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ON THE ROLE OF THE RESULTS OF RESEARCH OF THE 1988 SPITAK EARTHQUAKE IN THE DEVELOPMENT OF APPLIED SEISMOLOGY AND SEISMIC PROTECTION

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The destructive 1988 Spitak earthquake is one of the most multilaterally and detailedly studied earthquakes in the world. It had severe consequences, and the international community provided unprecedented humanitarian aid to the victims. Numerous scientific papers have been published about this earthquake based on the obtained factual data and the results of their analysis. All this played a significant role in the development of applied seismology and seismic protection.

The *main objective* is to identify the most significant accumulated factual data and the results of their analysis for modern science, to establish their role in the development of science and to indicate promising scientific tasks.

The *research methodology* is based on the assessment of the importance of factual data, the results of their analysis, the value of the problems solved and the determination of their prospects.

Results of the work: an attempt was made to determine role of the 1988 Spitak earthquake in the development of applied seismology and seismic protection; for the first time, the most important factual data are grouped; the important tasks that were solved on their basis are indicated; 7 promising scientific tasks are presented; the main literary sources of groups of factual data and the tasks solved on their basis are indicated; a number of factual data are presented that are little known for various reasons to a wide range of specialists.

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Introduction. Typically, many areas of applied seismology and seismic protection are developed on the basis of multilaterally and in-depth studied destructive earthquakes. Certainly, the Spitak earthquake of December 7, 1988

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(φ = 40.90; λ = 44.20, M = 7.0, hypocenter depth is 10 *km*, duration of main events is 30–45 *s*) is one of such earthquakes. The 1988 earthquake in Armenia is unique both in its catastrophic consequences and in the scope of research. Therefore, the 1988 Spitak earthquake played a certain role in the development of applied seismology and seismic protection for the following main reasons:

▪ It is one of the most thoroughly and comprehensively studied earthquakes in the world, both in scientific and humanitarian terms.

▪ It took place in a geologically complex region – a collision zone, where numerous geological structures and processes, are observed.

▪ The earthquake occurred on highly urbanized territory, as a result of which various types of buildings and structures were damaged, and basic life support structures were disrupted.

▪ The earthquake had severe and large-scale consequences in social, material, economic, cultural and other respects, which required an appropriate response.

▪ Could not adequately respond to the disaster with its own rescue forces, so multilateral external assistance was provided.

▪ The tragedy marked the beginning of unprecedented international solidarity and humanitarian aid.

▪ The 1988 Spitak earthquake marked the first time in Soviet history that the country's leadership formally requested international assistance, opening the "Iron Curtain" to humanitarian aid. More than 110 countries participated in the rescue and reconstruction efforts in Armenia.

Let us briefly consider the essence and some features of these reasons:

• Leading specialists from both the USSR and 42 other countries addressed various pressing issues in the disaster zone of the 1988 Spitak earthquake. Earthquake recordings were used to study the propagation of seismic waves, their passage through various geological structures, attenuation, and other characteristics. The multiplex nature of the main event of the December 7 Spitak earthquake was revealed, allowing it to be viewed as a process developing in time and space. Up to 40 temporary seismic stations were installed in the earthquake zone to record and study aftershocks, their manifestations, and distribution. Geologists and surveyors have thoroughly studied various structures (faults, seismogravitational formations, landslides, rockfalls, soil liquefaction, etc.) that have formed or become active on the earth's surface. Macroseismic data were collected not only for the territory of Armenia, but also for the territories of Georgia, Azerbaijan, Russia, and Turkey, and based on their generalizations, isoseismal maps were compiled and the features of the manifestation of earthquake intensity were studied. Specialists in earthquake-resistant design and construction studied the features of damage to buildings and structures, identified their causes depending on the intensity of the earthquake, the type of structure, local geological and geomorphological conditions, etc. Damage to the buildings of Armenian churches was separately studied. Important data were obtained about rapid response forces in the event of a disaster, including their effectiveness, the provision of various types of assistance to victims, and much more [1–11].

• The Spitak earthquake of 1988 occurred in the collision zone of the Arabian and Eurasian plates, where the Earth's crust is heavily fractured along numerous faults. The earthquake's formation environment due to regional horizontal movements of crustal blocks at a rate of up to 2 *cm*/year, is highly differentiated. It is estimated that the maximum magnitude of a probable earthquake in Armenia could be up to 7.5 [3, 8, 12, 13]. Connections between powerful earthquakes and regional faults and their intersection junctions have been established. Experts were unanimous in the issue of the connection between the 1988 Spitak earthquake and the highly active Pambak–Sevan fault. They played an important role in assessing seismic hazard and risk, which served as the basis for revising the norms and regulations for earthquake-resistant construction not only in Armenia, but also in other countries [8, 14].

• The earthquake zone has become a natural laboratory for studying the causes of severe consequences, assessing rescue needs, and developing disaster response methods. In the earthquake zone in an area of 10 000 km^2, home to one million people, 514 000 were left homeless. The second and third most populous cities of Armenia, Gyumri and Vanadzor, were destroyed. 32 cities and more than 400 villages were also significantly damaged, of which 11 cities and 58 villages were completely destroyed [3, 7, 10, 15]. The earthquake affected all 6 types of common apartment buildings and numerous 1–3 storey private stone houses, which suffered damage of varying degrees. For example, with seismic impacts of 9 and 10 points on the EMS-98 [16] (the intensity will be indicated below on this scale [17]). Most apartment buildings sustained severe damage (grades 4–5), and a significant number of stone private homes were rendered unusable. Main infrastructure lines (including the railway) located in the intensity zone of 9–10 points and higher were damaged [7, 14, 18, 19].

• The earthquake killed 25 000 people, left 40 000 injured in hospitals, and left 37 000 disabled. Direct material losses were estimated at $15–20 billion. The USSR planned to allocate $12.5 billion to the stricken Arm. SSR, but following the collapse of the USSR in 1991, less than half of this amount was allocated. The blockade of Armenia by Turkey and Azerbaijan significantly affected the recovery efforts [10].

• A number of important factors, such as perestroika and the revision of Soviet foreign policy, the large scale of the earthquake's severe consequences, the presence of a 7-million-strong Armenian diaspora in many countries, and others, played a significant role in the unprecedented humanitarian aid provided to the victims. 113 countries and numerous international organizations provided assistance to the stricken Armenia [10]. Approximately 900 professional rescuers and 30 000 specialists from various organizations (civil defense forces and the USSR army, volunteers, etc.) participated in the rescue efforts. Virtually the entire world extended a helping hand. All this served as an example of how, during a large-scale disaster in the world, many states and international organizations provide humanitarian, rescue, medical, material, and other assistance to the victims. This has become a global tradition, as evidenced, in particular, by the scale of assistance during the devastating earthquakes in Haiti in 2010 and Kahramanmaras in 2023, when more than 100 countries provided assistance to the Republic of Haiti, and 130 countries to Turkey [20, 21].

• So significant and important were the actual data according to the 1988 Spitak earthquake and the results of their analysis, obtained by specialists from all over the world, that IDNDR and IASPEI were created and further in 2023 the database was updated by scientific centers of the Russian Federation (RF) and the USA [21].

A special place is occupied by the factual data obtained from instrumental, geological, geomorphological, macroseismic, and other observations of the various manifestations of the 1988 Spitak earthquake, as well as the results of their analysis, which are widely presented in numerous collections and published works, reports, books, and articles have been written, scientific conferences have been organized, and abstracts and papers have been published, etc.

The Need for the Article. It was noted that there are certain difficulties in finding and using factual data on the Spitak earthquake, since not all factual data have been published (especially data obtained after 1992), a number of solved scientific problems in applied seismology and seismic protection have not received due attention, etc. In addition to the database [21] there are no generalizing works on the important results on the Spitak earthquake and the Spitak tragedy. They are necessary for:

a) reinterpretation of factual data together with similar data on recent earthquakes in light of modern knowledge;

b) effective organization of rescue operations based on quantitative calculations;

c) provision of various types of assistance to the affected population and for many other purposes. Their importance is also due to the fact that such data on destructive earthquakes in the world are extremely scarce. The importance of these data is evidenced by the fact that in 2023, the centers of the RF and the USA updated the “Database of the 1988 Spitak Earthquake. Data and Resources” [21].

Based on the above, there are the following reasons for writing this article, 37 years after the Spitak earthquake:

- The factual data and the results of their analysis were published primarily between 1988 and 1992, before the widespread digitization of scientific articles and their posting on search engines like Google. Often, if they are posted online, they are in the form of scanned pages of scientific papers.
- The dispersal of factual data and its analytical results across various scientific publications creates certain difficulties in locating them. A comprehensive work is needed that, at least as a first approximation, indicates their location.
- The rapid development of methods for assessing the seismic risk of territories requires taking into account important and additional features of the manifestation of powerful earthquakes on the earth’s surface, features of seismic impact on buildings and the causes of their damage, the importance of taking into account the migration of individual tremors of the main event over time and space, etc.
- There are important factual data and we have summarized them, which are little known to the general research community for various reasons: they were in the archive materials, were published 2–3 years or more after the earthquake, language barriers, and low availability of sources about others. Such data primarily includes data obtained from Armenian specialists. For example: the manifestation of earthquake intensity on the earth’s surface according to detailed macroseismic data, generalizations of statistical data on damage to typical apartment and public buildings depending on the intensity of the earthquake and local conditions, data on aftershocks for 1993–2025, detailed maps of damage to residential and public

buildings in the cities of Armenia depending on local conditions and their location in relation to the source, quantitative data on rescue operations, means and actions of rapid response forces, etc.

We have conditionally divided the factual data and the results of their analysis into two groups based on the scale and scope of application: *local* and *regional levels* (see Table). Data that are important for solving detailed problems of seismic protection and applied seismology for a certain territory (mainly Armenia) are classified as a local group level, while data that influences problem solving for any territory belongs to the regional level group. This article focuses on factual data and the results of their analysis at the regional level.

The purpose of this article is to identify the most significant factual data for modern science on the Spitak earthquake of 1988, their grouping and the results of their analysis, which significantly influenced and may influence the development of applied seismology and seismic protection. Some promising scientific problems that can be solved based on these data and data on recent powerful earthquakes around the world are also proposed.

To achieve this goal, the article attempts to address the following *main tasks*:

• identification of the main factual data of the 1988 Spitak earthquake and their grouping in the fields of applied seismology and seismic protection;

• identification of solved scientific problems based on these factual data, of great importance in the development of applied seismology and seismic protection with the indication their literary sources and level significance (local, regional);

• offer some promising scientific problems that can be solved on the basis of factual data from the 1988 Spitak earthquake, using similar data from recent powerful earthquakes around the world.

Results concern the methodology of the work, the identification of groups of factual data on the basis of which promising problems have been solved and can be solved.

Materials and Methods. The research methodology is based on the collection and systematization of important factual data and the identification of solved scientific and prospective problems. The main stages of this logical schain are the following: collection and assessment of the reliability of factual data → their grouping by branches of applied seismology and seismic protection → identification of the results of their analysis and solved scientific problems → identification of promising scientific tasks. The article is written on the basis of this diagram. Materials for the research data were selected from a huge amount of archive and literary data on the 1988 Spitak earthquake, which are presented in Table in 14 groups. At the same time in the Table indicated their sources and literary sources of the most important solved problems. Most of the factual data are presented in the following fundamental works:

1) in published summary reports [22–24];

2) in the summary report "Consequences of the Spitak earthquake of 1988 and its manifestation on the earth's surface" (funds of the Institute of Geophysics and Engineering Seismology (IGES) of the Academy of Sciences of the Arm. SSR, Leninakan, 1989, vol. 1 and vol. 2, head of work S.N. Nazaretyan;

3) in published monographs [10, 19] and articles [2, 4, 6, 13, 25–28];

4) in the extended database on the Spitak earthquake [21], compiled by research centers in the RF and the USA. These and other factual data and their sources are listed in more detail and specifically in Table.

The Main Groups of Factual Data and Some of the Most Important Tasks Solved on Their Basis. One of the important features The 1988 Spitak earthquake is the result of comprehensive and detailed research to obtain factual data in the main areas of applied seismology, geology, geomorphology, geodesy, and disaster response (including rescue operations) [2, 5, 6, 9, 12, 14, 22, 26, 29, 30–41]. Factual data (including so-called similar data, which have almost the same significance and are defined quite clearly) In general, they concern: instrumental records of earthquakes; manifestations of earthquake intensity on the Earth's surface; damage to different types of buildings and structures in different intensity zones and geological conditions; seismogeological effects, rescue operations and actions of rapid response forces, etc. They played an important role in the development of these scientific areas and can play the same role in solving modern problems. Table presents 14 groups of factual data representing the main branches of seismology and seismic protection. Some other indicators of factual data are also given and their literary sources are indicated.

Groups of factual data from the 1988 Spitak earthquake, on the basis of which problems of applied seismology and seismic protection were solved

No.	Groups of factual and other similar data	Some indicators of actual and similar data	Important tasks that have been solved and can be solved on the basis of the specified factual and similar data	Task level	Literary sources
1	Instrumental records of the earthquake	Seismograms, accelerograms, seismometer records such as IGIS, etc.	Determination of earthquake and aftershock parameters, types and magnitudes of seismic impacts on buildings, identification of wave field features, determination of the geological structure of the environment in which seismic waves pass, study of the behavior of buildings during an earthquake, etc.	regional local, local	[1, 2, 9, 21, 22, 24, 31, 33]
2	Basic parameters of an earthquake	Time, epicenter coordinates, magnitude, hypocenter depth and parameters of focal mechanisms	Assessment of seismic hazard and risk of the territory of the Republic of Armenia and individual objects, etc.	regional local, local	[1, 4, 6, 19, 21, 22, 24, 42]
3	The main event of the earthquake	Individual shocks, their parameters, time intervals between them, their location etc.	Establishing the connection between tremors and the faults formed, their influence on the macroseismic field and the distribution of aftershocks, establishing the picture of the destruction of buildings associated with the migration of individual tremors of the main event, etc.	regional local, local	[6, 13, 19, 22, 24, 27, 33]
4	Aftershock data	Catalogue, maps of epicenter locations, diagrams of distribution in time and depth, parameters of focal mechanisms	Segmentation of the aftershock zone, determination of the deep parameters of the resulting fault (depth, width and tilt), and the likely direction of the aftershock zone development. Identification of aftershock attenuation characteristics, including by segment and depending on the magnitude and depth of the shocks hypocenter, determination of the geological structure of the seismic wave passage environment, etc.	regional local, local	[1, 2, 4, 6, 21, 22, 24, 27, 36]

5	Regional geological structures formed on the Earth's surface	Main fault with a total length 37 *km* and its individual fragments of 10 *km* or more in length, seismic-gravity structures with the movement of rock masses weighing more than 2 mln tons, etc.	Seismotectonic mapping. Assessing seismic hazard and risk. Determining the distribution of earthquake intensity on the Earth's surface, block movement parameters, and tectonic stresses. Identifying the mechanisms of their formation, development, and more	regional local, local	[4, 6, 8, 13, 19, 22–24, 27, 35, 43]
6	Seismogeo-logical effects of local significance	FAULTS, collapses, landslides, rockfalls, soil liquefaction, etc.	Determination of their impact on damage to buildings and structures, detailed assessment of seismic hazard, seismic microzonation, compilation of macroseismic scales, etc.	local	[2, 8, 12, 19, 24, 41, 44, 45]
7	Macroseismic data	Data on building damage, changes in the geological and environmental environment, and human perceptions. Data from building surveys in 500 populated areas in Armenia, Georgia, Turkey, Azerbaijan, and Russia	Compilation of isoseismal maps at various scales (1:200 000 for the territory of Armenia and 1:500 000 (for the Caucasus Region). Study of the features of earthquake intensity manifestation on the Earth's surface, identification of the causes of local anomalous changes in seismic intensity, etc.	local	[15, 17, 21, 24, 40, 41, 46, 47]
8	Major losses of the earthquake	Human, material, cultural, economic, and other losses throughout Armenia and in cities. Losses of housing, educational and workplace facilities, healthcare facilities, etc. Damage to structural elements. Determining the number of homeless, hospitalized and evacuated, seriously ill, disabled, etc.	Establishing the scale, nature and causes of major losses, assessing the cost of direct losses, and the amount of restoration work. Calculating the number of damaged buildings and lines. infrastructure, losses of emergency response services, production, agricultural, cultural and other losses. Job losses, number of schoolchildren deprived of educational opportunities. Determining the number of victims in cities and villages, evacuees, and homeless people	local	[3, 10, 11, 20, 21, 24, 45, 46,]
9	Data on damage to different types of buildings and structures	The degree of damage to buildings and structures depending on the intensity, structural type, local conditions, etc.	The main causes of damage to buildings and structures, as well as errors made during design, construction, and operation, have been identified. Recommendations for improving the seismic resistance of buildings, a revision of Armenian building codes, the development of new seismic-resistant structures and standard buildings, and stricter rules for project evaluation and building operation have been provided. Methods for restoring and strengthening damaged buildings, increasing their seismic resistance, and more are proposed	regional local, local	[3, 7, 11, 15, 18, 19, 21, 23, 24, 26, 34, 43, 46, 48, 49, 50]
10	Maps of damage to different types of buildings in territories and cities	Maps of damage to typical residential and public buildings in the cities of Gyumri, Vanadzor, Spitak, Stepanavan, Akhuryan, Ashotsk, Amasia were compiled, indicating the type, number of storeys, soil and seismic conditions, terrain, etc.	Study of seismic resistance of elongated buildings depending on their location relative to the earthquake source and intensity. Quantitative assessment of the influence of engineering-geological and topographic conditions on changes in seismic intensity. Evaluation of the reliability of seismic microzonation methods	regional local, local	[10, 19]
11	Data on damage to buildings of Armenian churches depending on	Detailed data on damage to 50 churches, identifying damage patterns depending on intensity and local geological conditions and	to identify patterns of damage to cross – central domed church buildings depending on earthquake intensity and local conditions. To study the vulnerability of different structural types of church buildings and their individual elements,	local	[10, 19, 47]

	the intensity of the earthquake	topography. Description of the main damage	as well as the dependence of the nature of damage on geometric parameters of buildings. Creation of a special macroseismic scale for assessing the intensity of historical earthquakes in the Armenian Highland based on damage patterns and seismogeological effects		
12	Data on changes in geophysical, geodynamic fields and chemical composition of mineral waters before and after the earthquake	Data from hourly measurements of the magnetic field, radon emanation, artesian water levels at stationary stations and changes in the chemical composition of mineral waters both before and after the earthquake	Establishing the nature of changes in various field parameters to identify precursors of strong earthquakes. Evaluation of current seismic hazard using computer programs based on a set of measurement data at stationary stations, and studying the regime of these fields	regional local, local	[3, 24, 34, 51, 52]
13	Data on rapid reaction forces and their actions	The number of different rescue forces and means. Actions of interdepart-mental and municipal services for: life support (water, electricity, gas, heat supply, electronic communications), provi-ding emergency assistance (rescue, medical, fire), establishing order (police, protection of important facilities, traffic, migra-tion and population), pre-venting the occurrence of infections and epidemics (anti-epidemic, infectious), and burial of unknown victims (funerals)	Planning rescue operations, assessing the needs of rapid response forces, factors affecting their effectiveness, identifying errors in their actions and the causes of low effectiveness. Developing a methodology for effective action. Assessing the need for equipment and important resources (materials, medicines, accessories, etc.) for rescue operations, etc.	regional local, local	[3, 20, 21, 45, 46, 53]
14	Consequences are associated with poor preparedness of the population and local authroitis	Examples of thoughtless actions of people and poor preparedness of local authorities, which led to unnecessary losses and contributed to the emergence of a disaster	Publishing a textbook and materials on seismic protection for various groups of people and local governments. Developing rules for individual behavior before, during, and after an earthquake. Developing a methodology for teaching these rules to children of different ages. Publishing a popular book on illegal structural modifications to apartment and public buildings, factories, etc., which led to a reduction in their seismic resistance	regional local, local	[3, 46, 53]

Table shows that research into the 1988 Spitak earthquake yielded a vast amount of factual data across virtually all major areas of seismology, geotectonics, and seismic protection. This enabled leading global specialists to obtain scientific results that contributed significantly to the advancement of applied seismology and seismic protection. These results include studies of the structural features of the earthquake's epicentral and focal zones, the structural patterns of the aftershock zone and its dynamics, the manifestations of earthquake intensity on the earth's surface, data on the earthquake's seismic impact on buildings and structures, the causes of damage to buildings and structures, the actions of rapid response forces and the provision of various types of assistance to victims, the publication of new textbooks on seismic protection, and many other results that played a significant role in the development of methodological approaches, seismic hazard and risk assessment, and risk mitigation. Thirty-seven years after the earthquake, the significance of these scientific results in advancing these areas can be more confidently noted.

In order to improve the seismic safety of Armenia, coordinated steps have been taken. In particular:

a) in 1991, the National Seismic Protection Service under the Government of the Republic of Armenia was established, which in a very short time reached the international level;

b) a powerful and modern rescue service of the Ministry of Internal Affairs of the Republic of Armenia was created;

c) a number of laws were adopted, including the 2002 "Law on Seismic Protection" and numerous by-laws regulating works in various areas of seismic protection;

d) in 1994, Armenia, the first of the former Soviet republics, adopted Armenian building codes corresponding to local conditions;

e) methods for improving the seismic resistance of buildings and structures were developed;

f) the rules for the examination of construction projects and building operation were tightened;

g) methods for improving the seismic resistance of existing residential buildings, without evacuating residents, were proposed and implemented;

h) the RA government successfully implemented a large-scale program of "300 earthquake-resistant schools and 500 kindergartens";

i) an unprecedented large-scale construction of residential buildings was carried out in accordance with new, more stringent earthquake-resistant construction standards, etc. [3, 7, 15, 42, 49].

Some Promising Scientific Problems Arose from the Results of the Research into the 1988 Spitak Earthquake. In our opinion, the following are important scientific problems that can be solved in the future on the basis of factual data and the results of the solved problems:

a) *Developing a methodology and studying the multiple nature and other features of the main event of recent large earthquakes around the world.* This will allow us to consider an earthquake as a tectonic process developing in space and time. Along with the main parameters of an earthquake, they are important for determining the distribution of its intensity on the earth's surface, explaining patterns of damage to buildings and structures located far from the official epicenter of the earthquake, the formation or activation of regional faults, etc. For this, it will be necessary to use instrumental records, macroseismic data, and the formed large geological structures (see Table, No. 1–5). The first shock does not necessarily have the greatest magnitude. Most likely, this is due to the peculiarities of the "hook" of the movement of blocks along the fault, as a result of which the earthquake was prepared. Usually, the main parameters of the first shaking and the time intervals between shocks are reliably determined from seismograms. When determining the coordinates of the epicenters and the depths of the hypocenters of other tremors, it is necessary to use data sets, especially macroseismic and aftershocks. It is also advisable to use data on the formed surface structures, since their parameters, unlike deep ones, are determined quite reliably.

b) *To study the relationship between individual main event shocks generated by regional faults and the internal structure of the aftershock region of recent earthquakes* (see Table, No. 2–5, 7). This relationship has not been sufficiently studied, despite the fact that it is of great importance for segmenting the aftershock region, studying the dynamics of the aftershock zone development, determining the attenuation of the aftershock process in individual segments, establishing the attenuation of aftershocks depending on the magnitude and depth of the earthquake hypocenter, determining the probable direction of development of the seismic process, etc.

c) *Identification of the most complete list of causes of damage to buildings and structures of different types under certain seismic impacts* (see Table, No. 8–10). It is known that destructive earthquakes, like an "X-ray machine", reveal the causes of high seismic vulnerability in buildings and structures. Some of these causes are "hidden" and difficult to detect using existing methods. For this reason, when defining the term "seismic vulnerability" of buildings, some experts suggest determining the degree of vulnerability after an earthquake. This is reliable, but not acceptable for assessing seismic risk. An assessment of the vulnerability of an object should be conducted based on the probable patterns of damage due to an earthquake [18]. This is especially true for errors made in the design and construction of typical buildings (failure to comply with technology, use of materials that do not meet required standards, etc.) [7, 15, 18].

d) *Identification of low efficiency of rescue operations due to uncertainty of the location and time of operations* (see Table, No. 13). The effectiveness of rescue operations, along with known factors, is highly dependent on the time and location of their implementation. It is advisable to know them when planning rescue operations. The Spitak earthquake of 1988 and other earthquakes showed that in most cases the first 3–5 days are the most critical for effective action during a destructive earthquake, and the location of the main rescue operations is the earthquake intensity zone of 9–10 points, where in many developing countries there is large-scale destruction of buildings, people are trapped under the ruins and they get certain types of diseases [10]. Based on the three main consequences of a destructive earthquake: the intensity distribution on the Earth's surface (preliminary isoseismal map), areas of probable destruction of vulnerable buildings and associated disease groups, we can construct a map of probable areas for large-scale rescue operations. In the future, it is necessary to develop and quantify the characteristics of these three important factors and the provision of life-saving assistance.

e) *Based on a set of factual data* (see Table, No. 1, 4–9, 13) developing a methodology and assessment data for quickly calculating the primary losses and rescue needs within 2–3 *h* after an earthquake (without surveys in the earthquake zone). This task is especially important for developing countries, which, in the event of a disaster, will be forced to seek external rescue assistance.

f) *Study of social consequences associated with the insufficient living conditions of the population of the earthquake zone, especially when the recovery process is being delayed* (see Table, No. 13). It is obvious that the living conditions of the population (food, water, rest, preventive and medical care, environment, working conditions, etc.) The entire earthquake zone worsens, which causes various types of diseases. It is important to obtain quantitative data on this impact. These "poor living conditions" became the cause of the activation or emergence of certain groups of diseases [20].

g) *Data collection and study of the full cycle of a large earthquake: accumulation of energy in the Earth's crust, the main shock, aftershocks, healing of the geological environment and preparation of a new earthquake* (see Table, No. 2, 4, 5, 12). Data on the 1988 Spitak earthquake are of great importance for solving this fundamental problem. Especially of great importance in this case are data on the duration of the aftershock process for at least 36 years, the multiplicity of the main event, the amplitudes of block movement along the formed faults, the speed of horizontal movements of the earth's crust according to GPS, as a result of which the earthquake was prepared, etc.

Results and Discussion. Certainly, the 1988 Spitak earthquake is one of those earthquakes that definitely influenced the development of applied seismology-based on quantitative assessment data and results. The analysis was carried out and seismic protection methods were improved. In this specific case, an important role was played by the participation of one of the authors of this article, S. Nazaretyan, in the work on collecting factual data on the consequences of the 1988 Spitak earthquake and on the actions of 12 rapid response services as a specialist and head of work from the Academic Scientific Institute of the Institute of geophysics and engineering seismology of the Academy of Sciences of the Arm. SSR. He has written more than fifty articles on this data and the results of their analysis. Of particular importance are his two monographs [19, 20], which present a certain part of the collected factual data. The authors of this article sought to include in the list of references the main works, containing factual data on the 1988 Spitak earthquake, but understand the difficulties and even impossibility of such an attempt. If any important works have been omitted from this list, the authors of this article apologize.

Conclusion. All of the above allows us to draw the following main conclusions:

• The 1988 Spitak earthquake is unique in terms of the scale of its severe consequences, the detail and versatility of its scientific research, and the international response to the disaster. It played a significant role in the development of applied seismology and seismic protection. The earthquake zone has become a natural laboratory for research in many scientific fields.

• A basis for research in various areas The applied seismology was also based on the actual data on the Spitak earthquake of 1988, which were obtained through instrumental observations, field geological research, interpretation of space images, studies of the impact of earthquakes on buildings and structures, by surveying specialists and the population, etc. These data were obtained by leading specialists from the USSR and many other countries. We have attempted to group them into 14 groups that have played and will continue to play an important role in scientific research (see Table). The article presents 7 important scientific problems that can be solved on the basis of these and other factual data on recent powerful earthquakes around the world.

• The data obtained on the rapid response services during the Spitak tragedy are important for calculating the necessary forces and resources to increase the effectiveness of these forces in the event of a seismic disaster.

• The experience gained in providing humanitarian aid during the Spitak tragedy served as a catalyst for the development of international humanitarian aid during major disasters worldwide. This has become a global tradition for international organizations and states to provide urgent, free aid.

• The compiled list of scientific literature includes the main factual data and a number of significant works, including those completed in recent years, which were not included in the database on the Spitak earthquake of 1988 [21].

• The body of factual data on the 1988 Spitak earthquake, the results of scientific research, and the accumulated experience in responding to the tragedy played a crucial role in improving Armenia's seismic safety. New laws and regulations, new government structures, and virtually all documents ensuring the country's seismic safety were revised were created. Currently, no issue in Armenia's construction sector is resolved without taking into account the lessons of the Spitak tragedy.

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1988 Թ. ՍՊԻՏԱԿԻ ԵՐԿՐԱՇԱՐԺԻ ՀԵՏԱԶՈՏՈՒԹՅՈՒՆՆԵՐԻ ԱՐԴՅՈՒՆՔՆԵՐԻ ԴԵՐԻ ՄԱՍԻՆ ԿԻՐԱՌԱԿԱՆ ՍԵՅՍՄԱԲԱՆՈՒԹՅԱՆ ԵՎ ՍԵՅՍՄԻԿ ՊԱՇՏՊԱՆՈՒԹՅԱՆ ԶԱՐԳԱՑՄԱՆ ԳՈՐԾՈՒՄ

Ամփոփում

1988 թ. Սպիտակի ավերիչ երկրաշարժը աշխարհի բազմակողմանի և մանրակրկիտ ուսումնասիրված երկրաշարժերից մեկն է: Այն ունեցավ ծանր հետևանքներ, և միջազգային հանրությունն աննախադեպ մարդասիրական օգնություն ցուցաբերեց տուժածներին: Երկրաշարժի առանձնահատկությունների ու ստացված մեծաքանակ փաստական տվյալների ու դրանց վերլուծության արդյունքների, ինչպես նաև հետևանքների, դրանց պատճառների վերաբերյալ գրվել են բազմաթիվ գիտական աշխատանքներ: Այս ամենը նշանակալի դեր է խաղացել կիրառական սեյսմաբանության և սեյսմիկ պաշտպանության զարգացման գործում:

Հոդվածի հիմնական նպատակն է՝ առանձնացնել կուտակված առավել նշանակալի փաստական տվյալներն ու դրանց վերլուծության արդյունքները, ընդգծել դրանց դերը սեյսմաբանական գիտության զարգացման գործում և նշել հեռանկարային խնդիրները:

Հետազոտության մեթոդաբանությունը հիմնված է փաստական տվյալների կարևորության գնահատման, դրանց վերլուծության արդյունքների, լուծված խնդիրների կարևորության և դրանց հեռանկարների որոշման վրա:

Աշխատանքի արդյունքներն են՝ տրված է Սպիտակի 1988 թ. երկրաշարժի դերը կիրառական սեյսմաբանության և սեյսմիկ պաշտպանության զարգացման գործում; ամենակարևոր փաստական տվյալները առաջին անգամ խմբավորվել են 14 խմբերում; ներկայացվել են լուծված կարևոր խնդիրները: Առաջարկվում են 7 հեռանկարային գիտական խնդիրներ, որոնք կարող են լուծվել ստացված փաստական տվյալների և վերջին ժամանակների հզոր երկրաշարժերի տվյալների հիման վրա: Նշվում են մի շարք փաստացի տվյալներ և գիտական արդյունքներ, որոնք տարբեր պատճառներով քիչ են հայտնի մասնագետների լայն շրջանակին:

С. Н. НАЗАРЕТЯН, Г. Г. ХАЧАТРЯН, С. Г. БАКУНЦ, Р. А. АРУТЮНЯН,
А. А. КАЗАРЯН, Л. Б. МИРЗОЯН, Г. А. ИГИТЯН

О РОЛИ РЕЗУЛЬТАТОВ ИССЛЕДОВАНИЙ СПИТАКСКОГО ЗЕМЛЕТРЯСЕНИЯ 1988 Г. В РАЗВИТИИ ПРИКЛАДНОЙ СЕЙСМОЛОГИИ И СЕЙСМИЧЕСКОЙ ЗАЩИТЫ

Резюме

Разрушительное Спитакское землерясение 1988 г., являющееся одним из многосторонне и детально исследованных землетрясений мира, имело тяжелые последствия. Международное сообщество оказало беспрецедентную гуманитарную помощь пострадавшим. Об этом землетрясении написаны многочисленные научные работы на базе полученных фактических данных и результатов их анализа. Все это сыграло заметную роль в развитии прикладной сейсмологии и сейсмической защиты.

Основная цель – выделение наиболее значимых для современной науки накопленных фактических данных и результатов их анализа, установление их роли в развитии науки и указание перспективных научных задач.

Методология исследований опирается на оценке надежности и важности фактических данных, результатов их анализа, ценности решенных задач и определении их перспективности.

Результаты работы: сделана попытка определения роли Спитакского землетрясения 1988 г. в развитии прикладной сейсмологии и сейсмической зашиты; впервые сгруппированы важнейшие фактические данные; указаны важные задачи, которые были решены на их основе; представлены 7 перспективных научных задач; указаны основные литературные источники групп фактических данных и решенных на их основе задач; представлена информация о ряде фактических данных, малоизвестных по разным причинам широкому кругу специалистов.