BASIC DATA FOR COMPILATION OF A SPECIAL MACROSEISMIC SCALE FOR ASSESSING THE INTENSITY OF HISTORICAL EARTHQUAKES IN THE ARMENIAN UPLAND

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Abstract. *To compile a macroseismic scale for assessing the intensity of historical earthquakes in the Armenian Uplands, it is proposed to use two groups of the consequences of modern large earthquakes: characteristic damage to the buildings of Armenian churches and seismogeological effects. These consequences are more often found in written information about historical earthquakes of the Armenian Uplands and are quite reliable indicators for determining the degree of intensity.*

Key words: *intensity historical earthquakes, damage church buildings, seismogeological effects.*

Introduction

Preserving heritage in the form of written historical data on large earthquakes is important for determining the main parameters of strong earthquakes. However, it is necessary to have a special macroseismic scale for assessing the intensity of historical earthquakes for this, based on the consequences of earthquakes recorded in written evidence. Corentiy macroseismic scales use three groups of data of impact of an earthquake on objects to estimate intensity: damage to structures, geological objects and people and household items. Unfortunately, currently widely used scales do not include damage to historical monumental buildings depending on the intensity of the historical earthquakes. Types of geological consequences, the so-called seismogeological effects, strongly depend on local natural conditions (geology and geomorphology). The third group of impact-on people and household items, is not so significant [2,3,7]. In this regard, written information about strong earthquakes in the Armenian Uplands for more than 2000 years is unique [4,9,10]. They are preserved in many manuscripts of the Yerevan Matenadaran (research institute for ancient manuscripts).

Therefore, in order to use written historical evidence on the Armenian Uplands to determine the main parameters of past earthquakes, it is first necessary to create a special macroseismic scale based on the damage to historical buildings and the seismogeological effects [4,8]. Information about the historical earthquakes of the Armenian Upland covers a period of time of more than 2000 years. Moreover, the discovered written data are unique in that there are no long periods of their absence, which is very important for studying the patterns of their distribution over time. But despite this, three obvious periods of time with no or little evidence of earthquakes stand out: 550 BC-735 AD; 736-850; 13.20-15.30. For this is the absence, non-preservation of historical information, or its non-detection. Thus, in order to supplement the catalogues of historical earthquakes with new data, it is necessary to continue the search for new primary sources both in manuscripts in Armenian and other languages. Important data can be found in the surviving handwritten monastic journals [10].

Historical evidence of earthquakes on the territory of Armenia contains different data on their consequences. But for the purposes of this article, two groups are important: damage to church buildings and seismic-geological effects.

The main goal of this article is to separate from the consequences of modern large earthquakes in territory of Armenia those are described in the historical evidence of earthquakes in the Armenian Uplands (damage to buildings and seismogeological effects) and which can be "indicators" of the of intensity level assessment.

These consequences (effects) may be of basic importance for the creation of a special macroseismic scale for assessing the intensity of historical earthquakes.

Damage to Armenian church buildings during modern (XX century) earthquakes

In result of inspection of 50 church buildings served the basis for compiling the table of most typical damages of Armenian churches (Table 1) depending on the intensity of 1988 Spitak earthquake [7,9]. The intensity in the church area was determined on the base 1:200,000 scale isoseismal map of the 1988 Spitak earthquake, which was built on the damage degree of the stone 1-2-story, widespread, houses. Both the technical condition of the Armenian churches and their constructive type, the engineering-geological and soil conditions of the building area, etc., were studied in detail. Damage before the 1988 Spitak earthquake was specially studied, that is, due to the 1926 Leninakan earthquake with an intensity of 8-9 points, based on photographs, written data, descriptions of local residents and specialists, and a detailed study of cracks. The change in the intensity of the Spitak earthquake was calculated depending on the local conditions [7].

It is known that most of the church buildings damaged by earthquakes are domed, and the damage or collapse of the dome is very important information for assessing the intensity of the earthquake. Along with this, we have studied church buildings without a dome, as well damage is also important for estimating the intensity of earthquakes.

The table demonstrates that the numbers of observed same-type damage are rather stable. This enabled determining the prevailing intensities (number of events more than 2) that could have caused the considered type of damage in the church building and indicating the corresponding intensity value in the last column of the Table 1.

Table 1. Most typical damages of the Armenian churches due to the 1988 Spitak earthquake.

№	Most typical damages of churches	Number of events		Prevailing intensity by EMS-98
		Churches with domes	Churches without domes	
1	Complete destruction	1	3	X
2	Strong destruction (more than 50 %); Fall of the central dome	2	3	IX –X
3	Partial destruction (less than 50 %); Strong damage (presence of 4 and more through cracks on height of all walls).	3	3	IX
4	Some through cracks (2-3) on all height of church;	3	3	VIII-IX
5	Individual through crack on all height of church; Through cracks in separate parts of church.	6	5	VIII
6	Presence of small cracks, fall of separate stones.	2	5	VII-VIII
7	Absence of appreciable cracks	6	3	VII

Note: *The intensities of 1988 Spitak earthquake in numbers on the territory of church is determined in the map isoseismals [7] and ground conditions.*

Geological consequences of an earthquake (seismogeological effects)

To compile a list of probable seismogeological effects, depending on the seismic intensity for a certain territory, the most reliable way is to study the effects of modern large earthquakes in a given territory. Because the occurrence of seismogeological effects depends not only on the intensity of the earthquake, but also on local geological and geomorphological conditions [1,3,4,5]. On the territory of Armenia in the 20th century there were 4 earthquakes with an intensity of 7 or more unit: 1926 Leninakan (M=5.8, I=8-9, h=5 km), 1931 Zangezur (M=6 ,4, I=8-9, h=16 km), 1968 Zangezur (M=5.0, I=7-8, h=10 km) and 1988 Spitak (M= 7.0, I=10, h=10 km). Unfortunately, detailed data on seismogeological effects are available only for the Spitak earthquake. For the other three earthquakes the data is very scarce. Multilateral detailed field studies were not carried out on the first two earthquakes, and the 1968 Zangezur earthquake was not strong [5,6]. Therefore, in this article we are forced to rely on the geological consequences of the 1988 Spitak earthquake [7,10].

Table 2. The main seismogeological effects of the 1988 Spitak earthquake, depending on the intensity points [10].

N	**Seismogeological effects (quantitative datas are indicated in brackets)**	**Earthquake intensity zone according to EMS-98**
1	Formation of a main fault on the earth surface (total length 37 km, vertical amplitude up to 2 m and horizontal amplitude up to 1 m).	10
2	Formation or activation of large seismic-gravitational structures with the movement of rock masses (weight 2-3 million tons, moving distance 100 m along a slope of 20^0. Depth of the ravine formed in the rear – 25 m, width a – 50 m, length – 350 m. The height of the front "wall" is 5-7 m.).	10
3	Rockfalls (volume of stones rolling down from a height of up to 6-10 m^3) .	10
4	The formation of electrical sparks in the zone of a seismogenic fault, as a result of which dry grass ignited (the width of the ignition zone is up to 10 m).	10
5	Eruption of sandy pulp into the surface along cracks .	10
6	The formation of a pond due to the activation of landslides (pond dimensions 10x30 m, depth up to 2 m).	10
7	Fragmentation of the loose cover layer over seismogenic faults (width zones 10-15 m).	9, 10
8	Soil liquefaction ("islands" with a radius of 5-10 m).	9, 10
9	Formation of small landslides, rockfalls, soil liquefaction.	9
10	Activation of small landslides, numerous small rockfalls.	8, 9
11	The appearance or disappearance of springs. "Boiling" of water in rivers. Disruption of the flow (water balance) of springs (up to 50%). Changes in water level in wells (up to 60 cm).	8, 9
12	Minor changes in the landscape (rockfalls, landslides, cracks, activation of small landslides, etc.).	8
13	Virtually no noticeable geological consequences.	7

Note: *1. Intensity of the 1988 Spitak earthquake in the area of the church is determined based on the isoseismals map and the seismic category of soils [7].*

Conclusions

1. From written evidence of historical earthquakes in the Armenian Uplands, to compile a special macro-seismic scale for assessing the intensity of historical earthquakes, two groups of modern earthquakes consequences were selected: damage to buildings of Armenian churches and seismogeological effects.

They are the most reliable indicators of the intensity of historical earthquakes assessment. To establish relationships between the degree of intensity and different types of consequences (effects), it is proposed to use statistical data on the consequences of modern earthquakes that have been studied in detail and in many directions.

2. Characteristic damage to Armenian churches as a result of large modern earthquakes are fairly stable indicators of the degree of intensity (Table 1), for the following reasons: the uniformity and seismic resistance of church building structures (cross-domed plan of the central hall, three-layer stone walls with lime mortar, the presence of anti-seismic structural elements, etc.), careful selection of the construction site, high quality construction, etc.
3. A compiled list of seismogeological effects depending on the degree of intensity of large earthquakes (Table 2), which can be applied to other regions with a similar geological and geomorphological structure. Most effects, especially in the 10 and 9 intensity zones, are reliable for determining intensity levels. For zones with intensity up to 7 units, there are practically no noticeable geological consequences.
4. The developed approach and the specific results obtained can be useful in compiling special macroseismic scales for assessing the intensity of historical earthquakes in other regions.

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