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General Seismic Zoning of the Territory of Russian Federation: GSZ-2012

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Abstract—The paper reports on a new set of maps of general seismic zones (GSZ-2012) in the territory of Russian Federation. This set is considered to replace the previous GSZ-97 for use in building in regions of seismic hazard.

Keywords: seismic hazard prediction, general seismic zoning of the territory of Russian Federation, update of the earthquake source model, GSZ-2012 set of maps

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INTRODUCTION

The present paper continues the previous publication by the author (Ulomov, 2013), wherein an update of the then-current normative maps of general seismic zoning of the territory of Russian Federation (GSZ-97) was discussed and the foundations of a new generation of maps (GSZ-2012) were mentioned. The main principles of the methodology of probabilistic seismic hazard analysis (PSHA) and the content of the updated database of the initial geological and geophysical data collected over the last two decades have been analyzed, as has alternative models of earthquake source zones (ESZ). The principles of GSZ (transcribed from Russian “OCP”) harmonization, detailed seismic zoning (DSZ), and seismic microzoning (SMZ), and those of such normative documents as SNiP II-7-81*, SP 14.13330.2011, and some others, have been further developed (Ulomov, 2008, 2009; Aizenberg, 2010).

The present work discusses the main results of the update of the ESZ model assumed for the GSZ-2012 and those regarding the construction of the new set of maps.

As was reported in (Ulomov, 2009, 2013), research regarding the GSZ-2012 was stimulated by a new targeted federal program (TFP) named “Enhancement of stability for residences and life-support systems in seismic hazard regions in the Russian Federation in 2009–2013.” This TFP was approved by the government of the Russian Federation (Government Regulation no. 365) and extended until 2018. This TFP provided closer collaboration between the academic and applied-research institutes and organizations for the purpose of intensive research to specify seismic hazards and update the regulatory documents promoting seismic safety in the territory of Russia.

In 2009–2012, a large group of scientists, including some permanently employed in academic and applied-research institutes and organizations, worked at the Production and Research Institute for Engineering Surveys of Buildings (PRIESB). Researchers from the Schmidt Institute of Physics of the Earth, Russian Academy of Sciences, a leading institute in the field of seismology and seismic zoning, also participated in the work of this group. This group, the working group on the GSZ-2012 (WG GSZ-2012), included dozens of renowned scientists and leading specialists from many regions of Russia. The WG GSZ-2012 has completed a great labor in the creation of the GSZ-2012 set of maps, intended to replace the GSZ-97, which had been in use for more than 15 years. At the final stage of the work, WG GSZ-2012 published in (Ulomov, 2013) was expanded (see Appendix).

All database creation, calculations, and mapping for the GSZ-2012 were done digitally using the program ArcGIS 10 ESRI (GIS).

THE EARTHQUAKE SOURCE MODEL

The validity of the results of seismic zoning and of seismic hazard prediction, and, from this, the assessment of the social and economic risks, depends on how relevantly the seismogenerating geologic structures have been identified and how accurately the seismic regime parameters of these structures has been estimated.

In 1991–1997, owing to the development of new approaches to the seismic zoning of the territory of Russia and changes in the paradigm of deterministic constructions, a consistent methodology of probabilistic seismic hazard zoning was developed, a general unified database of initial seismological and geologic-

Table 1. The magnitude M distribution of earthquake number N for 1990–2011 in the territory of Russia and a 300-km zone beyond its boundaries

M	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5
N	3267	1867	924	402	144	83	31	33	10	4	1

geophysical data was created, and the essentially new lineament-domain-focus (LDF) model of earthquake source zones (ESZ) had been elaborated. The LDF model was used when constructing the GSZ-97 set of maps (Ulomov and Shumilina, 1999) and also during the author's participation in the international project Global Seismic Hazard Assessment Program (GSHAP) in 1992–1999 under the leadership of UN/UNESCO in the framework of the International Decade for Natural Disaster Reduction (IDNDR) (Giardini, 1999; Ulomov et al., 1999).

As a reminder, the LDF model of earthquake sources deals with four scales of seismogenerating structures: (1) a large region with an integrated characteristic seismic regime, including three main structural elements described below; (2) seismolineaments (SL), which can be generally characterized as the axes of three-dimensional seismoactive structures; SL reflect the structure of seismicity; (3) seismodomains (SD) that completely cover the studied territory and encompass the quasi-homogeneous (in the geodynamic sense) volumes of the geological medium characterized by scattered seismicity; (4) potential earthquake sources (PES) indicating the most dangerous sites (foci) of seismogenerating structures.

Lineaments, domains, and potential sources, as well as earthquakes proper, are classified in terms of maximal magnitude value (M_{max}) with an interval of $0.5M \pm 0.2$ (M. The minimum value of earthquake magnitude along the lineaments is assumed to be $M = 6.0$ (to be more precise, ($M = 5.8 \pm 0.2$). This is caused by the fact that sources with a smaller magnitude are identified insufficiently well at generalized seismic zoning (that is GSZ by its nature); in the case of DSZ, the threshold of magnitudes for lineaments can be decreased.

Earthquake sources with $M = 5.5$ (to be more precise, $M = 5.7$ and less, ± 0.2) belong to domains. Their upper threshold can also be decreased when detailing GSZ maps.

When computer simulation of seismicity, virtual sources from the model, long-term prolonged catalog are implemented by random (Monte Carlo method) at big number of implementations (Gusev and Shumilina, 1995; Ulomov and Shumilina, 1999). For lineaments structures in terms of the LDF model, three versions of incident angles of the central SL plane are considered (45°, 90° and 135°—these angles are given in the table of attributes in the GIS database for each lineament). The virtual sources are implemented at both sides of these planes within the sectors of ±20°, with the deviation depending on magnitude (Ulomov, 2013). In domains, virtual sources are implemented along the entire depth of the seismoactive layer (this value is also given in the GIS database).

The LDF model of ESZ, on whose basis all calculations and constructions of the GSZ-2012 maps were made, is shown in Fig. 1. Resulting from the analysis of methods for identifying that the ESZ assumed when constructing the GSZ-97 maps, and with the earlier and new data on seismicity, seimsotectonics, and active faults in the studied territory taken into account, the LDF model of the GSZ-2012 has been significantly updated.

E.g., the catalog of earthquakes occurring in the territory of Russia, including the 300-km zone beyond its boundaries, has been supplemented with 6766 seismic events with $M \geq 3.5$ occurred for the period of 1990–2011 (Table 1), in comparison with the catalog used in the GSZ-97.

Compared to the earthquake source model used in the GSZ-97, the LDF model of ESZ used in the GSZ-2012 has been modified as follows. A large number of active faults has been excluded due to their artifact nature. This was verified by the researchers who initially identified these faults as active (Trifonov, 1995; Shebalin et al., 2000). This point argued against the validity of the further use of the previous domain structure in the ESZ model. Therefore the domain component of the updated LDF model of ESZ for the GSZ-2012 has been completely changed according to the more grounded constructions of G.S. Gusev and his colleagues (Gusev et al., 2011; Ulomov, 2013).

The remaining and newly found active faults (over 2000 in total) have become, in addition to the survey of regional seismicity, the basis of updating the lineament structures and estimating the expected maximum earthquake magnitudes along with them. This time, many magnitudes were estimated by V.G. Trifonov and his colleagues with the geologic approaches used for magnitudes' parameterization on M_{max} (Wells, Coppersmith, 1994). In comparison to the structure of LDF model of ESZ in terms of the GSZ-97, only about 10% of the former SLs remained unchanged, if that. The parameters (geometric and/or size) have been changed for about 70 of the former SLs. Those unchanged are the SLs and domains (focal zones) along the Kuril island arc. For the territory of the Caucasus region, within the limits of 300-km zone beyond the boundary of Russia, only high-magnitude SLs have remained in the GSZ-2012, because they may

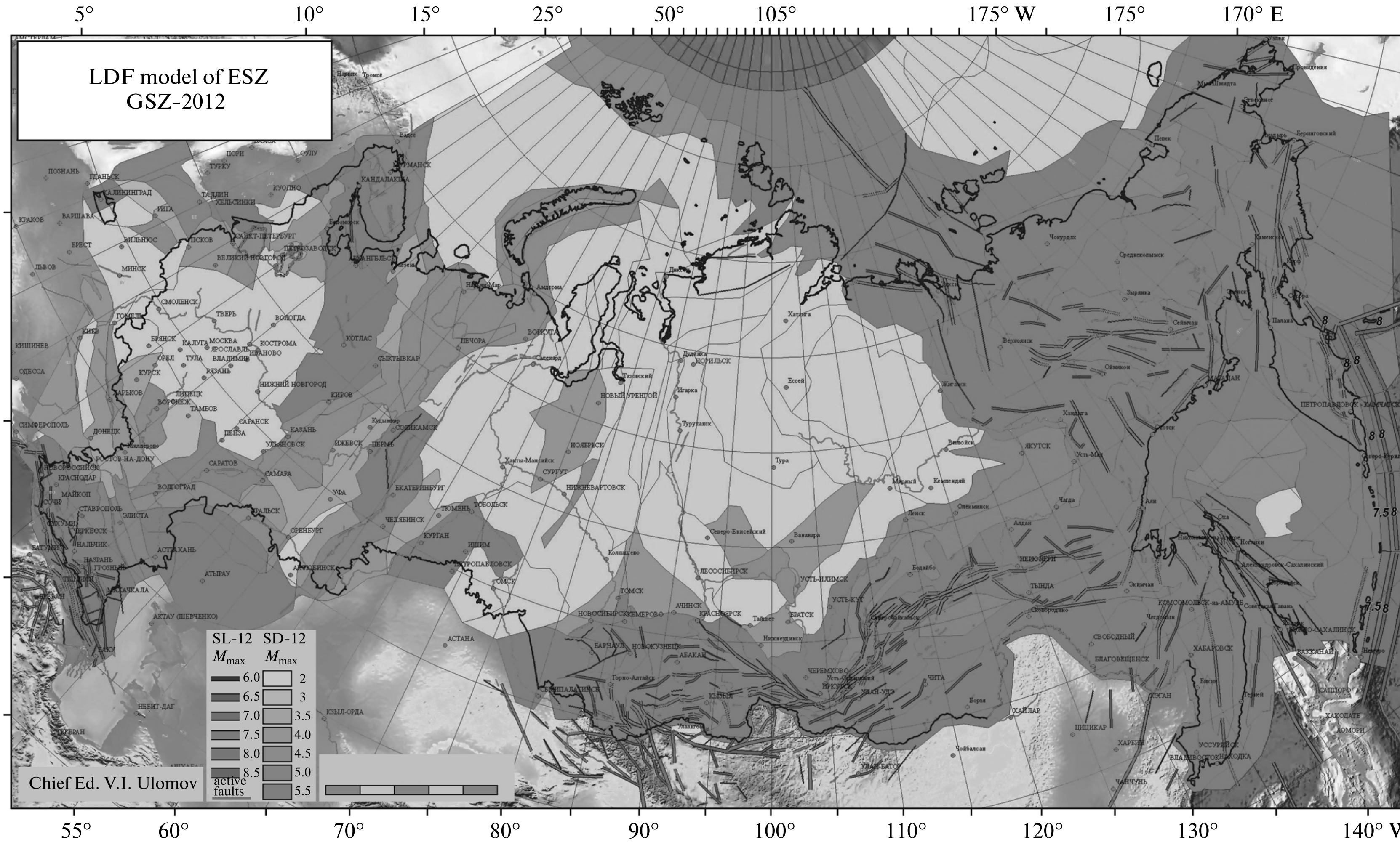

Fig. 1. The LDF model of earthquake sources used for constructing the GSZ-2012 maps. Responsible executives: V.G. Trifonov for active faults and seismolineaments; G.S. Gusev, seismodomains; A.A. Gusev, focal zones with $M_{\max} \geq 7.5$ and seismolineaments with $M_{\max} \geq 8.0$ in the Kuril Islands; V.I. Ulomov, seismolineaments of the Caucasus region and seismological parameterization of seismolineaments and seismodomains.

produce a certain, though insignificant, seismic effect within the territory of Russia.

The total number of SLs and their segments for the GSZ-2012 was 773, and that of seismodomains was 200. Both types of structures have been corrected by agreement with the initial authors; this work was carried out by the present paper's author, who is the chief editor of the GSZ-2012 maps and led the effort to seismologically parameterize all seismogenerating elements of the LDF model. Other participants were K.N. Akatova, N.S. Medvedeva, A.A. Nikonov, and S.A. Peretokin; the latter performed all computations for the GSZ-2012 using the program VOSTOK-2003, modified by him on the basis of developments by A.A. Gusev and V.M. Pavlov for the GSZ-97 (Ulomov, 2007).

In contrast to the GSZ-97 maps, which were constructed on a square computational grid of 25 km in size, construction of the GSZ-2012 involved the use of denser triangular grid with a distance of 15 km between the nodes; this grid covers the entire studied territory and is more accurate, taking the Earth's sphericity into account.

PROBABILISTIC SEISMIC HAZARD ASSESSMENT

The GSZ-2012 set of maps, including parts A, B, C, D, E, and F (Figs. 2–7) (Ulomov and Bogdanov, 2013), was constructed on the basis of updated initial databases, as well as the specified ESZ models and the seismic effects generated by these earthquake source zones. The summarized GSZ-2012 wall map, with each map given in a scale of 1 : 8000000 (analogous to the GSZ-97 wall map), is illustrated in Fig. 8.

The technology of the GSZ-2012 construction, as well as that of the GSZ-97, is methodically based on PSHA. The seismic hazard dynamics is caused by the peculiarities of the territory's seismic regime and by the recurrence period of earthquakes with different magnitudes.

The PSHA results are presented in the GSZ-2012 maps in the form of calculated expected seismic effects I, in terms of the macroseismic scale units, with the recurrence of expected seismic effect once per T years on average and with the probability P that the calculated expected seismic intensity will be exceeded in t years. The probability formula is the following:

$$P = 1 - \exp(-t/T), \text{ at } t \ll T - P = t/T.$$

E.g., at $T = 100$ years and $t = 50$ years $P = 39.35\%$; at $T = 500$ years and $t = 50$ years, $P = 9.52 \approx 10\%$; at $T = 1000$ years and $t = 50$ years, $P = 4.88 \approx 5\%$; at $T = 2500$ years and $t = 50$ years, $P = 1.98 \approx 2\%$, and so on.

As was mentioned, in the main GSZ-2012 maps the integer number designations of intensity units that are convenient for Russian surveyors and designers, are used; note that the updated earthquake intensity scale IZ-2012 is compatible with both the MSK-64 and EMS-98 scales.

ON THE APPLICATION OF THE GSZ-2012 MAPS TO BUILDING PRACTICE

The GSZ-2012 set of maps (Figs. 2–7) characterizes six levels of seismic hazard (A–F, respectively) in terms of integer number intensity units. These levels determine different types and levels of responsibility when projecting and earthquake engineering of the planned objects. Choice of the maps for the purpose of estimating the relevant social-economical risk for concrete objects is determined by the federal regulations and technical documents, or by customers in some cases.

As was said above, the degrees of seismic hazard indicated on the GSZ-2012 set of maps correspond to the probabilities—39 (map A), 10 (map B), 5 (map C), 2 (map D), 1 (map E), and 0.5% (map F)—that calculated expected maximum magnitudes will be exceeded during a 50-year interval (or that this magnitudes will not be exceeded in this time interval with probabilities of 61, 90, 95, 98, 99, and 99.5%, respectively).

The appearance of the GSZ-97 maps takes into account that estimated values of the expected seismic effects are applied to the same constructions not based on more than one map, as was done previously, but instead are based on two or more maps. The terms "projected earthquake" (PE) and "maximum expected earthquake" (MEE) appear. The former corresponds to the lower level of the expected seismic effects that may disturb, but not terminate an object's functioning. The latter corresponds to the upper level of the expected seismic level (i.e., occurrence of the stronger, though rarer seismic event). In this (latter) case, the calculation is made with the possible inelastic deformations that can render an object inoperative, but does not cause its complete destruction or deaths.

The recurrence periods of seismic effects for PE and MEE are chosen depending on the degree of responsibility and the construction type. For example, when projecting the earthquake-proof civil and industrial objects, SP 14.13330.2011 (the updated version of SNiP II-7-81*), which utilizes the GSZ-97 maps, takes a periods of 500 years into consideration (GSZ-97A map) for PE, while the periods of 1000 and 5000 years (GSZ-97B and GSZ-97C maps, respectively) are used for MEE. For hydraulic-engineering purposes, periods of 500 and 5000 years (GSZ-97A and GSZ-97C maps, respectively) are used; in the nuclear-power industry, 1000 and 10,000 years are used (GSZ-97B and GSZ-97D maps, respectively). Before the 2500-year period was introduced into the GSZ-2012, the value of seismic effects when projecting the transport constructions was determined using the seismic hazard curves from the available GSZ-97 maps A–D

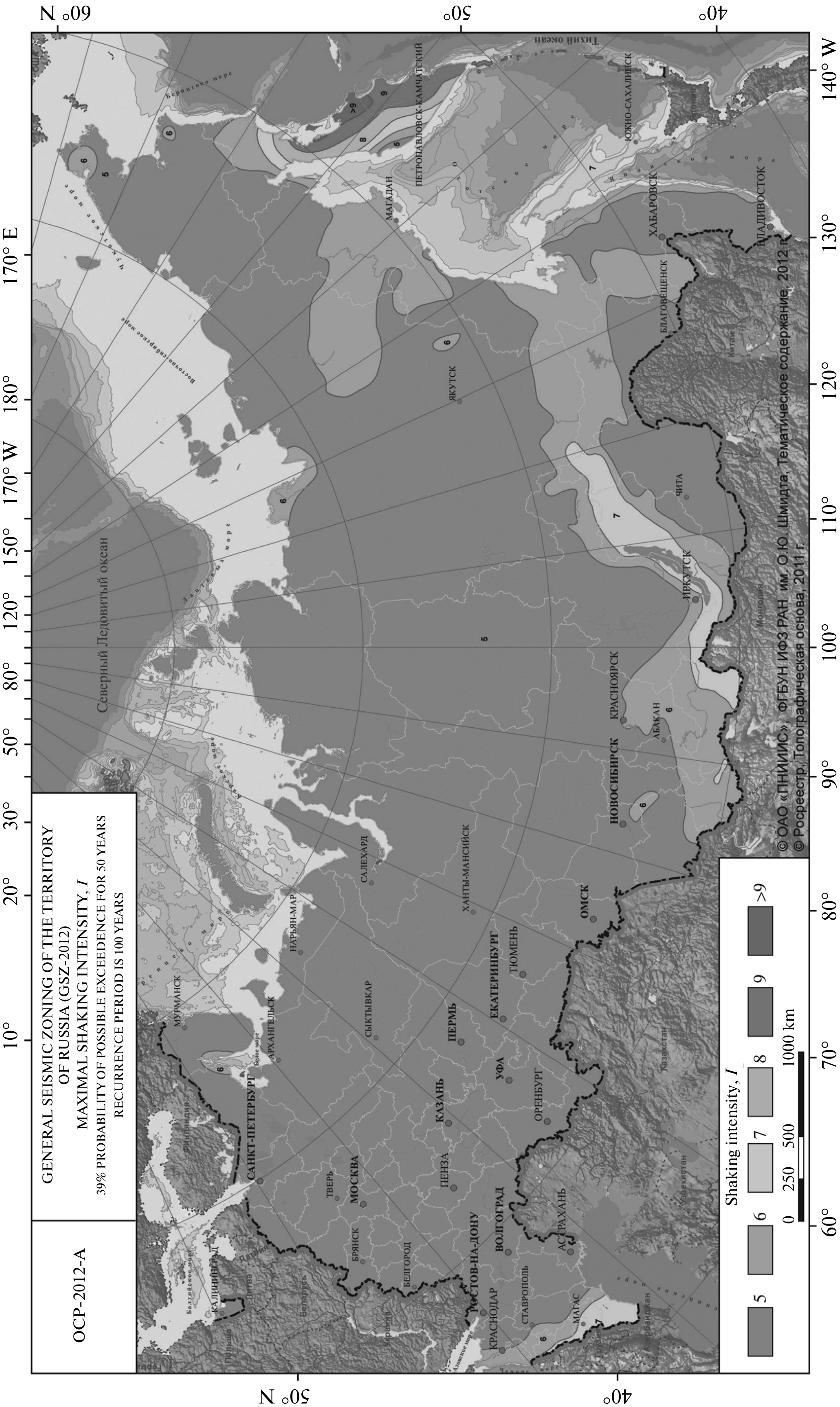

Fig. 2. OCP-2012–Map, corresponding to probability value $P = 39\%$ that maximum seismic effects in terms of macroseismic scale units will be exceeded within 50 years (earthquake recurrence interval is $T = 100$ years).

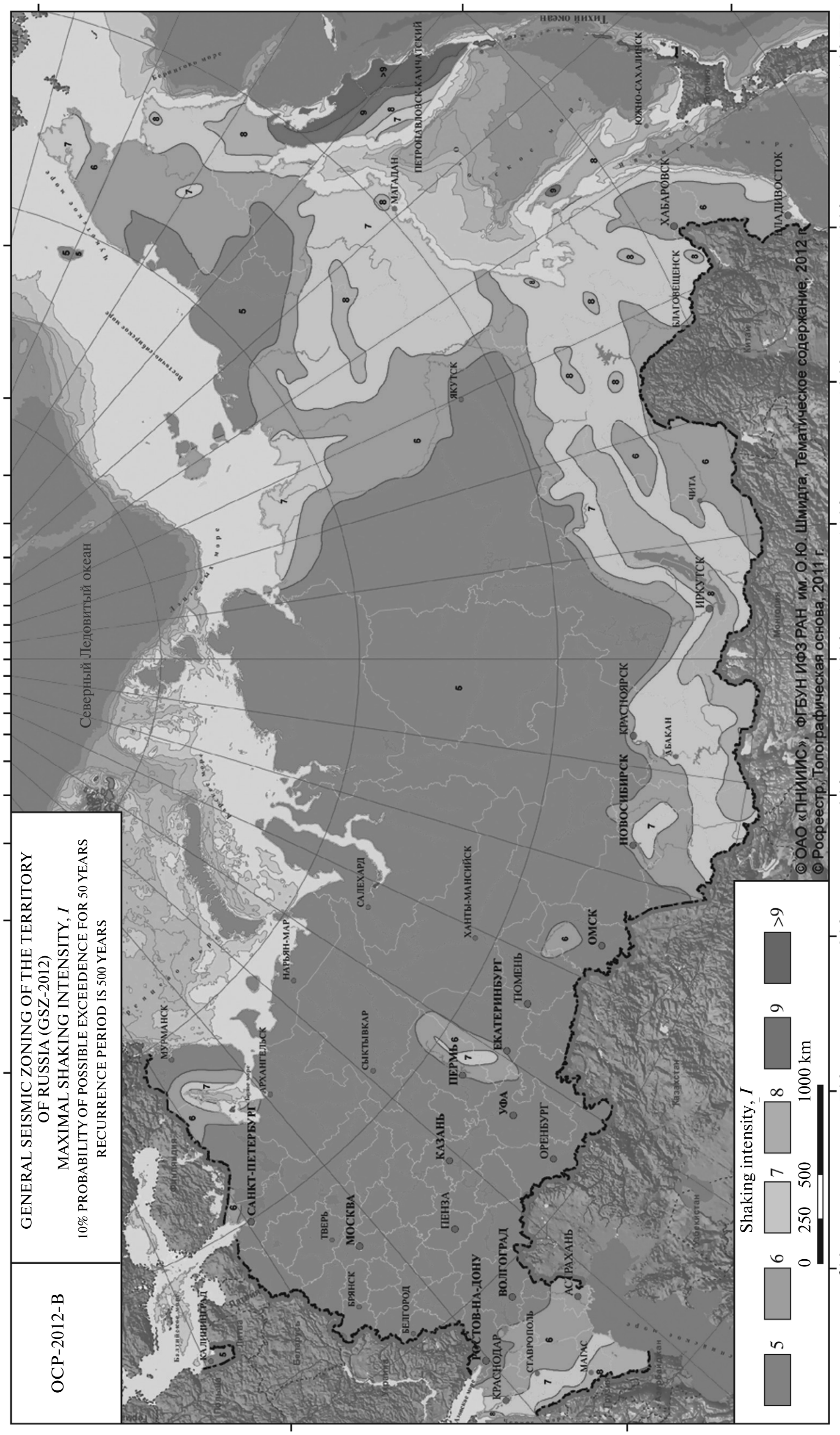

Fig. 3. The OCP-2012–Map, corresponding to probability value $P = 10\%$ that maximum seismic effects, in terms of macroseismic scale units, will be exceeded within 50 years (earthquake recurrence interval is $T = 500$ years).

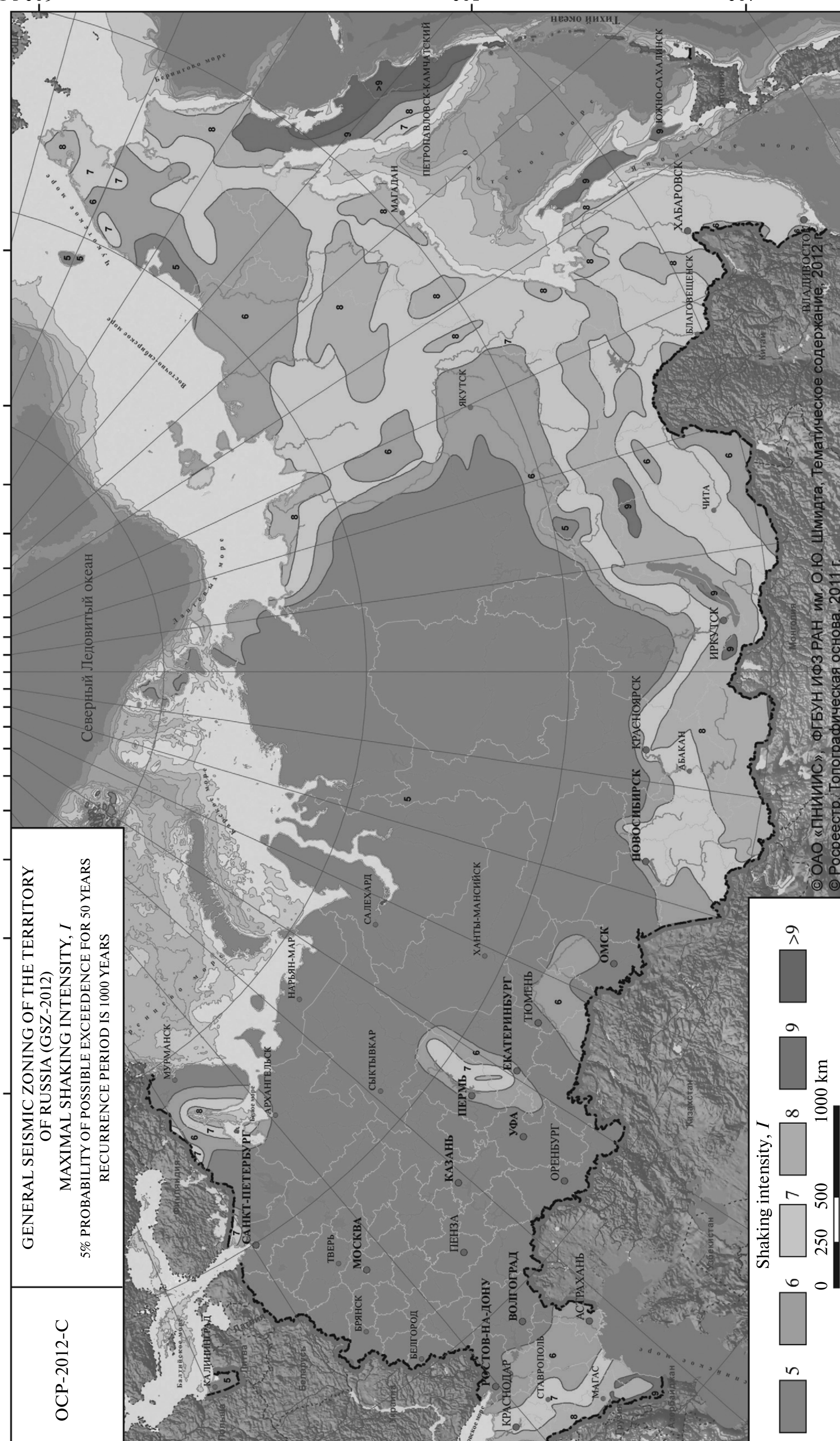

Fig. 4. The OCP-2012–Map, corresponding to probability value $P = 5\%$ that maximum seismic effects, in terms of macroseismic scale units, will be exceeded within 50 years (earthquake recurrence interval is $T = 1000$ years).

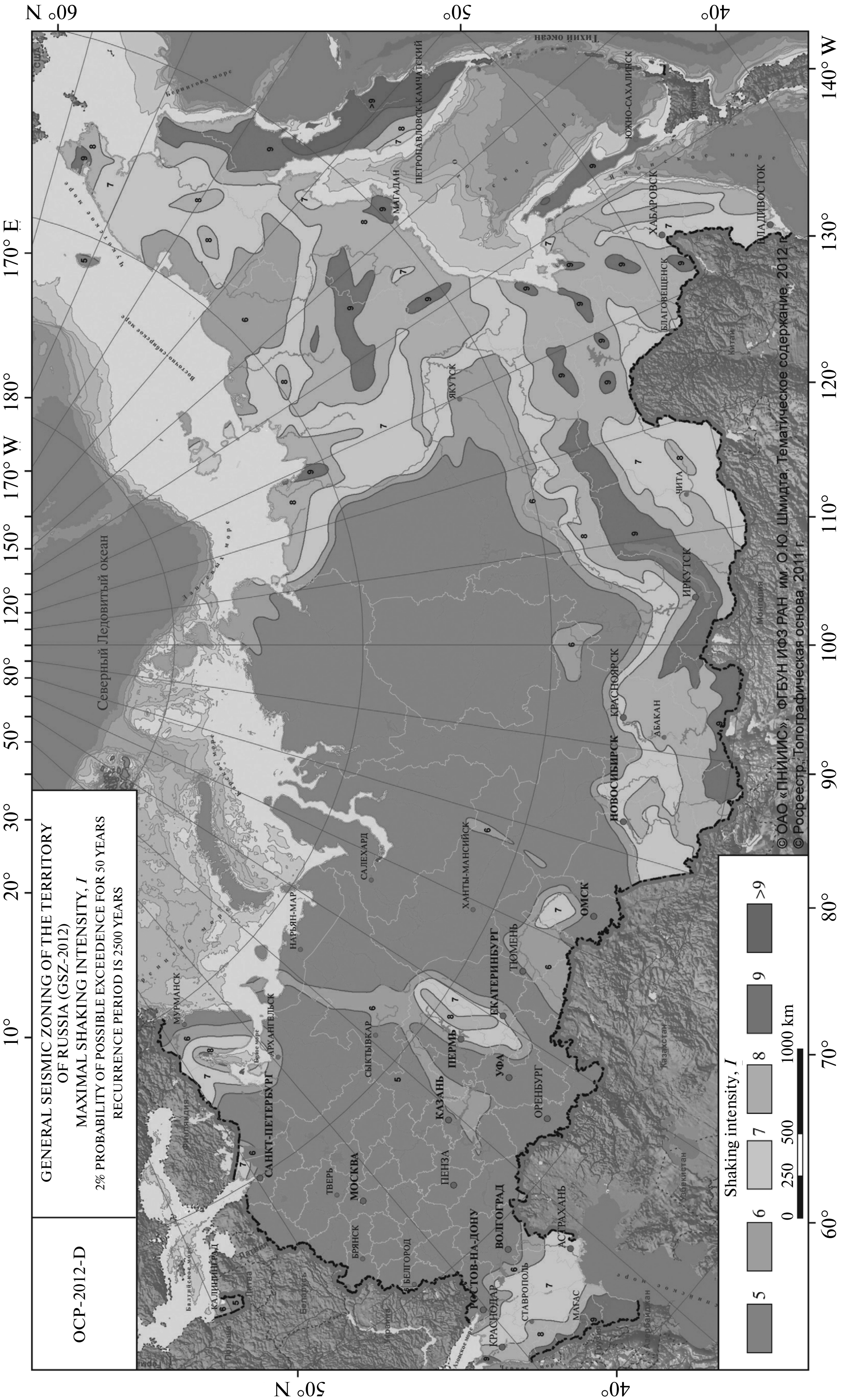

Fig. 5. The OCP-2012–Map, corresponding to probability value $P = 2\%$ that maximum seismic effects, in terms of macroseismic scale units, will be exceeded within 50 years (earthquake recurrence interval is $T = 2500$ years).

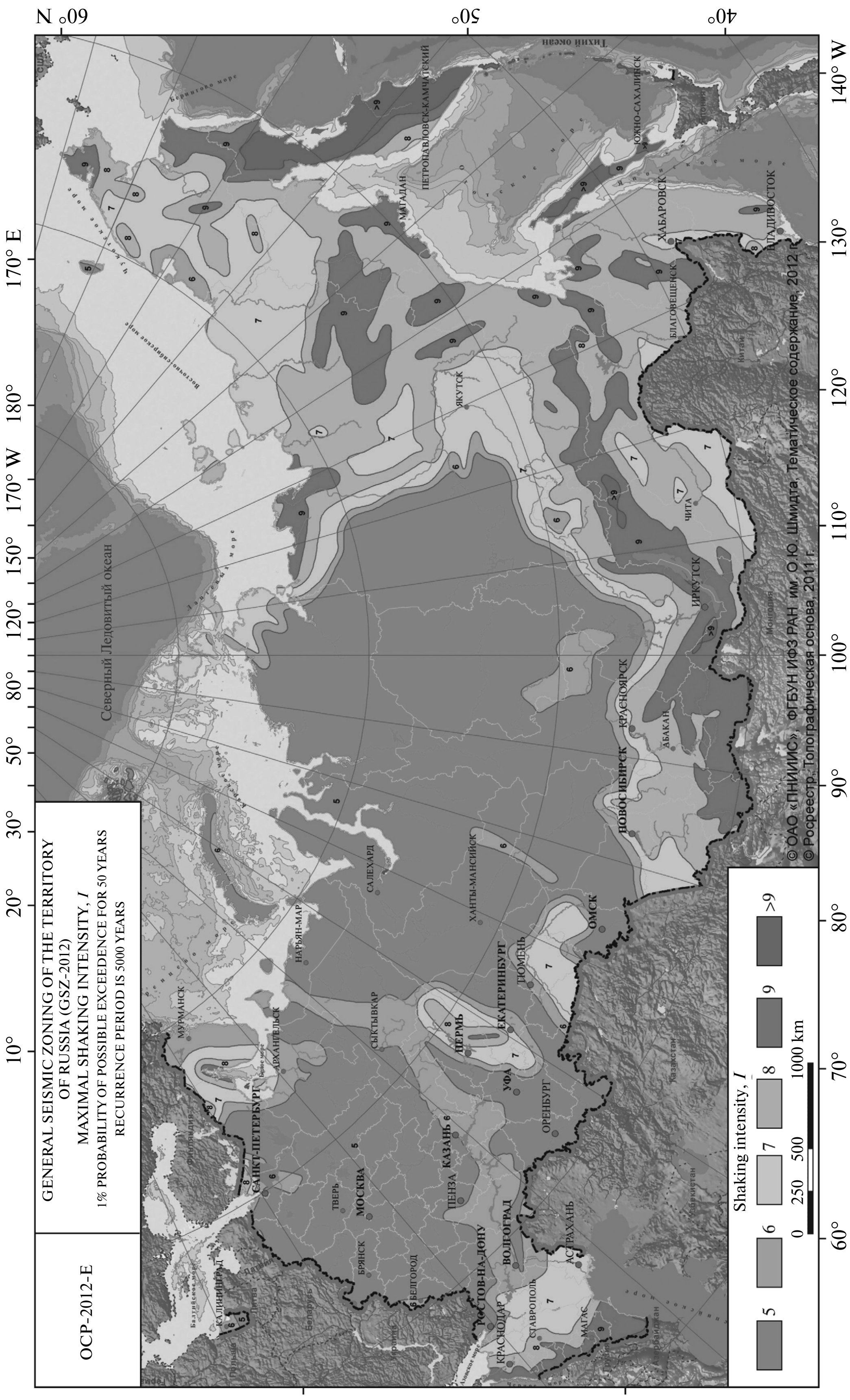

Fig. 6. The OCP-2012–Map, corresponding to probability value $P = 1\%$ that maximum seismic effects, in terms of macroseismic scale units, will be exceeded within 50 years (earthquake recurrence interval is $T = 5000$ years).

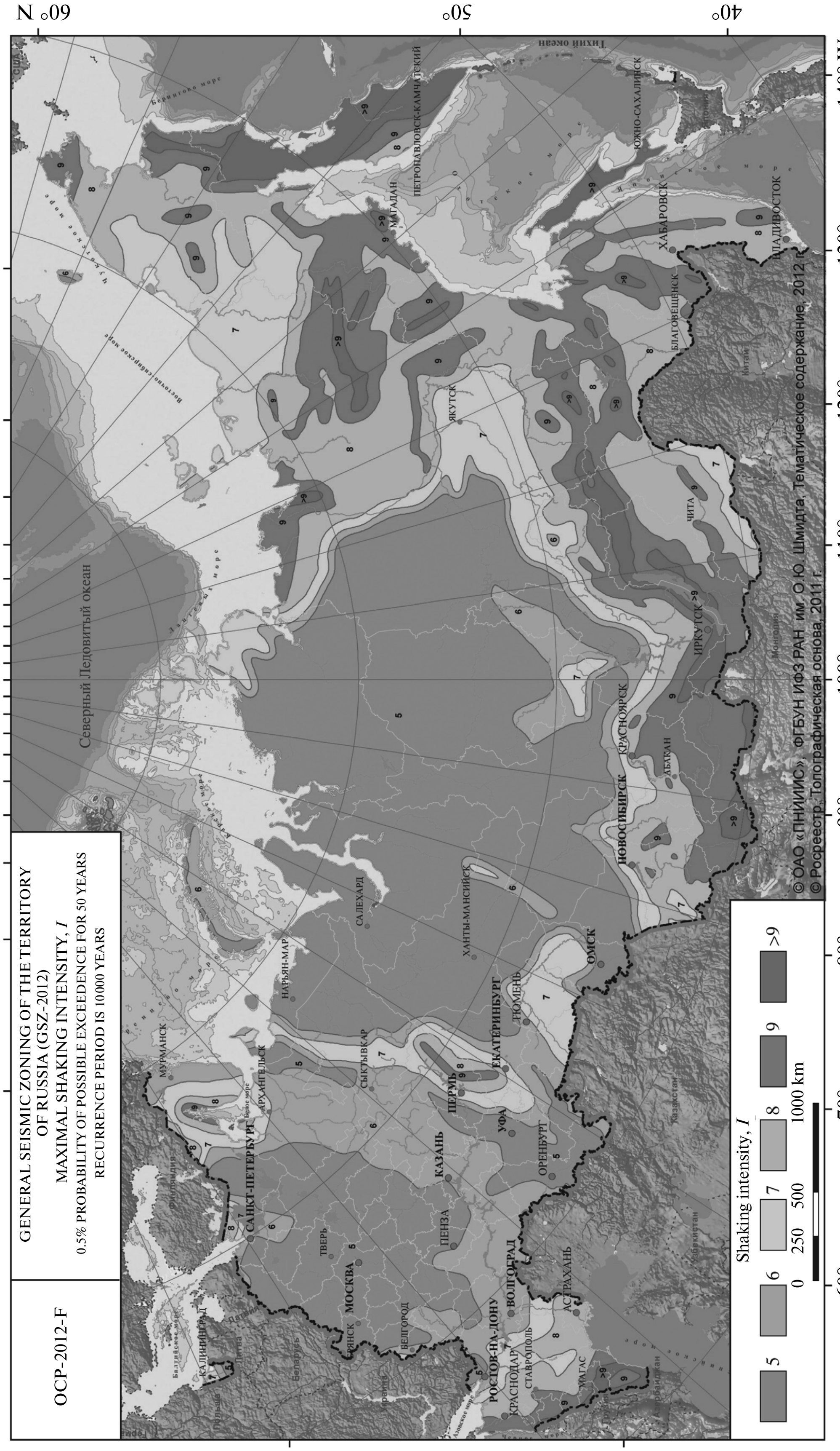

Fig. 7. The OCP-2012–Map, corresponding to probability value $P = 0.5\%$ that maximum seismic effects, in terms of macroseismic scale units, will be exceeded within 50 years (earthquake recurrence interval is $T = 10000$ years).

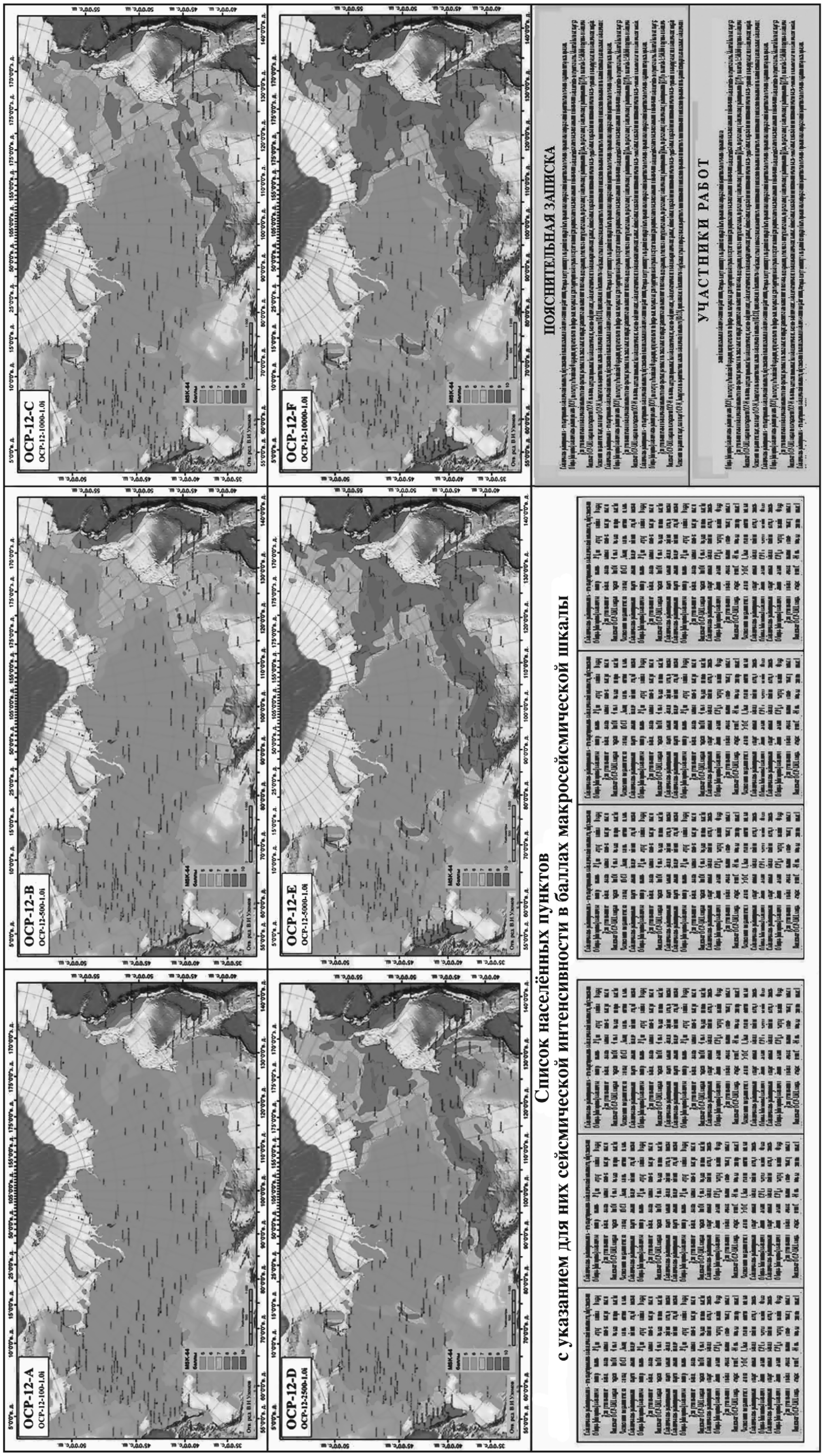

Fig. 8. Summarized OCP-2012 map (wall map), 1 : 8000000.

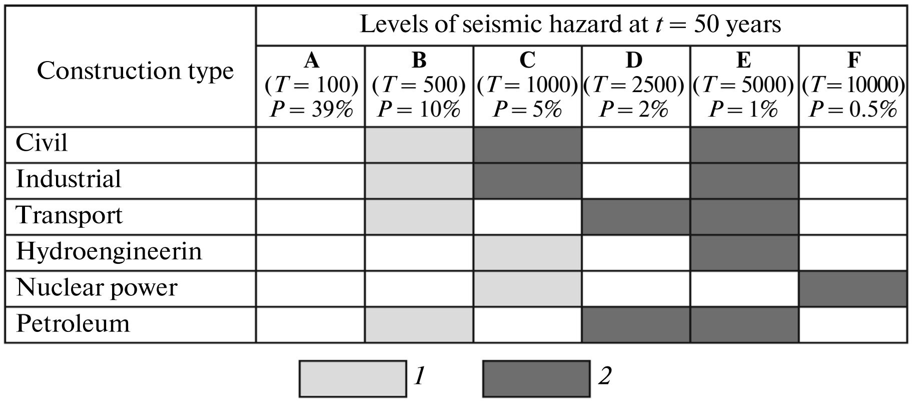

Fig. 9. Examples of GSZ-2012 set of maps application in building practice: (*1*) projected earthquake; (*2*) maximal expected earthquake. T is recurrence interval of seismic effects that occur once per T years; P is the probability that intensity of seismic effects will be exceeded within 50 years, %.

(Ulomov, 2008). The same was done when projecting petroleum-industry objects.

Examples of possible combinations of maps when estimating the projected (PE) and maximal expected (MEE) earthquakes are exhibited in Fig. 9.

Since the new GSZ-2012 set of maps is supplemented in periods of 100 and 2500 years, a broader interval of values of seismic effects can be covered and more valid curves of seismic hazard can be obtained. The maps with T = 100 years can be applied when projecting the temporary constructions of lower level of responsibility.

Table 2 and Fig. 10 compare the areas of zones with different seismic intensities based on the GSZ-2012 and GSZ-97 maps for the same recurrence periods T, as a percentage of the territory of the Russian Federation. As is seen, the general pattern of seismic zoning remains the same. However, the GSZ-2012 maps, owing to their higher degree of detail in comparison to the GSZ-97 maps, showed fewer areas of very high (9 and higher intensity) estimates of seismic hazard.

Estimates of seismic effects indicated in the GSZ-2012 maps are refer to average soil conditions (2nd category of soils in terms of their seismic properties, according to SNiP II-7-81* and SP 14.13330.2011).

CONCLUSIONS

The uncertain conditions always exist in the nature, and various errors in determination of physical parameters of earthquake sources and those in assessing the macroseismic effects from these sources will always

Table 2. The areas of zones of different seismic intensity for different recurrence intervals based on the GSZ-2012 and GSZ-97 maps, as a percentage of the total area of Russia

Intensity, I	GSZ-2012				GSZ-97			
	T, years				T, years			
	500	1000	5000	10000	500	1000	5000	10000
≤5	58.4	51.4	42.4	36.5	58.1	53.4	40.6	34.5
6	17.0	14.6	9.0	12.1	14.8	12.7	12.3	14.3
7	18.2	20.3	15.9	12.9	17.9	18.5	13.2	8.9
8	5.0	11.3	19.7	19.2	7.1	10.0	19.3	17.6
9	0.6	1.5	11.0	14.5	1.9	4.9	9.7	15.7
>9	0.8	0.9	2.0	4.8	0.2	0.5	4.9	9.0

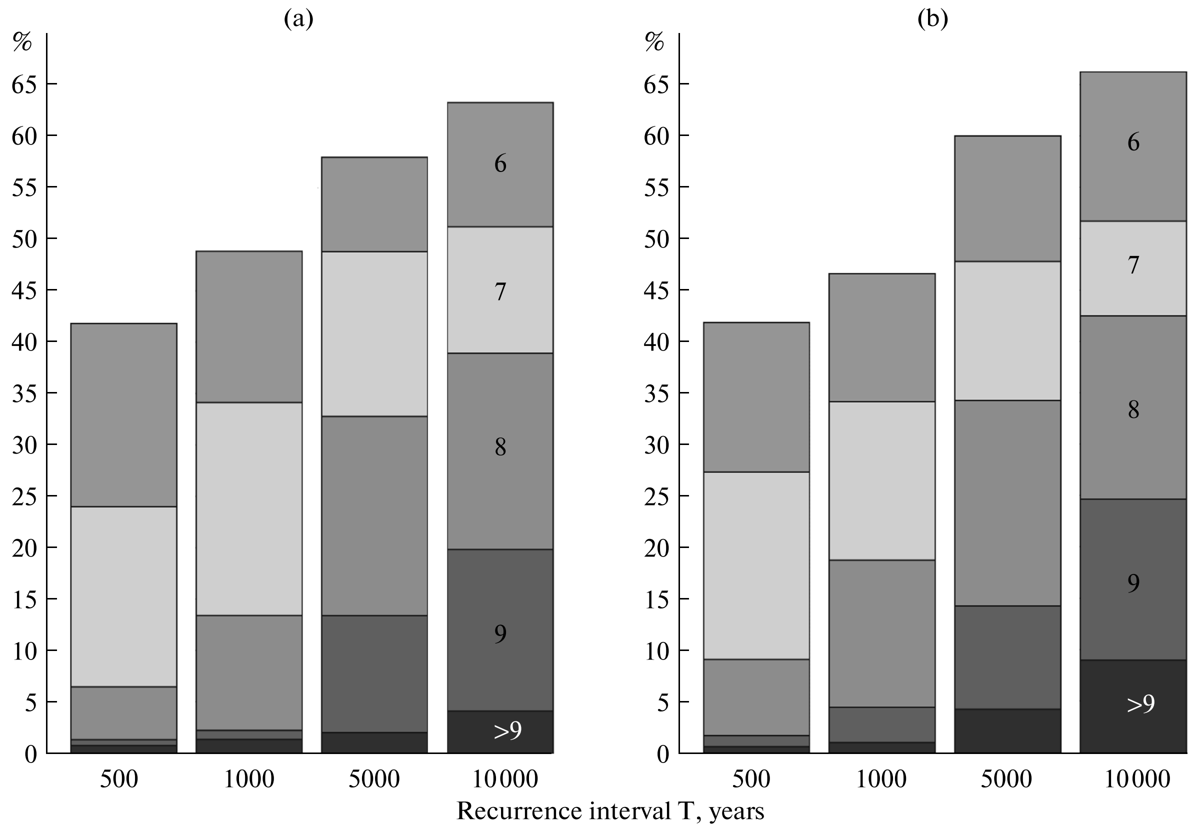

Fig. 10. Comparative view of areas of zones with different seismic intensities (I = 6–9 and >9) based on the GSZ-2012 (a) and GSZ-97 (b) maps at different recurrence intervals, in percentage of the entire territory of Russia (see Table 2).

take place. All these points on aggregate make the purely deterministic approach to seismic zoning invalid and therefore the probabilistic approach is the only possible basis for seismic zoning. Certain risk will always take place, but it must be reduced to the minimum and to the acceptable level in social-economical sense. This is what the GSZ-2012 maps provide: they help estimate the seismic hazard for objects of different responsibility categories in terms of six seismic hazard levels measured by different probability of possible exceedance of predicted seismic effects during the set time intervals.

The GSZ-2012 set of maps, jointly with its appendices (maps of peak accelerations and those in decimal intensity units of 0.5 and 0.1) and the reasoning methodical materials (earthquake catalog, LDF model of ESZ, etc) is made in the form of CD entitled "Seismic safety of Russia"; the publisher who is the same as the publisher of Engineering Survey (Inzhenernye Izyskaniya) magazine—OOO Geomarketing—will publish this CD online (Ulomov and Bogdanov, 2013).

As for the maps of acceleration values, they are determined in the GSZ-2012 by recalculating the intensity points of the updated IZ-2012 seismic scale developed under the leadership of F.F. Aptikaev (Aptikaev and Erteleva, 2011a, 2011b) and not from instrumental measurements of strong motions of the ground, as has been done for a long time in many countries abroad. We do not yet have the ability to measure them in Russia because of the insufficiently developed network of respective stations. The use of the world database of strong motions in the ground can be more or less applicable, thanks to their respective differentiation in terms of seismogeodynamical conditions of the analogous region. Furthermore, use of the records of accelerations from weak and moderate earthquakes, without the tectonic skip types in sources taken into consideration, as is done by some researchers, is not a reliable approach.

Nevertheless, the author believes it will be useful to publish the GSZ-2012 set of maps in terms of peak ground motions, including a summarized wall map for all six levels of seismic hazard. Representation of seismic effects in the form of acceleration, as well as the larger number of GSZ-2012 maps relative to the GSZ-97 set, will promote harmonization between the Russian and non-Russian standards.

All the GSZ-2012 maps constructed, before their inclusion into the Federal State System of Territorial

Planning and other regulatory documents, can be considered as information sources and used when engineering surveys, detailed seismic zoning, and seismic microzoning.

APPENDIX

PARTICIPANTS IN THE WORKS ON GSZ-2012

Organizations—responsible partners: OAO Production and Research Institute for Engineering Surveys on Buildings (PRIESB, chief executive manager M.I. Bogdanov, Cand. Geol.-Miner. Sci.); Schmidt Institute of Physics of the Earth RAS (IPE RAS, executive manager is A.O. Gliko, Academician)

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REFERENCES

Aizenberg, Ya.M., Normative basis for seismic engineering: On the problem of update of the SNiP II-7-81* "Building in Regions of Seismic Hazard: Designing Norms," *Stroit. Ekspert*, 2010, nos. 19–20, pp. 19–21.

Aptikaev, F.F. and Erteleva, O.O., A project of new seismic scale for Russia: Pt. 1, *Inzh. Izysk.*, 2011a, no. 10, pp. 62–71.

Aptikaev, F.F. and Erteleva, O.O., A project of new seismic scale for Russia: Pt. 2, *Inzh. Izysk.*, 2011b, no. 11, pp. 86–92.

Giardini, D., The Global Seismic Hazard Assessment Program (GSHAP)-1992/1999, *Ann. Geophys.*, 1999, vol. 42, no. 6, pp. 957–1230.

Gusev, A.A. and Shumilina, L.S., Some Methodological Problems of General Seismic Zoning, in *Seismichnost' i seismicheskoe raionirovanie Severnoi Evrazii* (Seismicity and Seismic Zoning of Northern Eurasia), Ulomov, V.I., Ed., Moscow: OIFZ RAN, 1995, vols. 2–3, pp. 289–300.

Gusev, G.S., Imaeva, L.P., and Akatova, K.N., Geodynamical activity zoning of the neotectonic struktures for the purposes of general seismic zoning of the territory of Russian Federation (GSZ-2012), in *Tr. VII Obshcherossiiskoi konferentsii "Perspektivy razvitiya inzhenernykh izyskanii v stroitel'stve v Rossiiskoi Federatsii"* (Proceedings of the VII All-Russia Conference "Perspectives of Development in Engineering Survey for Building in Russian Federation"), Moscow, 2011, pp. 207–208.

Shebalin, N.V., Trifinov, V.G., Kozhurin, A.I., Ulomov, V.I., Tatevossian, R.E., and Ioffe, A.I., a unified seismotectonic zonation of Northern Eurasia, *J. Earthquake Predict. Res.*, 2000, vol. 8, no 1, pp. 8–31.

Trifonov, V.G., World map of active faults (preliminary results of studies), *Quat. Int.*, 1995, vol. 25, pp. 3–12.

Ulomov, V.I., The software and mathematical tools for constructing the probabilistic maps of seismic zoning by the GSZ-97 methodology, *Geofiz. Issled.*, 2007, vol. 7, pp. 29–52.

Ulomov, V.I., Engineering-seismological survey in building, *Inzh. Izyskaniya*, 2009a, no. 9, pp. 28–39.

Ulomov, V.I., Update of the general seismic zoning maps for the territory of Russian Federation, *Seismostoik. Stroit. Bezop. Sooruzh.*, 2008b, no. 5, pp. 14–20.

Ulomov, V.I., Update of normative seismic zoning in the framework of the integrated information system for the seismic safety of Russia, *Seism. Instrum.*, 2013, vol. 49, no. 2, pp. 87–114.

Ulomov, V.I. and Bogdanov, M.I., A new set of maps of general seismic zoning for the territory of Russian Federation (GSZ-2012), *Inzh. Izyskaniya*, 2013, no. 8, pp. 8–17.

Ulomov, V.I. and Shumilina, L.S., *Problemy seismicheskogo raionirovaniya territorii Rossii* (Problems of Seismic Zoning for the Territory of Russia), Moscow: VNIINTPI Gosstroya Rossii, 1999.

Ulomov, V.I., Shumilina, L.S., Trifonov, V.G., Kronrod, T., Levi, K., Zhalkovsky, N., Imaev, V., Ivastchenko, A., Smirnov, V., Gusev, A., Balassanian, S., Gassanov, A., Ayzberg, R., Chelidze, T., Kurskeev, A., Turdukulov, A., Drumya, A., Negmatullaev, S., Ashirov, T., Pustovitenko, B., and Abdullabekov, K., Seismic Hazard of Northern Eurasia, *Ann. Geophys.*, 1999, vol. 42, no. 6, pp. 1023–1038.

Wells, D.L. and Coppersmith, K.J., New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, *Seism. Soc. Am. Bull.*, 1994, vol. 84, no. 4, pp. 974–1002.

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