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PROBABILISTIC SEISMIC HAZARD MAPS FOR ALBANIA

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SUMMARY

Albania is a Balkan country with high rate of seismicity, and earthquake risk reduction has been an important, on-going socioeconomic concern. We adapt the experience and methods used for Canadian seismic hazard maps to present, for the first time, probabilistic spectral hazard maps for Albania. A revised catalogue of Albanian earthquakes, from 58 A.D. to 2000, with magnitude Ms>4.5 in the region between 39˚N and 43˚N and 18.5˚E and 21.5˚E was used in this study. Ten seismic source zones are used to define the seismicity. We have used the Ambraseys et al. (1996) strong ground motion relations for rock to produce 5% damped spectral acceleration values at 0.2, 0.5, 1.0 and 2.0 seconds (as well as peak ground acceleration) for a return period of 0.0021 per annum (equivalent to a 10% chance of non-exceedence in 50 years). The four spectral parameters maps will allow the construction of site-specific Uniform Hazard Spectra for all of Albania, and are suggested as the basis of the next version of the KTP-N.2-89 Technical Aseismic Regulations to improve earthquake-resistant design code in Albania.

INTRODUCTION

The International Decade for Natural Disaster Reduction (1990-1999), through the different application of modern science, technology, and increased worldwide awareness, fostered prevention to reduce the risks of natural disasters. The Global Seismic Hazard Assessment Program (GSHAP), an IDNDR Demonstration Project, targeted the assessment of seismic hazard as the first step toward earthquake risk mitigation [1].

Aseismic building regulations have been applied in Albania since 1952. The static method adopted in the first regulations for the seismic calculation of structures, was replaced in 1963 by a version of the dynamic method. Currently, Aseismic Regulation KTP-N.2-89 is in force in Albania [2, 3].

As a first step to our new evaluation of the seismic hazard of Albania we reviewed the seismic zonation of Albania at a scale 1:500,000 published in 1980 [4] and more recent studies of the seismotectonics, seismic source zones and seismic hazard of Albania [5, 6, 7, 8, 9, 10, 11].

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Albania is geologically and seismotectonically a rather complicated region. The country is characterized by obvious microseismicity (a high number of small earthquakes), sparse medium-sized earthquakes (magnitude M 5.5 - 5.9), and rare large earthquakes (magnitude M>6.5). Most strong Albanian earthquakes have occurred along three well-defined seismic belts [12].

- the Ionian-Adriatic coastal belt extending northwest to north-northwest and coinciding with the boundary between the European plate and the Adria microplate.
- the Peshkopia-Korca belt, extending north-south in the eastern part of the country, and
- the Elbasani-Dibra-Tetova transverse belt, extending southwest-northeast across the former two belts.

Neotectonic Structure

The Albanian orogen lies on the south-westernmost part of the Eurasian plate, and is a convergent zone due to northeastward movement of the Adriatic plate (= Adria microplate). The orogen is divided into two domains of the present-day tectonic regime: a coastal domain of compression dominated by northwest to north-northwest striking thrusts and folds, and an interior domain of extension dominated by north-striking normal faults (Figure 1). Two offshore regions, the South Adriatic Basin and the Periadriatic Foredeep, have not been further considered because the first has few earthquakes and the activity rate of the second is too low to make a significant contribution to the hazard. The Pliocene-Quaternary embraced strong and progressive uplift in the Mediterranean region, particularly in Albania. The commencement in the Pliocene was distinguished by extensional tectonics, which affected the interior domain of the country and created its horst-graben structures. The faults have been statistically analyzed and their importance assessed for each seismogenic zone [figure 3 in 10].

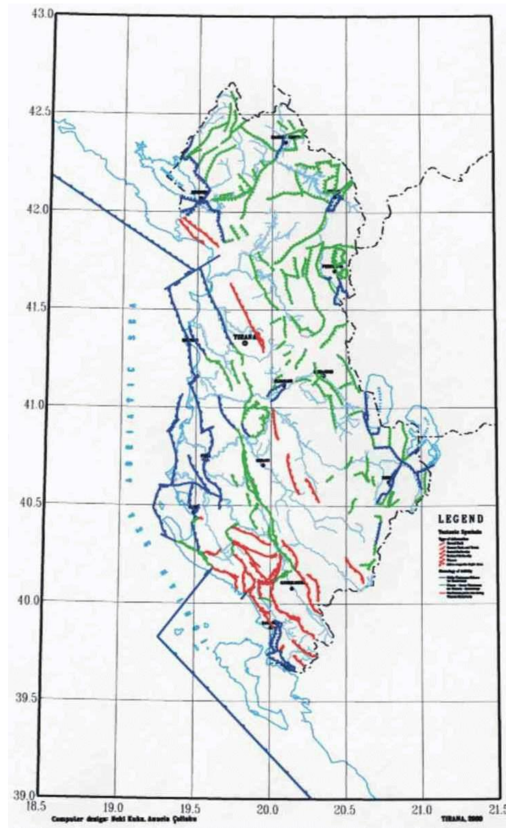

Figure 1. Map of active faults in Albania [10].

METHOD

We apply Cornell-McGuire methodology [13] similar to that adopted by Basham et al. [14] for Canada's 3rd Generation maps but incorporating the insights found during the development of Canada's 4th Generation maps [15, 16]. We have retained the use of seismic source zones in the absence of detailed information about the activity rate of specific faults in Albania.

A single probabilistic seismic hazard model was created for Albania. It comprises ten seismic source zones: three coastal zones, five inland zones along active graben structures, an eastern background zone, and a source in Macedonia to represent earthquakes near Skopje. A consensus based on standard methods was used to define the source zone boundaries, to select years for which the earthquake catalogue was complete, to choose upper bound magnitudes, and to fit the magnitude-recurrence curves. Details of the choices follow.

In contrast to the Peak Ground Acceleration (PGA) values used in KTP-N.2-89, we present the first 5% damped horizontal spectral acceleration values for the 0.2, 0.5, 1.0, and 2.0 second periods that can be used to generate Uniform Hazard Spectra (UHS) for the range of periods important for common engineered structures. The spectral acceleration parameters are denoted by Sa(T), where T is the period. We also present

PGA values, which are chiefly for backward analysis but may also be used for liquefaction analyses. We express the values in units of %g and report them to 2 significant figures (an appropriate level of precision), except for some small 2.0 s values for which one significant figure is appropriate.

A single suite of strong motion relations will suffice for Albania, provided it is soundly based on relevant data. It would be good if it predicted ground motions similar to the consensus from other workers' results, rather than predicting extreme values. We recommend that hazard be depicted for a "rock" condition (with velocity in excess of 700 m/s) in order to fit with the scheme used by Eurocode 8 [3].

We used the 10% chance of non-exceedence in 50 years (written subsequently as 10%/50 year), equivalent to an annual probability of 0.0021 (or 475 year return period), for the new seismic hazard maps. While there has been a move to base national building codes on the 2%/50 year probability level in order to provide a better basis to assess seismic hazard across the country for the target building performance [17], it was not felt necessary for Albania at this time.

SEISMICITY MODEL

Earthquake Catalogue

The revised catalogue of Albanian earthquakes [6] forms the basis of our study (Figure 2). The subset of the catalogue used for hazard calculation includes earthquakes with magnitude $Ms \geq 4.5$ that occurred in the region between 39.0°N and 43.0°N and 18.5°E and 21.5°E (see Fig. 2) between 58 and 2000 A.D. The magnitudes for historical earthquakes are evaluated from intensity information (Io, or epicentral intensity on the MSK-64 Scale) using the conversion formula $Io = 1.5\ Ms - 0.986$ [18]. For historical earthquakes in Greece the Albanian catalogue uses the coordinates and magnitude values given by Papazachos [19], and for earthquakes in the former Yugoslavia it uses the "Balkan Region - Catalogue of Earthquakes" [20].

Earthquake Source Zones

Seismic source zones were determined from consideration of the present-day tectonic regime of the region, as discussed above, the subset of the Albanian catalogue, and the full catalogue for smaller earthquakes from 1964-2000 (Fig. 2)[21]. From these considerations, the regional seismicity of concern to Albania was divided into 10 seismic sources (see Figures 1 and 3; zone coordinates are available from the authors), which includes some redefinition of eight zones previously discussed for Albania together with an interior background zone and a source zone to model earthquakes in the Skopje region [22]. Parameters used for the probabilistic seismicity model are given in Table 1 and the zones based on work summarized by Aliaj [10] are:

1. **Lezha-Ulqini (LU)** a coastal zone containing pre-Pliocene WNW-striking pure-compression thrust faults that parallel the Dalmatian coastal offshore line. The thrust faults are cut by rare ENE-trending strike-slip faults.
2. **Periadriatic Lowland (PL)** a coastal zone containing post-Pliocene oblique-compression thrust faults, N- to NNW-striking, which are cut by rare ENE-trending strike-slip faults.
3. **Ionian Coast (IC)** a coastal zone containing pre-Pliocene NW-striking pure-compression thrust faults, which are cut by rare strike-slip faults.
4. **Peja-Prizreni (PP)** an interior zone in Kosova comprising three normal fault systems, N- ENE- and WNW-trending, along the boundaries of Dukagjini Pliocene-Quaternary Depression.
5. **Kukesi-Peshkopia (KP)** an interior zone comprising Pliocene-Quaternary N-trending normal-fault controlled grabens.
6. **Ohrid-Korca (KO)** an interior zone comprising the Pliocene-Quaternary normal-fault controlled Ohrid graben, and Korça and Erseka half-grabens, which are generally N-trending.
7. **Shkodra-Tropoja (ST)** a transverse interior zone comprising NE-striking normal faults, mainly along the boundary of Mirdita ophiolite zone.

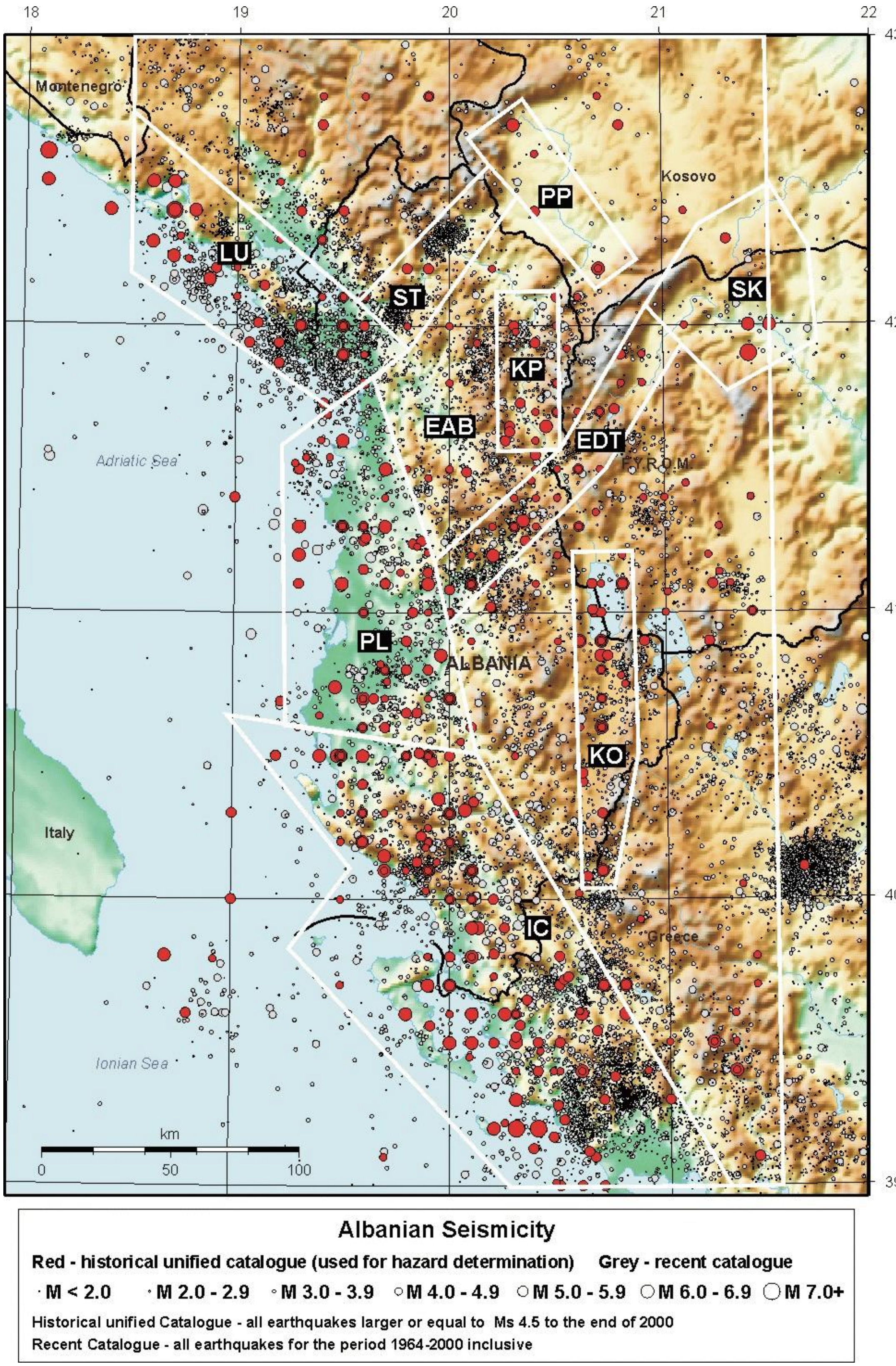

Figure 2 Seismicity of Albania. Red dots show earthquakes used for the estimation of hazard, gray dots represent other earthquakes. Source zones on this map show more clearly on Figure 3.

Table 1. Parameters for the ten seismic source zones

Zone Name / Code	Zone Area (km^2)	Earthquakes used	Beta	Alpha (No)	Mx	Rate of M>6 p.a.	Rate density
Ohrid-Korca, KO	2760	44	1.44	242	6.9	0.0315	11.4
Kukesi-Peshkopia, KP	1480	21	1.75	481	6.9	0.0104	7.0
Ionian Coast, IC	16600	151	1.40	692	7.0	0.115	6.9
Elbasani-Dibra-Tetova, EDT	2660	46	1.99	3142	6.9	0.0167	6.3
Periadriatic Lowland PL	7460	75	1.61	914	7.0	0.0458	6.1
Lezha-Ulqini, LU	5140	39	1.52	293	7.2	0.0272	5.3
Skopje, SK	3300	5	2.08	2541	7.2	0.00913	2.8
Shkodra-Tropoja, ST	1570	11	1.99	778	6.9	0.00418	2.7
Peja-Prizreni, PP	1740	5	2.03F	418	6.8	0.00173	1.0
Eastern Albanian Backgr. EAB	57200	75	2.03F	6075	6.5	0.0199	0.35

Notes: Skopje values adopted from [22]. "Rate density" is 10^6 times annual rate for $M \geq 6$ per km^2. F=slope fixed as discussed in text.

8. Elbasani-Dibra-Tetova (EDT) a transverse interior zone comprising fragmentary NE-striking normal faults.

9. Skopje (SK) is a zone adopted together with its magnitude recurrence parameters from Talaganov [22] to describe the seismicity near Skopje.

10. Eastern Albanian Background (EAB) a background zone comprising the interior part of Albania and neighboring regions that lies to the east of the coastal zones and is not included in any of the zones named above.

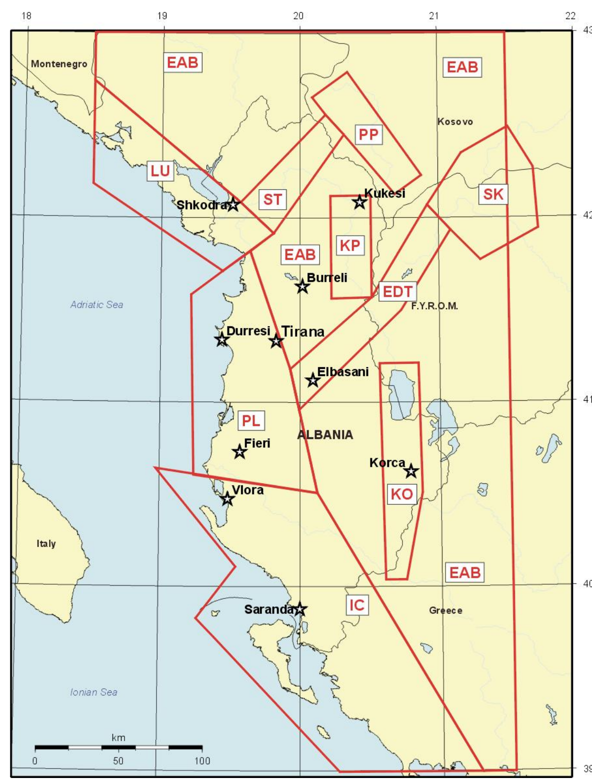

Figure 3. Seismic source zones used for the hazard maps. EAB encompasses all interior regions not in a named source.

Earthquake Selection and Magnitude-Recurrence Parameters

Earthquakes with epicentres within each source zone were selected from the subset of the Albanian Catalogue. Completeness years were established for all of Albania as follows: Magnitude ≥4.5 complete since 1901, M≥6 since 1800, and M≥7 complete since 1200. Magnitude intervals of 0.1 magnitude units were used to display the magnitude recurrence curves even though the magnitude uncertainty of many of the historical earthquakes event is on the order of ¼ to ½ unit. No explicit correction for the magnitude uncertainty [23] has been attempted. The number of earthquakes passing completeness is often a measure of the reliability of the magnitude-recurrence statistics, so we report them in Table 1.

We use the maximum likelihood method of Weichert [24] to compute the magnitude recurrence parameters. Examples for two source zones, PL and KP, are shown in Figure 4. The cumulative rates of earthquakes are represented by solid circles with stochastic error bounds and the best-fit curve (bold) are flanked by curves representing upper and lower error bounds. The main curves are asymptotic to an assumed upper-bound magnitude while the upper and lower error bounds are asymptotic to values 0.2 units higher and lower.

An examination of recurrence slopes in adjacent source zones showed that the recurrence slope could be averaged over several zones, and the activity then fitted under the constraint of a common slope. This procedure is used for zones with too few earthquakes to independently fit both slope and intercept recurrence parameters. The recurrence slope of β=2.03 derived from all the earthquakes contained in the EAB zone (including those in the contained zones) was imposed zone PP. It is notable that the computed recurrence slope for EAB without the earthquakes of the included source zones is 2.92. In our view, the steep value of the EAB recurrence slope reflects the fact that most of the large earthquakes that might belong in the background zone have been "explained" by placing them into a named zone. Hence, we used the regional value of the recurrence slope to compute hazard for EAB. The change increased the expected rate of M6 earthquakes in EAB from 0.006 p.a. to 0.02 p.a.

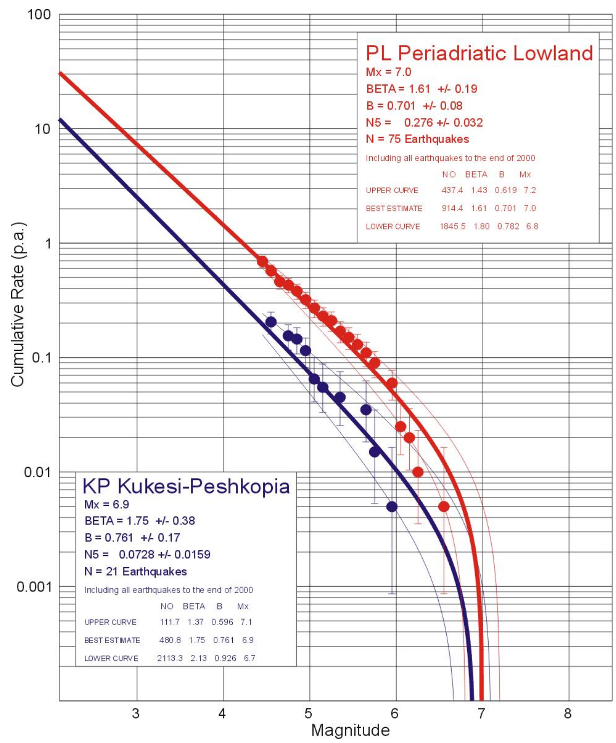

Figure 4. Magnitude-recurrence data and curves for PL and KP zones.

Maximum magnitude

While the activity rate is controlled by the total number of events observed above the lower threshold, properly weighted according to their period of observation, the hazard is strongly affected by the choice of upper-bound magnitude. Estimates of upper-bound magnitude were made for each source zone by considering the largest observed earthquake in the zone, the size of past Albanian earthquakes in related belts, the tectonic reasonableness of large earthquakes, and in a conservative fashion by considering upper-bound magnitudes assigned in more stable environments such as Canada. There was a conscious attempt to avoid linking activity rate to upper-bound magnitude chosen (which often suggests that large earthquakes cannot happen in low activity areas) or to adding a simple 0.5 units to the size of the largest earthquake (which often has a similar effect). These methods would commonly result in upper-bound magnitudes as low as 5.5 or 6.0 (e.g. for PP or ST), which are implausible given the size of past earthquakes in nearby similar zones (e.g. KO).

Depth

A reasonable default depth for Albanian earthquakes is 10 km. However, as the Ambraseys [25] strong motion relations do not use earthquake depth as a parameter, this information is not used in the hazard calculation.

STRONG GROUND MOTION RELATIONS

After examining some recent ground motion relations applicable to the Balkan region we chose Ambraseys [25] to compute the ground motions for our rock site condition (average velocity >750 m/s). The Ambraseys relations were determined for M_S magnitudes and are hence consistent with magnitudes of M>4.5 events in the Albanian earthquake catalogue. Ambraseys [25] follow the work of Boore [26] by using "pseudo depths". Each pseudo depth represents an effective depth that is derived for a particular period from the regression analysis used to determine the ground motion relations, and it is used instead of the actual earthquake depth distribution.

Reference Ground Condition for Albania

For the preparation of national hazard maps it is essential to choose a reference ground condition for which to map hazard. KTP-N.2-89 used rock or firm soil (Soil category I). Because rock was adopted for Eurocode 8, it is the appropriate choice for the next hazard maps for Albania. Choices in North America are usually in the mid-range between very hard and very soft ground (thus minimizing uncertainty in the amplification or deamplification factors) and typically represent "stiff soil", rather than being rock. For example Canada's next building code has adopted "Site Class C", defined by a 360 to 750 m/s average shear wave velocity in the uppermost 30 m [27].

RESULTS

Seismic hazard values were calculated for a grid extending over Albania and neighboring regions and used to create national contour maps for the five ground motion parameters chosen (Figures 5 and 6). The four spectral values (together with spectral values at a few additional periods) were used to construct Uniform Hazard Spectra (UHS) for some important cities to illustrate the range and period dependence of seismic hazard across Albania (Figure 7). Approximate UHS can be constructed for other localities by reading the four values off Figures 5-9. We tabulate hazard values for some selected cities and towns in Table 2.

Table 2. Hazard at 10%/50 year probability for selected Albanian cities and towns (%g).

City	Lat N	Lon W	Sa(0.2)	Sa(0.5)	Sa(1.0)	Sa(2.0)	PGA
Tirana	41.33	19.83	77	58	28	9.6	32
Durresi	41.34	19.44	86	66	31	10.3	35
Elbasani	41.12	20.09	90	66	30	10.1	38
Shkodra	42.07	19.52	75	57	28	9.3	30
Vlora	40.47	19.48	88	69	33	11.0	36
Fieri	40.73	19.57	86	68	32	10.8	35
Korca	40.62	20.79	99	75	34	11.0	41
Kukesi	42.08	20.43	81	58	26	8.6	34
Burreli	41.63	20.02	48	40	20	7.6	18

The change of seismic hazard as a function of probability ("hazard curve") for Tirana is illustrated in Figure 8. The slope of the curve between probabilities of 10%/50 years and 2%/50 years is of especial interest because national multiplicative factors have sometimes been applied to values at one probability level to estimate hazard at a different level considered more appropriate for design [16]. The curve also gives an indication of the ground motions that might be used for high-reliability designs, though as the current hazard model was intended for 10%/50 year hazard its estimates for low probability hazard may be inaccurate [16].

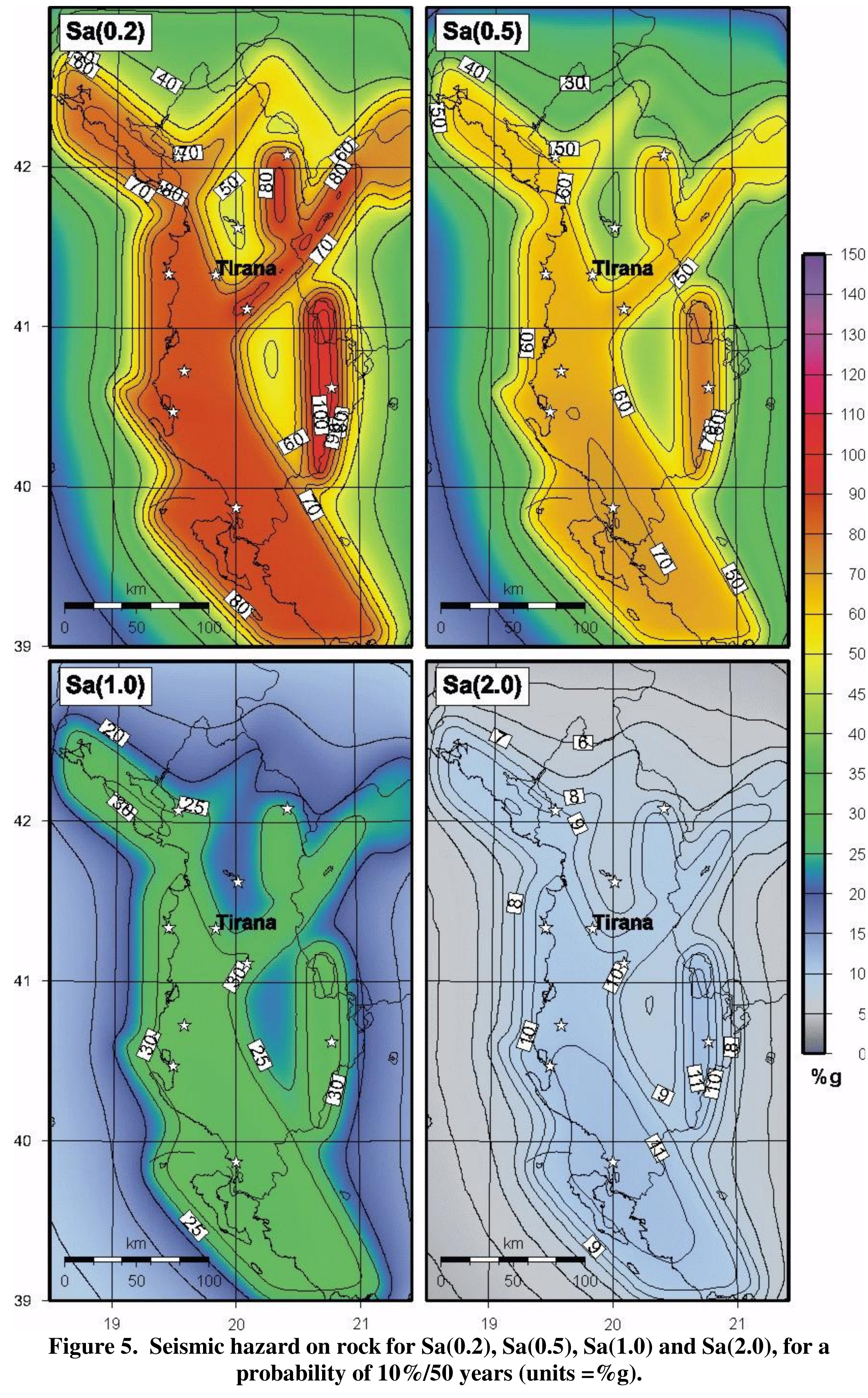

Figure 5. Seismic hazard on rock for Sa(0.2), Sa(0.5), Sa(1.0) and Sa(2.0), for a probability of 10%/50 years (units =%g).

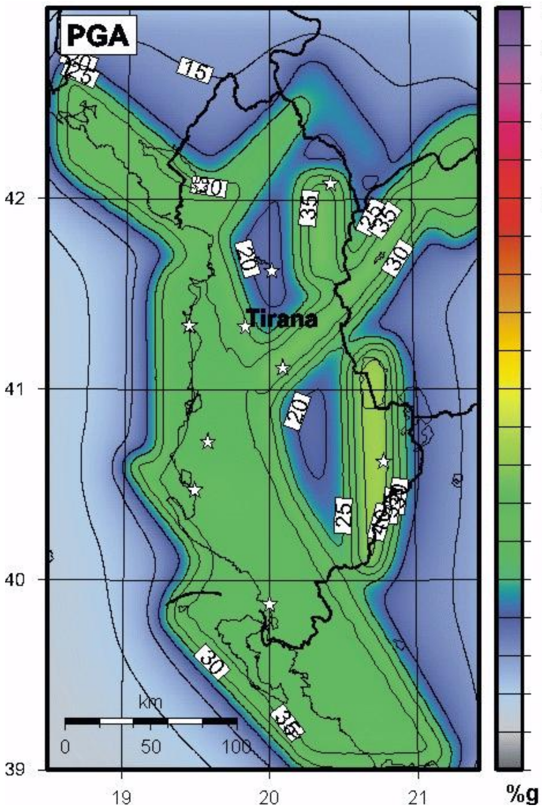

Figure 6. PGA hazard on rock for a probability of 10%/50 years (units =%g).

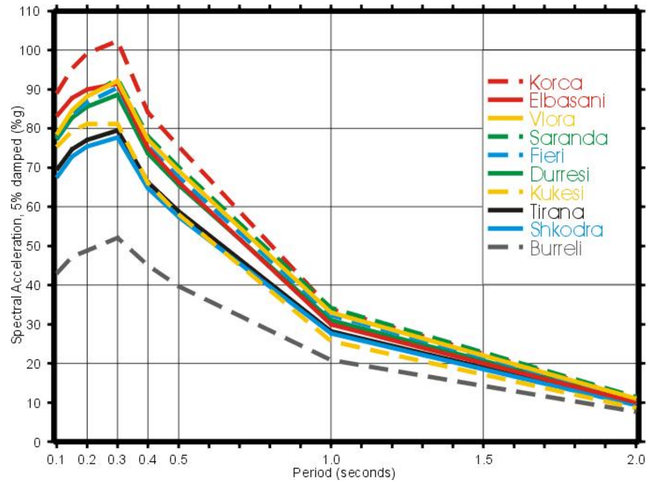

Figure 7. UHS for Albanian cities.

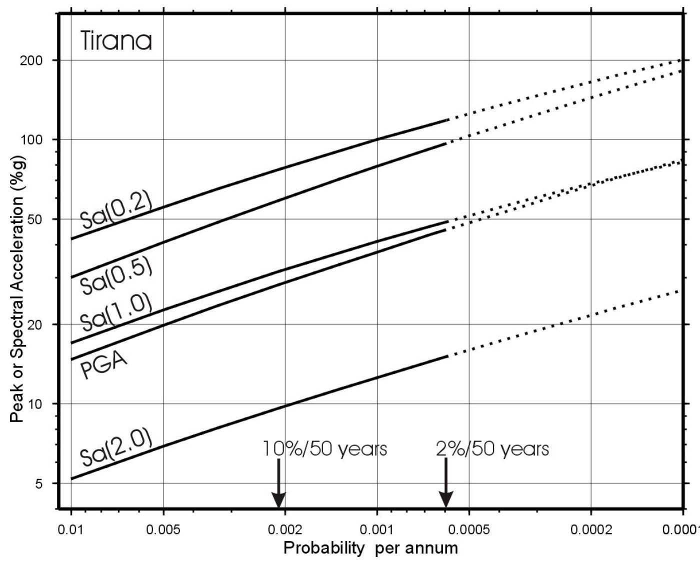

Figure 8. Hazard curves for Tirana

DISCUSSION

Distribution of Estimated Hazard Across Albania

The seismic hazard maps reveal that the region of highest hazard is the Korca-Ohrid zone. Hazard is high to moderate in the coastal regions and near the named interior seismic zones. In other places the hazard is relatively low, as in central and northern Albania. A section along latitude 40.8N indicates the relative earthquake activity rates (from Table 1) and how these relate to the estimated hazard for three representative source zones, a coastal zone with compressional faulting, an interior zone with normal faulting, and the background interior zone (Figure 9). The short-period hazard in the KO zone is 18% higher than in the PL zone and both places have twice the hazard near the city of Gramshi.

All five seismic hazard maps (Figures 5-6) have similar features, as follows.

- The pattern of hazard is closely related to the geometry of the seismic source zones that have been adopted. This is quite normal for short-period parameters such as PGA and Sa(0.2), but it is also evident in the map for Sa(2.0).

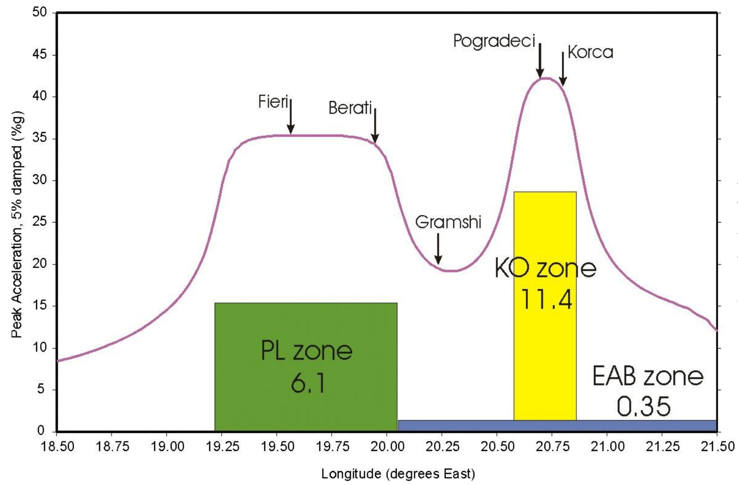

Figure 9. Cross section of Albania along 40.8N showing the position of the source zones, their activity rate, and the resulting Sa(0.2) hazard.

- Gradients of hazard are quite steep for short-period hazard measures (see also Figure 9). This effect contributes to the way the hazard contours reflect the geometry of the zones, and is the result of the rapid attenuation of short-period ground motion with distance fundamental to the strong ground motion relations used. The consequences are that nearby towns may have very different short-period hazard Note: The steep gradients are unfortunate for engineering design as small changes to the scientific inputs (for example, moving a zone boundary by 10 km) can have a large impact on the hazard at a site. This is an impact that might be unjustified had the actual uncertainty in the source zone boundary been included.
- Although we included a background zone for eastern Albania, the effect on the hazard is quite small, as is also evident from Figure 9 (some other tests we have run suggest that the background zone increases the eastern hazard by only about 10-15%).
- Although the high hazard regions of Albania (that is those localities inside the named seismic zones) have generally similar hazard, an exception is KO, which (as discussed above) has high activity within a narrow zone. A similar explanation applies to KP versus LU.
- For the coastal regions the hazard is similar in the south and centre (IC and PL), but slightly lower in the north (LU). This is surprising as the 1979 earthquake in LU was the largest near Albania in recent times. However, the historical record of the past 800-1950 years indicates that an event the size of the 1979 earthquake is quite rare in LU. Indeed the rate of magnitude 6+ earthquakes is much lower in LU than in IC and PL. Even on a rate-per-unit-area or earthquake-density basis (a key factor controlling the hazard level) LU has the lower rate (Table 1). We also know that the hazard difference is smaller than it appears on the contour maps, as spot comparisons suggest only a 10% difference for PGA.

Comparison with GSHAP results

The GSHAP map for the Albania area [28] indicates most of Albania has higher hazard than almost all of Italy. The similarities of the GSHAP hazard map (Figure 10) to our own (Figure 6) are the lower hazard in the northern coast than the central and southern coast and the ridge of hazard northeast of Tirana. Of course the GSHAP source zone model is very generalized, and lacks sources such as KO. The level of hazard also warrants comparison. Like our PGA map, the GSHAP map is calculated for 10%/50 year probability on rock. The comparison (GSHAP; our values, in %g) is: Tirana (36; 32), Vlora (39; 36) and Shkodra (30; 30), which indicates good agreement considering the uncertainty in reading values off the GSHAP map.

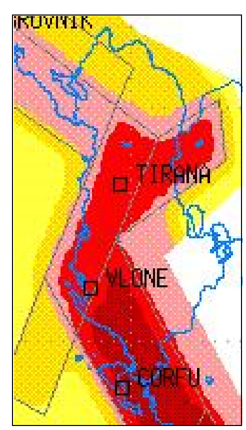

Figure 10. GSHAP seismic hazard map for Albania (PGA on rock at 10%/50 years). Source: http://seismo.ethz.ch/gshap/adria/fig06.gif

Contours versus zones

The contour maps presented here represent a scientific representation of the seismic hazard. They allow an engineer to read off the spectral value for each period and then construct a UHS for his particular site. This approach that will be used by the 2005 National Building Code of Canada [17]. It contrasts with the previous, 1995, National Building Code which divided Canada into seven zones and specified the design value to be used in each zone. The zone approach has some drawbacks because it leads to underdesign for sites just on the low side of a zone boundary, overdesign for sites just on the other side, and a step jump in design across the boundary that has no basis in fact. On the other hand, where there is little difference in hazard it may not matter whether zonal values are used or not.

A possible zone-based approach for Albania

Given the seismic hazard maps in this paper a case could be made for defining just a few design zones in Albania. For example the regions above and below Sa(0.2)=90%g could define high and moderate regions, with the high region having a design value of 110%g and the low one a value of 75%g. If considered necessary, an additional higher zone for KO above the Sa(0.2)=120%g contour could be created with a design value of 135%g. Either scheme would then be applied to other spectral parameters to choose their zonal values, and adopting common boundaries, leading to 2 or 3 design UHS for the entire country. In most cases the difference between the zonal value and the contoured value would be less than 15% (one part in seven). The zonal values and boundaries could be chosen so that the design values were a little on the conservative side, so as to minimize any problems associated with the steep gradients in short-period hazard (discussed above). Although such a simplified approach would mean that the UHS would not be customized to each site, the error in doing this is likely small.

Improvement from change to Uniform Hazard Spectrum

Irrespective of whether a zonal approach is used or not, the UHS for Albania could now reflect the actual ground shaking at each period, rather than KTP-N.2-89, which used a single spectral shape for each soil category that was scaled to PGA. The practical effects of this may be rather small, as it can be seen from Figure 11 that all the UHS shown have a rather similar shape.

Need for improved soil amplification factors

The proposed scheme allows the uniform presentation of seismic hazard for Albania. The choice of "rock" as the reference soil is appropriate, as it is the basis for Eurocode 8. However, we are not making any judgment as to whether rock is a typical foundation condition in Albania. Period-related adjustments will need to be made to compensate for ground conditions different from rock, and these may also recognize the non-linear effects. Such effects, including the lesser amplification of strong motions under strong shaking, the deamplification of short-period motions on thick soils, and the change in spectral shape according to soil softness were already included in a non-site-specific way in the response spectrum approach of KTP-N.2-89 [29]. However, KTP-N.2-89 considered only amplification of the computed hazard relative to Soil Category I (rock or firm soil), and gave no credit for sites on rock rather than firm soil. The scheme adopted for the 2005 National Building Code of Canada [27] and based on the U.S. NEHRP provisions could be adapted to adjust the rock UHS for other site conditions in Albania.

Some remaining issues to be addressed

During the preparation of this paper we have noted a few issues that deserve further attention. In the earthquake catalogue we have concerns about the location and magnitude of the older/larger historical events, especially those that fall in or near the EAB zone. However, this seems unlikely to change the hazard values very much. We note that many magnitude-recurrence curves, like the one for PL on Figure 4, show a discontinuity in earthquake rate at magnitude 6, which is an indication of inhomogeneous magnitude conversions. Again this seems unlikely to change the hazard values very much. We have a concern that some aftershocks in the catalogue may be skewing the activity rates, though we are mindful that one declustering attempt severely reduced the number of independent events that remained. For ground motion relations the hazard effects of a few alternative relations should be examined. For example it would be wise to investigate the application of ground motion relations derived from normal faulting earthquakes to the Albanian interior zones, as this might change the relative hazard levels between the interior and the coastal parts of Albania. Finally, this analysis does not incorporate the effects of uncertainty in the input parameters although the uncertainty in the ground motion relations (sigma) is of course included. Modern probabilistic seismic hazard analysis incorporates uncertainty into the analysis [e.g., 30], but at this time this extra degree of sophistication is not deemed essential for our 10%/50 year probability maps. We have, however, considered the sources of uncertainty and could develop such a model in the future. The results presented here need to be evaluated against other results, such as the use of smoothed seismicity to generate seismic hazard maps [31].

Seismic risk in Albania

A new suite of national seismic hazard maps provides an opportunity to assess seismic risk in Albania, where seismic risk is defined in terms of *seismic hazard * vulnerability*. A full assessment of seismic risk in Albania involves much non-seismological data, knowledge and skills to translate the effects of seismic hazard shaking into likely losses. It is thus beyond the scope of this paper, and beyond the current mandate of the Seismological Institute. However, a first approximation is extremely useful for allocating resources to those places where the benefits will be largest. Adams [32] assessed the distribution of urban seismic risk in Canada from ∑ *probability of damaging ground motion * city population*. For the probability, we have used the probability of exceeding a short-period damage threshold (18%g), which might be consistent with damage in the recent Gjilan Earthquake [33]. Choosing different thresholds or ground motion parameters would produce results that differ in detail, but substantially mimic the risk distribution shown in Table 3 and Figure 11. Tirana accounts for at least one quarter of the urban seismic risk, perhaps considerably more if the official population figure is an underestimate. Albania's six largest cities at risk account for over two-thirds of the urban risk.

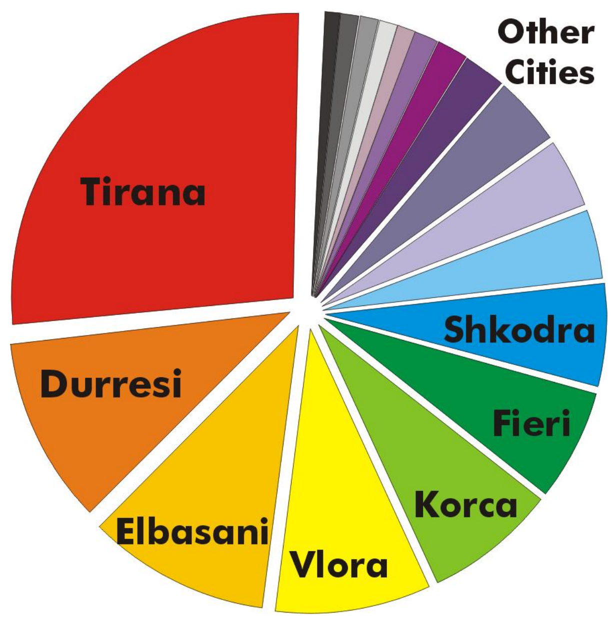

Figure 11. Urban seismic risk in Albania

Table 3. Estimate of relative seismic risk for Albanian cities

Location	Lat (N)	Long (E)	Population	Return period (years)	Annual probability	Pop. * Ann Prob.	% total risk
Tirana	41.33	19.83	367446	114	0.00875	3215	26.9
Durresi	41.34	19.44	108964	87	0.01151	1254	10.5
Elbasani	41.12	20.09	91218	73	0.01368	1248	10.4
Vlora	40.47	19.49	86926	83	0.01199	1042	8.7
Korca	40.62	20.79	60732	64	0.01567	952	8.0
Fieri	40.73	19.57	61011	82	0.01224	747	6.3
Shkodra	42.07	19.52	88208	129	0.00776	685	5.7
Other cities	-	-	261787	-	-	2799	23.5
Total cities			1126232			11942	100.0

CONCLUSIONS

We have summarized the basis for the new probabilistic seismic hazard maps for Albania that are based on spectral parameters. However, the improved seismicity source model developed, the new ground motions adopted and the use of spectral parameters for the first time will permit site-specific uniform hazard spectra to be constructed, and hence allow improved earthquake-resistant design. That in turn should lead to more earthquake-resistant buildings and safer communities.

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