Models for Area Seismic Source Definition and Parameterization for Georgia and the Surrounding Region

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ABSTRACT

Models of area seismic source (ASSs) are the basic and most important inputs required for Probabilistic Seismic Hazard Analysis (PSHA), because on them mainly depends the reliability of the final results of seismic hazard assessment. Determinations of these models include the delineation of ASSs and their parameterization. In practical applications, when clear procedures for constructing ASSs do not exist, this leads to large variations in the computed hazard.

In the Caucasus, where active faults are clearly defined and parameterized, and seismicity is relatively well documented, a method of ASS delineation is used, which was developed by us. The procedure for constructing ASSs is based on the delineation, along the active fault, of an area with a certain width. The width of the ASS is dependent from fault plane dip and width, from the thickness of seismically active layers and from geometrical sizes earthquake source. ASSs asymmetry relative to the axial line of the fault is a characteristic feature of these construction. On the basis of these method, ASSs were delineated for Georgia and the surrounding region.

Each ASS is expressed by a set of parameters that will represent the basic input for seismic hazard assessment. $M_{\text{max}}$ assessments were implemented on the basis of three seismological and two geological methods. The magnitude-frequency distribution $b$ parameter was calculated for 16 generalized tectonic units, for which seismic statistics were quite complete, and the $a$ parameter was determined for each ASS. A study of the depth distribution of earthquakes showed that seismicity in this region is mainly shallow.

Keywords: Georgia, seismic source, seismic hazard, active faults, magnitude-frequency distribution, earthquake depth.

1 Introduction

The development of seismogenic source models is one of the first steps in the implementation of Probabilistic Seismic Hazard Analysis (PSHA).

In practice, PSHA studies use mainly three types of seismogenic source model: 1 – point source, where seismicity is concentrated in a small area at very long distance from the site; 2 – line source, where seismicity is related to a active faults; 3 — area seismic source, where seismicity is related to localized active geological structures or where the historical seismicity is assumed to be uniformly distributed. Theoretically, each seismogenic source should be associated with an individual fault or its segment. However, in actual practice, due to lack of data about all the faults and dispersion of the epicenters of historical earthquakes, area seismic sources (ASS) are preferentially used, which cover one or more active faults and have homogeneous characteristics of seismicity (Gupta, [8]).

It is worth noting that in practical applications, when clear procedures for constructing ASS do not exist, this leads to large variations in the computed hazard and to unreliable results. Therefore, in the absence of formal and consistent procedures for the development and parameterization ASS, the problem of their delineation is often a controversial one in the practice of PSHA (Weatherill and Burton, [16]).

ASS models should be based on the definition of seismotectonic laws (models), which in turn are based on the three-dimensional comparison of real geometric dimensions of geological (e.g. faults) and
seismological (e.g. earthquake sources) objects. However, there are differences in the approaches by which basic seismotectonic schemes are constructed.

The main seismotectonic concept, used in this study, is based on the crustal divisions into separate blocks, under conditions of continuous crustal deformation caused by endogenous processes. Relative mutual displacement of blocks leads to the accumulation of potential energy in some transition zones of interblock. These accumulated energy can be released during the earthquakes. So it is necessary to reveal special distribution of such transition zones and related earthquakes for delineation of ASS. Therefore, to solve this problem is required to have data of active faults for investigated area.

2 Tectonic and seismotectonic background

Since the delineation of active faults depends partly on the subjective judgment by experts, various schemes of active faults can be obtained by different authors. In our study, we used only those schemes for active faults in Georgia (see Figs. 1a-b) that were published in peer-reviewed journals. These publications are Caputo et al., [4] and Adamia et al., [1]. The active fault scheme presented in the latter was further improved by the authors taking into account the latest results obtained in the framework of the EMME project (Danciu et al., [5]).
In order to assess the seismic hazard of the whole territory of Georgia by means of the PSHA method, it is also necessary to consider ASSs within at least 100 km from the borders of Georgia, considering the fact that seismicity increases to the south (Turkey, Armenia, Iran) and east (Azerbaijan) from Georgia, and that it rapidly decreases to the west (Black Sea) and north (Northern Caucasus, Russian Federation) (Fig. 3). Therefore, for Georgia, two different maps reporting the active faults (see Fig. 2a-b) and a seismotectonic map were compiled (Fig. 3). Information about active faults of the study area and associated parameters as well as about seismicity was derived from the mega-database, developed by the EMME project.

(a)

(b)

Fig. 2. Tectonic map of the investigated region reporting only active faults: (a) the faults are from Caputo et al. [4] and from Danciu et al., [5]; (b) the faults are from Adamia et al.,[1] and from Danciu et al., [5]. In the legend, active faults are highlighted in different colors according to data from different countries, provided in the mega-database of the EMME project (see Danciu et al., [5]).
3 Methodology for ASSs delineation and its application

Area seismic source models used in this study are defined according to the following principles: a ASS is defined as a seismically homogenous area, in which every point is assumed to have the same probability of being the epicenter of a future earthquake; the seismic potential (e.g., $M_{\text{max}}$) of any ASS has to be distinctly different from the other adjacent ASS; when compiling a map of ASS, zones of high seismic potential overlap with the zones with lower potential.

ASS models consider two basic geometric elements: firstly – a linear zone, representing the projection of the three-dimensional active fault, which reflects the structural seismicity; secondly - a geographical polygon, that delineate an area with quasi-homogeneous geological characteristics and are characterized by diffuse seismicity. The latter is located between the zones of the first type and is a background area.

The Caucasus is a region where active faults are well defined and parameterized, and seismicity is relatively well documented, so the source zones are fairly obvious. Therefore, in the present study, a method of ASS delineation is used, which was developed by us and includes formal and consistent procedures.

As shown in Figure 4, a proper procedure for ASS delineation requires the following information:

- The geometric parameters (length, width, depth) of the considered active fault and its segments.
- The dip of the fault plane, location of branching faults, width of the cataclastic zone. The thickness of the seismically-active layer.

In addition, the relationship of individual, moderate and strong earthquakes with the considered, active fault is based on the following factors related to earthquake sources:

- Data on the geometric size of the earthquake sources, position of the hypocenter (epicenter coordinates, depth).
- Data on the orientation of the scattering area of foreshocks and aftershocks, data on the direction of higher isoseismals.
- Data on the location of the dislocation and landslides caused by the earthquake.

Fig. 3. Seismotectonic map: active faults, from Adamia et al. [1] and from Danciu et al. [5] and seismicity with $M_{w}>5$ for Georgia and the regions around it (Zare et al., [19]; Varazanashvili et al., [15]).
Fig. 4. Scheme illustrating the procedure for determining the width of the ASS, i.e. the width of the projection of the three-dimensional fault on the Earth's surface.

The procedure for constructing a ASS is based on the delineation, along the active fault, of an area with a certain width. In this case, the width of the ASS is crucial in the creating a model ASSs for the study region. In turn, the width of the ASS is dependent on fault width, the dip of the fault plane, the thickness of the seismically active layer, the geometrical size of the source of the maximum possible earthquake (Fig. 4). The ASS asymmetry relative to the axial line of the dipping fault is a characteristic feature of this construction.

To illustrate the application of this procedure for ASS delineation, Figure 5 shows the location of the epicenter of the 2011 Sairme earthquake, in south-western Georgia, with $M_w=5.6$, $h=21$ km, and $I_o=7$ (MSK) (Varazanashvili et al., [15]) in relation to active faults and the ASSs, which clearly demonstrates the reliability of the procedure used for constructing the ASS along the fault. On the map of Figure 5, ASSs with the maximum possible magnitude $M_{\text{max}} = 6$ are shown in blue, whereas the ASSs with $M_{\text{max}} = 5$ are in light blue colour.

Only by using the above procedure, it is possible to identify the connection of the focus of the Sairme earthquake with the ASS, located along the western segment of the Surami active fault. Given the dip-direction and the dip angle of the fault and the distance from the epicenter to the projection of the fault axis on the surface, the resulting depth of the hypocenter is 20 km, that practically coincides with instrumental depth ($h=21$ km) and once again testifies to the correctness of the geometric reconstruction.
The location of the Sairme earthquake epicenter, 2011 in south-western Georgia, in relation to active faults and ASSs.

The geometrical parameters (length and penetration depth) of active faults were derived from the corresponding database of active faults, developed in the framework of the EMME project and from correlation dependence (for the width of the fault) based on Aleshin et al., [3], which is best suited to the conditions of Georgia and the regions around it:

\[
\log S = 0.77 \log L - 1.20
\]

where \( S \) – the width of the fault, and \( L \) – the length of the fault. From the same database were collected also the data about the dip angle of the fault plane.

The thickness of seismically active layer in this study were set at 14 major tectonic units allocated in Georgia and around it. For this was used the distribution of the number of earthquakes by depth in each selected tectonic unit (see Section 4.3).

Geometrical sizes of the earthquake sources of various magnitudes in Georgia were determined by correlation dependencies from the work of Ulomov [14]:

\[
\log L_M = 0.60 M - 2.50 \quad \text{with } M \geq 6.5
\]

\[
\log W_M = 0.15 M - 0.42 \quad \text{with } M \geq 6.5
\]

\[
\log L'_M = 0.24 M - 0.16 \quad \text{with } M < 6.5
\]

where \( L_M \) and \( W_M \) are the length and width of the projection of earthquake volume sources (ellipsoid) on the Earth's surface, and \( L'_M \) – diameter spherical sources.

Orientation in space sources of moderate and strong earthquakes has been established on the basis of a joint analysis of the respective information specified above. These materials have been collected from the seismic database, created at the M. Nodia Institute of Geophysics of TSU.

The procedure for constructing a ASS corresponding to a given active fault, as indicated above, is based on the delineation, along the fault, of an area with a certain width. The width of the area, in turn, depends on the dip angle of the fault plane, the width of fault dynamic impact zone (the position of branching faults, the width of the fractured zone and the thickness of the seismoactive layer) (see Fig. 4). Depending on which map of active faults (see Fig. 2) we took as the basis for constructing ASSs, model 1 and model 2 were obtained for the ASSs in the study area.
Thus, based on the above described method, two ASSs models were obtained for the study area (Fig. 6a-b).

Fig. 6. ASSs models for Georgia and the regions around it: (a) based on Model 1. (b) based on Model 2.

4 Parameterization of ASSs

For each ASS, a model must be selected, which is expressed by a set of parameters that represent the basic input for the seismic hazard assessment.

In ASS model, the following parameters are considered:

i. The maximum magnitude.

ii. Parameters of the magnitude-frequency distribution of the earthquakes.

iii. The parameters of earthquake depth distribution.
The values of some ASSs parameters in this study area were set only in large, isolated tectonic units, in and around Georgia, according to Adamia et al., [2]. Then, these tectonic units were generalized (see, for example, Fig. 7), so that each ASS fell into some sort of Generalized Tectonic Unit (GTU). Many boundaries between GTUs are reflected in the structure of seismicity, as dividing lines between zones with different rates of seismicity.

![Diagram of tectonic units and ASSs](image)

**Fig. 7.** Generalized tectonic units (GTUs) and ASSs (according to Adamia et al., [2]).

### 4.1 Maximum magnitude \( (M_{\text{max}}) \)

In the PSHA, the assessment of the expected maximum earthquake magnitude \( (M_{\text{max}}) \) for each ASS is required. Such assessment is conducted by using multiple methods for the estimation of \( M_{\text{max}} \). In Georgia and the areas around it, for the purpose of hazard assessment, five methods to estimate \( M_{\text{max}} \) (within individual ASS) were used. Of these, three are of seismological and two of geological nature.

The seismological methods use historical and instrumental records of seismicity and, in particular, the assessment of the magnitudes of the largest earthquakes observed within each ASS \( (M_{\text{obs}}) \), plus an increment to determine \( M_{\text{max}} \). Also, \( M_{\text{max}} \) is assigned by extrapolation of the magnitude-frequency dependence of earthquakes in each ASS to the specified recurrence period value (e.g., 2475 years). The geological methods adopted for determining \( M_{\text{max}} \) in the ASS, are focused on the use of the geographical extent of the active faults and their individual segments, as it is expected that they control the \( M_{\text{max}} \) in each ASS (Wells and Coppersmith, [18]; Shebalin et al., [11]; Wheeler, [19]).

Below, the basic concepts of the five used methods are described in more detail. In particular, the first method for evaluating the \( M_{\text{max}} \) is based on the definition of the largest observed magnitude in a ASS \( (M_{\text{obs}}) \), plus an increment to determine \( M_{\text{max}} \). Also, \( M_{\text{max}} \) is assigned by extrapolation of the magnitude-frequency dependence of earthquakes in each ASS to the specified recurrence period value (e.g., 2475 years). The geological methods adopted for determining \( M_{\text{max}} \) in the ASS, are focused on the use of the geographical extent of the active faults and their individual segments, as it is expected that they control the \( M_{\text{max}} \) in each ASS (Wells and Coppersmith, [18]; Shebalin et al., [11]; Wheeler, [19]).

According to the second method, the \( M_{\text{max}} \) is equal to \( M_{\text{obs}} \) plus an increment. Like in the case of the first method, it is a straightforward one and can be applied anywhere in the investigated region. However, it provides in many area only a lower bound on \( M_{\text{max}} \) and it is suitable only for ASS, where large historical earthquakes were observed (Wheeler, [19]).

The third method for \( M_{\text{max}} \) assessment uses a magnitude-frequency extrapolation of observed records. The magnitude-frequency equation can help determine the magnitude for a given recurrence period. The question is what return period should be considered in any given ASS, to estimate \( M_{\text{max}} \). Experience of
seismic hazard assessment for Georgia and surrounding areas showed that the seismic hazard maps with a 1% \((T \leq 4750 \text{ years})\) return period of events and 2% \((T \leq 2475 \text{ years})\) probability of exceedance within 50 years differ very little from each other, i.e. after \(T = 2475 \text{ years}\) there is a saturation value of seismic hazard. The maps with a 2% probability of exceedance cover almost all the observed maximum earthquakes recorded over the 2000 years of historical observations. Therefore, the 2475-year return period can be taken for the purpose of \(M_{\text{max}}\) assessment in this region.

In the fourth method, \(M_{\text{max}}\) is estimated considering the maximum length \((L_{\text{max}})\) of an active fault (or fault system), which falls into a given ASS. In particular, the \(M_{\text{max}}\) can be estimated by the maximum length \(L_{\text{max}}\) of an active fault, provided that 10% of the fault’s length falls into the ASS. This method uses a nomogram \(M_{\text{max}}(L_{\text{max}})\)-dependence from Shebalin et al., [11], which takes into account the level of development of active fault systems in the ASS (single faults, weak fault system or developed fault system) and various seismotectonic situations in the ASS (active, moderately active or weakly active).

The fifth method evaluates the \(M_{\text{max}}\) by taking into account the size of active fault segments and fault systems. The key point of this method is the fact that earthquakes typically occur due to the rupture of individual fault segments. Thus, carrying out the segmentation of a fault, the determination of the size of individual segments provides a basis for assessing the maximum length of a future rupture and, consequently, the expected maximum magnitude (DePolo et al., [6]; Wells and Coppersmith, [18]; Pizzi and Paladini, [10]). For the calculation of the \(M_{\text{max}}\) in the investigated region, we used the regression equation of subsurface rupture length \((L)\) on moment magnitude \((M_w)\), and in particular the formula (Wells and Coppersmith, [18]):

\[
M_w = 4.38 + 1.49 \log(L),
\]

which is best suited to the seismotectonic conditions of Georgia and its surrounding areas. Since in the four methods for determining \(M_{\text{max}}\) use magnitude in terms of surface waves \((M_S)\), for conversion from \(M_S\) to \(M_w\) have been used the formula provided by Zare et al., [20]).

The final values of the \(M_{\text{max}}\) in terms of moment magnitude \((M_w)\) were estimated in the investigated region by averaging individual values obtained through the above described methods. Analysis of the results showed that the used geological methods relatively overstate the estimated value of \(M_{\text{max}}\), and seismological methods, on the contrary, relatively understate. Fig. 8a,b show maps of the investigated region, differentiated by average values of the \(M_{\text{max}}\), obtained using the above methods. These maps are the basis for the calculation of the new Georgian seismic hazard maps for different probabilities of exceedance in 50 years.
4.2 Recurrence of earthquakes

The next main step in the probabilistic seismic hazard assessment is the definition of recurrence law for each ASS. Recurrence law may be determined from Gutenberg-Richter frequency-magnitude distributions \( \log_{10} N(M) = a - b * M \) and in particular by its parameters: \( b \) - the slope of magnitude-frequency occurrence curve (bGR); \( a \) - level of the corresponding graphics (aGR). The values of parameters \( a \) and \( b \) vary depending on the sizes of temporal and spatial window. Parameter \( a \) is associated with the level of seismicity rate in a specific area, whereas parameter \( b \) determines the ratio of numbers of larger to smaller earthquakes and it is also associated with the seismic stress (see, for example, Pailoplee and Choowong, [9]).

Therefore, to characterize a ASS in the investigated region, it is required to solve the problem of the determination of \( a \) and \( b \) values.

The primary data source for determining \( a \) and \( b \) values is a new instrumental earthquakes catalogue for Georgia over the 1900-2018 period, with \( M_W \geq 4.0 \) events, as well as the earthquake catalogue for the Middle East region, from the EMME project (Zare et al., [20]) for the 1900-2006 period, with \( M_W \geq 4.0 \) events; this was integrated by data on earthquakes for the 2007-2018 time interval from catalogues from neighboring countries. Parameters \( a \) and \( b \) of earthquake recurrence law are estimated for independent events (declustered earthquake catalogue) and completeness intervals for area sources using declustered catalogue by the Gardner and Knopoff, [7].

First in the study area, parameter \( b \) was calculated through the maximum likelihood (MLE) procedure of Weichert, ([17]), for the 16 GTUs in which the data of earthquakes were sufficient for reliable determination of this parameter. The \( b \)-value obtained for each GTU is generalized for all ASS falling into given GTU. Then, recurrence parameters \( a \) and \( b \) were independently estimated for ASSs with number of earthquakes more than 10 with the same MLE. For ASSs with smaller number of earthquakes (less than 10 events), the \( b \) value was adopted from corresponding GTUs and the corresponding activity rate, \( a \), was estimated by the distribution of the total number of events in the GTU to the smaller ASS.

Fig. 9a, b show examples of recurrence curves for GTUs: Western Greater Caucasus and Adjara-Trialeti zone.
4.3 Earthquakes depth distribution

Studying the distribution of earthquakes depths within the crust or upper mantle, gives us important information about the Earth's structure and the tectonic setting where the earthquakes are occurring, i.e. is an important indicator of seismicity type. In the continental crust, seismicity is usually concentrated in the upper crust and the lower crust is much less active.

This section discusses the depth distribution of the seismicity in 14 GTUs of the investigated extensive region around Georgia. The number of earthquake sources in the investigated region shows statistically a high degree of dependence on the depth location in the crust. Most of the earthquakes are located in the sedimentary and granite layers, while the deeper layers (Basalt and upper mantle) show relatively less seismic activity.

In particular, Figures 10a, b provide the distribution of earthquake depths according to the 1900-2018 data for the GTUs of the Greater Caucasus and Adjara-Trialeti zone. An analysis of these distributions shows that, in both cases, about 95% of earthquakes occur at depths of ≤20 km, which means that the thickness of the main seismically-active layer is 20 km. About 4% of earthquakes occurred at depths of 21 to 40 km, and...
the remaining 1% occurred at depths >40 km. As regards all the 14 GTUs, an average of about 85% of the total number of earthquakes occurred in the 1- to-20-km depth range. The weaker earthquakes \((M_W<5.5)\) took place in sedimentary units, whereas the stronger ones \((M_W \geq 5.5)\) occurred in granite units. About 10% of earthquakes occurred at depths of 21 to 40 km, and the remaining 5% occurred between depths of 41 to 160 km (Tibaldi, et al., [12]).

Thus, it is clear that most of the seismicity in this extensive region is shallow, and this conclusion is particularly important with respect to the choice of ground-motion models to be used in seismic hazard calculations.

![Fig. 10](image)

**Fig. 10.** Number of earthquakes (Tsereteli et al., [13]) with different depths (km) for GTUs: (a) Greater Caucasus; (b) Adjara-Trialeti zone. 1 – Distribution of the number of earthquakes according to depth (from 1900 to 2018); 2 – Moving averaging curve.

5 Final remarks

The delineation and parameterization of ASSs are among the first steps in the implementation of a PSHA. In practice, area seismic sources are preferentially used, which cover one or more active faults and have homogeneous characteristics of seismicity. In practical applications, in the absence of formal and consistent procedures the issue of ASSs delineation is often a controversial one in the field of PSHA. The main seismotectonic concepts for the definition of ASSs are based on the subdivision of the crust into separate blocks.

In identifying of potential ASS is necessary to clarify the spatial location of active faults and earthquake sources. For Georgia, the used tectonic maps are the ones (see Fig. 1a, b) that were published in high-rank, peer-reviewed journals: Caputo et al., [4] and Adamia, et al., [1]. For the extensive area around Georgia, other tectonic maps were used, derived from the mega-database, developed by EMME the project.

A method for ASS delineation in Georgia has been developed, based on the definition, along the active fault, of an area with a certain width. In turn, the width of the ASS is dependent on fault width, the dip angle of the fault plane, the thickness of the seismically active layer, and the geometrical parameters of the earthquake source. This was illustrated by way of an example from the 2011 Sairme earthquake epicenter, in south-western Georgia.

Finally, on the basis of this methodology, ASSs models were obtained for the whole study area.

Five methods were used to estimate \(M_{\text{max}}\) within individual ASSs. Two map versions for the studied region were constructed, differentiated in agreement with the averaged values of \(M_{\text{max}}\).
As regards the ASSs, also the earthquake recurrence law was established from the Gutenberg-Richter magnitude-frequency distribution, and its $a$ and $b$ parameters were determined. Based on the completed instrumental catalogue of earthquakes for Georgia and surrounding regions for the 1900-2018 period, and by the maximum likelihood (MLE) procedure of Weichert, [17], parameter $b$ was determined for 16 GTUs. Then, parameter $b$ and $a$ was calculated for each ASS.

The distribution of the depth of earthquakes was studied for 14 GTUs in Georgia and its surrounding areas. Our analysis of the obtained distributions has enabled us to document that most of the seismicity of this region is at shallow crustal levels.

The above results were used to come up with the new Georgian seismic hazard maps, for different exceedance probabilities in 50 years.

References


ვერაზაშვილი დ. წერეთელი რეზიუმე

სეისმური კერების არეების (სკ) მოდელების აგება და პარამეტრიზაციის სტატისტიკური გარემო და გრაფულ-გეოგრაფიულ ტექნიკის

 m. განაშენიანები, რ. ჯურჯიანი

რეზიუმე

სეისმური კერების არეების (სკ) მოდელების განვითარება ქართული საქმიანობის პირველი მანქანი სეისმური საშიშროების ანალიზის (ასს) გამოთვალებისთვის, რადგან სეისმური საშიშროების შეფასების მაღალი უდევნების სხვადასხვა მონაცემთა თვითმმართველობით.

ამ მოდელების განვითარება ბრძოლა სეისმური კერების არეების (სკ) გამოთვლის და შემდგომმა განსაზღვრის. ეს მოდელმა არჩევს სასწორი სპექტრული პარამეტრები, რომლებიც არამეგობრივი სკ-არების მასაზომო პარამეტრები, ასე რომ შესაბაზებლობა ჰქონდა საერთაშორისო მაინც და არანანტონი რეალიზაციაში.

ვერაზაშვილი, ჰაიდარ არჩევანი რეალიზობდა არსამარტოობის და პარამეტრიზაციის განმტკიცებით, ხოლო სეისმური საშიშროების გაადგილების - სიძველეთაღმართვით, გამოთვლინა სკ-არებზე გამოყოფილი ქვეყნის ღრმა გამოთვლით მოეთხოვა. სკ-ის განახლების ვარიანტს არხზე თვისდებოდა გამოყოფილ სკ-არების მდგომარეობის გამოთვლის ხელშეკრულება.

სკ-ის სიგანე დამოკიდებული იქნა სკ-არების შემადგენლობის, რეალური ტექნიკური ტექნიკის შესაძლებლობები, პროექტის ჭრის თავისებურს ჰონებამ გრაფულ-გეოგრაფიულ ტექნიკის. სკ-ს საქმისებრო რეალიზმი გამოყოფილ სკ-არების მიხარჯვამ არამეგობრივი გამოთვლით მონაცემში.

ყოველი სკ განახლებული რეალური ტექნიკის შესაძლებლობა, რომელიც განახლებული შემდგომ საქმიანობის შედეგად მიდგა სეისმური საშიშროების შეფასების შენახვის. მათ-ის შესაღება ხდებოდა საშიშროების და თხოვნის ექსპლუატაციის შეფასების შემდგომ. სკ-ზე ორიენტაცია ჰქონდა საშიშროების ექსპლუატაციის შემდგომ: 1) სეისმურობის მქონე რეგიონი ნაკადმა მიზნით არ გახდებოდა სკ-ზე არსებობით, ხოლო პარამეტრული არ გამოყოფილი სკ-ზე-თხოვნის. მონაცემების სიგანე და საშიშროების შეფასების შენახვის გამოყოფა, რომ შემთხვევა, რომ იგი განახლებული ვერაზაშქვით იყო რეალური ტექნიკის შეფასების შემდგომ.
Модели определения и параметризации зон сейсмических очагов для Грузии и окружающего региона

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Резюме

Развитие моделей зон сейсмических очагов (ЗСО) является первым шагом в осуществлении анализа вероятностной сейсмической опасности (АВСО), так как от них в основном зависит достоверность окончательных результатов оценки сейсмической опасности. Определение этих моделей включает разграничение ЗСО и их параметризацию. Следует отметить, что в практических приложениях, когда не существуют четкие процедуры построения ЗСО, это приводит к большим изменениям в вычислениях опасности и к неправдоподобным результатам.

На Кавказе, где активные разломы четко определены и параметризованы, а сейсмичность относительно хорошо документирована, используется, развитый нами метод разграничения ЗСО. Процедура построения ЗСО основана на выделении вдоль активного разлома площади определенной ширины. Ширина ЗСО зависит от данных о ширине разлома, наклона плоскости разлома, мощности сейсмоактивного слоя, геометрических размеров очага землетрясения. Асимметрия ЗСО относительно осевой линии разлома является характерной чертой этих построений. На основе этого метода были выделены ЗСО для Грузии и окружающего региона.

Каждая ЗСО выражается набором параметров, которые будут представлять собой базовые данные для оценки сейсмической опасности. Оценки $M_{\text{max}}$ проводились на основе трех сейсмологических и двух геологических методов.

Параметр $b$ распределения амплитудно-частотных характеристик был рассчитан для 16 обобщенных тектонических единиц, для которых сейсмическая статистика была достаточно полной, а параметр $a$ был определен для каждой ЗСО. Изучение глубинного распределения землетрясений показало, что сейсмичность в этом регионе в основном неглубокая.