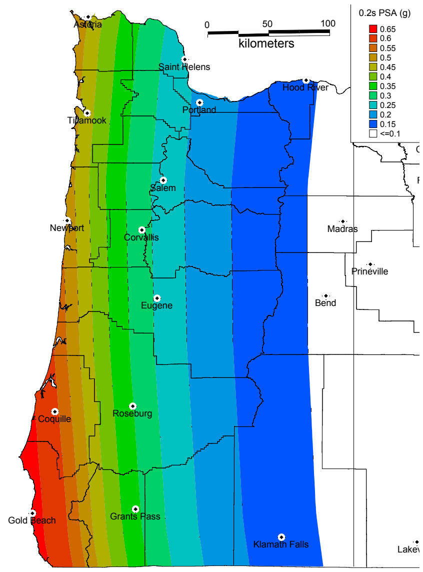

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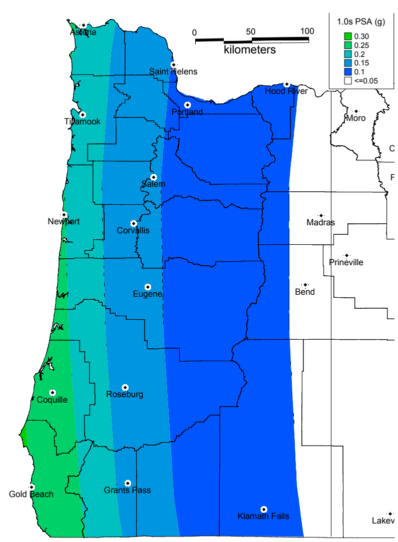

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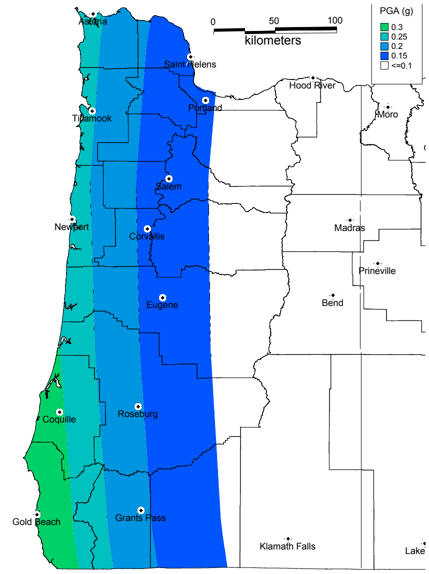

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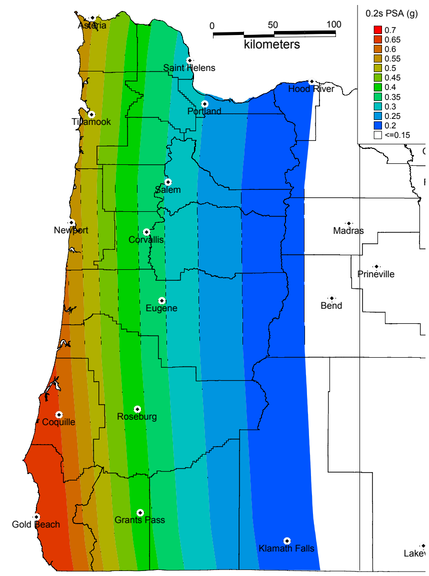

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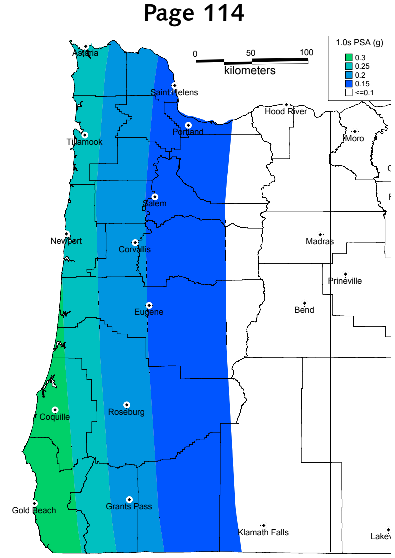

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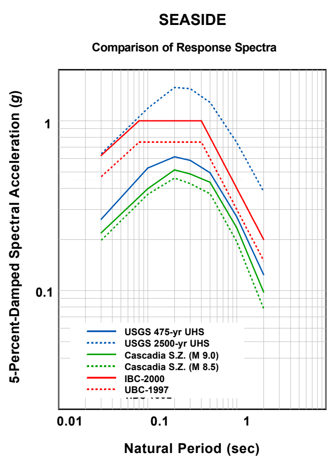

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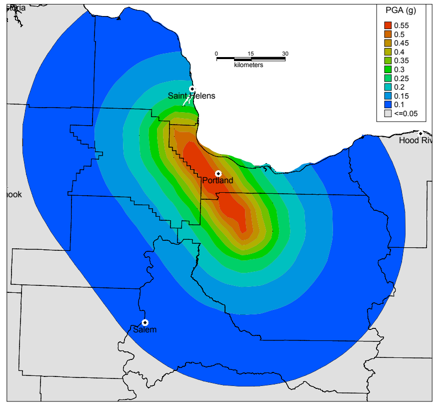

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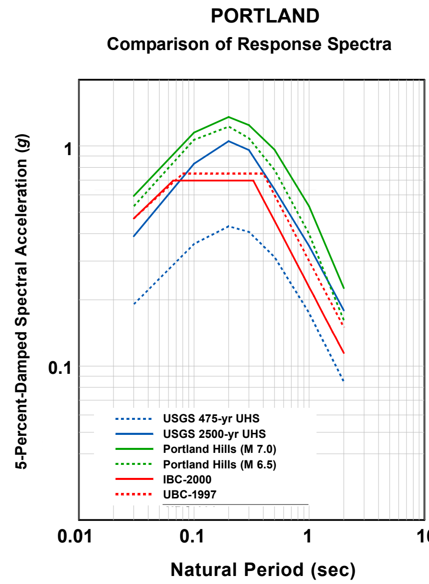

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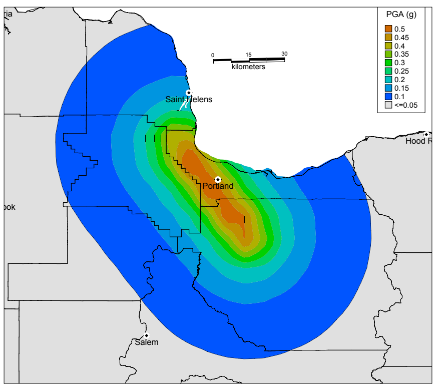

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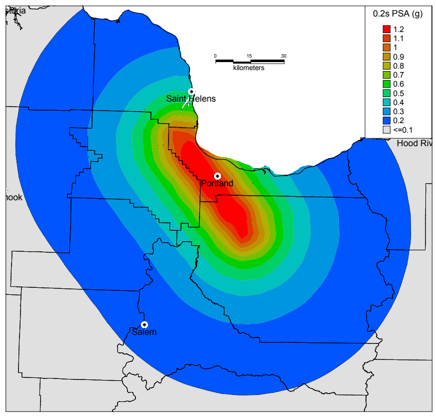

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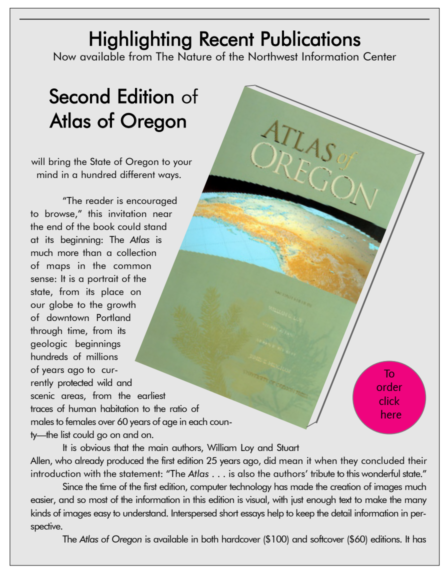
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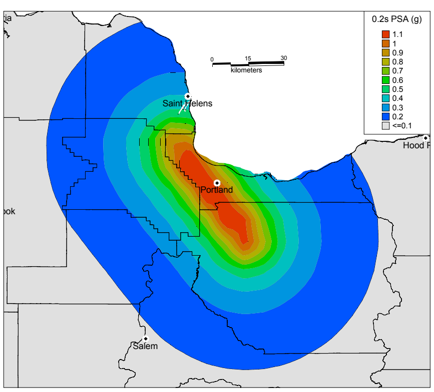

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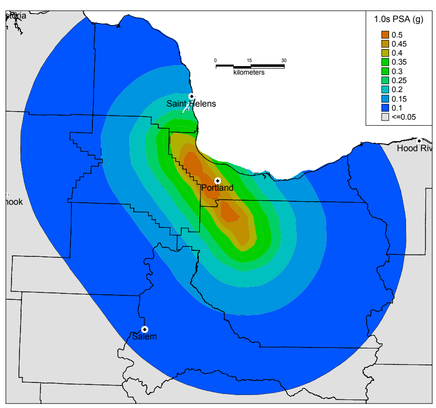

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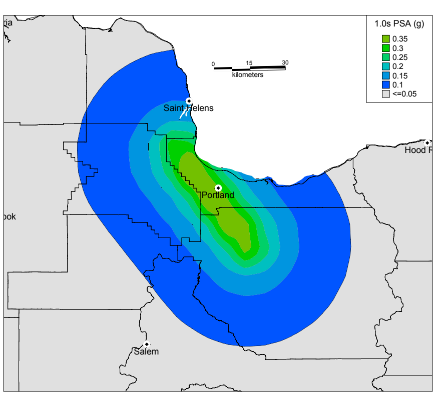

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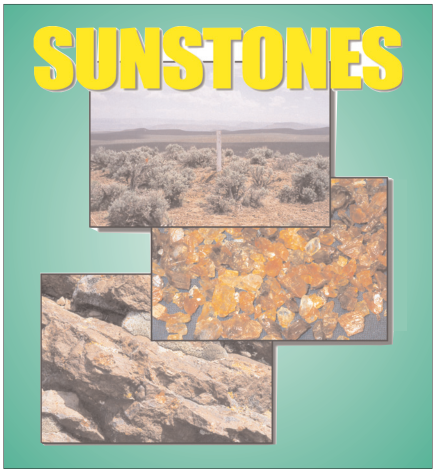

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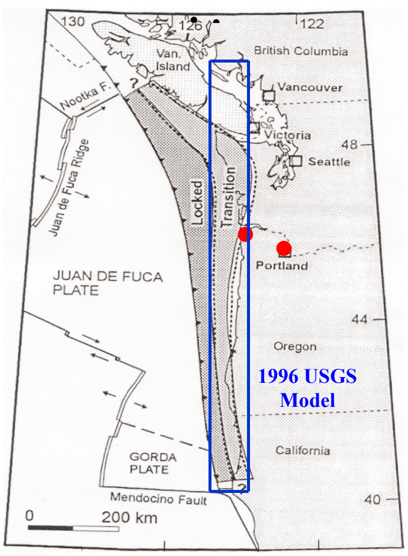

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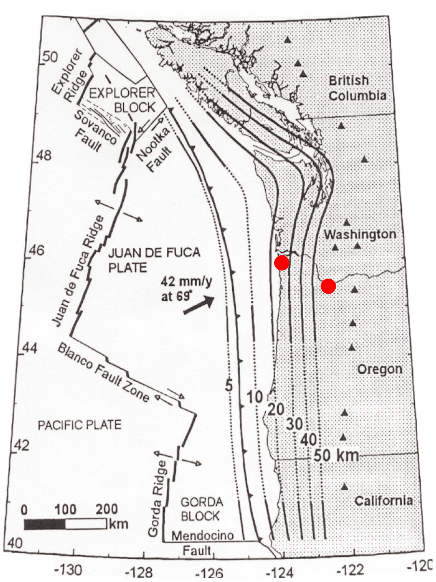

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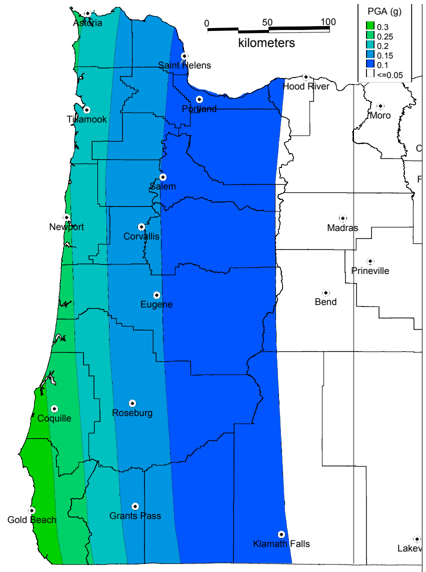

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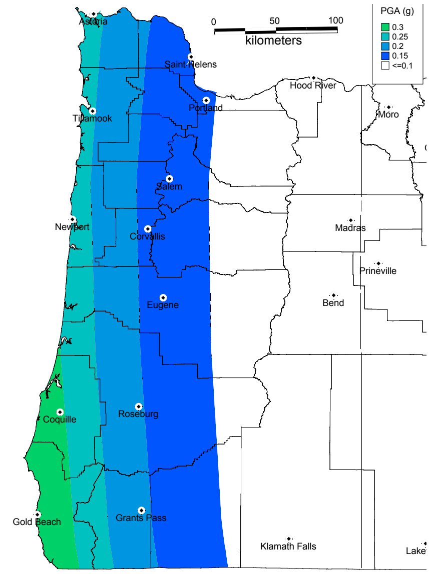

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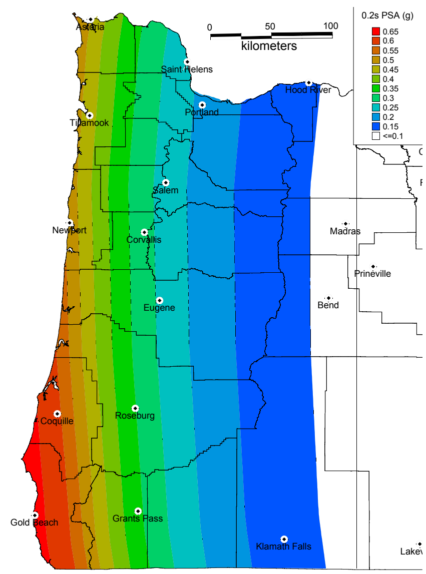

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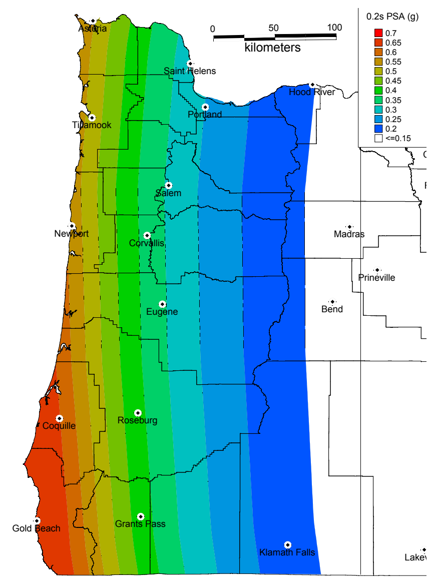

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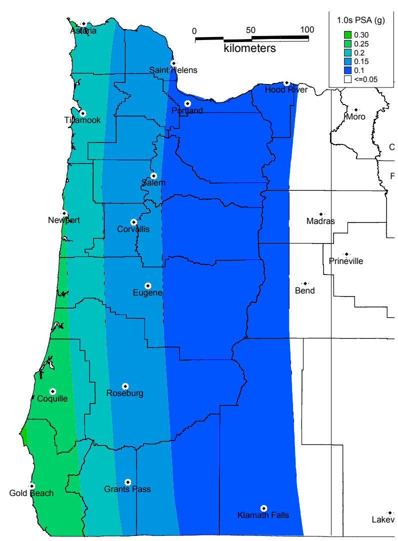

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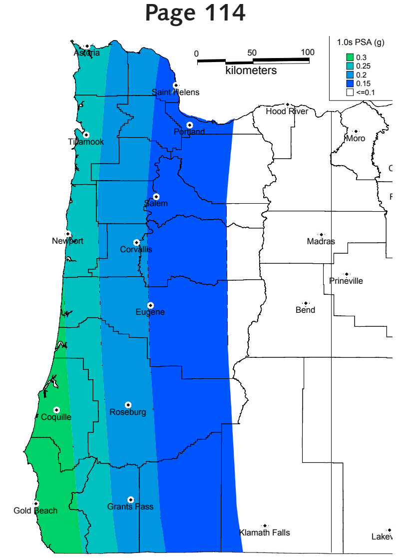

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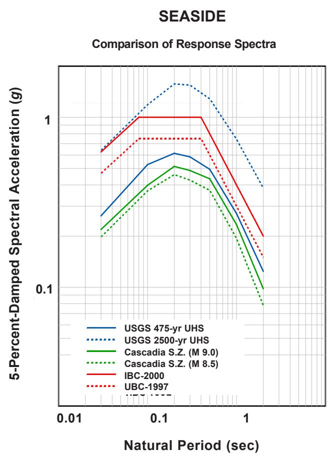

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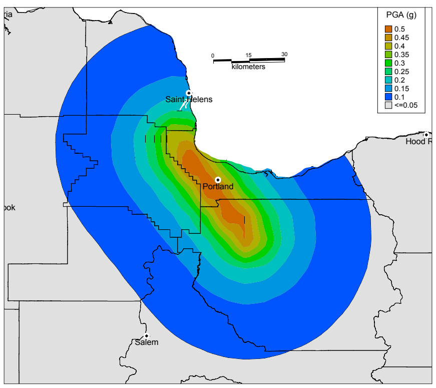

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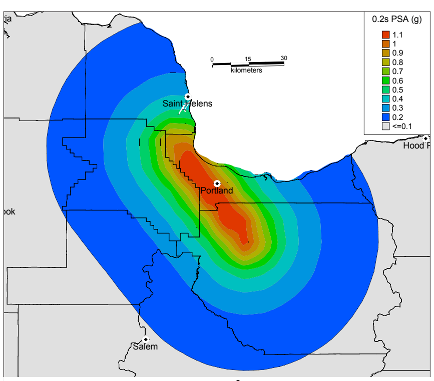

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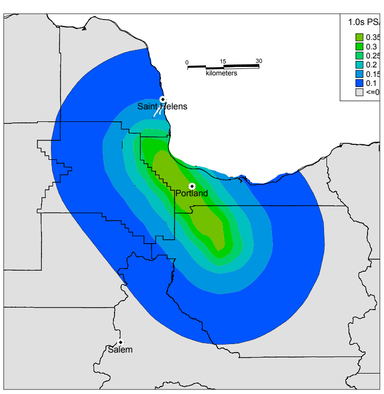

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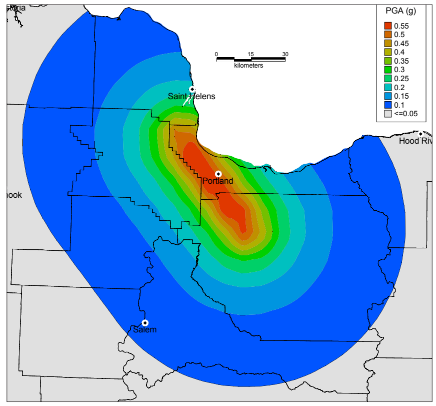

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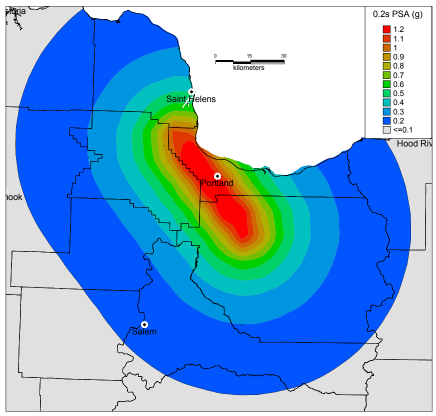

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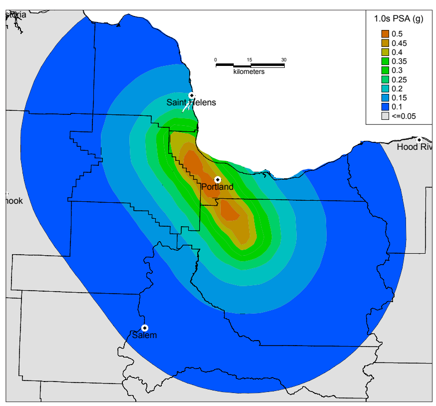

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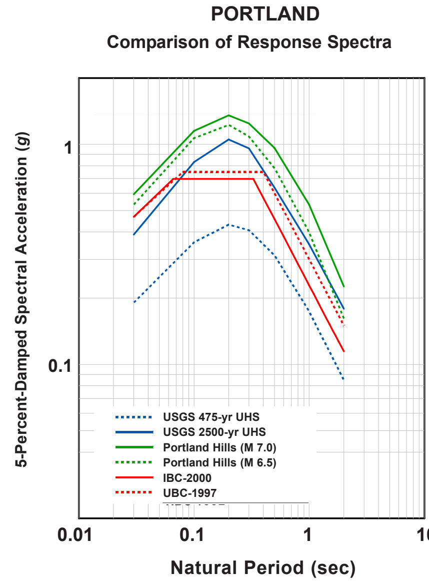

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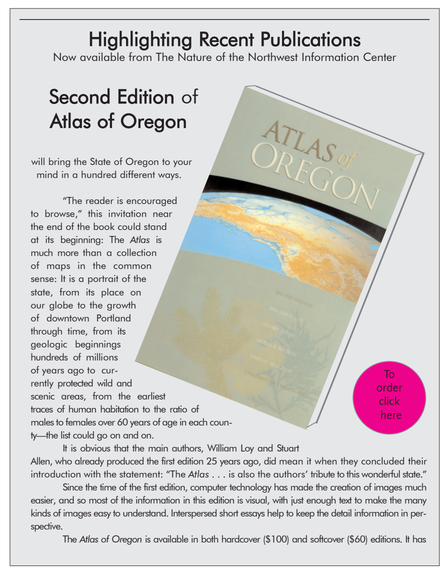

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