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With 57 Illustrations

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ისტორიული მიწისძვრები საქართველოში (1900 წ.-მდე) - წყაროების ანალიზი და კატალოგის შედგენა

57 ილუსტრაციით

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Preface

The southern Caucasus is an earthquake prone region where devastating earthquakes have repeatedly caused significant loss of lives, infrastructure and buildings. For modern building codes and land-use regulations in this part of the world a reliable seismic hazard assessment is required. Modern instrumental seismicity is only a part of the data base to assess the seismic hazard.

The matter is that the instrumental period (around 100 years) is very short in comparison with the recurrence time of strong earthquakes in the southern Caucasus (of 1000 years' order), which means that assessment of seismic hazard based on instrumental data might seriously underestimate its real value. Consequently, widening of seismic catalogue time scale is a must for regions, such as the southern Caucasus, with relatively long waiting times of strong earthquakes. In turn this means that it is of major importance for correct assessment of seismic hazard of Georgia to compile a reliable catalogue of historical earthquakes.

Remainders of landslides, surface traces of slipped faults are natural indicators of sometimes prehistoric earthquakes and can be found via paleoseismological investigations, but the information on historical seismicity is only provided in highly developed areas. To combine these different sources of information on seismicity in a compilation of seismicity a multidisciplinary approach is required where e.g. teams of seismologists, geologist and historians work together in a systematic way. The southern Caucasus has been an early culturally highly developed region which provides a wealth of information on earthquakes in historical times. These earthquakes have been addressed in this compilation.

The teams have been successful in the identification of the reliability and insufficiency of the information – either natural or historical. They had to deal with the incompleteness in the historical descriptions and were also aware of potential misinterpretations and the general seismotectonic conditions of Georgia.

The new compilation is a synthesis of 44 earthquakes for each of which parameters such as date, location, magnitude and focal depth are summarized. The detailed description of the individual earthquakes enables the reader, on the bases of citations of historical descriptions, to obtain an overview on basic quantities of information used for individual events. Furthermore, the reasoning for the individual intensity classification is justified.

The total compilation of these data leads to an improved map of the maximum damage distribution for historical earthquakes in Georgia, which is important as contribution to modern seismic hazard and risk assessment.

January 15, 2011 B. Müller, T. Chelidze

წინასიტყვაობა

სამხრეთ კავკასია სეისმურად აქტიური რეგიონია, სადაც დამანგრეველ მიწისძვრებს არაერთხელ გამოუწვევიათ მოსახლეობის, ინფრასტრუქტურის და შენობა-ნაგებობების მნიშვნელოვანი დანაკარგები. მსოფლიოს ამ ნაწილში თანამედროვე სამშენებლო ნორმების და მიწათსარგებლობის წესების დასადგენად აუცილებელია სეისმური საშიშროების საიმედო შეფასება.

თანამედროვე ინსტრუმენტული სეისმურობა არის მხოლოდ ნაწილი მონაცემთა ბაზისა, რომლითაც ფასდება სეისმური საშიშროება. საქმე ის არის, რომ ინსტრუმენტული პერიოდი (დაახლოებით 100 წელი) ძალიან მოკლეა სამხრეთ კავკასიაში ძლიერი მიწისძვრების განმეორებადობის პერიოდთან (1000 წლის რიგის) შედარებით, რაც ნიშნავს, რომ ინსტრუმენტულ მონაცემებზე დაფუძნებულმა სეისმური საშიშროების შეფასებამ შეიძლება ვერ განსაზღვროს მისი რეალური სიდიდე. მაშასადამე, სეისმური კატალოგის დროითი ჩარჩოების გაფართოება აუცილებელია ისეთი რეგიონებისთვის, როგორიც სამხრეთ კავკასიაა, სადაც შედარებით ხანგრძლივია ძლიერი მიწიძვრების მოლოდინის დრო. თავის მხრივ ეს ნიშნავს, რომ საქართველოს სეისმური საშიშროების სწორი შეფასებისთვის დიდი მნიშვნელობა აქვს ისტორიული მიწისძვრების საიმედო კატალოგის შედგენას.

მეწყრული წარმონაქმნები, რღვევებზე წანაცვლების ზედაპირული კვალი ზოგჯერ არის ისტორიამდელი მიწისძვრების ბუნებრივი ინდიკატორი და ისინი შეიძლება ნაპოვნი იქნას პალეოსეისმოლოგიური გამოკვლევებით, მაგრამ ისტორიული სეისმურობის შესახებ ინფორმაცია მოიპოვება მხოლოდ მაღალი განვითარების მქონე რაიონებში. სეისმურობის დადგენისას მასთან დაკავშირებული ინფორმაციის სხვადასხვა წყაროების გაერთიანებისთვის საჭიროა მულტიდისციპლინური მიდგომა, როდესაც მაგალითად სეისმოლოგების, გეოლოგების და ისტორიკოსების გუნდები სისტემატურად თანამშრომლობენ. სამხრეთ კავკასია წარსულში კულტურული თვალსაზრისით მაღალგანვითარებული რეგიონი იყო, რაც უზრუნველყოფს მდიდარ ინფორმაციას მიწისძვრებზე ისტორიული დროის განმავლობაში. Eეს მიწისძვრები არის განხილული წარმოდგენილ განზოგადოებაში.

გუნდებმა მიაღწიეს წარმატებას ბუნებრივი ან ისტორიული ინფორმაციის სანდოობისა და უკმარობის ობიექტურ შეფასებაში. მათ საქმე ჰქონდათ არასრულ ისტორიულ აღწერებთან და აგრეთვე იცოდნენ, რომ ანგარიშგასაწევი იყო პოტენციური უზუსტობანი ინტერპრეტაციაში და საქართველოს ზოგად სეისმოტექტონიკურ მოდელებში.

ახალი განზოგადოება არის 44 მიწისძვრის სინთეზი და მათთვის დადგენილია ისეთი პარამეტრები, როგორიცაა თარიღი, ადგილმდებარეობა, მაგნიტუდა, კერის სიღრმე. ინდივიდუალური მიწისძვრების დეტალური აღწერა მკითხველს აძლევს საშუალებას, ისტორიული აღწერების ციტატების საფუძველზე, მიიღოს ზოგადი წარმოდგენა ძირითადი ინფორმაციის მოცულობის შესახებ, რომელიც იყო გამოყენებული ინდივიდუალური მოვლენებისთვის. გარდა ამისა, მოცემულია დასაბუთებული მსჯელობა ცალკეული მოვლენის ინტენსიობის კლასიფიკაციის შესახებ.

ამ მონაცემების განზოგადოება საშუალებას იძლევა აიგოს საქართველოში ისტორიული მიწისძვრებით გამოწვეული მაქსიმალური დაზიანებების განაწილების გაუმჯობესებული რუკა, რომელსაც მნიშვნელოვანი წვლილი შეაქვს თანამედროვე სეისმური საშიშროების და რისკის შეფასებაში.

15 იანვარი 2011 წ. ბ. მიულერი, თ. ჭელიძე

Contents

1
Introduction

The intention of this compilation of historical earthquakes in Georgia is to provide an up-to-date tool to improve the seismic hazard assessment of Georgia. This can be used for the proper design of land-use and building codes in order to contribute to the safety of the country.

Georgia is a region with around two thousand years of historical data on earthquakes. Long-term seismic history is an important information basis for the allocation of earthquakes sources, and reliable assessment of seismic hazard and risk. Such information about the strong earthquakes is contained mainly in the seismological, historical, archaeological and geological sources and finally it is accumulates in the earthquakes' catalogues. Therefore, the completeness of these catalogues, especially in their very long, historical part (before 1900) is very important because a lack of data on the destructive historical earthquakes cannot be compensated even by complete instrumental data.

For regions with rich historical past such as Georgia which is known for its vulnerability to devastating earthquakes, a detailed and reliable knowledge of the historical seismicity is of great importance for regional seismic hazard assessment. Historical chronicles collected in museums, libraries and special archives of Georgia, the Caucasus and the Middle East, reports on archaeological excavations from the archaeological centers of Georgia, seismodislocation research materials from various geological institutions in Georgia and its neighboring countries, contain numerous descriptions of seismic events which occurred on the territory of Georgia in the historical past. Survived historical sources indicate the presence of high seismicity which entailed numerous human casualties and destruction on the territory of Georgia during the historical period.

Since 2007 within the framework of the international research project INTAS-South Caucasus 9130 ("Stress Related Geohazards in South Caucasus") a work was launched which studied the primary sources of historical earthquakes (of pre-instrumental period) in Georgia based on multi-disciplinary approach, i.e. through the sharing of techniques and analysis of data of historical seismology, paleoseismology, archeoseismology, seismotectonics, geomorphology, etc. This work continued in the international research projects: NATO SFP 983038 ("Seismic Hazard and Risk Assessment for Southern Caucasus – Eastern Turkey Energy Corridors") and EMME ("Earthquake Model of the Middle East Region"), which ultimately made it possible to identify, organize and use the necessary information to make a new unified parametric catalogue of historical earthquakes in Georgia. We studied 47 historical earthquakes and rated the intensity for each populated locality with a particular methodology. The final parametric catalogue for 44 historical earthquakes containing the data on the date and location of the epicenter, magnitude and depth of the focus and intensity in the epicenter, is presented. Three earthquakes had to be excluded from consideration because of the uncertainty in the input data. This catalogue to some extent reduces the spatial and temporal heterogeneity of the material met in previous catalogues and improves the precision of determining the basic parameters of historical earthquakes.

After sorting, replenishing and revising the data on historical earthquakes of Georgia we decided to present the results not only as a catalogue of key parameters (date, coordinates of epicenter, depth, magnitude, intensity at the epicenter) of historical earthquakes, but as a "descriptor" for each event introduced in the catalogue. The "descriptor" contains: a description of the earthquake based on various sources and evaluation of the intensity by MSK scale, a short analysis of these data; final earthquake parameters indicating the precision of their determination. It also contains a map of isoseismals, intensity points, seismodislocations, landslides and avalanches, earthquakes epicenters and tectonic faults.

We hope that the new catalogue of historical earthquakes in Georgia and a proper database will serve the seismic safety of the country.

2
Seismotectonic Conditions of Georgia

Georgia, the southernmost part of Eastern Europe, situated between the Russian Federation (to the north) and Armenia and Turkey (to the south), occupies the western part of the South Caucasus. It is bounded to the west by the Black Sea and by Azerbaijan – to the east. The landscape of Georgia is characterized by extreme variations of natural environment – contrasting relief and diverse landscapes with varied climate zones, hydrogenous regimes, topsoils, vegetation, mineral deposits, thermal and mineral springs, etc. The main morphological units of Georgia are the mountain ranges of the Greater and Lesser Caucasus separated by the Black Sea-Rioni (Colkhis) and Kura (Mtkvari)-South Caspian intermountain troughs (Fig. 1).

Fig. 1. Georgia – the western part of the Black Sea-Caspian Sea region (Adamia et al., 2008).

The tectonics and geological evolution of Georgia and the Caucasus, or Black Sea-Caspian Sea region as a whole, are largely determined by the region's position between the still-converging Eurasian and Africa-Arabian lithosphere plates, within the wide zone of a continental collision and deformations.

The territory of Georgia hosts only some of the mentioned zones: the Greater Caucasus and Achara-Trialeti fold-thrust mountain belts, the Rioni and Kura intermountain depressions, the Northtranscaucasian (the Georgian Block) and Southtranscaucasian (the Artvin-Bolnisi Block) terranes, the Javakheti and Keli-Kazbegi volcanic highlands with extinct volcanoes (Fig. 2).

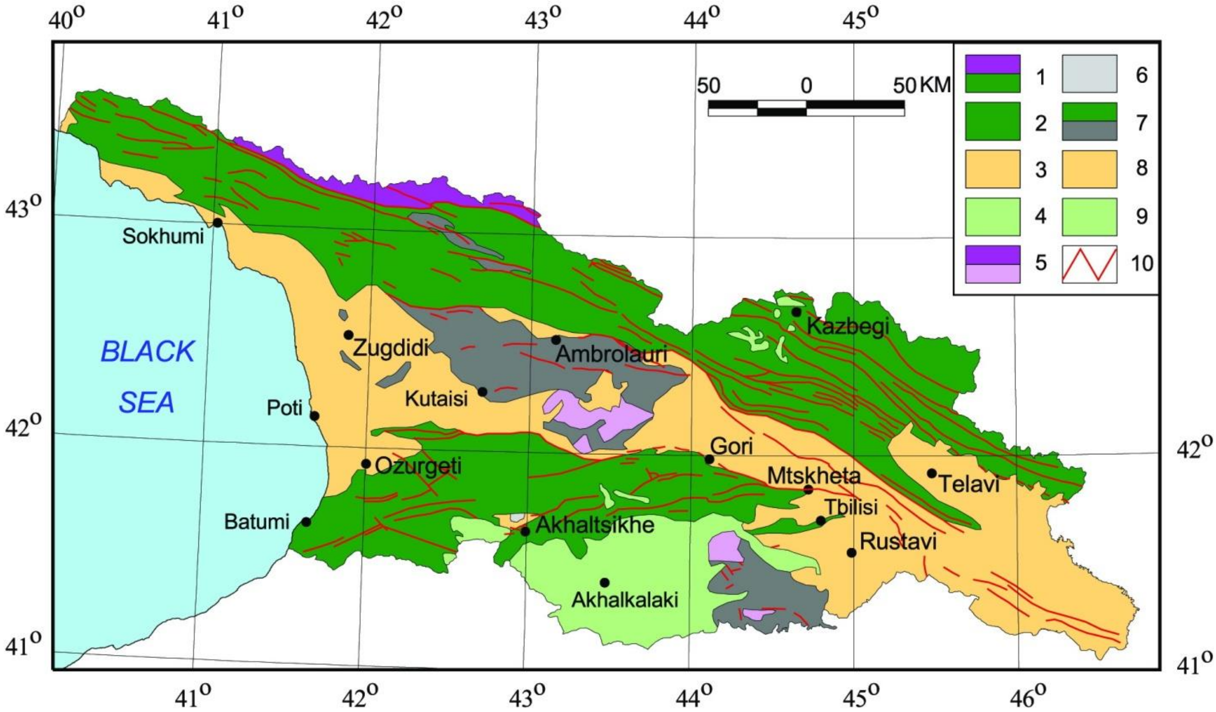

Fig. 2. Tectonic map of Georgia (Adamia et al., 2008).
Main tectonic units: Fold-trust mountains: 1 – Great Caucasus, 2 – Atchara-Trialeti; Intermountain through: 3 – Transcaucasian, 4 – Neogene-Quaternary volcanic highlands and extinct volcanoes. Main tectonostratigraphic unites (TSU): Precollisional: 5 – Precambrian-Paleozoic basement, 6 – Paleozoic TSU, 7 – Mesozoic-Early Cenozoic; Syn-postcollisional TSU: 8 – Oligocene-Quaternary molasses, 9 – Neogene-Quaternary continental volcanic complex, 10 – Faults.

Recent geodynamics of Georgia and adjacent territories of the Black Sea-Caspian Sea region, as a whole, are determined by its position between the still-converging Eurasian and Africa-Arabian plates. According to geodetic data (Fig. 3), the rate of this convergence is ~20-30 mm/y, of which some 2/3 are likely to be taken up south of the Lesser Caucasian (Sevan-Akera) ophiolitic suture, mainly in south Armenia, Nakhchivan, Northwest Iran and Eastern Turkey. The rest of the S/N directed relative plate motion has been accommodated in the South Caucasus chiefly by crustal shortening (DeMets et al., 1990; Jackson and Ambraseis, 1997; Allen et al., 2004; Reilinger, 2006).

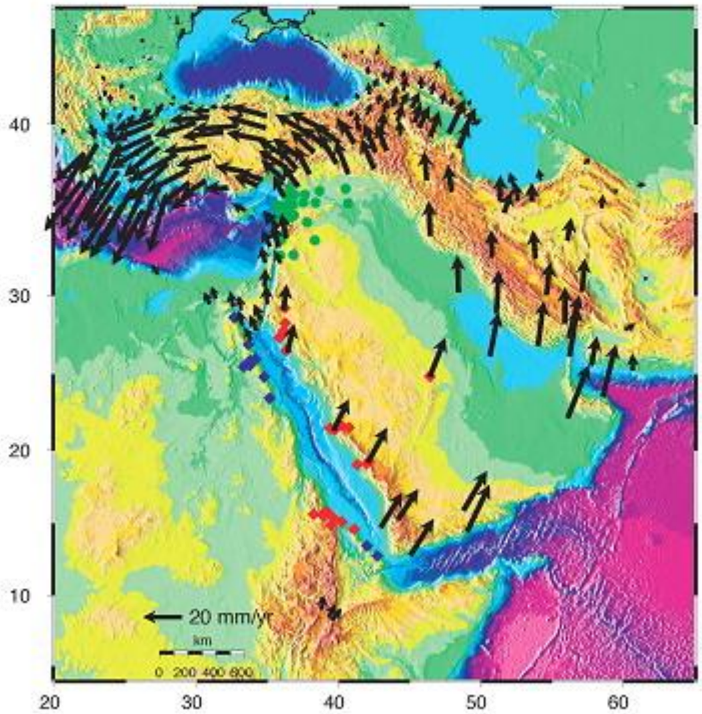

Fig. 3. GPS-derived station velocities for the zone of interaction of the African, Arabian, and Eurasian plates from data spanning the period 1988-2005 (Reilinger, 2006).

Georgia, where due to collision of two lithosphere plates a crustal strain accumulates and large earthquakes occur is one of the best places for studying regional tectonic processes and for prediction of many processes evolving in the Earth's crust (i.e., tectonic and seismic processes, seismic hazard, induced exogenous processes-landslides, debris flows, etc.). High geodynamic activity of the region expressed in both seismic and aseismic deformations, is conditioned by the still-ongoing convergence of lithospheric plates and northward propagation of the Afro-Arabian continental block at a rate of several cm/year. This is indicated by numerous paleoseismodislocations, contrasting neo-tectonic movements and related seismic activity.

Seismoactive structures are identified mainly on the basis of the correlation between neotectonic structures of the region and earthquakes. The correlation is based on the data derived from comparison of real sizes 3-dimensional geological and seismological objects (faults, earthquakes focuses). The direct result of such investigation, first of all, was identification of zones of earthquakes focuses and their parameterization. The complex network of faults determines the division of the region into a number of separate blocks (terrains) of different orders varying one from another by their dimensions, genesis and geologic nature. Geological, paleobiogeographical, and paleomagnetic data provide evidence that these terrains, before being accreted together into a single complicatedly-built fold-and-thrust belt, have undergone long-term and substantial horizontal displacements within the now-vanished oceanic area of Tethys. The boundary zones between these terrains represent belts of maximum geodynamic activity with widely developed tectonic, volcanic, and seismic processes. Almost all of the main faults of the region are clearly expressed in different geophysical fields. They are distinctly visible in the aerial photographs and space images.

Three principal directions of active faults compatible with the dominant near N-S compressional stress produced by northward displacement of the Arabian plate can be distinguished in the region – longitudinal (WNW-ESE or W-E) and two transversal (NE-SW and NW-SE). The first group of structures having the so-called "Caucasian" strike is represented by compressional structures: reverse faults thrusts, nappes, and strongly-related deformed fault-propagation folds. In contrast to these faults the transversal faults are also mainly compressional structures having somewhat a considerable strike-slip component. The tensional nature of sub-meridian faults is evidenced by intensive Neogene-Quaternary volcanism related to these faults in some areas of South Georgia (the Javakheti highland), the Transcaucasia, and the Greater Caucasian range. NE-SW left-lateral strike-slip faults are the main seismoactive structures in NE Turkey, southern parts of Western Georgia and Armenia. Right-lateral strike-slip faults and fault zones are developed in SE Georgia (Fig. 4).

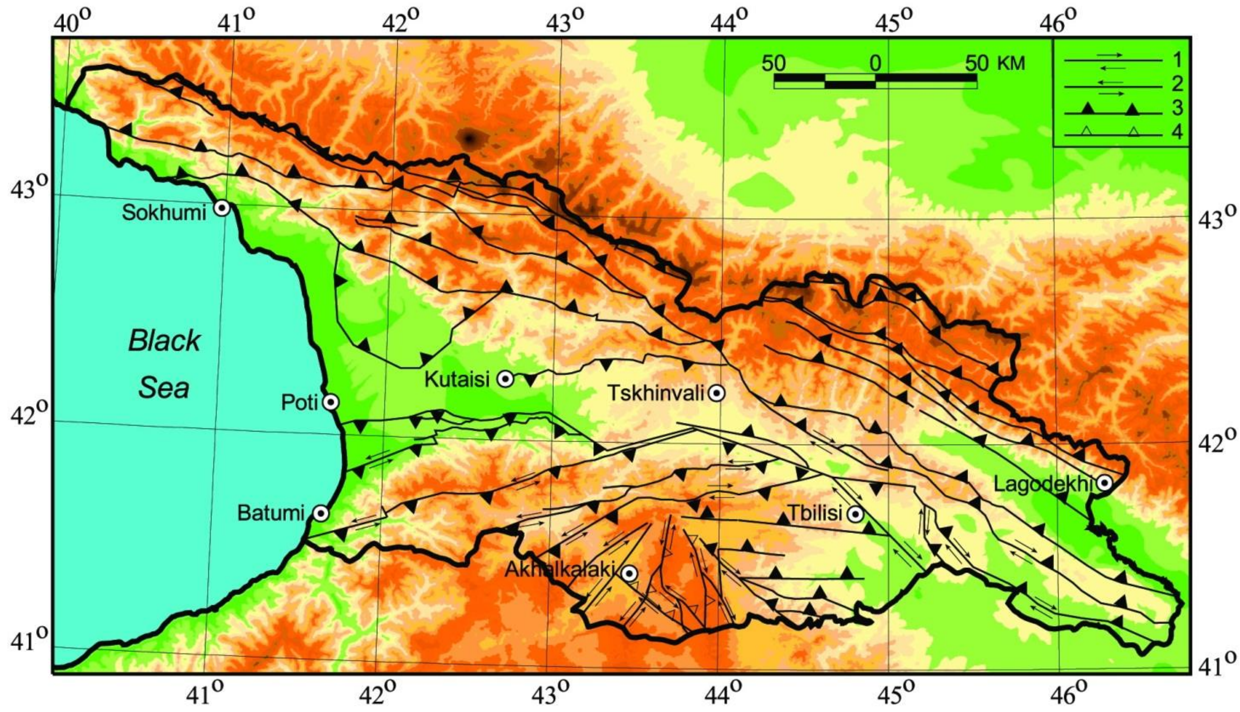

Fig. 4. Active faults of Georgia (Adamia et al., 2008).
Faults kinematics: 1 – right-lateral strike-slips;
2 – left-lateral strike-slips; 3 – reverse faults and thrusts;
4 – normal dip-slips.

Analysis of the focal mechanism of some strong earthquakes in Georgia shows that crustal blocks located to the west of the line running in the submeridional direction across the Javakheti volcanic highland (the volcanoes Aragatz in Armenia; Agridag, Tendurek, Suphan and Nemrut in Turkey) have experienced westward lateral escaping, whereas the crustal blocks located to the east of this line provide evidence of ESE-directed lateral displacement. These data are well corroborated by recent GPS measurements (Adamia et al., 2008).

Over the past historical period of time in Georgia the observed seismicity is characterized as moderate. All historical and instrumental observed strong and moderate earthquake sources ($4.5<M_S<7$) were located along the fault systems of the Greater and Lesser Caucasus and intermountain depressions. The earthquakes distribution by fault plane solution type for moderate and strong earthquakes show just three stress regime as SS (strike slip), TF (thrust fault) and TS (thrust strike). To the contrary, the same histogram of small earthquakes shows all types of stress regimes, though both distributions are quite similar according to preferential mechanism as SS TS and TF. Therefore, the moderate and strong earthquake reflects the regional tectonics that is largely determined by the position of the Caucasus between the still converging Eurasian and Africa-Arabian lithosphere plates. By this classification the south slope of Greater Caucasus is characterized preferable by thrust faults, while the Javakheti upland is more characterized by strike slip faults. The Kura depression is more characterized with thrust-right lateral strike slips faults (Fig. 5).

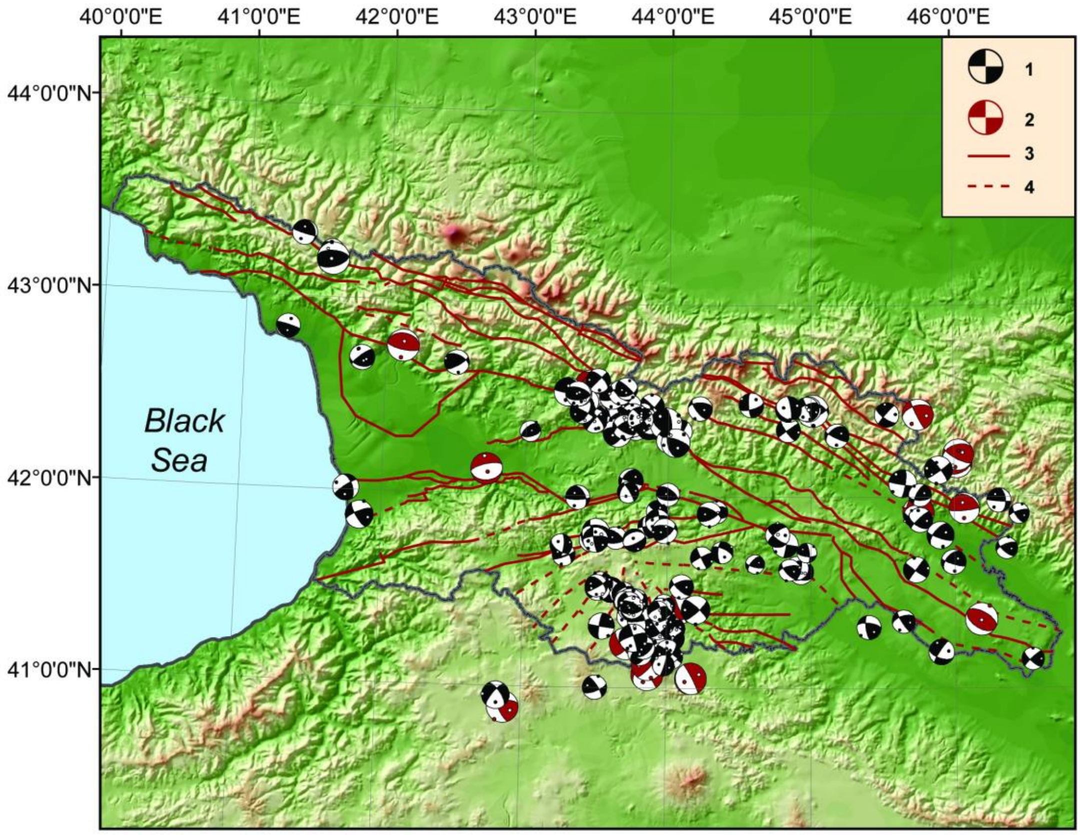

Fig. 5. Earthquake fault plane solutions for Georgia. 1 - Earthquakes fault plane solution using first motion sign; 2 - Earthquakes fault plane solution using frequency sensitive moment tensor inversion technique; 3 - visible active faults; 4 - blind active faults.

3
Previous Works and Sources of the Catalogue

This work discusses the historical earthquakes that occurred in Georgia during the period between 1250 BC and 1900, and the problems associated with their study.

Many monuments of cultural heritage and architectural buildings that are centuries old have the signs of seismic effects. In 85 A.D. a large settlement existing since ancient times and located to the west of the present town Gori, was destroyed. The Tmogvi fortress situated on the Javakheti plateau was ruined in 1088. Historical seismic events in the second millennium (1283, 1350, 1530, 1614, 1742 and etc.) destroyed houses, churches and castles and claimed hundreds of thousands of lives. In this sense, an investigation of selected architectural monuments on the territory of Georgia is very important to obtain more precise information about the main parameters of seismic events of the historical past.

International and national databases of earthquakes keep approximately 50 earthquakes with M_S>3.5 that occurred during the historical period on the territory of Georgia. The strongest ones of them occurred in: Tmogvi (in 1088, M_S=6.5, I_o=9); Samtskhe (in 1283, M_S=7, I_o=9.5); Alaverdi (in 1742, M_S=7, I_o=9.5), etc. The well-known catalogues by I. Mushketov and A. Orlov (1893), N. Malinovsky (1935), V. Stepanyan (1942), Ye. Bius (1948) and etc. contain a great deal of information about these earthquakes.

An attempt to systematize this information was made in the New Catalogue of Strong Earthquakes (1977, 1982) and later in the Catalogue of Strong Earthquakes (M_S≥6) on the territory of the Caucasus that was supported by GSHAP (Shebalin, Tatevossian, 1997). These catalogues were based on the published and manuscript data, numerous articles and research reports concerning individual earthquakes, archive materials, reports from eye witnesses, extracts from geographical descriptions by travelers, press reports and etc. Unfortunately, these catalogues do not contain sufficient and systematic information from primary sources of the description of historical earthquakes, so that contradictory information passed unchanged through these publications. Despite the wide range of analytical work done in compiling these catalogues some arguable interpretation of the data on certain historical earthquakes, inaccuracies in determining the parameters are still preserved in these fundamental studies. In addition, significant information existent in numerous original sources has remained undeveloped. This additional information can provide important data for the quantitative parameterization for the newly discovered historical earthquakes of Georgia. It is noteworthy that only incomplete information on geologic, geomorphologic (seismodislocations, great seismogravitational phenomena, etc.) and archaeological data (traces of past earthquakes in the archaeological excavations, etc.) were used for the parameterization of historical earthquakes in Georgia in each of the above mentioned earlier catalogues.

During the historical period the Georgian State was characterized by high organized institutions on different levels of politics, churches etc. with well-documented history and a wide range of accessible historical, archaeological, geological and other types of materials. The main sources for the study of historical earthquakes in Georgia are diaries of travelers who visited the areas affected by earthquake, historians' chronicles written in Georgian, Greek, Armenian and Russian, existing catalogues and modern seismological articles. Most of these sources are available in the archives of corresponding institutions, archives of large libraries and museums, private foundations in Georgia and abroad, web sites.

This catalogue is based on original documents. Most of them are available at Ilia Chavchavadze National Parliamentary Library of Georgia, National Scientific Library of Georgia, Georgian National Museum, K. Kekelidze Institute of Manuscripts. Consistent consideration of these documents enabled to observe historic seismic events from a new viewpoint, reconstruct them and identify the scales and seismotectonic conditions for their formation, the significance in the evaluation of seismic hazard.

4
Methodology and Laws of Macroseismic Field

Methodology for the establishment of a catalogue of historical earthquakes is based on the transformation of descriptive data of damage in terms of macroseismic intensities as well as on determination of its location, magnitude, focal depth and their errors.

Many researchers have questioned the reliability of using inaccurate and sometimes contradictory historical data for direct assessment of macroseismic intensity even at the epicenter of an earthquake (I_o) and the area affected by it and especially for further evaluation of the magnitude (M) and the focal depth (h) by means of these data. However, the special procedure, namely the control determination of the basic parameters of the present earthquakes, in which above parameters had been determined solely on the basis of macroseismic data and the results had been compared with the main parameters of the earthquakes determined by instrumental data, showed that the method for processing macroseismic data allows to determine the basic parameters of an earthquake with sufficient reliability.

The methodology of interpretation of macroseismic data of historical earthquakes includes the following main tasks:

- Systematic compilation of all available sources of information concerning each historical earthquake.
- Parameterization of historical earthquakes on the basis of macroseismic field equations (equation (M, h, I_o) correlation, equation of attenuation macroseismic intensity). Evaluation of the quality and accuracy of the received parameters.
- Use of models of isoseismals of various magnitudes earthquakes constructed for the territories of Georgia, reconstruction of historic earthquakes with few macroseismic data.
- Complex analysis of macroseismic, archaeological, seismotectonic, geomorphological and other types of data.

Solution of this task was based on the following principles for compiling a catalogue of historical earthquakes:

- The catalogue should consist of only unified parameters.
- The catalogue should include all known historical seismic phenomena ranging from ancient times. All events should be classified in a single system.
- The most precise values of fundamental parameters determined from the totality of existent data should be selected for each phenomenon. The errors of these parameters should also be evaluated.
- In preparing the catalogue all the available information should be used for the identification of each historical earthquake. This process should not be limited to considering only well-known sources. It should search additional data that enable to increase significantly the amount of information and discover new earthquakes.
- Preparation of data for the catalogue should be held in two phases. At first it is necessary to collect and systematize, classify, chronologically arrange the data and eventually create a chronological framework for the catalogue. Consequently, the collected data should be analyzed, the unified basic parameters of earthquakes should be defined and finally they should be as accurately assessed as it was done in (New catalog..., 1980; Shebalin, Tatevossian, 1997).

Some general definitions of unified basic parameters of historical earthquakes were formulated:

- Each parameter should be defined (if possible) by several methods.
- Values of each parameter should be chosen so that there was no contradiction in the original data.
- In case a parameter is indefinable the really available extreme (maximum and minimum) values should be evaluated and then the average value of this range should be accepted as the final value of the parameter.

The relation between the main parameters of an earthquake and the attenuation uniformity of macroseismic intensity is well expressed by the macroseismic field equation system. It consists of two parts: a correlation equation that is a link among the epicenter intensity (I_o), the magnitude (M) and the focal depth (h) of an earthquake; a macroseismic formula characterized by the earthquake intensity attenuation according to the hypocentric distance ($d_i=\sqrt{\Delta_i^2+h^2}$ where Δ_i is the epicenter distance to the i point). Equations with effective attenuation combination are more frequently used in practice (Shebalin, 1968):

$$I_o=bM-\nu lgh+c \quad , \qquad (1)$$

$$I_o-I_i=\nu lg\frac{\sqrt{\Delta_i^2+h^2}}{h} \quad , \qquad (2)$$

here v, b and c coefficients are separately defined for each region.

The v coefficient is called an effective attenuation. The intensity and the development of the earthquake are tightly connected with it. In fact v shows the rheology of the earthquake epicenter region and defines the extent values of the shocks caused by the waves from the focus on the Earth surface.

In order to obtain reliable values of the above coefficient it is necessary to have reliable data about the earthquake intensity, the instrumental magnitude, the intensity value in the epicenter and an isoseismal at an individual point.

For such information we revised the macroseismic and instrumental data of the significant earthquakes which occurred in 1900-2000 in Georgia. A number of studies (New Catalog…, 1982; Bius, 1948; Bius, 1952, 1955; Tskhakaia, Papalashvili, 1973; Macroseismic data…, 1984 and others) and materials about macroseismic effects of individual earthquakes kept in the archives of Institute of Geophysics were used as sources for the macroseismic data.

According to these materials the isoseismal maps were specified and in some cases constructed for 34 earthquakes. The new data about M_S magnitudes of certain earthquakes were taken from the research (Shebalin, Tatevossian, 1997).

On the bases of the interpreted material by means of a certain methodology (Shebalin et al., 1976) the coefficients of macroseismic field equations have been calculated for the territory of Georgia. In particular, by relations of attenuation coefficient and average isoseismal radii

$$\frac{lg r_{i+1}}{r_i}=\frac{1}{\nu} \quad , \qquad (3)$$

v values were defined for individual earthquakes, and after averaging this data we received $\bar{\nu}$=3.4±0.1 for the territory of Georgia. There was an attempt to define v values for individual tectonic zones of Georgia, but any reliable results different from the existing values were not reached.

On the second stage, first the h_i macroseismic depth was evaluated for individual earthquakes by means of the equation (2), and then by the equation (1) the other two coefficient values were calculated: b=1.5 and c=3.1 (Fig. 6).

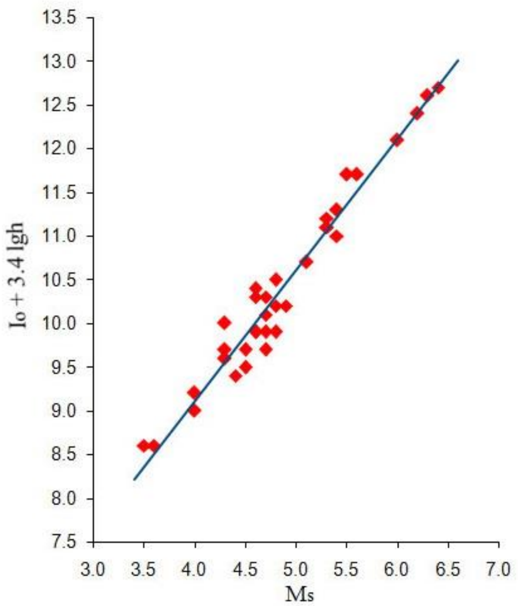

Fig. 6. Definitions of *b* and *c* coefficients of macroseismic field equation for Georgia.

Thus, the macroseismic field equation for the territory of Georgia is formulated as:

$$I_o=1.5M_S-3.4lgh+3.1 \quad , \quad (4)$$

$$I_o-I_i=3.4lg\frac{\sqrt{\Delta_i^2+h^2}}{h} \quad , \quad (5).$$

During the evaluation process it was noticed that near the M_S>6 earthquakes focus zones (approximately within the frames of first three isoseismals) the value of attenuation coefficient is significantly great ν=4.5÷5. This value was verified on the examples of other strong earthquakes of the Caucasus and was mainly corroborated. In this case as well, the coefficients of equation system were calculated b=1.5 and c=4.0 (Fig. 7). Despite the lack of data the macroseismic field equation system for M_S>6 earthquakes is approximately formed as follows:

$$I_o=1.5M_S-4.7lgh+4.0 \quad , \quad (6)$$

$$I_o-I_i=4.7lg\frac{\sqrt{\Delta_i^2+h^2}}{h} \quad , \quad (7)$$

and on its bases we can make certain assessments (Javakhishvili, Varazanashvili, Butikashvili, 1998).

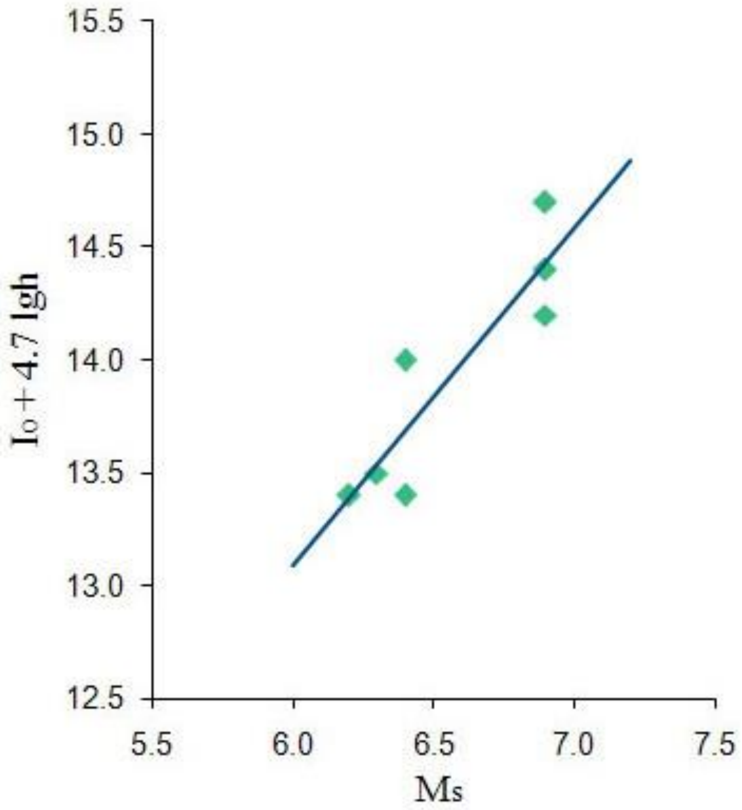

Fig. 7. Definitions of *b* and *c* coefficients for the *M*s>6 earthquakes focus zones in the Caucasus.

By means of interpreting the macroseismic field of Georgia and on the bases of earlier analogical researches (Makrushina, Shebalin, 1982) the isoseismals ellipse models were made for earthquakes of different magnitudes (Table 1). Average declination of real isoseismal contours from the corresponding models contours is 25% (Varazanashvili, 1999).

Table 1. Sizes of isoseismal models

M±0.2	*	*I*=6 (MSK)	*I*=7	*I*=8	*I*=9
7.0	*l*	240 (km)	125	75	40
	s	140	70	40	20
6.5	*l*	165	90	55	15
	s	125	60	30	10
6.0	*l*	140	65	35	-
	s	105	40	15	-
5.5	*l*	95	45	15	-
	s	70	30	10	-
5.0	*l*	60	30	-	-
	s	40	20	-	-
4.5	*l*	40	20	-	-
	s	25	10	-	-
4.0	*l*	20	-	-	-
	s	15	-	-	-

* *l*, *s* – long and short axes of the ellipse.

5
Evaluation of Basic Parameters of Historical Earthquakes

Thus, after establishing the laws of the macroseismic fields of Georgia by analysis of the recent events we evaluated the basic parameters of historical earthquakes. First the date of an earthquake was estimated, then its location, i.e. the coordinates of an earthquake epicenter. In this case the real isoseismal center was adopted for the location of the epicenter of the earthquake, and in case of a small amount of data – the isoseismal model center. The intensity of the epicenter and intensity of each populated area affected by historical earthquakes is estimated on the basis of MSK macroseismic scale, meanwhile analyzing all sources of information and the quality of the material.

In case when macroseismic intensity of historical earthquakes was known for many populated areas, the focal depths of these earthquakes were evaluated by macroseismic formula of the type (2) and specifically by Shabalin's nomograms (New Catalog..., 1982), constructed for different ν values – the intensity attenuation coefficient.

In case of pure macroseismic data the depth of the focus of a historical earthquake was estimated by means of the laws established in the work (Varazanashvili, 1999). Particularly, in 1900-1997 during this work for the $M_S \geq 3.5$ earthquakes of the instrumental period, individually for each four tectonic zones of Georgia (Greater Caucasus and Achara-Trialeti fold-thrust mountain belts, Rioni and Kura intermountain depressions, Javakheti volcanic highland) empirical $N=f_1(h)$ and $M_{max.ob}=f_2(h)$ relations were constructed connecting the number of the earthquakes (N), the observed maximal magnitude ($M_{max.ob}$) and the depth (h). It became obvious that for the above four zones they are approximately similar as shown in the Figures 8 and 9.

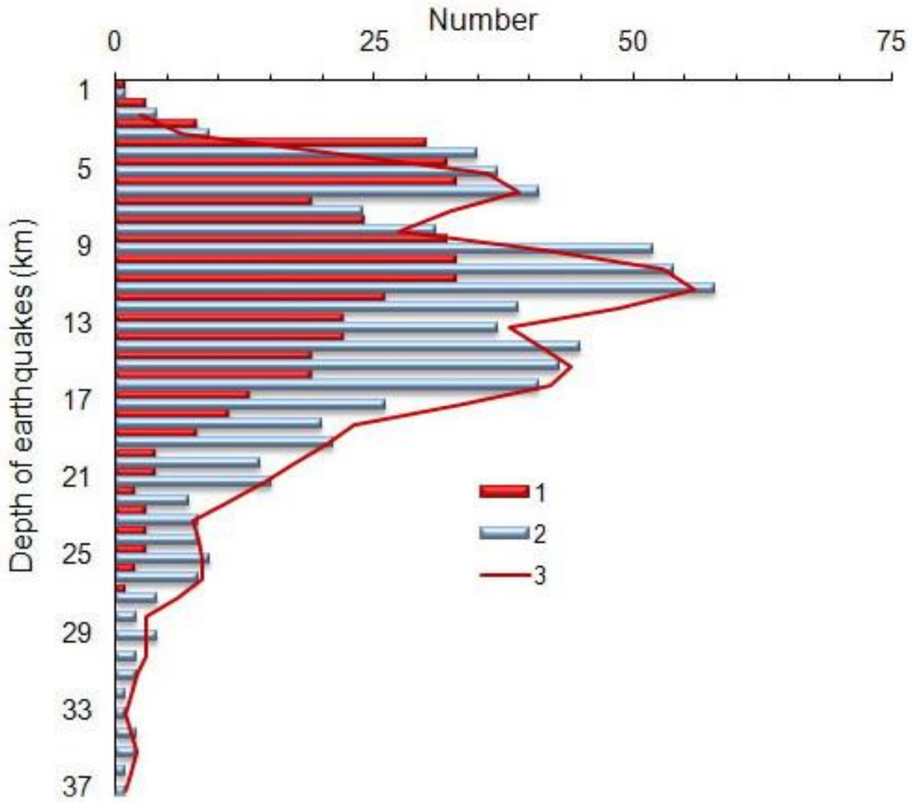

Fig. 8. Histogram of $N=f_1(h)$ relations for: 1 – time period 1962-2009;

2 – time period 1900- 2009; 3 – trend line that was drawn through the moving averaging by step 2 (of time period 1900-2009).

The *N(h)* histogram shows three main depth ranges: Δh_1=3÷8 km ($\bar{h}_1$=5 km), Δh_2=8÷13 ($\bar{h}_2$=11 km) and Δh_2=13÷18 ($\bar{h}_2$=15 km). Hereby, the $M_{max.ob.}(h)$ limiting contour shows that the first range is associated with relatively weak earthquakes (M_S<5) and the second and third ones – with strong earthquakes (M_S≥5). Besides, it is obvious from the histogram (Fig. 7) that earthquakes in Georgia occur mainly in the upper crust (up to 35 km) (Varazanashvili, 1999).

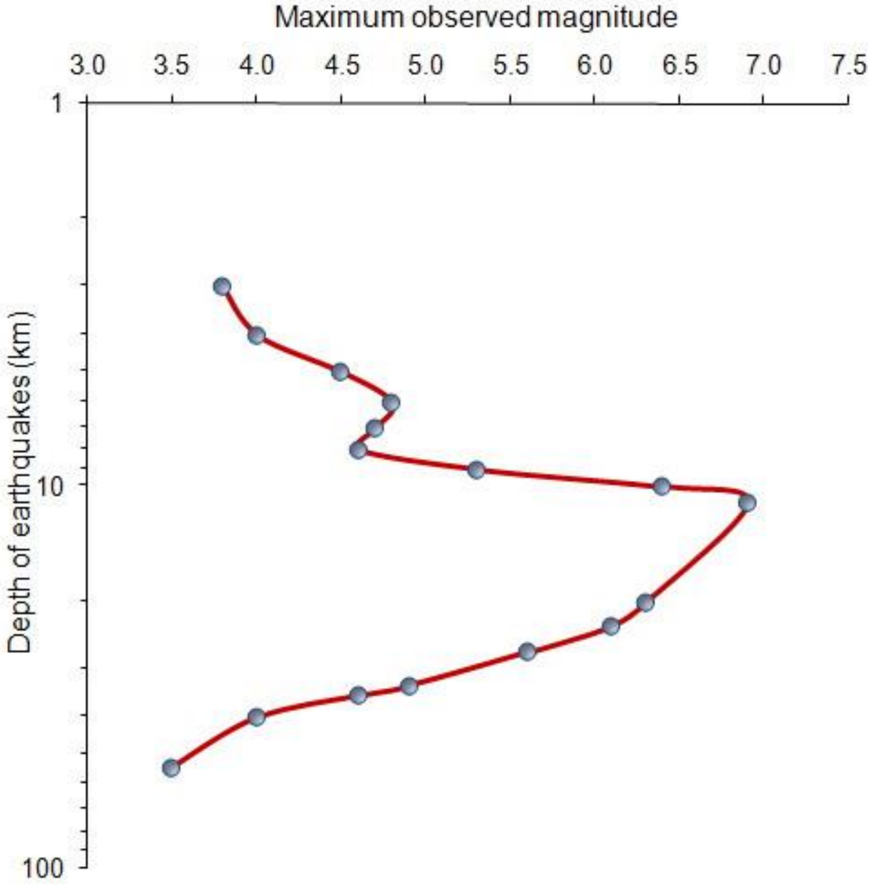

Fig. 9. Limiting contour of $M_{max.ob.}=f_2(h)$ relation.

In addition, when the historical earthquakes were independently determined according to magnitude, for example, by seismodislocation scale (Khromovskikh et. al., 1979) or instrumentally (mostly for the historical earthquakes, of the end of the XIX century), then the depth (h_{IM}) was evaluated by the correlation equation type (1). This equation was used in the assessment of the magnitude (M_S) on macroseismic depth (h_I) and the intensity in the epicenter (I_o) for the most historical earthquakes in Georgia.

As additional information (and in some cases, basic information) the material on modern seismogeological study of the Caucasus and Georgia, in particular, are used in this work for interpretation of macroseismic data of historical earthquakes (e.g., Khromovskikh et. al., 1979; Khromovskikh, Nikonov, 1984; Tsereteli, Varazashvili, 1986; Tsereteli et al., 2008, and others). The basic concept, in this case lies in the spatial and genetic connection of foci of strong earthquakes with fault zones. Therefore, a comprehensive study of active faults, including the traces of their seismotectonic reconstruction (dislocations, major landslides, avalanches, etc.) is of great importance for specification of the seismic history of the area. Use of geological and geomorphological techniques for the study of residual deformation of earthquakes, especially dislocations and large seismogravitational phenomena provide additional possibilities for identification of active tectonic faults of the Earth's crust and for diagnostics of distribution of large earthquakes.

6
New Catalogue of Historical Earthquakes of Georgia and Unknown Historical Seismicity of the Region (discussion of results)

This parameterized catalogue represents the full database of historical earthquakes that affect the territory of Georgia. It is a compilation of detailed unified historical seismic and other types of information and covers about 20 centuries. Comparing the data in this catalogue with an adequate data from New Catalog of Strong Earthquakes... (1982) and Catalogue of Large Historical Earthquakes... (Shebalin, Tatevossian, 1997) we can say that among the 44 earthquakes listed in the catalogue 1 of them is previously unknown events determined according to new sources; 37 events have been revised on the basis of all collected original sources and their main parameters were re-evaluated; 6 events were adopted without any re-evaluation.

Actually all historical earthquakes of magnitude $M_S \geq 6$ caused significant destruction, casualties and secondary phenomena of earthquakes, i.e. landslides, avalanches, dislocations, etc.

The Table 2 presents a list of historical earthquakes; it illustrates the seismic activity in Georgia for the period up to 1900. Fig.10 shows the spatial distribution of historical earthquakes on the territory of Georgia (according to Table 2). It also shows the epicenters of the earthquakes of the instrumental period (since 1900). Comparing the seismicity of these two periods, one can see that in some areas of Georgia there is a clear distinction between them. In particular, the seismicity of some certain large area (Fig. 10, a) in the western part of the Greater Caucasus (within Georgia) in the historical period was much higher than the one of the instrumental period and consequently, many places that in the past had a high seismic potential in this area now are quiet zones. The same can be said on two other less extensive areas in the eastern part of the Achara-Trialeti fold-thrust mountain belts (Fig. 10, b) and to the west of Javakheti highland (Fig. 10, c). In addition, these two areas are densely populated and include the administrative centers of Georgia such as towns Akhaltsikhe, Gori, Mtskheta, etc. Over time, the conditional probability of occurrence of large earthquakes and seismic risk in these areas is growing as the early active zones can be re-activated due to accumulation of tectonic stresses.

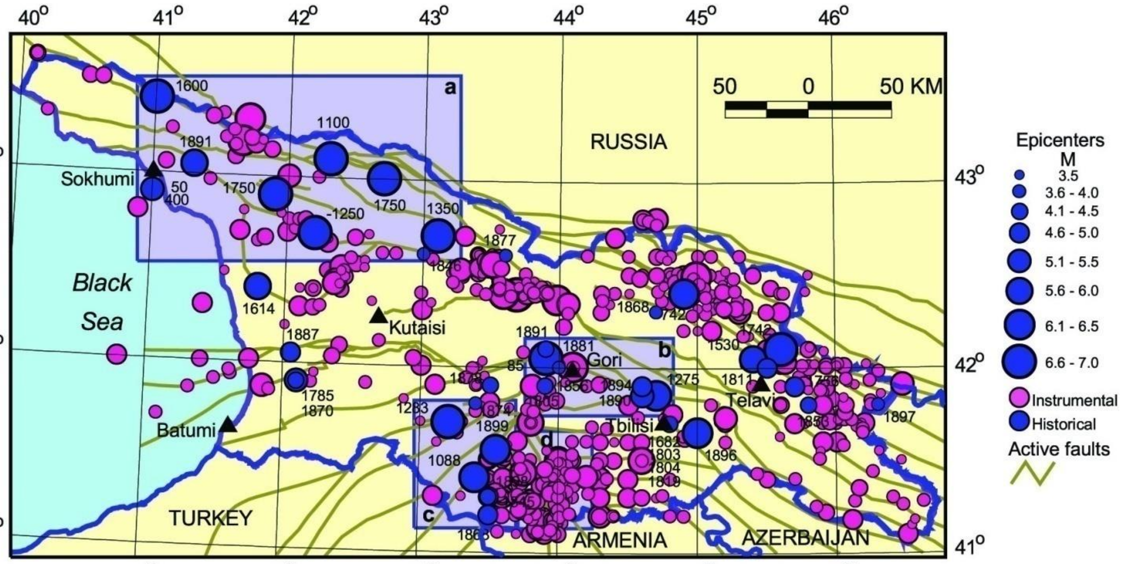

Fig. 10. Map of instrumental and historical seismicity of Georgia.

The example of the 1350 Lechkhumi-Svaneti earthquake showed that within the zone of active faults of the southern slope of the Greater Caucasus, in the vast area between the epicenter of the 1963 Chkhalta earthquake and the devastating 1991 Racha earthquake, the large historical seismic events are registered not only by paleoseismogeological methods (earthquakes in 1250 BC, 1100, 1600, 1750 AD, etc.) but also as historical data (Fig. 10, a). This in turn confirms the existence of a single high intensity seismic hazard zone (9 MSK) along the northern border of Georgia. The 1088 Tmogvi earthquake and especially the 1283 Samtskhe earthquake (occurred, respectively, along Atskuri and Tabatskuri sinistral strike-slip faults) have shown that the historical-geographical province of Georgia – Samtskhe at one time demonstrated very high seismicity (Fig. 10, b). Despite this area nowadays represents a quiet zone, the seismic potential revealed by the historical data should be reflected on the seismic zoning map of the area (Varazanashvili, Papalashvili, 1998). The 1985 A.D. Bebnissi earthquake and the 1275 Mtskheta earthquake occurred along the Achara-Trialeti North Faults Zone prove the assumption of seismologists that besides the 1920 Kartli devastating earthquake some great earthquakes occurred in the historical past to the west and east of the town Gori (Fig. 10, c) that indicates to the high seismic hazard in the area (Varazanashvili, et al., 2006). However, it is also clear that very high seismic activity in the central and eastern parts of Javakheti highland is not revealed by historical materials (Fig. 10, d). The above refers to the fact that to some extent the material included in this catalogue still is not still homogeneous. This especially concerns the magnitudes of the earthquakes, i.e. if we taken into account earthquake recurrence law in Georgia, then the threshold of representation of historical earthquakes is very high (M_S>6.5). This means that a number of strong historical earthquakes has not yet been identified and therefore requires further search of various kinds of sources that may contain data about historical earthquakes.

The Fig.11 is the summarized and generalized map of major historical earthquakes' isoseismics of Georgia, showing the distribution of zones of maximum damage (zone of intensity 7, 8 and 9 MSK) in the country for the historical period (before 1900). On this map, between the two zones of high intensity (I≥8 MSK) in the axial part and the southern slope of the Greater Caucasus clearly emerges a seismic gap which was filled in 1991 by the Racha earthquake and its aftershocks.

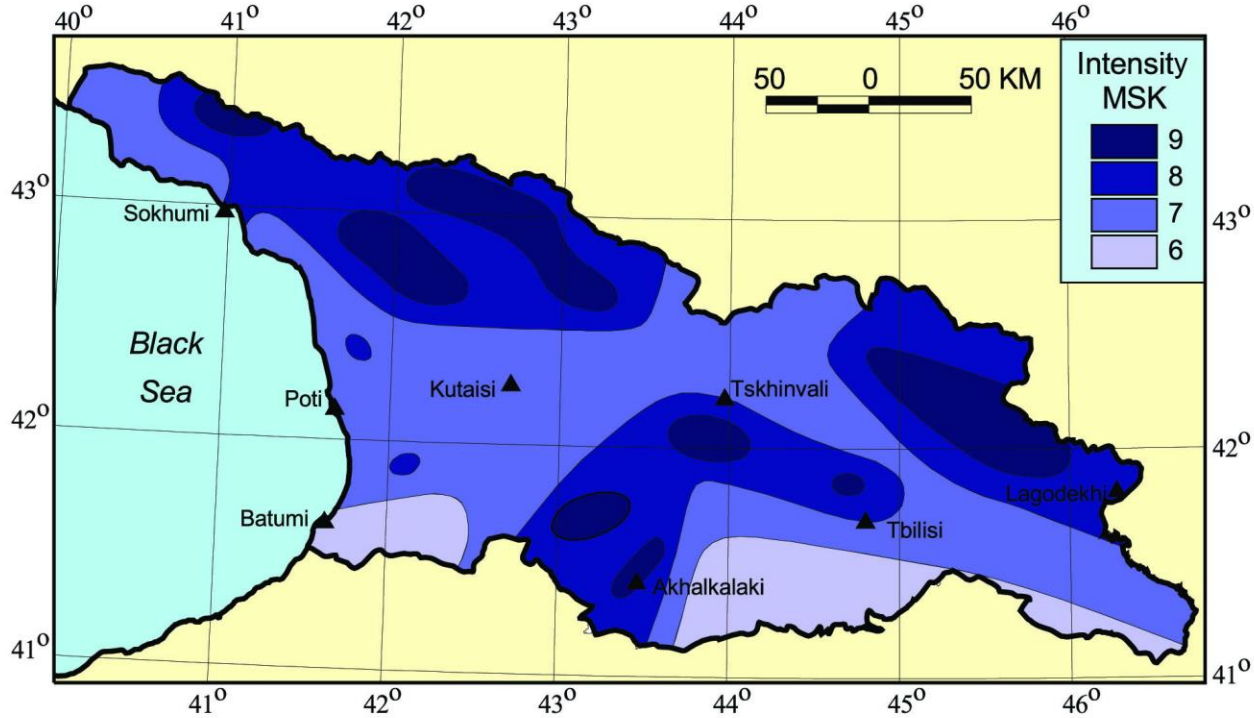

Fig. 11. Summary map of distribution of maximum damage caused by large historical earthquakes in Georgia.

The new catalogue of historical earthquakes of Georgia is a result of a long, hard work of collecting, compiling and analyzing various data on past earthquakes. We believe that it will provide necessary and more reliable information about unknown historical seismicity of Georgia and will serve as the study of seismic hazard in the country.

Table 2. New parametric catalogue of historical earthquakes in Georgia

EVENT No	**DATE**					**EPICENTRE**		**DEP**	M_S	I_o	**COMMENTS (Name of Earthquake)**
	YR	**MNH**	**DY**	**H**	**MIN**	**LAT**	**LON**				
1	-1250	00	00	00	00	42.70	42.20	10	6.6	9.5	Kvira
2	0050	00	00	00	00	42.90	41.00	10	5.5	8.0	Dioscuria
3	0085	00	00	00	00	42.05	43.90	15	7.0	9.5	Bebnisi
4	0400	00	00	00	00	42.90	41.00	10	5.5	8.0	Sebastopolisi
5	0742	00	00	00	00	42.40	44.90	18	6.4	8.5	Jvari pass
6	1088	04	22	00	00	41.40	43.40	15	6.5	9.0	Tmogvi
7	1100	00	00	00	00	43.10	42.30	15	7.0	9.5	Nenskra-Abakura
8	1275	00	00	00	00	41.85	44.70	15	6.5	9.0	Mtskheta
9	1283	00	00	00	00	41.70	43.20	15	7.0	9.5	Samtskhe
10	1350	00	00	00	00	42.70	43.10	15	7.0	9.5	Lechkhumi-Svaneti
11	1530	00	00	00	00	42.05	45.40	15	5.7	8.0	Alaverdi I
12	1600	00	00	00	00	43.40	41.00	15	7.0	9.5	Bzipi
13	1614	00	00	00	00	42.40	41.80	10	6.0	8.5	Tsaishi
14	1682	06	13	22	30	41.70	44.80	07	4.2	6.5	Tbilisi I
15	1742	08	05	00	00	42.10	45.60	20	7.0	9.0	Alaverdi II

16	1750	00	00	00	00	42.90	41.90	15	7.0	9.5	Akiba
17	1750	00	00	00	00	43.00	42.70	15	6.9	9.5	Labaskaldi-Tseri
18	1756	00	00	00	00	41.90	45.70	10	4.7	7.0	Kacheti I
19	1785	05	00	00	00	41.90	42.10	10	5.5	8.0	Shemomqmedi
20	1803	10	29	00	00	41.70	44.80	07	3.8	6.0	Tbilisi II
21	1804	10	11	17	00	41.70	44.80	09	3.8	5.5	Tbilisi III
22	1805	02	21	19	00	41.90	43.90	10	4.4	5.5	Gori area
23	1811	01	01	05	00	42.00	45.50	10	5.0	7.5	Kakheti II
24	1819	02	28	00	00	41.70	44.80	07	4.5	7.0	Tbilisi IV
25	1845	05	24	01	00	41.30	43.50	08	4.6	7.0	Javakheti I
26	1846	04	23	21	00	42.60	43.00	07	3.8	6.0	Jvarisa
27	1853	03	18	00	30	41.80	45.80	10	4.2	6.0	Kakheti III
28	1856	02	13	04	00	42.00	44.00	12	3.8	5.0	Gori
29	1868	02	18	17	00	41.20	43.50	15	4.9	6.5	Javakheti II
30	1868	12	09	16	30	42.30	44.70	25	4.0	4.5	Pasanauri
31	1870	07	19	14	30	41.90	42.10	10	4.2	6.0	Ozurgeti
32	1874	02	25	19	30	41.80	43.40	10	3.8	5.5	Borjomi
33	1877	08	08	06	30	42.60	43.60	05	3.8	6.5	Utsera
34	1878	11	26	23	00	41.90	43.50	15	4.3	5.5	Borjomi area
35	1881	08	24	20	00	42.00	44.00	17	4.0	5.0	Kartli
36	1887	07	16	17	45	42.05	42.05	12	4.9	7.0	Lanchkhuti
37	1890	10	28	19	00	41.85	44.60	15	5.2	7.0	Mtskheta area I
38	1891	00	00	00	00	43.05	41.30	15	6.0	8.0	Amtkeli
39	1891	03	27	18	30	42.10	43.90	22	4.5	5.5	Qareli area
40	1894	11	29	10	30	41.90	44.60	24	5.0	6.0	Mtskheta area II
41	1896	09	22	03	53	41.65	45.00	25	6.3	7.5	Tbilisi area
42	1897	02	03	02	00	41.80	46.30	10	3.8	5.5	Lagodekhi area
43	1898	08	13	00	00	41.30	43.50	10	4.2	6.0	Javakheti III
44	1899	12	31	10	50	41.55	43.55	09	6.1	9.0	Akhalkalaki

7
Detailed Description of Historical Earthquakes

In this section we present detailed descriptions taken from the original sources of special historical earthquakes. The legend of maps appropriate to each historical earthquake is given in Fig. 12. It should also be noted that the GIS-map with all the towns and villages in Georgia is presented on the website: www.ig-geophysics.ge

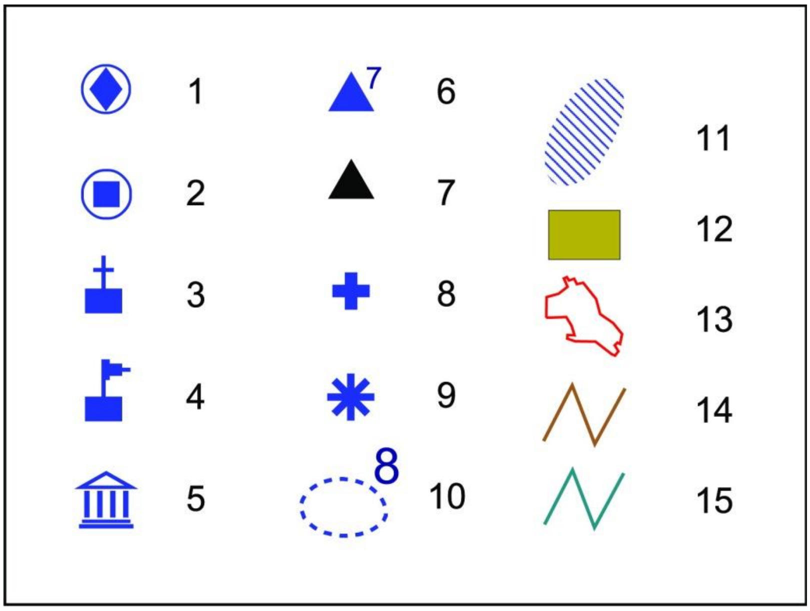

Fig. 12. The legend of maps presented in this section:
1 – seismodislocations; 2 – landslides; 3 – churches; 4 – castles; 5 – palaces;
6 – settlements of intensity (MSK scale); 7 – villages and towns; 8 – passes;
9 – epicenters of earthquakes; 10 – isoseismals; 11 – areas with intensity (MSK scale); 12 – building of Tbilisi city; 13 – borders of old Tbilisi;
14 – active faults; 15 – rivers.

1250 B.C. Kvira EQ

"Some survived deformations of the Kvira structure were discovered on a branch of the Egrisi range in the mountainous surroundings of the Kolkheti lowland. The deformations are located 15 km to the north-east from the high arc dam (Enguri hydroelectric power station, height – 271 m) built in the gorge of the river Enguri.

The structure is a result of an earthquake with intensity of not less than 9 as in 2.5 km distance its main normal dip-slip has cut one permanent and five temporary watercourses and has made some rapids, suspension riverbeds and one tectonic dam alongside the erosive hollow thalweg at the site of a former lake of 2 500 m². A 40-50 l/sec joint debit of 12 springs is connected with the fault line. The descend of the western wing of the seismogenic normal dip-slip and creation of a narrow single-sided graben of 500 m length and 60 m width has changed the hydrologic regime of the territory. The river Tsintskali flowing southwards together with its right-side tributaries has been cut by the seismogenic fault in its head and closed by the ascended wing of the main fault. Now it flows to north-east in the Jolori basin in the Kvira structure area.

The paleoseismogenic Structure Kvira is several thousand years old (2000 B.C. – 500 A.D.). The normal dip-slip terraces are noticeably evened by denudation, the seismogenic dam is washed off and the lake in the graben has sunk" (Khromovskikh, Nikonov, 1984; Khromovskikh et al., 1979).

Thus, taking into consideration the assessments and the field investigations described in the above sources we conclude that it is impossible to define the precise date of the earthquake identified on the basis of the Kvira structure, while there are no relevant historical data. Meanwhile, it is quite possible to determine accurately the epicenter of the earthquake (Fig. 13). Moreover, if taken into account that the average depth of the seismically active layer (10-15 km) for Georgia is known

(Varazanashvili, 1999) and the epicenter intensity of the earthquake must have been 9 or more, then by the first approximation and on the basis of the research (Shebalin, Tatevossian, 1997) it is possible to evaluate its main parameters: date – 1250 B.C. (Δt=±1000 year); epicentre coordinates – φ=42.70°, λ=42.20° (ΔE=±0.2°); depth – h=10 km (Δh=5-20); magnitude – M_S=6.6 (ΔM=±0.7); intensity in the epicentre – I_o=9-10 (ΔI_o=±1). Here and in following: Δt is the error in estimating the date of the earthquake; ΔE – error of epicentre coordinates; Δh – error of depth; ΔM – error of the magnitude; ΔI_o – error of intensity in the epicentre.

Sources:

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, p. 114 (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 83-85 (in Russian).

Varazanashvili, O. 1999. Seismic hazard assessment of Georgia by deterministic and probabilistic methods. Journal of Georgian Geophysical Society (A). Vol. 4, pp. 35-45.

Shebalin, N., Tatevossian, R. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers, Dordrecht, pp. 201-232.

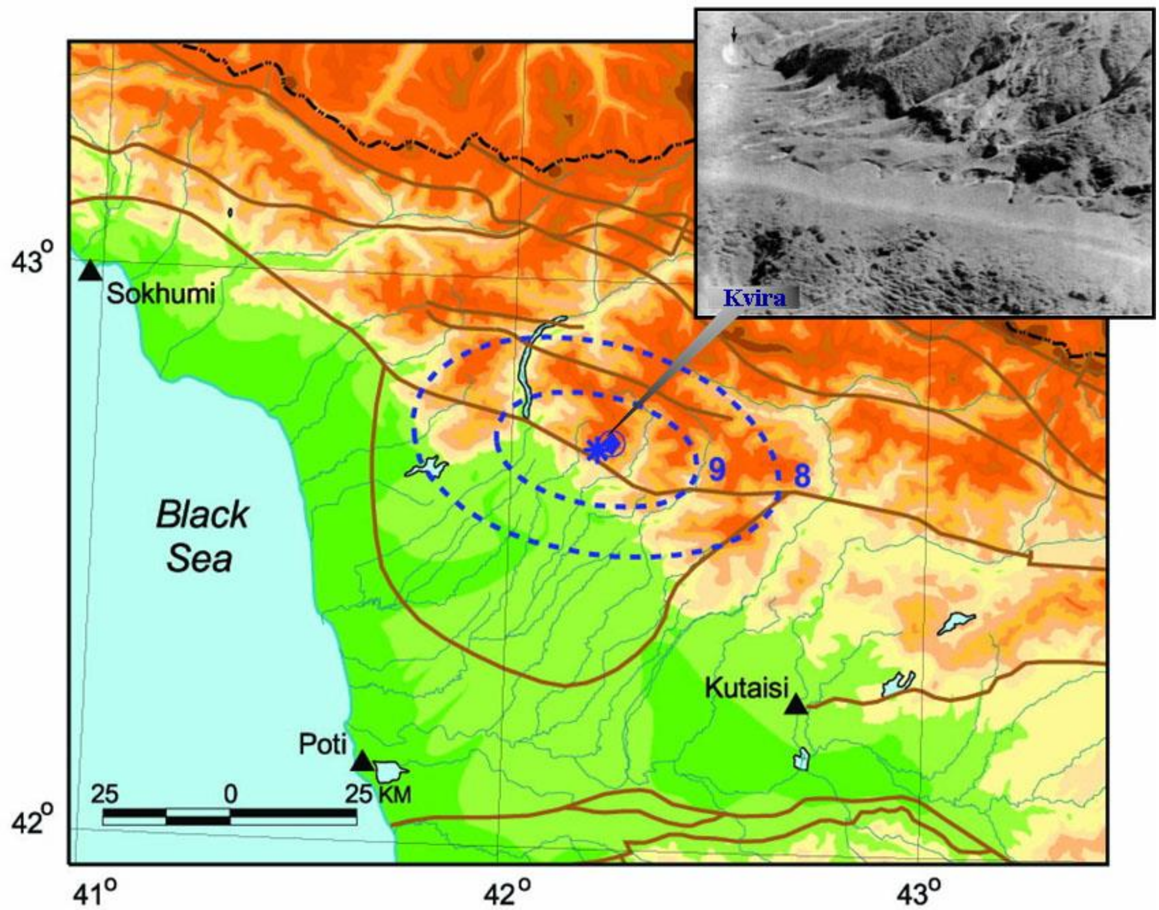

Fig. 13. Map of intensity distribution for the Kvira Earthquake, 1250 B.C.

50 A.D. Dioscuria EQ

"Has Dioscuria collapsed due to the landslides or tsunami caused by earthquakes?" (New Catalogue…, 1977).

"The city of Dioscuria existed during eight centuries at the site of present Sokhumi city. In the first century A.D. due to a strong earthquake it collapsed and sunk in the sea" (Khromovskikh, Nikonov, 1984).

"A terrible quake shook the land, the beach separated apart and the city disappeared into the rough sea" (Lashkhya, 1956; Ananin, 1977).

"Traces of major landslides and landslide displacements in the area (Sokhumi) have not been found. Besides, the complete integrity of these mountain peaks outside the narrow coastal zone make it possible to suppose that the maximum intensity of ancient earthquakes in the Black Sea region did not exceed VIII" (Khromovskikh et al., 1979).

On the bases of the present material we conclude that in the bay zone of Sokhumi the activation of a fault was caused by a strong earthquake (Fig. 14). Its probable parameters are: date – 50 A.D. (Δt=±100 year); epicentre coordinates – φ=42.90º, λ=41.00º (ΔE=±0.5º); depth – h=10 km (Δh=5-20 km); magnitude – M_S=5.5 (ΔM=±0.5); intensity in the epicentre – I_o=8 (ΔI_o=±1).

Sources:

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 70 (in Russian).

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, p. 97 (in Russian).

Lashkhya, Sh. V. 1956. On contemporary changes of the shore line in Abkhazia. Acad. Scf. USSR, News, Ser. Geol., No. 12 (in Russian).

Ananin, I. V. 1977. Seismicity of the Norten Caucasus. Nauka Publ. House, Moscow, pp. 70-71 (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 132-133 (in Russian).

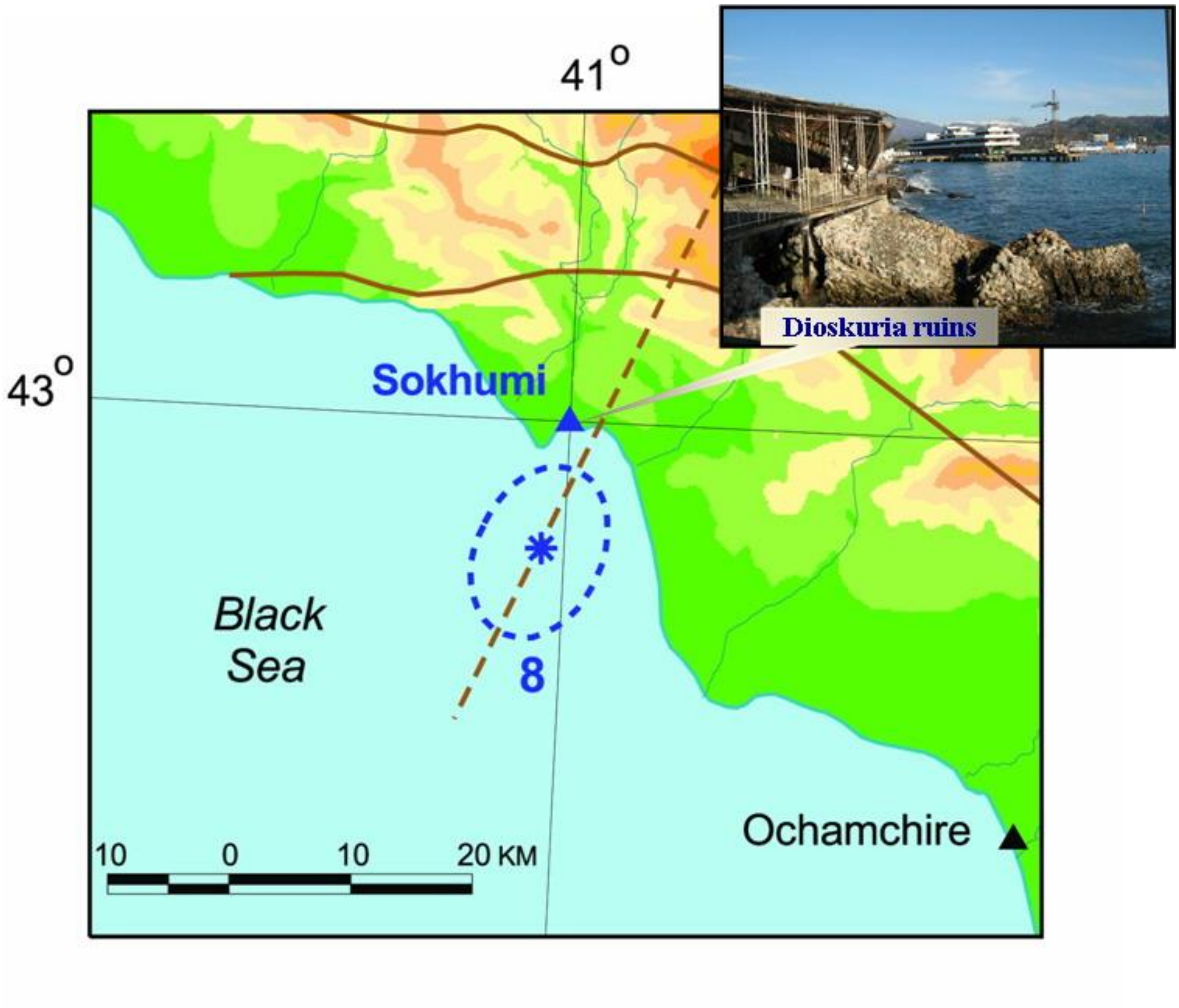

Fig. 14. Map of intensity distribution for the Earthquakes of Dioskuria, 50 A.D.

85 A.D. Bebnisi EQ

“A thrust was discovered on the eastern edge of village Bebnisi near the epicenter of the 1920 Kartli Earthquake with intensity 8-9. The eastern wing of the thrust is descended by 1.2 m. It has broken the alluvion sediment of the second terrace and the base composed of Miocene sandstone and gravelite. The age of the thrust must be one or two thousand years – it is obviously seen on the second upper terrace of the river Mtkvari. As to L. Koghoshvili, the shingle of the descended thrust wing has been tightly fixed to the basic sediments and some certain pebbles have driven in the sandstone of the uneven fault surface. All those indicate to impulsive displacements” (Koghoshvili, 1970; Khromovskikh, Nikonov, 1984).

The Damchkhvreula landslide is located among the II and III terraces of the right slope of the gorge of the river Mtkvari on the territory of the former village with the same name. In this area the surfaces of the II and III terraces of the Mtkvari are inclined by 10-15° and the river sediments are washed off. This fact indicates to the current deformations at the bottom of the northern slope of the Trialeti ridge. On this territory the Miocene sediments are destructed by gravitational processes and the surface of the terraces are characterized by reverse topography. The overturning of such great blocks must have been caused of shocks of a strong earthquake that occurred after the formation of the first terrace. At present the blocks of the landslide are stabile. We suppose that such seismic phenomenon was the reason for the emigration of the village inhabitants and the collapse of the church the ruins of which have survived to our times. The name of the village also refers to this seismic phenomenon as “Damchkhvreula” means “destroyed” (the information was obtained during the 2007 complex geological-geomorphological and geophysical expeditions and explorations).

The landslides of Tinistskali and Ruisi are situated in the eminence on the left slope of the gorge of the river Mtkvari near town Gori. The landslides cover the area of about 2 km in length across the river and 300-500 m in width including the fourth terrace. The territory covered with the landslides is approximately 1 km^2 and 30 million m^3 in volume. The landslides have developed in complex Miocene molasses sediments formed due to the current tectonic faults. The landslides are of block-creep type and have formed a terraced hill relief. The landslide relief is spread over the area to the first terrace surface and at some places covers some part of it. The relief combines the stable segments of the site and the dynamically active ones that create danger for the main Tbilisi-Leselidze highway. This large territory of landslides has undoubtedly originated due to a strong earthquake that probably occurred here (Tsagurishvili et al., 1987; Tsereteli et al., 2008).

The gorgeous Urtkhvi landslide is located in the right gorge of the river Bijnura (a tributary to the river Suramula) in Khashuri region. The landslide is developed in the Oligocene-Miocene sediments and covers the upper Cretaceous carbonate sediments complicated due to the Surami-Gokishura creep.

The seismogenic Urthkhvi landslide territory covers the area of more than 100 ha, the average thickness – 30-50 m and the volume – 40 million m^3. The head of the landslide has been torn off at the top of the slope at the contact of the carbonate and Oligocene rocks in the zone of the tectonic fault. The 700 m long landslide has cut the Bijnura riverbed and left 10-15 m high landslide sediments on its banks. These sediments consist of Tertiary clay-sandstones and carbonate rocks entangled with each other. The geomorphological destruction of the landslide area must be a result of a strong earthquake that probably occurred in the historical period. This might be confirmed by the fact that a large part of a village is situated on a significant area of the landslide and a low gorge terrace has locally developed in the landslide sediments near the riverbed (Tsagurishvili, et al., 1977; Kurdadze, et al., 1980; Tsereteli, Gaprindashvili, 2009).

According to I. Gagoshidze (2001) an archaeological expedition made a discovery in Kartli region (Jikashvili, 2005). 25 km north-west from town Gori during the excavations of the antique monuments of Dedoplis Valley in the south of village Takhtisdziri and Dedoplis Gora (Hill) near village Doghliauri they discovered an enormous overall system of buildings (heathen temples, a royal palace, etc.) that were ruined at the end of the first century A.D. It is certain that the palace (and the other buildings as well) built of airbrick, with tight walls of three meters in width and armored with wood was ruined due to a strong earthquake at the last quarter of the first century, approximately 85 A.D. (Gagoshidze, Tsotselia, 1991; Gagoshidze, 2001).

This information corroborates the scientists’ idea that according to the analysis of seismic potential and the law of earthquake reiteration there had been another strong earthquake besides the one in 1920 in Kartli (Varazanashvili, 2006). According to the data the main parameters (Fig. 15) of this earthquake are the following: date 85 A.D. (Δt=±10 year); coordinates – φ=42.05º, λ=43.90º (ΔE=±0.2º); depth – h=15 km (Δh=8-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicenter – I_o=9-10 (ΔI_o=±1).

Sources:

Kogoshvili, L. V. 1970. Live tectonics of Georgia and its impact on the relief. Metsniereba Publ. House, Tbilisi, pp. 135-136 (in Russian).

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, p. 118 (in Russian).

Tsagurishvili, A. G. et al. 1987. Specialized engineering-geological survey in scale 1:25 000 left bank of r. Kura between village Tashiskari and r. Liakhvi. Tbilisi (in Russian).

Tsereteli, E., Gaprindashvili, M. et al. 2008. Estimation of engineering-geological conditions Sveneti-Ruisi plot of Tbilisi-Leselidze road. Tbilisi, p. 8 (in Georgian).

Tsagurishvili, A. G., Kunchulia, G. V. et al. 1977. Specialized engineering-geological survey in scale 1:25000 left bank of r. Kura between village Kvishkheti and r. Liakhvi. Vol. 1, Tbilisi, p. 450 (in Russian).

Kurdadze, M. Z., Tsereteli, E. D. et al. 1980. Engineering-geological report on specialized survey in scale 1:10000 Khashuri district. Vol. 1, Tbilisi, p. 428 (in Russian).

Tsereteli, E., Gaprindashvili, M. 2009. Estimation of engineering-geological conditions Khashuri-Surami Alternative options of Tbilisi-Leselidze road. Tbilisi, p. 7 (in Georgian).

Jikashvili, L. 2005. Under the earth the buried sheets of history. Newspaper Kviris Palitra, 45 (558) (in Georgian).

Gagoshidze, I., Tsotselia, M. 1991. Plaques with Aramaic inscription from Dedoplis Gora – problem of the history of Transcaucasia. Metsniereba Publ. House, Tbilisi, pp. 47-78 (in Georgian).

Gagoshidze, I. 2001. A royal palace in first-century Iberia. The royal palace institution in the first millennium B.C. Ed: I. Nilsen. Monographs of the Danish Institute at Athens, v. 4, pp. 259-283.

Varazanashvili, O., Tsereteli, N., Sumbadze, B., Mukhadze, T. 2006. Seismotectonic conditions and Seismic Risk in Gori. Bulletin of the Georgian Academy of Sciences, vol.174 (3), pp. 423-426.

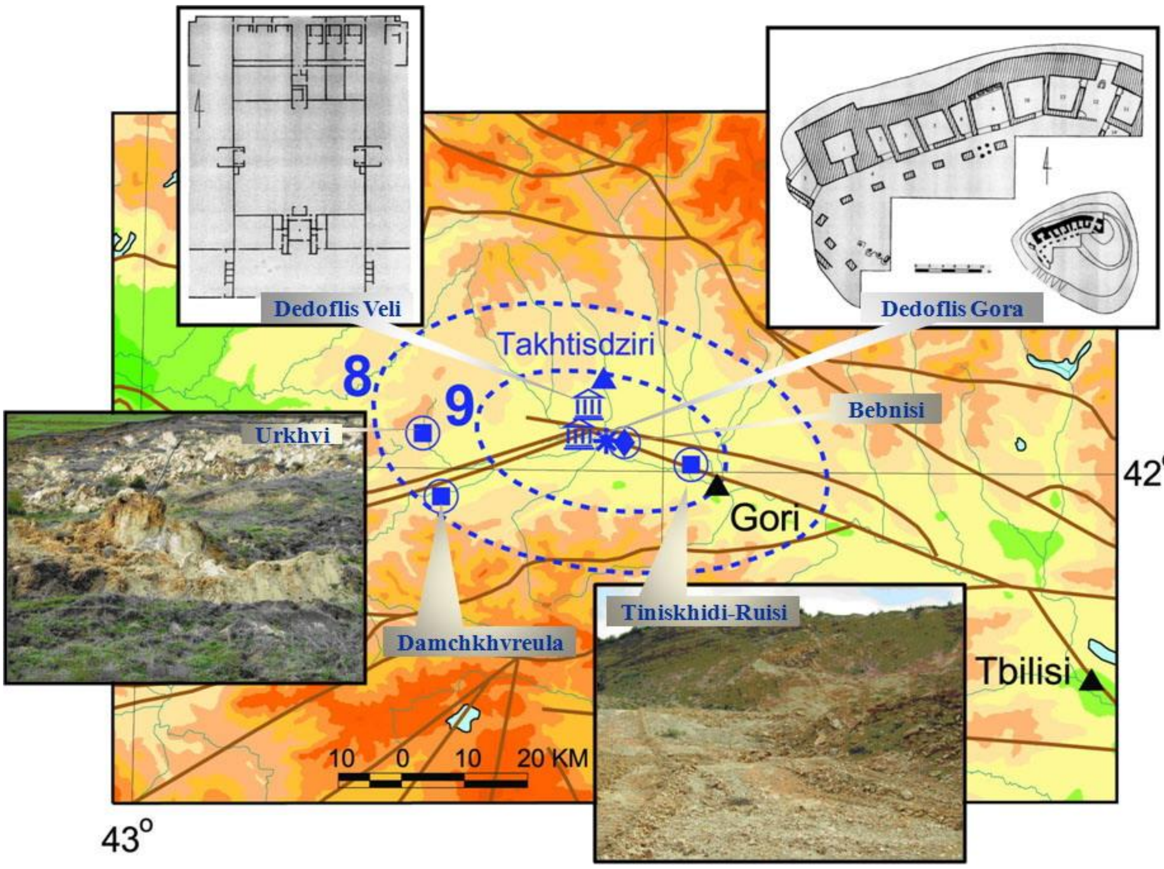

Fig. 15. Map of intensity distribution for the Bebnisi Earthquake, 85 A.D.

400 A.D. Sebastopolis EQ

“Sebastopolis city (Sokhumi bay). The walls of the fortresses were damaged and burnt” (New Catalogue…, 1977).

“Such catastrophes were numerous in the area. At the place of collapsed Dioskuria the Romans built a city of Sebastopolis. But in the IV and VI centuries the city was ruined due to the earthquakes” (Khromovskikh, Nikonov, 1984).

“The walls of Sebastopolis disintegrated at some places and later were tightened with counterforts … Soon they leant towards the sea” (Lashkhya, 1956; Ananin, 1977; Shervashidze, Solovev, 1960).

“The ruins of the city are at the bottom of the Sukhumi bay. These phenomena can not be caused of slow dislocations of the Earth surface. Disappearance of the biggest part of Sebastopolis into the sea is en evident result of rapid seismic dislocations. The subsided ancient buildings and cultural layers in the depth of the beach, the ruins of ancient walls discovered by V. Chernyavski in the XIX century at the bottom of the Sukhumi bay away from the beach also indicate to earthquake phenomenon” (Khromovskikh, Nikonov, 1984; Shervashidze, Solovev, 1960; Khromovskikh et al., 1979).

We suppose that in the IV century BC an earthquake with devastating results took place like the one in the first century A.D. (Fig. 16). The probable parameters of this earthquake are following: date – 400 BC, (Δt=±100 year); epicentre coordinates – φ=42.90º, λ=41.00º (ΔE=±0.5º); depth – h=10 km (Δh=5-20 km); magnitude – M_S=5.5 (ΔM=±0.5); intensity in the epicentre – I_o=8 (ΔI_o=±1).

Sources:

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, pp. 70 (in Russian).

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, pp. 97 (in Russian).

Lashkhya, Sh. V. 1956. On contemporary changes of the shore line in Abkhazia. Acad. Scf. USSR, News, Ser. Geol., No. 12 (in Russian).

Ananin, I .V. 1977. Seismicity of the Northern Caucasus. Nauka Publ. House, Moscow, pp. 70-71 (in Russian).

Shervashidze, L. A., Solovev, L. N. 1960. Studies of ancient Sebastopolis. Soviet Archaeol., No. 3, pp. 171-180 (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R .M., Zhilkin, V .N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 83-85 (in Russian).

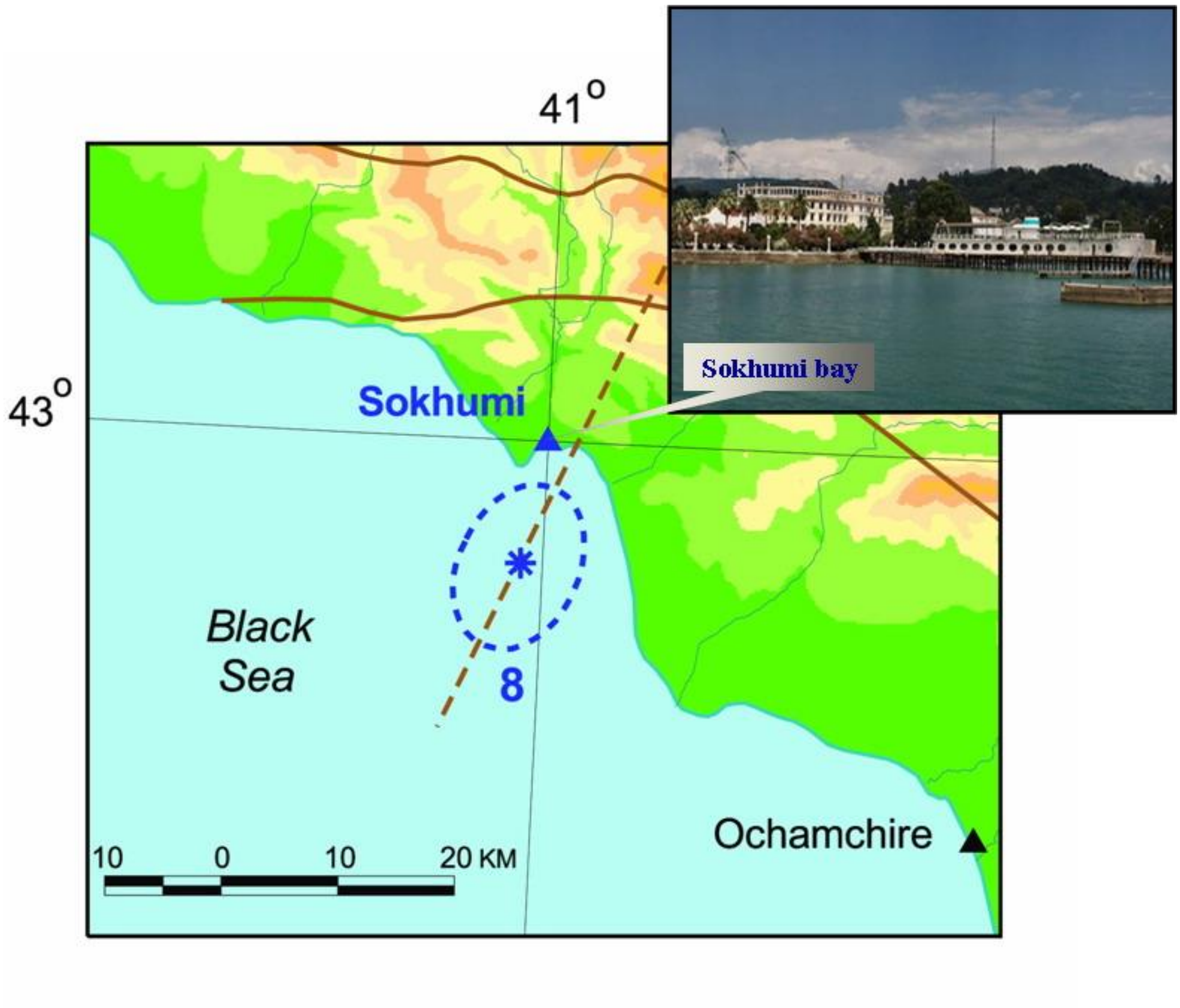

Fig. 16. Map of intensity distribution for the Earthquakes of Sebastopolis, 400 A.D.

742 A.D. Jvari Pass EQ

"In the Georgian oil paper synaxary of the early XI century there is the following note: "August 26,741. By this day we remember the great shock of the ground from which God rescued us above our hopes" (Janashvili, 1902; Nikonov, 1995).

"August (26), 741. An Earthquake in the Caucasus" (Stepanyan, 1942; Bius, 1948).

"741-743-744 – This is a very interesting case, when the original source of information is known, so the fact of the earthquake is doubtless but the name of the locality could be interpreted in different ways. In all cases the reference text is Theophan's descriptions" (a Byzantine confessor who lived in 760-818). "…a sign appeared in the north, and dust fell in various places. There was also an earthquake at the Caspian Gate". In antiquity and Middle Ages the Caspian Gate was the name of three passages: 1) the Derbent Pass between the spurs of the Caucasus and the Caspian sea, 2) the pass over the Greater Caucasus Ridge along the Aragvi and Terek valleys and through the present Krestoviy Pass, and 3) the pass in the Elburz Ridge north-west of Teheran. Ambraseys and Melville (Ambraseys, N., Melville, C. 1982) accepted the Iranian version, Guidoboni and Traina (Guidoboni, E., Traina, G. 1995) followed the first possible interpretation, and Nikonov considers the second as the most reliable in (Nikonov, 1995). We will not give here a discussion of the interpretation of the name Caspian Gate, very detailed one is done by Nikonov in (Nikonov, 1995) and we follow that interpretation in the catalogue. Here we would like to note that this case is a good illustration of the statement that it should be a feed-back between task and catalogue. If the false alarm is much more favorable than missing the target (for example, in case of nuclear power plant construction near one of this places) it is better to "keep" this earthquake in all three localities because the basic description itself does not contain anything more than the name "Caspian Gate" and all reasons pro and contra each possible location are just interpretations. But in case of general seismic hazard assessment it is better to leave in the catalogue just one, the most probable interpretation" (Shebalin, Tatevossian, 1997).

Concerning this earthquake (Fig. 17) we shear the conclusions of the research (Shebalin, Tatevossian, 1997) and adopt the earthquake parameters as it is described in the work: date –742 B.C. (Δt=±1 year); epicentre coordinates – φ=42.40°, λ=44.90° (ΔE=±1.0°); depth – h=18 km (Δh=12-27 km); magnitude – M_S=6.4 (ΔM=±0.5); intensity in the epicentre – I_o=8-9 (ΔI_o=±1).

Sources:

Janashvili, V. 1902. Earthquakes of the Past. Proceedings of the Caucasian Section of Russian Geographical Society. Tbilisi, vol. 15, p. 302 (in Russian).

Nikonov, A. 1995. On the first millennium A.D. Large earthquakes in the Greater Caucasus: Revision of original data and catalogue. Physics of the Solid Earth, 30, 7/8, 688-693.

Stepanyan, V. 1942. Short chronology of the most signicant earthquakes in the historical Armenia and adjacent regions. Pub. Arm. branch of the AS USSR, Yerevan, pp. 59-72 (in Armenian).

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 23 (in Russian).

Ambraseys, N., Melville, C. 1982. A history of Persian earthquake. Cambridge.

Guidoboni, E., Traina, G. 1995. A new catalogue of earthquakes in the historical Armenian area from antiquity to the XII century. Annaly di Geofisica, 38, 1, 85-147.

Shebalin, N., Tatevossian, R. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers, Dordrecht, pp. 201-232.

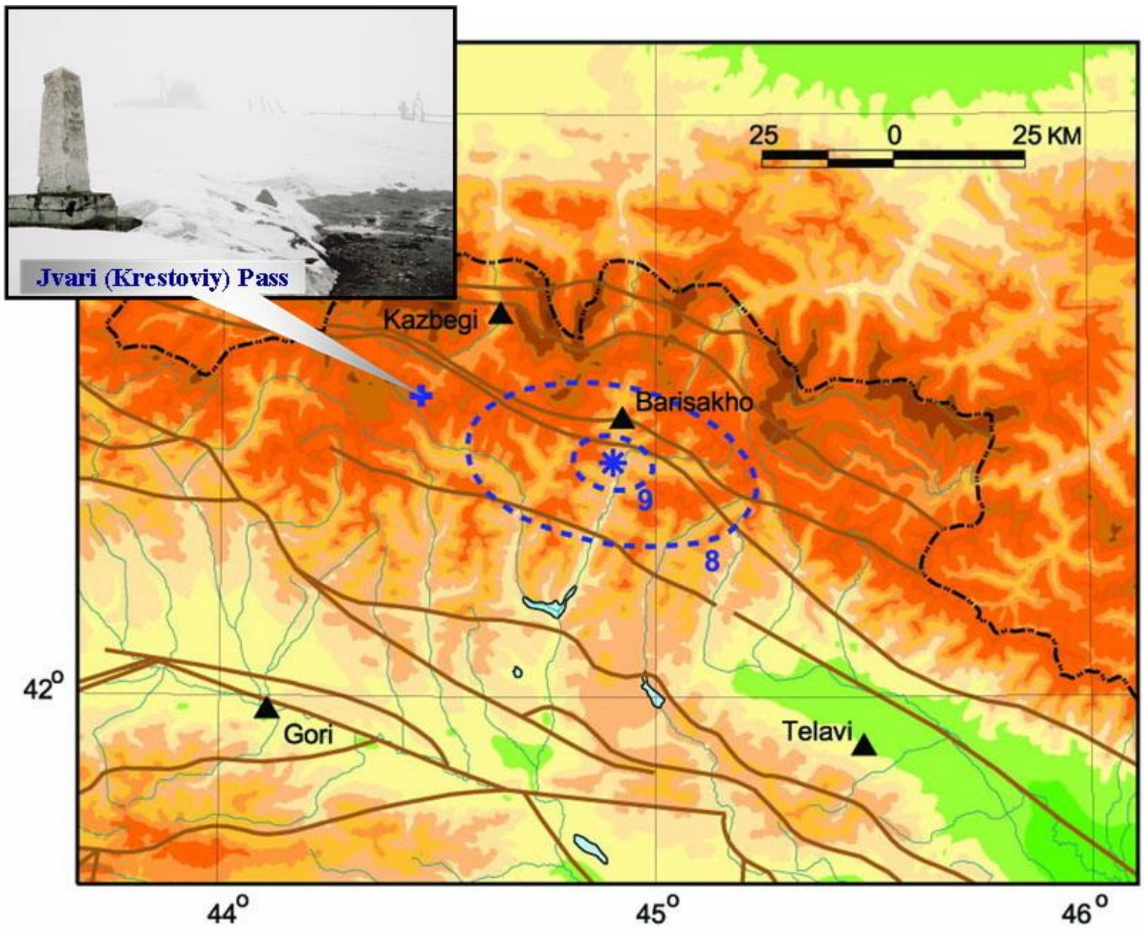

Fig. 17. Map of intensity distribution for the Jvari Pass Earthquake, 742 A.D.

1088.04.22 Tmogvi EQ

"1088/1089 – We saw all that with our own eyes. It was God's wrath upon us for we did not repent our sins and did not obey His will. That is why on the day the happy people were celebrating the Easter the land trembled so strongly that the high mountains and cliffs collapsed and turned into dust. Towns, villages and churches were ruined; the homes disappeared into the Earth and became a graveyard for their owners. The Tmogvi fortress collapsed and Kakhaber, son of Niania and his wife were left in the ruins. The terrible earthquake lasted almost the whole year. A great number of people died at that time" (Kartlis Tskhovreba, 1955).

"God was angry with us because of our sins. And there occurred an earthquake on the Easter day. Cliffs, cities, fortresses and other buildings collapsed and a lot of people died at 1088 AD, and the earthquake lasted for a year" (Niko Dadiani, 1962).

"1088. God was angry with us because of our sins and on the Easter day the Earth quaked. Cliffs, cities, fortresses and other buildings collapsed and a lot of people died. Such an earthquake lasted for a year" (Prince Vakhushti, 1973).

"King David was crowned and there occured an earthquake" (Chronicles of Abkhazians, 1982).

"On Thursday noon, May 31 there was an earthquake. The churches, castles and other buildings were ruined, many people died and all the human beings were frightened" (Gaprindashvili, 1976). This Nuskhuri (old Georgian alphabet) script of the XI century is survived on the western wall at the exit by the sanctuary of Kharitoni Cave at the David-Garedja Desert. Although the script states the date as Thursday, May 31 it refers to the well-known earthquake that according to the historian of King David Agmashenebeli started on the Easter day – April 22, 1088 and lasted for a year. We suppose that the date on the wall refers to the date of its inscription or to the strong aftershock of the Tmogvi earthquake (Chechelashvili et. al., 1998).

The Bertaqana rock avalanche has formed on the right slope of the river Mtkvari in the west of the former village Bertaqana. It was formed due to the Tmogvi earthquake that caused the destruction of the town. The earthquake was followed by aftershocks that lasted during the whole year and by active development of landslide-gravitational processes. The area of the Bertaqana rock avalanche is almost 4 km^2 and the volume – over 500 million m^3. The rock avalanche has crossed the river Mtkvari to the left side, blocked the riverbed by a 100 m high dam and buried three upper terraces of the gorge. This process was followed by origination of 3 km long lake in the south of the rock avalanche that is geologically corroborated by existence of the (30-35 m) lake sediments. The remains of the rock avalanche have survived as a jut on the left side of the river. The rock avalanche has broken off the west edge of the Akhalkalaki plateau and covered the dolerite lava and underlying rocks of the Kissatibi suite. Between the broken-cliff and the talus of the rock avalanche that is 150 m high there is a 300-350 m wide semi-bow-shaped depression filled with gravitational colluvium.

The earthquakes of the same period are connected with the Nakalakevi landslide situated on the right slope of the river Mtkvari on the territory of the village with the same name. This landslide is separated from the above described Bertaqana rock avalanche with the 1 km wide Tmogvi terrace. This is a rock-avalanche-landslide type gravitational product with more than 15 km length alongside the river. The maximal distance between the broken-off cliff and the base is 900 m. Its unequal hill relief covers an area of more than 2 km^2. The most part of the village is situated on it. The landslide is entirely composed of melange of the Kisatibi suite (volcanic breccias, tufoconglomerates, diatomites, volcanic ashes) and the Akhalkalaki dolerite lava. The Bertaqana rock avalanche and the Nakalakevi landslide have formed similarly. The dynamic triggering factor for the tectonically destructed rocks was the earthquakes. The only difference is in the mechanism. In the case of the Nakalakevi landslide the dolerite lava and the Kisatibi suite rocks slipped because of coincidence of declination of the rock layers and the relief topography. The volume of the Nakalakevi landslide is 40 million m^3. The Nakalakevi landslide-gravitational phenomena were the reason for the burial of the Tsunda settlement under the avalanche and formation of the lake with the same name (Tsereteli, 1969; Tsagurishvili et al., 1979; Tsereteli, Gaprindashvili, 2007).

It is noteworthy that in both publications of New Catalogue (New Catalogue…, 1977, 1982) the 1088 Tmogvi earthquake is considered as an earthquake with moderate strength. After the detailed analyses of its primary sources it became clear that the Tmogvi earthquake with its devastating scales and intensity was no weaker than the one at Samtskhe (1283) (Varazanashvili, Papalashvili, 1998). In the first stage it was confirmed by the description of King David Agmashenebeli's historian (Kartlis Tskhovreba, 1955). Consequently to the above said it is obvious that the Tmogvi earthquake had much wider scales than it is described in the New Catalogue and in the (Shebalin, Tatevossian, 1997) research (Fig. 18). Its main parameters could be considered as: date – 22 April, 1088 (Δt=±7 days); epicentre coordinates – φ=41.40º, λ=43.40º (ΔE=±0.2º); depth – h=15 km (Δh=8-30 km); magnitude – M_S=6.5 (ΔM=±0.5); intensity in the epicentre – I_o=9 (ΔI_o=±1).

Sources:

Kartlis Tskhovreba. Published in 1955. Manuscript, v.1, Issued by S. Kaukhchishvili, Tbilisi, pp. 323-324 (in Georgian).

Niko Dadiani. Published in 1962. Life of Georgians. Tbilisi, p. 20 (in Georgian).

Prince Vakhushti. Published in 1973. Description of the Georgian Kingdom. Issued by S. Kaukhchishvili, Tbilisi, p.155 (in Georgian).

Chronicles of Abkhazians, I. Published in 1982. Tbilisi, p. 233 (in Georgian).

Gaprindashvili, G. 1976. Inscription from the “Cave Kharitona” of Gareji Monastery on the earthquake. Matsne (series of history) 2, 184-186 (in Georgian).

Chechelashvili, G., Napetvaridze, R., Papalashvili, V., Aivazishvili, I., Makhatadze L., Gugushvili, T. 1998. Material damage from the earthquake in Georgia. Metsniereba Publ. House, Tbilisi, p. 13 (in Georgian).

Tsereteli, J. 1969. Volcanic relief of Javakheti highland, Metsniereba Publ. House, Tbilisi, 262 pp. (in Georgian).

Tsagurishvili, A.G. et al. 1979. Engineering-geological studies in scale 1:25000 in the valley of the Kura River from the village Atskuri to the state border. Vol 1, Tbilisi, 310 pp. (in Russian).

Tsereteli, E., Gaprindashvili, M. 2007. Impact on the Environment project on the rehabilitation of Samtskhe-Javakheti road Tbilisi, 59 pp. (in Georgian).

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, 535 pp. (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, 608 pp.

Varazanashvili, O., Papalashvili, V. 1998. Reconstruction of strong earthquake parameters by historical data of XI-XIV cc. in Georgia. Journal of Georgian Geophysical Society (A), vol. 3, pp. 77-84.

Shebalin, N., Tatevossian, R. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers, Dordrecht, pp. 201-232.

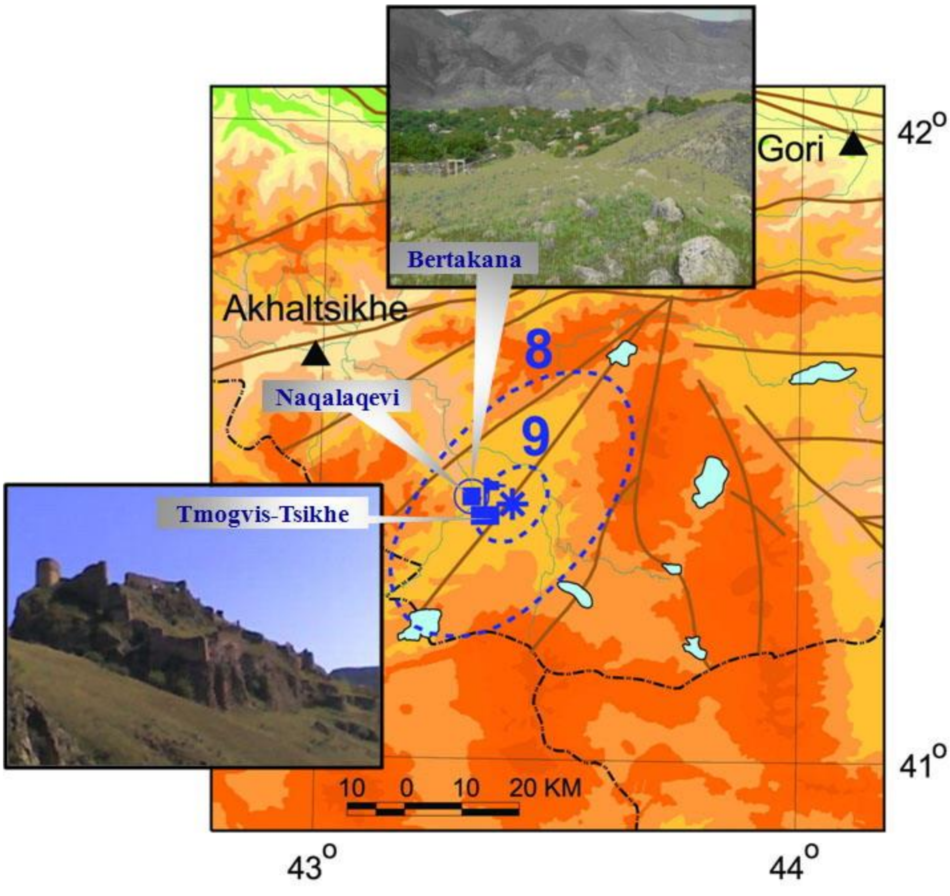

Fig. 18. Map of intensity distribution for the Tmogvi Earthquake, April 22, 1088.

1100 Nenskra-Abakura EQ

"After the divide of the rivers Bzipi and Chkhalta and the epicenter of Chkhalta Earthquake (1963) there is the area of the Chkhtani Hole. Here in the main slip zone of the Caucasus some normal dip-slip ditches and slips of 3 km length and 6-15 m depth were discovered. There may be found fragments of firmest Paleozoic crystal slates, gneiss end granite in the gorge of the river Nenskra. On the slope of mountain Utviri the temporary tributary watercourses of the river are cut off by normal dip-slip fissures, but as usual there are no dams on the thalwegs. They were flattened a long time ago or at some places are filled up with talus. Though, on some significant segments the talus is still being absorbed into the fissures.

Seemingly, the Nenskra structure originated earlier than the Bzipi dislocation and is no younger than two thousand years old. By type and length its faults are similar to the Chkhalta dislocation formed in 1963 after the earthquake with intensity 9. Besides, these fault fields (old and new) are in 30-35 km distance from each other in the same structural zone. They originated from the main Caucasus thrust-slip and seismogenic faulting of the Utviri thrust.

There are no buildings in the Chkhalta Hole that could give us any information about the paleo-earthquake. But in 10 km from the Nenska structure on the left side of the river Nakra and in the basin of the river Enguri there are Svanetian tower-castles that are 30 m in height and have shape of truncated cones. Basements of some towers lay in 3 m depth in the ground and the ground floors (height 6-7 m) are built of stones and lime mortar that makes the building resistant to seismic shocks. Still in Svaneti in the basins of the rivers Nakra and Enguri the parts of some towers and temples have seismogenic deformations, at some places they are entirely ruined.

On the left side of the river Enguri where it leaves Svaneti and bends to the Black Sea there is the dislocation of the Abakura structure. It is situated near Bakilda ridge at the crossing of the faults of Lakhamula-Gomi and Khetskvara (Tita-Nodashi). In 4 km distance the main thrust of the structure has broken through the firmest rocks of gabro-diorites and gabro-piroxanites and made a terrace-escarp of 7 m height. It has horizontally displaced the head-river by 50 m. In the east the seismogenic fault crosses the northern branches of the Laila-Lekheli mountain massif and continues underneath the deformed glacier.

The perpendicular sections of the metamorphic rocks, the disintegrated river-beds, the dams in the gorges, the enormous crater-like holes on the top of the Bakilda Ridge indicates to the seismic origin of the Abakura structure. The structure seems to be a part of the epicenter zone of the earthquake with intensity 9-10 that spread over the western part of the Svaneti Ridge in the recent past. It is natural that the seismogenic faults of the structure are located near the landslides that have displaced the friable and cliff rocks of 20 million m^3 in the basins of the rivers Enguri, Laili and Khumperi. The survived torn surfaces of flint slates, Triassic sandstone and Jurassic clay slates indicate to the similar ages of the landslides. Their closeness to the paleoseismogenic Akiba structure, the volume and the area covered by them refers to the seismogravitational genesis of the displacements on the slopes.

The territory of landslides (approximately 100 km^2) is similar to the landslide area (approximately 80 km^2) that originated in 1963 after the Chkhalta Earthquake with intensity 9.

The age of the Abakura Structure was determined in accordance with the following data. The hole, a closed fragment sized 100×30 m of the main seismogenic ditch of the Abakura Structure with 1.7 m sediments in it, was filled with erosive friable products from a 22 500 m area. Thus, the possible quantity of the friable sediments filling the hole is approximately 5 100 m^3.

On conditions that 1 mm/m^2 friable products are washed away every year the sediment amounts to 22.5 m^2/y. As all those friable products are located in the hole, it is possible that it was being filled during 230 years that is considered as the maximum age of the structure. As a matter of fact the Abakura structure might have originated even earlier, as before the sediments filled up the seismogenic ditch it had partially absorbed the fragmented products. But the survived tectonic dams in the torn riverbeds refer to younger age of the Abakura Structure" (Khromovskikh, Nikonov, 1984; Khromovskikh et.al., 1979).

Having analyzed the above mentioned material we may conclude that: a) the paleoseismodislocational structures of Nenskra and Abakura are located 15 km distance from each other in the same fault zone of the main creep of the Caucasus; b) they are of similar ages – 500-1600 A.D. (Khromovskikh et.al., 1979); c) it is possible that they were formed in the epicenter zone of the same earthquake; d) the chroniclers might not have noticed this earthquake as it occurred on an unpopulated territory (Fig. 19). Thus, the assessment of the parameters of the strong earthquake identified on the bases of paleoseismodislocations of Nenskra and Abakura is such: date – 1100 (Δt=±100 year); epicentre coordinates – φ=43.10º, λ=42.30º (ΔE=±0.2º); depth – h=15 km (Δh=7-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, pp. 112-114 (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 79-83 (in Russian).

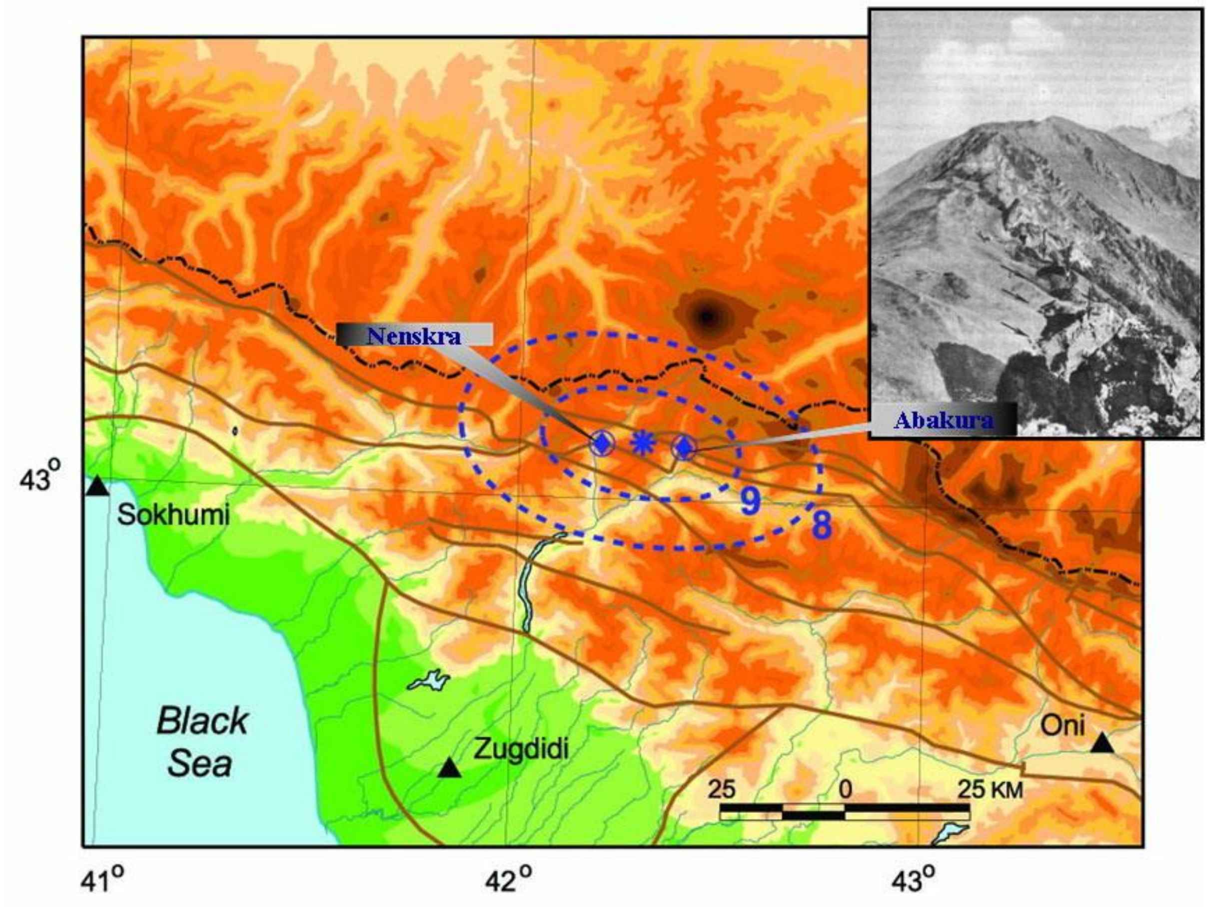

Fig. 19. Map of intensity distribution for the Nenskra-Abakura Earthquake, April 22, 1100.

1275 Mtskheta EQ

"In the Natskhori gorge of the river Aragvi L. Koghoshvili (1970) discovered two parallel normal dip-slips with northern wings raised by 1.5-20 m. The normal dip-slip has broken through the alluvial sediments of the first terrace and the clay sandstones and the slates underneath. Near the displacements surface the pebbles are inclined towards the northern wings of the normal dip-slip and at some places are vertically oriented (alongside the long axes). In the upper wing some pebbles have driven in the torn layers. This fact indicates to pulse-like displacements (or earthquake) that took place a couple of thousand years ago" (Koghoshvili, 1970; Khromovskikh, Nikonov, 1984).

An anonymous Georgian chronicler (Chronicler, 1987) informs: "...There occurred a terrible earthquake only in Samtskhe and the shocks lasted for a month. ...The Cathedral was ruined in Mtskheta."

Prince Vakhushti᾽s (Prince Vakhushti, 1973) information is almost similar: "The earth trembled on Thursday... The earthquake occurred in Samtskhe and nowhere else. Mtsketa was also ruined."

"Vakhtang Gorgasali rebuilt Mtskheta with a stone mortar and highly decorated it. He assigned the Cathalicos as well. Then being destroyed by an earthquake (the Church of Svetitskhoveli) it was restored by King George V (the Splendid, 1318-1346)" (Prince Vakhushti, 1904).

An Armenian historian Samuel Anetsi shortly informs that there "was an earthquake in 1285 in Tbilisi" (Samuel Anetsi, 1989).

There exist the following data in Code of Historic and Cultural Monuments of Georgia: The Complex of Samtavro – due to the 1283 earthquake its dome fell down and was restored at the edge of XIII-XIV centuries; The Complex of Svetitskhoveli – during its existence was many times under danger of destruction. In 1283 it was damaged by the earthquake. In the XIV century King George the Splendid (1314-1346) restored the dome of the temple (Description..., 1990).

In the first 1977 edition of the New Catalogue of Strong Earthquakes (New Catalogue..., 1977) the epicenter of the above mentioned earthquake was considered near town Gori. Seemingly, such a decision was influenced by the macroseismic data from the two regions quite distant from each other: Samtskhe – a historical-geographic province of Georgia of those times and town Mtskheta. The epicenter was pointed between these seismogenic zones. But in the 1982 American edition of New Catalogue (New Catalogue..., 1982) this version was denied and it was regarded that there had been two individual strong earthquakes in Samtskhe (1283) and in Mtskheta (1275).

The seismogenic landslide of Khandaki is located to the south of village Khandaki on the right terraced slope of the gorge of the river Mtkvari. The landslide has originated due to the tectonic faults in the intersecting upper cretaceous carbonate sediments that are lithologically presented as an alternation of strata of marly limestones and volcanogenic breccias. In these sediments a large landslide-gravitational block has developed which is morphologically presented as a 700 m long and 40-60 m high hill displaced northwards by 300 m to the second terrace of the river Mtkvari. The constituent rocks of this gravitational hill are destructed, fragmented and form blocks inclined by different angles. The landslide is stable. It must have originated due to a strong earthquake (the information is obtained during the 2007 geological-geomorphological and geophysical expeditions).

Thus, as noted above, in the reports of the anonymous Georgian chronicler describing the Samtskhe earthquake there is a postscript stating that the temple of Svetitskhoveli was also destroyed in Mtskheta. The historical-geographical province of ancient Georgia – Samtskhe was approximately at 130 km distance from Mtskheta, so that the devastating earthquake (I_o=9-10) in the Samtskhe could cause shocks with intensity $I \approx 6$-7 in town of Mtskheta. The strength of the shocks could increase to intensity $I \approx 7$-8 due to poor soil condition beneath the temple Svetitskhoveli, but they could not destroy either the temple of Svetitskhoveli or the Samtavro church in Mtskheta or the Bebris Tsikhe castle in the Natskhori gorge, destruction of which has been reported in other sources (Khromovskikh et al., 1979). Therefore, the version of the powerful earthquake that emerged in the second half of XIII millennium in Mtskheta (~1275) is more credible. Besides in the Natskhori Gorge to the north of town Mtskheta L. Koghoshvili (1970) found two seismodislocational structures of approximately the same age as the newly discovered Mtskheta earthquake (Fig. 20). We assume that the main parameters of the Mtskheta earthquake are: date – 1275 (Δt=±10 year); epicentre coordinates – φ=41.85°, λ=44.70° (ΔE=±0.2°); depth – h=15 km (Δh=8-30 km); magnitude – M_S=6.5 (ΔM=±0.5); intensity in the epicentre – I_o=9 (ΔI_o=±1).

Sources:

Kogoshvili, L. V. 1970. Live tectonics of Georgia and its impact on the relief. Metsniereba Publ. House, Tbilisi, 220 pp. (in Russian).

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, p. 118 (in Russian).

Chronicler. Published in 1987. Centennial Manuscript. Issued by R. Kiknadze, Tbilisi, pp. 167-168 (in Georgian).

Prince Vakhushti. Published in 1973. Description of the Georgian Kingdom. Issued by S. Kaukhchishvili, Tbilisi, p. 230 (in Georgian).

Prince Vakhushti. Published in 1904. Geography of Georgia. Translated by M. Janashvili. West Caucasian section of RGS, book 24, issue 5, Tiflis, pp. 67-68 (in Russian).

Samuel Anetsi. Published in 1989. Echmiadzin, 2-3, 88 (in Armenian).

Description of historical and cultural monuments of Georgia. 1990. Book 5. Tbilisi, pp. 254, 262 (in Georgian).

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 73 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 171.

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 79-83 (in Russian).

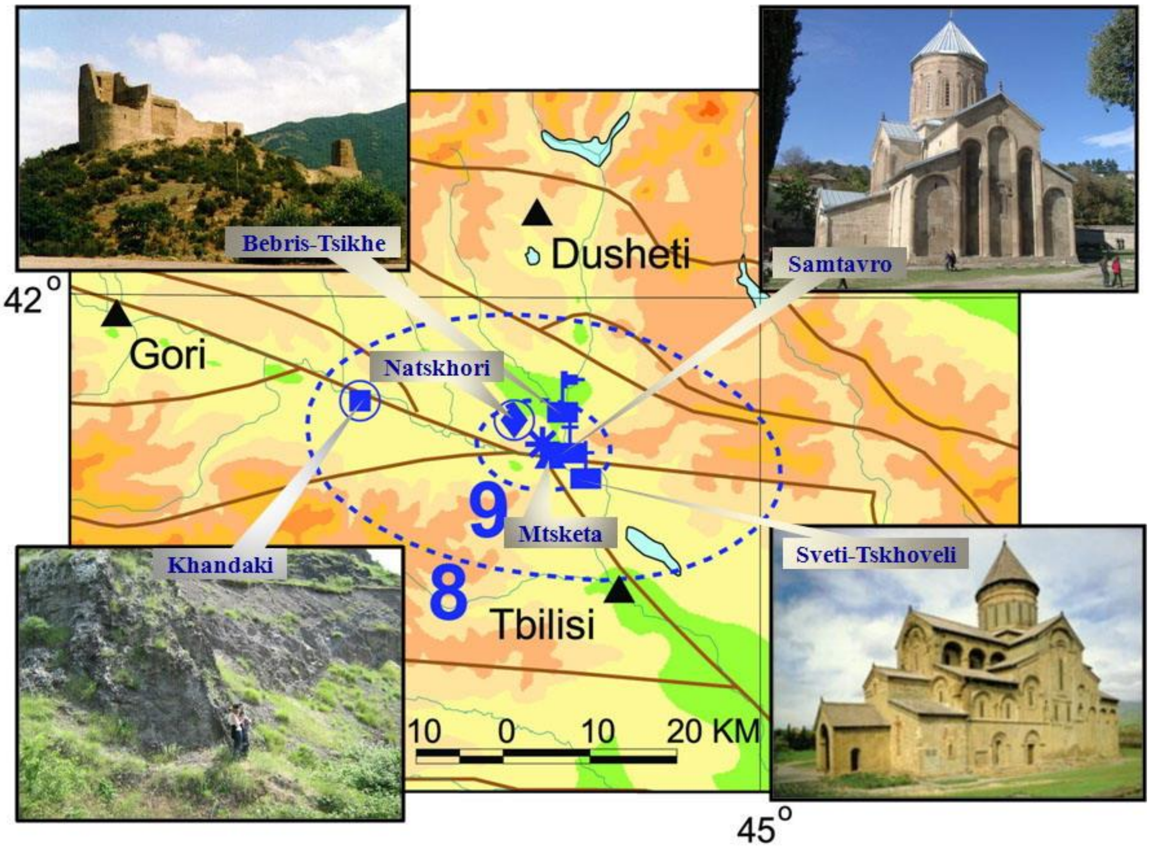

Fig. 20. Map of intensity distribution for the Mtskheta Earthquake, 1275.

1283 Samtskhe EQ

An anonymous Georgian chronicler informs that: “There was a strong earthquake on Wednesday of the Holy Week, later there was a week one on Thursday, but nobody paid attention to it. On Easter Saturday at three o᾿clock in the morning a terrible earthquake shocked the land. Temples and monasteries, churches and fortresses, houses and other buildings, mountains and hills all collapsed, cliffs turned into dust, the Earth opened and oil-tar-like water broke out from there, high trees trembled and fell down; the church at Atskuri also collapsed. The icon of Virgin that was situated in the middle of the church during the service was saved undamaged as the dome fell down and covered it like a hat. This terrible earthquake that lasted for a month occurred only in Samtskhe. Nothing was damaged elsewhere. But in Mtskheta the Cathedral collapsed and a great number of people died. Temples, churches and fortresses were all in ruins. There was a great sorrow and sobbing all around” (Chronicler, 1987; Kartlis Tskhovreba, 1959).

Prince Vakhushti᾿s (Prince Vakhushti, 1973) information is nearly similar: “The Earth quaked on Thursday... The earthquake occurred in Samtskhe and nowhere else. Mtskheta was also ruined.”

“Above the Tikhrevis-Khevy gorge on the southern bank of the Kura there is Atskveri – a gorgeous fortress. The residents here are Meskhs (local Georgians in the region), Armenians, Jews-merchants and elite Mohammedans. There is a great church of Saint Virgin beautifully arranged with a dome, and the residence of the Metropolitan... Nowadays only three dilapidated walls of the huge Atskuri temple have survived. As considered it belongs to the VII century. In the XIII century it was destroyed by an earthquake and later was restored again” (Prince Vakhushti, 1904).

As Niko Dadiani reports (Niko Dadiani, 1962): "…Good was wrathful with us and that was the reason of the terrible earthquake. Churches, fortresses and all the buildings collapsed and the tar-like water broke out from the earth. This happened on the Easter day."

Some description of the Samtskhe earthquake is given in the History of Georgia edited by G. Melikishvili (History of Georgia, 1991): "A terrible earthquake was added to the great poverty. Many churches, monasteries, fortresses, houses and other buildings collapsed, even the cliffs turned into dust, the land separated apart. The shocks lasted for the whole month. A great number of people died and the most who survived – became homeless and indigent. The epicenter of the earthquake was in Samtskhe, but its impact was so great in Kartli that even Mtskheta Cathedral was ruined."

Let us review the date of the earthquake. According to Prince Vakhushti the earthquake occurred in 1283. Niko Dadiani informs: "Sargis Jakeli died at that time." It is known that Sargis died in 1285. There is also the interesting research by R. Kiknadze (Kiknadze, 1982), where the author links the earthquake date to the year of the death of one of the Mongolian leaders. In his opinion the earthquake occurred on April 14, 1275. But we regard the year 1283 as the occurrence date of the Samtskhe earthquake as it is described in the most data of the historical documents.

There are some data as well: "Year 1261. A great earthquake occurred in Georgia and tremendously affected the country" (Bius, 1948); and "In 1261 an earthquake occurred in Killikia. An earthquake occurred in Georgia as well and caused a great deal of damage to Georgians" (Mkhitar Airivanetsi, 1989). It is acceptable that these data indicate to the Samtskhe earthquake (New Catalogue..., 1977, 1982).

The huge seismogenic Atskuri landslide is located to the north-west part of the Trialeti Ridge slope on the territory of village Atskuri. This landslide must be caused of the seismic activity of the active faults of Kodiana-Blordza and Arjevani-Bakuriani. In the archaeologists' viewpoint the earthquakes of this period must have caused the destruction of the Atskuri Cathedral of the XI century. In the south of village Atskuri, at the north end of the Trialeti Ridge there are morphologically seen three huge landslide blocks with a total area over 2 km^2 and the volume 1 billion m^3. The average depth of the block deformations is 50-60 m. The relative difference in the landslide area height is 350-390 m. The landslide has developed in the flysch sediments of the upper Eocene. Its southern boundary crosses the middle Eocene volcanic rocks separated by a tectonic fault and to the north it is spread to the surface of the second terrace of the river Mtkvari (The information is obtained during the 2007 geological-geomorphological and geophysical expeditions).

The Dgvari landslide covers the northern wing of the central segment of the outcrop eminence of the anticline morphostructure of the Trialeti ridge and the Tori-Tadzrisi synclinal folds on the territory of village Dgvari. Its area is 10 km^2 and the volume – over 300 million m^3. The landslide consists of the areas of different generation, genesis, age and geological structure and has two different morphological and hypsometric levels: 1) some slightly inclined flat surfaces in 1200-1400 m from northern boundaries of the Trialeti ridge; 2) a 1500-2000 m high, slightly fragmented by erosion, terraced-denudated-hill relief crossed by the Baku-Tbilisi-Ceyhan pipeline on its south-east edge. The landslide area on the upper morphological terrace is characterized with a slow and deep block-type creep, and on its lower level – by active plastic movement. Such differentiated dynamics and homeostatic condition of the landslide area is caused by the heterogeneous surrounding that stimulates landslide processes, by tectogravitational pressure on the constituent rocks of the lower morphological level formations and periodical activation of the earthquakes in the tectonic slip zone.

The geomorphological specification of the landslide relief indicates to the fact that the starting stage of its genesis preceded the settlement of village Dgvari as it is situated on the old body of the landslide (Tatashidze et al., 2006; Tsereteli et al., 2007).

The seismogenic Naokhrebi-Potskhovi rock avalanche has originated on the right slope of the gorge of the river Potskhovi, in the west of village Naokhrebi. Its area exceeds 3 km^2 and the volume is 1.8 km^3. The rock avalanche has blocked the gorge of the river Potskhovi that partly cuts the talus to 40-50 m depth and created 1.0-1.2 m high so called "groove terrace" on the left side; on the right side it has formed a 40-60 m high hill relief composed of the material of large blocks and detritus-clay fraction entangled with one another. Near the riverbed on the 82 m high terrace the material of the rock avalanche is composed of Oligocene sediments that must have driven into the tectonic fault zone during formation of the rock avalanche caused by a strong earthquake. This fact is corroborated by the morphological characteristics and the "terraced groove surface" formed after the creation of the rock avalanche. The rock avalanche must have originated in the late Holocene-historical period (Tsereteli, Gobejishvili et al., 2008; Tsereteli, Gobejishvili et al., 2008).

Among the strongest Caucasian seismic phenomena described in historical documents, the Samtskhe Earthquake of the XIII century is distinguished from others. The analysis of the macroseismic information given in the primary sources shows that the epicenter of the earthquake was located near village Atskuri (moreover, it is confirmed by Ye. Beous' work (Bius, 1948) informing that village Okona situated near village Atskuri was destroyed) and the shocks of high intensity were spread over the eastern part of Samtskhe (Fig. 21). It seems that in the epicenter of the earthquake the intensity was 9-10 ± 1 that is characteristic for the earthquakes with maximum magnitude M_S=6.6-7.0 in the Caucasus (e.g. the recent earthquake in Spitak in 1988 and in Racha region in 1991, M_S=6.9). Thus, according to the analysis the parameters of the Samtskhe earthquake are: date – 1283 (Δt=±10 year); epicentre coordinates – φ=41.7°, λ=43.2° (ΔE=±0.5°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:

Chronicler. Published in 1987. Centennial Manuscript. Issued by R. Kiknadze, Tbilisi, pp. 167-168 (in Georgian).

Kartlis Tskhovreba. 1959. Manuscript, v.2, Issued by S. Kaukhchishvili, Tbilisi, pp. 287-288 (in Georgian).

Prince Vakhushti. Published in 1973. Description of the Georgian Kingdom. Issued by S. Kaukhchishvili, Tbilisi, p. 230 (in Georgian).

Prince Vakhushti. Published in 1904. Geography of Georgia. Translated by M. Janashvili. West Caucasian section of RGS, book XXIV, issue 5, Tiflis, p. 160 (in Russian).

Niko Dadiani. Published in 1962. Life of Georgians. Tbilisi, p. 90 (in Georgian).

History of Georgia. 1991. Edit. G. Melikishvili, Metsniereba Publ. House, Tbilisi, p. 161. (in Georgian)

Kiknadze, R. 1982. Questions of a source study of history of Georgia, I. Metsniereba Publ. House, Tbilisi, pp.175-176 (in Georgian).

Varazanashvili, O. Papalashvili, V. 1998. Reconstruction of strong earthquake parameters by historicl data of XI-XIV cc. in Georgia. Journal of Georgian Geophysical Society (A), vol. 3, pp. 77-84.

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 24 (in Russian).

Mkhitar Airivanetsi. Published in 1989. History of Armenia, Echmiadzin, 2-3, 88 (in Armenian).

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 73 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.171.

Tatashidze, Z., Tsereteli, E., Gaprindashvili, M., Tsereteli, N., Taliashvili, D. 2006. Dgvari Landslide (Borjomi region) and the risk of its Implication on Baku-Tbilisi- Ceyhan pipeline Functioning. Bulletin of the Georgian National Academy of sciences, 173, No. 2, Tbilisi, pp. 304-306.
Tsereteli, E., Gobechia, G., Gobejishvili, R., Gaprindashvili, M., Tsereteli, N., 2007. Some problems of geologic hazard of main pipeline Baku-Tbilisi-Ceyhan (BTC) in the central part of Trialeti morphostructure (territory of Georgia). Georgian Enginering News. No. 4, pp. 102-107.
Tsereteli, E., Gobejishvili, R., Tsereteli, N., Gaprindashvili, M., Gongadze, M., Dvalishvili, G. 2008. About law of development of landslides processes in Akhaltsikhe depressions and about occurrence in 2008 of the Wakhani landslide. Proceedings V. Bagrationi Institute of Geography (new series), No. 2 (81), Tbilisi, pp. 28-33 (in Georgian).
Tsereteli, E., Gaprindashvili, M., Kalandadze, G. 2008. Visual engineering-geological estimation of objects of using ore in Akhaltsikhe and Adigeni areas and in territory of Vale settlement. Tbilisi, 13 pp. (in Georgian).

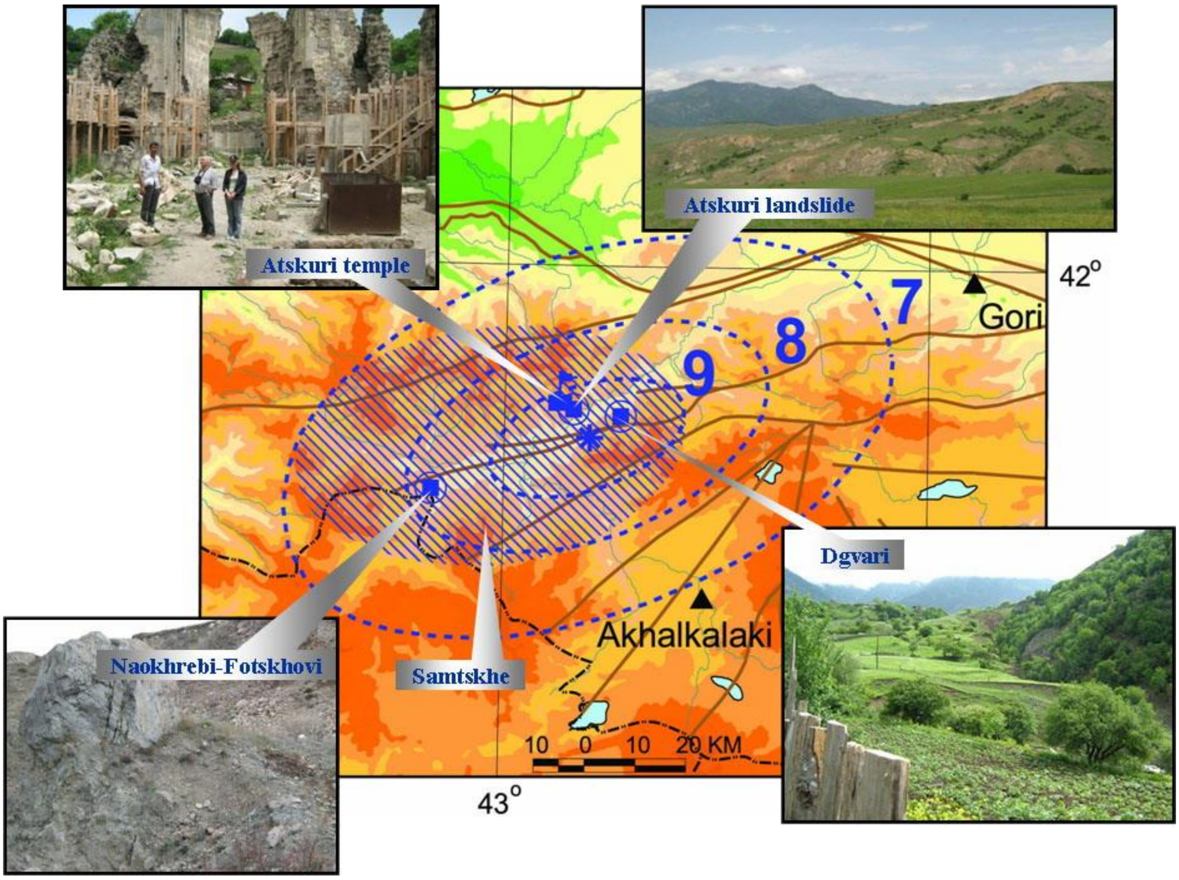

Fig. 21. Map of intensity distribution for the Samtskhe Earthquake, 1283.

1350 Lechkhum-Svaneti EQ

In New Catalogue of Strong Earthquakes (New Catalogue..., 1977) there is the description of a XIV century earthquake of intensity 8-9 located supposedly in the North Caucasus in the gorge of the river Chegemi with an agreed date – 1350 ± 100 and some notes about it: The Chegemi gorge; rock slips in the mountains; buried villages. The information is based on two North Caucasian sources (Nikitin, 1974; Materials..., 1974). In the 1982 American edition of catalogue (New Catalogue..., 1982) the parameters of the earthquake are changed. Its magnitude is considered as 6.5; and the area north-east from Mestia is assumed as the place of its origin. Some information is added to the note: In Georgia several villages have been buried underground and a church has been ruined near Chrebalo. The sources refer to some additional research (Khromovskikh et al., 1979) based on E. Takaishvili's (Takaishvili, 1937) and V. Sologova's (Manuscripts of Svaneti, 1988) works (Varazanashvili, Papalashvili, 1998).

In his book "A 1910 archaeological expedition in Lechkhumi and Svaneti" (Takaishvili, 1937) E. Takaishvili tells: "From Alpana we headed to Labechina that is in eight kilometers from Alpana. After the Tsageri church the church of Labechina is the best one in Lechkhumi. It is situated on a high hill on the right side of the river Rioni. The church had been roofed with bedplates, but nowadays it is covered with shingle. The dome belongs to the XII-XIV centuries, the time when Gabriel Labechinian rebuilt the church after it was entirely ruined due to a strong earthquake. There is just one leather manuscript of the Gospel survived in the church. At the end of John's Gospel there is quite a long letter by Gabriel Labechinian. In it he tells that he rebuilt the church after it had been destroyed by the earthquake. There is another letter in different calligraphy of Nuskha-Khutsuri (old Georgian alphabet) in one column, supposedly written no later than XIII-XIV centuries: "…Many years passed after that and God sent us a terrible earthquake for our sins. Everything built by the first Labechinians and me was ruined within a day. In the church all the icons and equipments broke down and fragmented. A great sorrow was all around. Nobody could decide whether to stay or leave this place. Nobody was able to imagine that Labechina could be built again. Neither did I intend to stay …"

"...Independent Svaneti is one of the parts of Upper Svaneti that is spread over the gorge of the river Enguri… Independent Svaneti consists of the communities of Ushguli, Kala… Kala community is situated beyond the Latpari Pass… The first village here is Davberi… On the left of the village, on a separate hill there are the churches of Kvirike and Ivlita, a former monastery… (Svanetians call this church "Lagurka")… There is a script on the arch: "I, Giorgi, son of Antony restored this St. Kvirike church ruined by an earthquake. Let God forgive the sins to those who remember me." As described in the work (Manuscripts of Svaneti, 1988) this script written in the XIV century with Asomtavruli (old Georgian alphabet) letters is placed on the middle arch of the southern column inside Lagurka church. In this work V. Sologova notes that the churches of Labechina and Lagurka are situated relatively on the southern slope of the Lechkhumi Ridge and on the northern slope of the Svaneti Ridge that make an entire mountain system and present the southern branch of the Greater Caucasus. In V. Sogolava's opinion (Manuscripts of Svaneti, 1988): "…In Labechina church the destruction scales were greater than in Lagurka. Although, Giorgi, son of Antony states that the church was ruined by an earthquake, in fact it was not entirely devastated. All the walls of Lagurka, except a small part of the south-eastern wall, have survived with their original forms and paintings, whereas it is obvious that the walls of Labechina church have been rebuilt and the original building stones are used for a second time, e.g. all the XI century stones with scripts on them are displaced or reshaped, some have cut edges, some are placed upright down or laterally in the rows…"

"...On the left divide of the valley of the river Tskhenistskali there is a giant landslide of Gobi with the length of 7 km and width up to 2 km and the slipped unconsolidated rocks up to 125 million m^3 in volume. It might be formed during an earthquake that destroyed the Church of St. Kvirike and fortress Murkmeli several centuries ago.

The fortress is located on the left bank of the river Enguri near village Ushguli on a hill composed of Lias shales. Unlike many ancient monuments which were rebuilt after the earthquakes, the fortress Murkmeli survived to our days in the form in which it remained after the disaster. The entire building consists of three castle towers and ramparts. The eastern tower about 12-15 m is preserved in the best way. Its walls built of slate on limestone cement, like other towers, have cracks of 5-7 cm width.

The most damaged one is the western tower. Its northern and eastern walls are almost completely destroyed, while others are deformed, separated from each other by 5-8 cm. The southern wall leans outwards and the western one – inwards. The southern wall of the eastern tower leans in the similar way. In the rampart between the northern and eastern towers a 10 m segment of 0.6-0.7 m wide block is almost tumbled" (Khromovskikh, Nikonov, 1984).

"According to a popular legend, this castle was built by Queen Tamara's order. Despite the absence of the chronicle data we may definitely assume the fact of the destruction of this fortress by an earthquake... As a Svanetian legend states the rocks cracked not far from the fortress many centuries ago. One of these fractures was classified as a seismodislocation that proves the possibility of a periodic recurrence of destructive earthquakes in this area" (Khromovskikh et. al., 1979).

The Zhoshkha-Gendushi landslide is located in the lower basin of the river Askistskali (right tributary to the river Rioni) and almost entirely covers the territories of Zhoshkha and Gendushi villages.

The Zhoshkha-Gendushi landslide has developed in the north wing of the Racha syncline. This wing covers the area 2 km in width and 4 km in length from the Labechina-Gendushi anticline (the southern tectonic creep of the Gvelistavi-Sakalmia dividing hill) to the gorge of the river Askistskali. Its area is 8 km^2. The landslide processes have developed in Oligocene-Miocene gypsum containing sandstones alternation and have transported some large blocks of Cretaceous marl and breccia limestone in the tectonic fault zone. At the 40-60 m depth in the area of the landslide the Tertiary rocks are destructed and entangled due to exotectogenic processes. Morphologically its terraced and wavy-hill surface indicates to the multiple regeneration of the landslide.

The location of the above mentioned villages on the landslide and the dendrochronological state of the hundred-years-old walnut and oak trees indicate to the fact that primary landslide processes must have been formed in the historical past and their reactivation must have began after the devastating 1991 Racha earthquake (Tsereteli, 1965; Tsereteli, Gaprindashvili, 2005).

The Ghviara-Kldisubani landslide in the Racha syncline zone is one of the largest (20 km^2) and deepest (almost 50-60 m deep) seismogravitational products. It is located in the lower basin of the river Ritseula and morphologically covers the terraced right side of the river Rioni. In the north it borders Sahelio-Sadmeli hill composed of Cretaceous carbonate rocks characterized by a lateral creep and a tectonic fault with the length of more than forty meters. The landslide has formed in the suite of the Oligocene-Miocene clay-sandstone. In the first stage the clay-sandstone suite composed of upper Cretaceous limestone and gypsum displaced to the south-east without destructing the structure and created 200-250 m wide graben-like depression between the landslide and the broken-off slope. There are some micro-folds in the southern zone of the landslide. After the first stabilization of the landslide the settlements of Ghviara and Kldisubani appeared on it. Though, multiple abyssal landslide processes took place and that are thought to be provoked by earthquakes. This assumption is confirmed by the morphology of the landslide and the survived former settlements on it (Tsereteli, 1965).

According to the data of the primary sources we can assume that in the mountains of the Chegemi gorge there was a landslide or rock fall that followed an earthquake with intensity $I \geq 7$; In Svaneti (historical-geographical province of Georgia), due to the earthquake the churches of St. Kvirike and St. Ivlita and Murkmeli fortress were damaged that could be caused by shocks of intensity $I \geq 7$; in Lechkhimi (historical-geographical province of Georgia) the Labechina Monastery built of the firm soil was entirely destroyed that could be a result of an earthquake with intensity $I \geq 8$. Close to this monastery (at 3 and 9 km distance) two landslides have developed. Taking into consideration that in Georgia numbers of villages were buried under ground due to earthquakes we can assume that this seismic phenomenon of the XIV century had too great macroseismic reflection on the territory of Georgia (Fig. 22). Particularly, its epicenter was in the area of the Lechkhumi Ridge. The seismogravitational structure Gobi seems to be connected with the earthquake as far as their location and age are similar (Varazanashvili, Papalashvili, 1998). According to the summarized macroseismic data and estimated isoseismal models of different magnitude levels (Varazanashvili, 1999) we can regard the basic parameters of the Lechkhum-Svaneti earthquake as: date – 1350 (Δt=±100 year); epicentre coordinates – φ=42.70°, λ=43.10° (ΔE=±0.5°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 74. (in Russian)

Nikitin, P. N. 1974. Chronology of local earthquakes in the Northern Caucasus. Authors archives, Pyatigorsk (in Russian).

Materials from the North Osetia republic central archives, MVD. 1974. Ordzhonikidze (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.74.

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 35-37 (in Russian).

Takaishvili, E. 1937. Archeological expedition at Lechkhum-Svaneti in 1910. Paris, pp.11-122, 178-184 (in Georgian).

Manuscripts of Svaneti, II. Published in 1988. Edit. by V. Sologova, Tbilisi, pp. 89-90 (in Georgian).

Varazanashvili, O., Papalashvili, V. 1998. Reconstruction of strong earthquake parameters by historical data of XI-XIV cc. in Georgia. Journal of Georgian Geophysical Society (A). Vol. 3, pp. 77-84.

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, 115-117 pp. (in Russian).

Tsereteli, E. 1965. Geomorphology a southern slope of the central part of Grate Caucasus (within Racha). Part 1. Tbilisi, 215 pp.

Tsereteli, E., Gaprindashvili, M. 2005. Engineering-geological conclusion about the hazard of landslides that have arisen in the village Genduschi Ambrolauri administrative area. Tbilisi, p. 15 (in Georgian).

Varazanashvili, O. 1999. Seismic hazard assessment of Georgia by deterministic and probabilistic of methods. Journal of Georgian Geophysical Society (A), vol. 4, pp. 35-45.

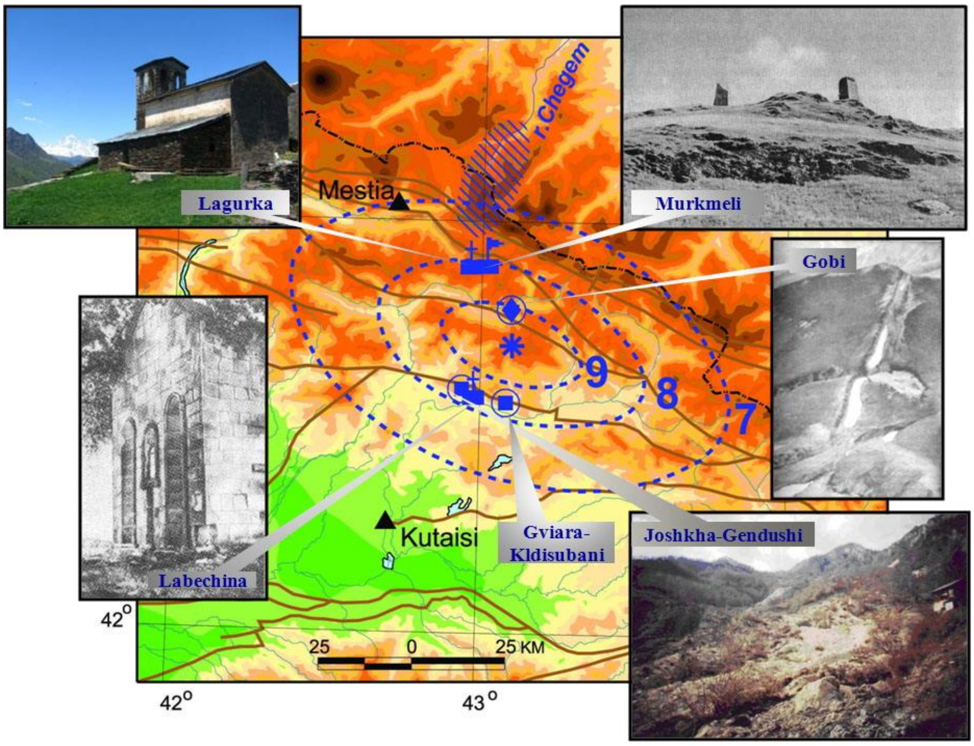

Fig. 22. Map of intensity distribution for the Lechkhum-Svaneti Earthquake, 1350.

1530 Alaverdi EQ

"The Monastery of Alaverdi was founded by Ioseb Alaverdian in the middle of the VI century. At the beginning of the XI century Kvirike, King of Kakheti built a great Cathedral on the site of St. George's Church, mostly known as Alaverdi. …Alaverdi has been damaged for many times by enemy and earthquakes" (Georgian Soviet Encyclopedia, 1987).

"Here stood St. George's Church since the ancient times. In its place Prince Kvirike built the present Cathedral (Alaverdi) in the XI century. In 1530 its dome was destroyed by an earthquake and later restored by Leon" (Prince Vakhushti, 1904).

"Year 1530. A strong earthquake in Alaverdi (Georgia). It destroyed the dome of the church of George, the Great Martyr, that was later reconstructed by King Leon" (Bius, 1948).

In spite of few historical data we can say that in Georgia the eastern part of the southern slope of the Caucasus was seismically too active during the whole historical past (Fig. 23). This can be confirmed by the 1530 Alaverdi earthquake with the probable parameters: date – 1530 (Δt=±1); epicentre coordinates – φ=42.05°, λ=45.40° (ΔE=±0.5°); depth – h=15 km (Δh=8-30 km); magnitude – M_S=5.7 (ΔM=±0.5); intensity in the epicentre – I_o=8 (ΔI_o=±1).

Sources:

Georgian Soviet Encyclopedia. 1975. Vol. 1, Tbilisi, p. 260 (in Georgian).
Prince Vakhushti. 1904. Geography of Georgia. Translated by M. Janashvili. West Caucasian section of RGS, book 24, issue 5, Tiflis, p. 160 (in Russian).
Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 25 (in Russian).

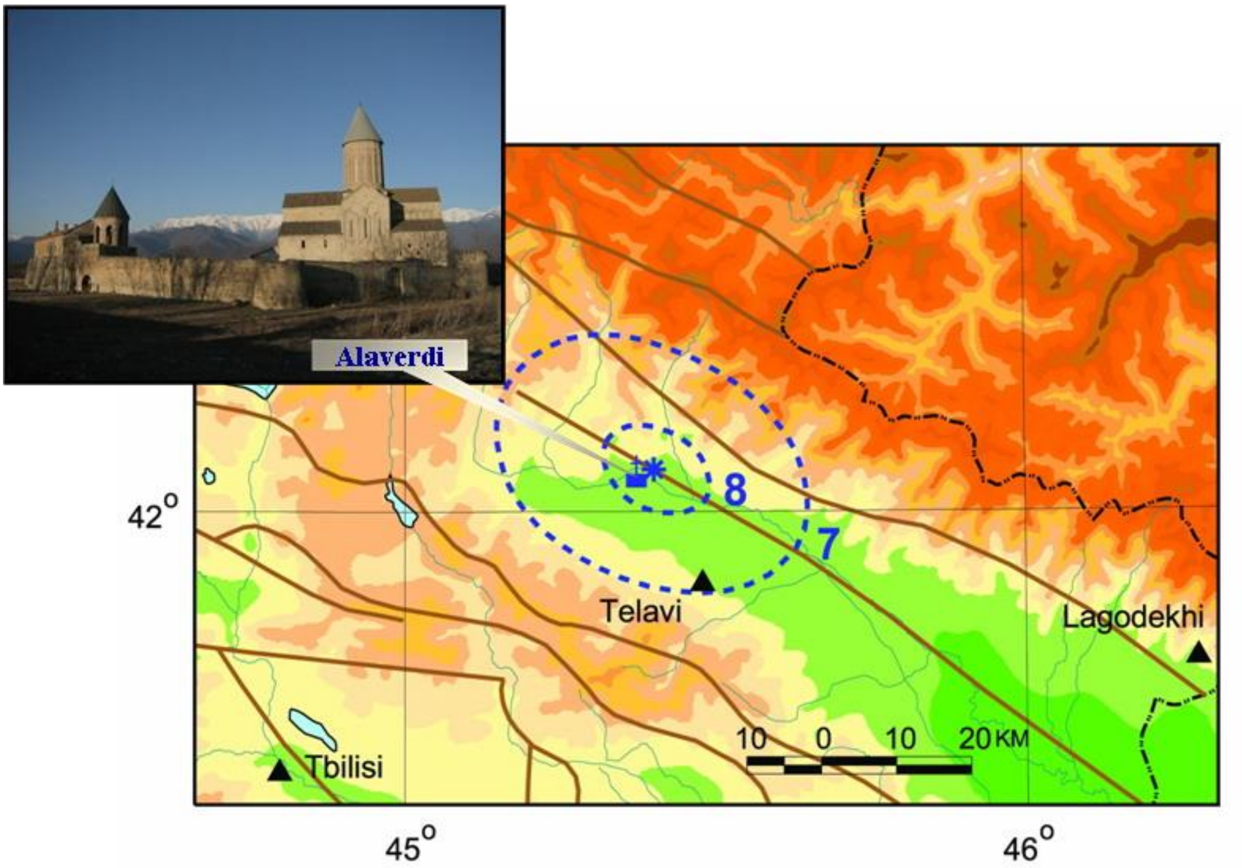

Fig. 23. Map of intensity distribution for the Alaverdi Earthquake I, 1530.

1600 Bzipi EQ

"The Bzipi Range, composed of solid rocks (porphyry, sandstone, etc.), in its divide is cut with an enormous fissure-ditch with the length of 5.5 km. The four mountain tops that are located in 1.5-2 km distance from one another were truncated by the fissure and lowered by 5 m along the fault surface. There are gigantic closed crater-like depression (diameter – 100 m, depth – 25 m) full of massive rocks blocks alongside the open fault. The common length of the deformed valley is approximately 7.5 km.

The seismodislocations of the Bzipi structure are located at the junction of the main Caucasus and Lakorozi-Otau creep-thrusts. In the north-west from the structure there is a landslide (rock-avalanche) above Lake Ritsa. Both, the landslide and the structure are connected with the active (north) wing of the Ritsa fault distinguished by L. Koghoshvili (Koghoshvili, 1970); according to the seismodislocation sizes and its preservation quality it points to the earthquake with intensity not less than 9 and the date of origination no earlier than several hundred years ago. It is acceptable that the origination of the lake caused by a landslide 250 years ago and the formation of the Bzipi structure at the same time are interdependent phenomena" (Khromovskikh, Nikonov, 1984; Khromovskikh et al., 1979).

Thus, one of the strongest earthquakes was identified on the bases of the paleoseismodislocation of Kvira distinguished after field investigations. The probable parameters of the earthquake that originated several hundred years ago and had the intensity not less than 9 in the epicenter (Fig. 24) are: date –1600 (Δt=±100 year); epicentre coordinates – φ=43.40°, λ=41.00° (ΔE=±0.2°); depth – h=15 km (Δh=8-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:
Kogoshvili, L. V. 1970. Live tectonics of Georgia and its impact on the relief. Metsniereba Publ. House, Tbilisi, 220 pp. (in Russian).
Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, pp. 111- 112 (in Russian).
Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 70-77 (in Russian).

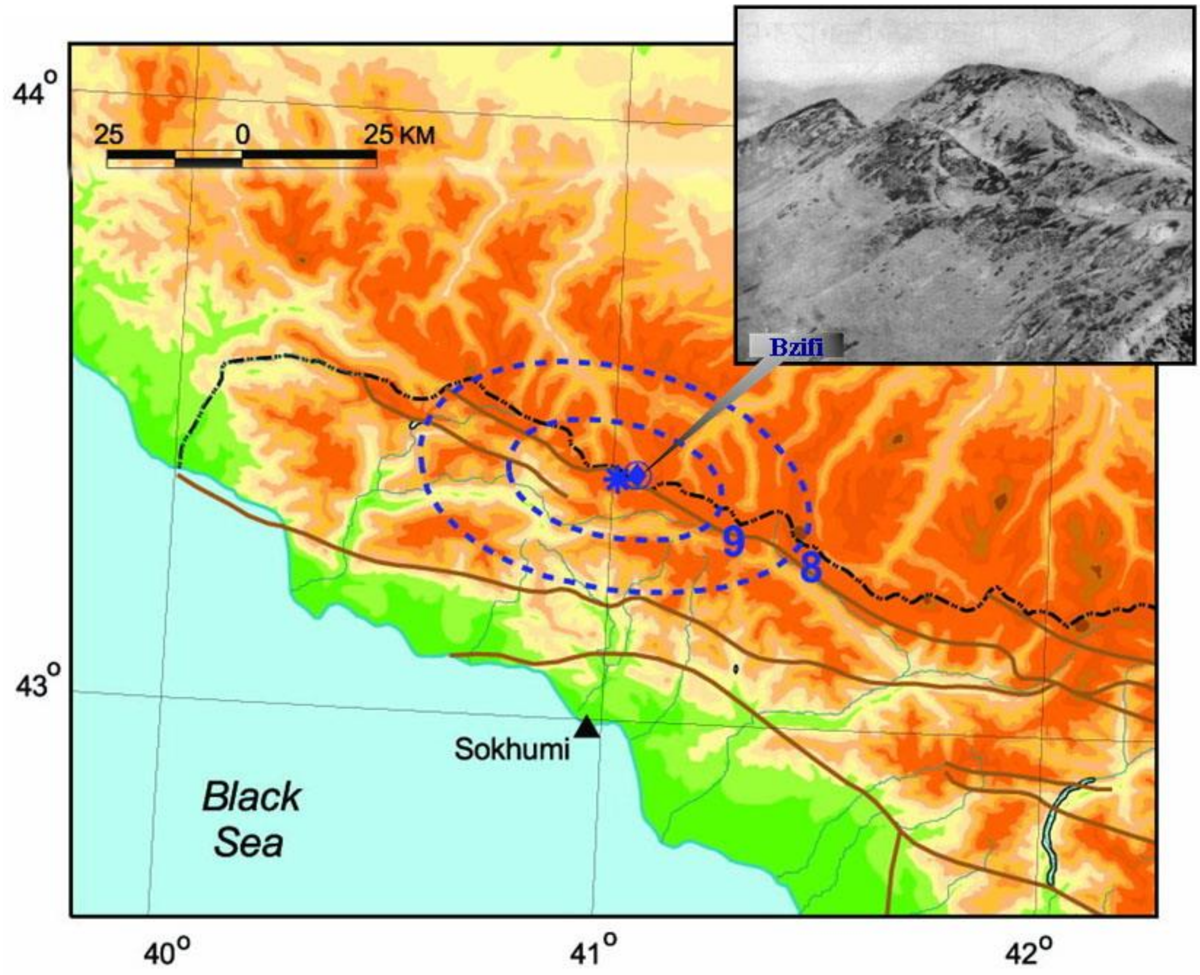

Fig. 24. Map of intensity distribution for the Bzifi Earthquake, 1600.

1614 Tsaishi EQ

"The church of Tsaishi destructed due to an earthquake was rebuilt by Cathalicos Malakia, son of Gurieli..." (Niko Dadiani, 1962).

"On the bottom of the Dzelitskhoveli Icon of Tsaishi Church there is a script with the information about the destruction of the church and its restoration by Cathalicos Malakia. In particular it tells that when Malakia, son of Giorgi Gurieli was the head of Jumati Church of Tsaishi he had the walls painted and equipped the church from the basement to the dome. In a years time there occurred a strong earthquake and the shocks lasted for the whole year. Many churches and villages were destroyed. Tsaishi church, its fence and other buildings were ruined, the icons and the equipment of the church – all broke down. The following year, when the earthquake shocks terminated, Malakia, now Cathalicos-Patriarch of Abkhazia, began to rebuild the church. He equipped it with icons and had the Dzelitskhoveli Icon adorned in 1619" (Niko Dadiani, 1962).

The date of the earthquake is indicated in the text of the script. "…when …the earthquake stopped, the following year I was assigned as the Cathalicos of Abkhazia", i.e. a year after the earthquake terminated Malakia was assigned as the Cathalicos. According to historical sources (Zakaraia, 1981; Gelati church book..., 1897; Kakabadze, 1913) Malakia became the Cathalicos of Abkhazia in 1616. The restoration of Tsaishi Church began in the same year as it is confirmed by the Gulani script at Gelati: "The same year, on May 13, Monday, the restoration of Tsaishi Church started" (Gelati church book…, 1897). By the calendar the Monday of the 13^{th} May fell in 1616. Taking into consideration the above information P. Zakaraia suggests that the earthquake occurred in 1614 (Zakaraia, 1981).

"The earthquake shocks of great strength that lasted for the whole year (1614) destroyed not only the Tsaishi ensemble but the nearest churches and villages as well. The script (on the icon that was restored in 1616-1619) informs that the church, the fence and other buildings of the ensemble were devastated to the basement and the entire inventory was annihilated. In P. Zakaraia's opinion "The most part of the building was destroyed, but the remains give us the idea about its original form" (Zakaraia, 1956).

The Tsaishi Ensemble is situated on an eminence (15 m height from the river edge) on the right side of the river Jumati near Tsaishi village. The eminence is composed of limestones that are inclined by 70º to the south-east. All the buildings of the Tsaishi Ensemble are built with limestone plates (width – 20 cm and more) on a cement basement and stand on the basic rocks – limestones" (Khromovskikh et. al., 1979).

"The fragments of the original church of Tsaishi ruined by the 1614 earthquake are placed in the walls of the new church" (Georgian Soviet Encyclopedia, 1987).

E. Jibladze and I. Riznichenko (1972) reckon that the earthquake intensity was 9 (M=6.5, K=16). If so, the earthquake epicenter would have been near Tsaishi and in terms of "average soil" the intensity would have been more than 9. That is also proved by the duration of the shocks. There must be some links between the earthquake and the Poti-Abedati fault. Its high seismic action is confirmed by the earthquake teams in 1940 in Samegrelo and in 1957 in Gegechkori. (Risnichenko, Jibladze, 1972; New Catalogue..., 1977).

According to the above historical data we may conclude that seemingly the earthquake occurred immediately on the area of Tsaishi village (Fig. 25). It was strong but had not such scales as it is described in the (Risnichenko, Jibladze, 1972) work. Otherwise there would have been much more damage and killed people in this densely populated area of Samegrelo and this fact could not have remained unnoticed by the chroniclers. Thus, we consider the parameters of this earthquake as: date – 1614 (Δt=±1year); epicentre coordinates – φ=42.40º, λ=41.80º (ΔE=±0.1º); depth – h=10 km (Δh=5-20 km); magnitude – M_S=6.0 (ΔM=±0.5); intensity in the epicentre – I_o=8-9 (ΔI_o=±1).

Sources:

Niko Dadiani. Published in 1962. Life of Georgians. Tbilisi, p. 151 (in Georgian).
Zaqaraia, P. 1981. Georgian central-vaulted architecture, XI-XVIII cc. 3, Tbilisi, p. 91 (in Georgian).
Gelati church book of St. George. Published in 1897. Chronicle, II, Tfilisi, p. 455 (in Georgian).
Kakabadze, S. 1913. Original book of Tsaishi. Tfilisi, p. 1 (in Georgian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 34-35 (in Russian).
Zaqaraia, P. 1956. Architectural complex of Tsaishi. Khelovneba Publ. House, Tbilisi (in Georgian).
Georgian Soviet Encyclopedia. 1987. Vol. 11, Tbilisi, p. 185 (in Georgian).
Risnichenko, Yu. V., Jibladze, E. A. 1972. Seismic activity and large earthquakes of the Caucasus. Proc. AS USSR, Fizika. Zemli, No.1, pp. 36-49 (in Russian).
New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 74 (in Russian).

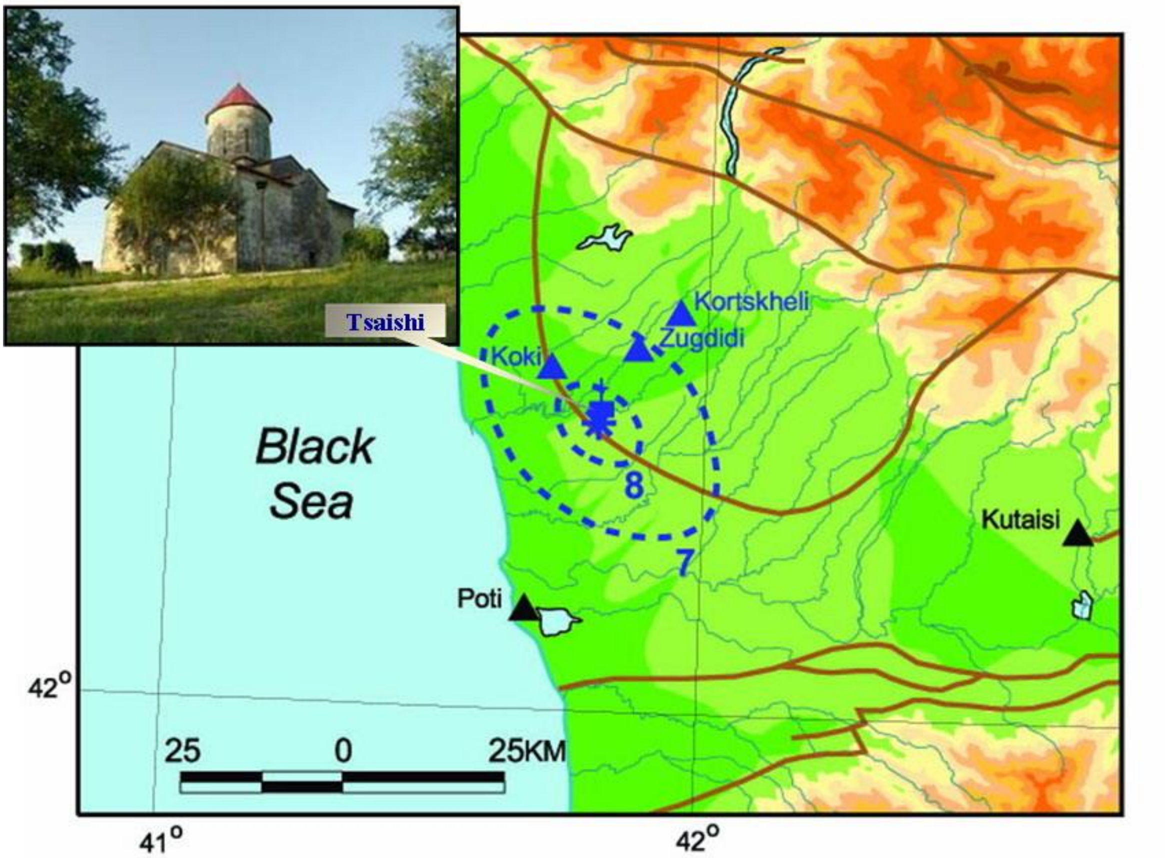

Fig. 25. Map of intensity distribution for the Tsaishi Earthquake, 1614.

1682.07.13 Tbilisi EQ

An Italian traveler Dionigio Farli wrote in his notes: "Year 1682. King Giorgi celebrated the wedding of his relative. During the wedding, on July 13, 1682 at about 2:30 A.M. an earthquake occurred in Tbilisi. One would think that during the time of "Have mercy on me" a wagon loaded with iron scraps ran over the cave. Fear gripped the old and young. After the rumbling had stopped the houses began to shake. Only the lower houses were not damaged. Terrified residents stayed the night outdoors. The entertainment was interrupted and all the nobility returned to their estates" (Kartlis Tskhovreba, 1959; Jibladze, 1980).

There are not found any additional data about the 1682 earthquake in the historical sources. We suppose that like the 2002 Tbilisi earthquake (Ms=4.6, I_o=7-8) it was a local one but characterized with less strength (Fig. 26). The parameters of the 1682 Tbilisi earthquake are considered as: date – June 13, 1682; 22:30 (Δt=±1 hour); epicentre coordinates – φ=41.70°, λ=44.80° (ΔE=±0.2°); depth –

h=7 km (Δh=3-14 km); magnitude – M_S=4.2 (ΔM=±0.5); intensity in the epicentre – I_o=6-7 (ΔI_o=±1).

Sources:

Kartlis Tskhovreba. Published in 1959. Manuscript, v.2, Sabchota Saqartvelo Publ. House, Tbilisi (in Russian).

Jibladze, E.A. 1980. Energy of earthquakes, seismic regime and seismotectonic motions of Caucasus. Tbilisi, p. 157 (in Russian).

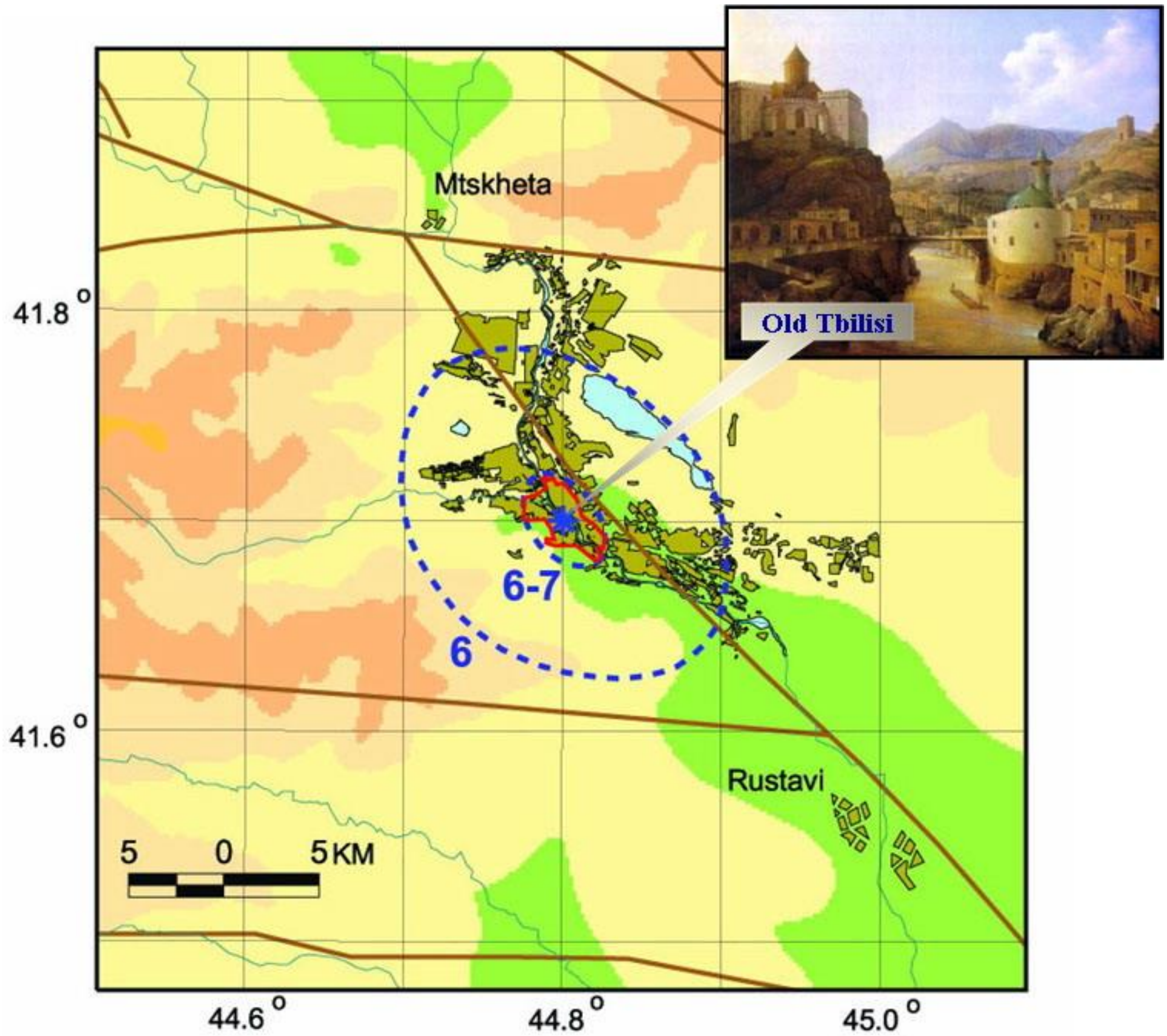

Fig. 26. Map of intensity distribution for the Tbilisi Earthquake I, June 13, 1682.

1742.08.05 Alaverdi EQ

"The earthquake was so strong that the earth trembled during forty days and nights. It was very horrific. In Kakheti region the Alaverdi Cathedral and the fortresses of Laliskuri and Akhmeta were ruined, some of the Caucasus mountains collapsed and a lot of people were left underneath. Many buildings collapsed in Kartli as well. …It was in August of 1742" (note: as Papuna Orbeliani informs, Alaverdi Temple ruined by the 1742 earthquake was restored in 1750…) (Papuna Orbeliani, 1981).

"Year – 1742. The Earth quaked, the dome of the Alaverdi Church collapsed on July 4" (Karbelashvili, 1967).

"Year – 1742. In Kakheti Kingdom there were six shocks in one day. The Alaverdi Cathedral was ruined and village Dido was devastated. It was Saturday, July 24" (note: the 24th of July in 1742 was indeed Saturday) (Davit Reqtori, 1967).

"Year – 1742. The earth trembled and the dome of the Alaverdi Cathedral collapsed, on July…" (Purtselaanti, 1967).

"As a result of God's wrath there was an earthquake in 1742. The Alaverdi Church was ruined as well as the Khodasheni Fortress..." (Prince Vakhushti, 1973).

"July 24, 1742. A Strong earthquake occurred in Kakheti. In Alaverdi it destroyed the temple, devastated Dido village and ruined the fortress Khodasheni as well as the fortress Laliskuri in Akhmeta. Many buildings collapsed in Kartli. During the day the earthquake struck 7 times. The vibrations lasted during 40 days. This earthquake might serve as the reason for the destruction of the Ninotsminda Church belonging (Prince Vakhushti, 1904) to 1824 (Stepanyan, 1942; Janashvili, 1902). The date is given as July by (Stepanyan, 1942), (Prince Vakhushti, 1904) indicates to the year 1741" (Bius, 1948).

The Alaverdi earthquake parameters based on the primary data are described in both editions of New Catalogue (New Catalogue..., 1977, 1982). According to the summing analyses of these data and the new sources from North Caucasus A. Nikonov in his research (Nikonov, 1987) concluded that this seismic phenomenon must have been of larger scales than it is described in the New Catalogue. In Nikonov's opinion the isoseismals with intensities 8 and 9 and the focus of this strong earthquake were of anti-Caucasus direction and he called it the Dido-Andia earthquake. In the work of (Shebalin, Tatevossian, 1997) the parameters of this earthquake are given similarly as in the work of (Nikonov, 1987).

The reanalyzes of all the reliable sources and the seismotectonic conditions for formation of an earthquake showed: a) according to the destructive quality and scales the intensity in the epicenter of this earthquake may be evaluated as I_o=9; b) on the basis of the area of isoseismal constructed by A. Nikonov the focal depth of this earthquake must have been not less than 40 km that requires the magnitude 7.5 in case of intensity 9 in the epicenter. This evaluation is quite different from the ones given in New Catalogue (M_S=6.0) and Nikonov's research (M_S=6.7); c) at the probable epicentre site of this earthquake there are not discovered any active geologic structures of the anti-Caucasus direction that could make us suppose that an earthquake has occurred at this site.

Thus, as it seems the centre of the devastating 1742 Alaverdi earthquake must have been within the boundary of the active fault zone of Lagodekhi (so called Barisakho-Vandami) of the Caucasian direction (Adamia et al., 2005; Adamia et al., 2008). The results of reconstruction of the macroseimic field of this earthquake are shown in the corresponding Fig. 27. It is evident that the isoseismals have Caucasian NE-SW orientation. The high intensity (7, 8, 9) isoseismals cover Tbilisi and town Mtskheta in the west, and in the east – Dido (historical-geographic province of Dagestan at that time). In his work (Nikonov, 1987) describes several North Caucasian inhabited territories as objects of intensity I<7-8. By our interpretation these territories are situated within the contours of the isoseismals with intensity 6. We suppose that for these territories the intensity is either overestimated or it has really increased due to the effects of the local soil, or the earthquake has been stronger (e.g. M_S=7.5) and correspondingly the isoseismals areas had been much larger. The last theory is the least probable as during the historical period no earthquake with magnitude more than 7 has been recorded on the territory of Georgia. According to the above facts the parameters of the Alaverdi earthquake are: date – August 5, 1742 (Δt=±1 day); epicentre coordinates – φ=42.10º, λ=45.60º (ΔE=±0.2º); depth – h=20 km (Δh=10-40 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9 (ΔI_o=±0.5).

Sources:

Papuna Orbeliani. Published in 1981. Story of Kartli. Edited by Elene Tsagareishvili. Tbilisi, pp. 57-58 (in Georgian).

Karbelashvili, P. Published in 1967. Chronicle, III - khi S5302, Tbilisi, p. 632 (in Georgian).

Davit Reqtori. Published in 1967. Chronicle, III - khi S2515, Tbilisi, p. 618 (in Georgian).

Furtselaanti. Published in 1967. Chronicle, III - cssa 1446-137, Tbilisi, p. 626 (in Georgian).

Prince Vakhushti. Published in 1973. Description of the Georgian Kingdom. Issued by S. Kaukhchishvili, Tbilisi, p. 630 (in Georgian).

Prince Vakhushti. Published in 1904. Geography of Georgia. Translated by M. Janashvili. West Caucasian section of RGS, book 24, issue 5, Tiflis (in Russian).

Stepanyan, V. A. 1942. Short Chronology of the most importnt earthquakes in Armenia and neighboring regions. Armenian Acad. Scf. USSR, Yerevan (in Armenian).

Janashvili, V. 1902. Earthquakes of the Past. Proceedings of the Caucasian Section of Russian Geographical Society. Tbilisi, vol. 15 (in Russian).

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 26 (in Russian).

New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, p. 76 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.76.

Nikonov, A. A. 1987. The strongest historic earthquakes in the Caucasus. Bollettino di Geofisica Teorica ed Applicata, v. 29, № 116, pp. 333-339.

Shebalin, N. Tatevossian, R. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers, Dordrecht, pp. 201-232.

Adamia, Sh., Chabukiani, A., Kuloshvili, S., Maisuradze, G. 2005. Elicitation of alternative seismic sources interpretations and characterization. ISTC CauSin Project CA-651, Final Report.

Adamia, Sh., Mumladze, N., Sadradze, N., Tsereteli, E., Tsereteli, N., Varazanashvili, O. 2008. Late Cenozoic tectonics and geodynamics of Georgia (SW Caucasus). Georgian International Journal of Science and Technology ISSN 1939-5825. Nova Science Publishers, vol. 1, issue 1, pp. 77-107.

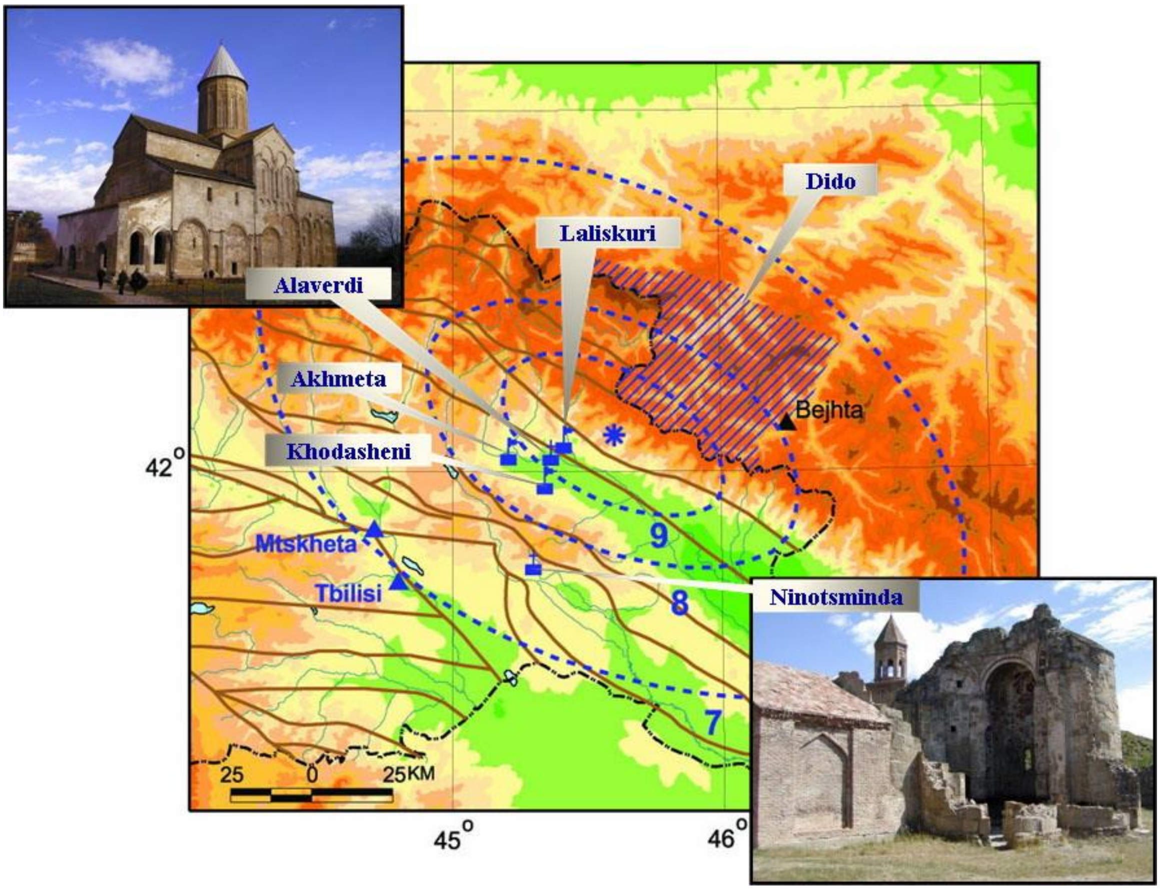

Fig. 27. Map of intensity distribution for the Alaverdi Earthquake II, August 5, 1742.

1750 Akiba EQ

"The structure Akiba is situated near the head of the river Ghalidzga, on the left side of its tributary – the river Avichikva. A number of fault structures have been discovered there, among them – the normal dip-slips Tsestou, Ghalidzga and Avichikva that are continued by the structure Akiba. The faults in the local earthquake foci are presented by normal dip-slips of latitudinal orientation. So it is most possible to assume the normal dip-slips mechanism for the formation of the paleoseismogenic structure Akiba. Moreover, as it was documented some normal and reverse dip-slips complex dislocations were determined alongside the fault. In the terms of the regional compression the existence of thrust as one of the structure elements is quite natural.

The main deformations of the Akiba structure morphologically appears as a landslide amphitheatre formed in the Jurassic tufogenic layers. The inner edge of the main landslide is linked with the tectonic fault. At the north-eastern ending of the structure the fault is presented as a thrust that changes the declination of the glacial scratching in the southern part of the Avichikva gorge and in the south-west it appears as a normal dip-slip that cuts the riverbeds. The visible length of the faults does not exceed several hundred meters, the vertical amplitude – several meters. The main fault with its buried part is 3.7 km long. A 200 000 m^2 cliff stratum has fallen from the lower wing of the thrust and inclined on the slope by 17°.

The front part (9 million m^3) of the main landslide is dislocated by 1300 m from the 20 m upper edge and at some places blocked the Avichikva gorge. The inner fissure of the landslide has cut the gorge of the tributary river, consequently followed by formation of a 20 m waterfall.

All the above mentioned facts, the dual-phase formation of the structure Akiba and susceptibility of surrounding slopes for further soil dislocations make obvious the seismogravitational genesis of the landslide deformations.

In its western part the main edge of the landslide is sub-parallel to the old fragmentation and melonitization zone directed to the displacement of the cliff massif. In the east it is sub-parallel to the new thrust line that breaks the tufogenic layer. If conceptually joined at the back of the structure Akiba, these faults will create a flexure of the same form as the main fissure of the landslide. It is possible that the central part of the main normal and reverse dip-slips of the structure buried under the landslide also bears some certain elements of the older faults.

Thus the location of the structure Akiba and the fissure form of the back edge of the landslide were primarily defined by the net of the old and new faults. As the cut riverbeds and glacial scratching declination show the seismogravitational landslide was caused by activation of one (or more) of the faults. The tectonic fracturation of tufogenic cliff massif benefited its formation and displacement onto the clay and slate layers" (Khromovskikh et. al., 1979).

On the basis of the above described detailed field investigations and their analysis (Fig. 28) the Akiba event was identified in the work as one of the strongest earthquakes (Khromovskikh et al., 1979). Despite of absence of corresponding additional historical sources we assume that this earthquake really occurred, though the time of its origination is uncertain. Thus, the probable parameters of the earthquake are: date – 1750 (Δt=±100 year); epicentre coordinates – φ=42.90°, λ=41.90° (ΔE=±0.2°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=7.0 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:

Khromovskikh, V .S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 85-88 (in Russian).

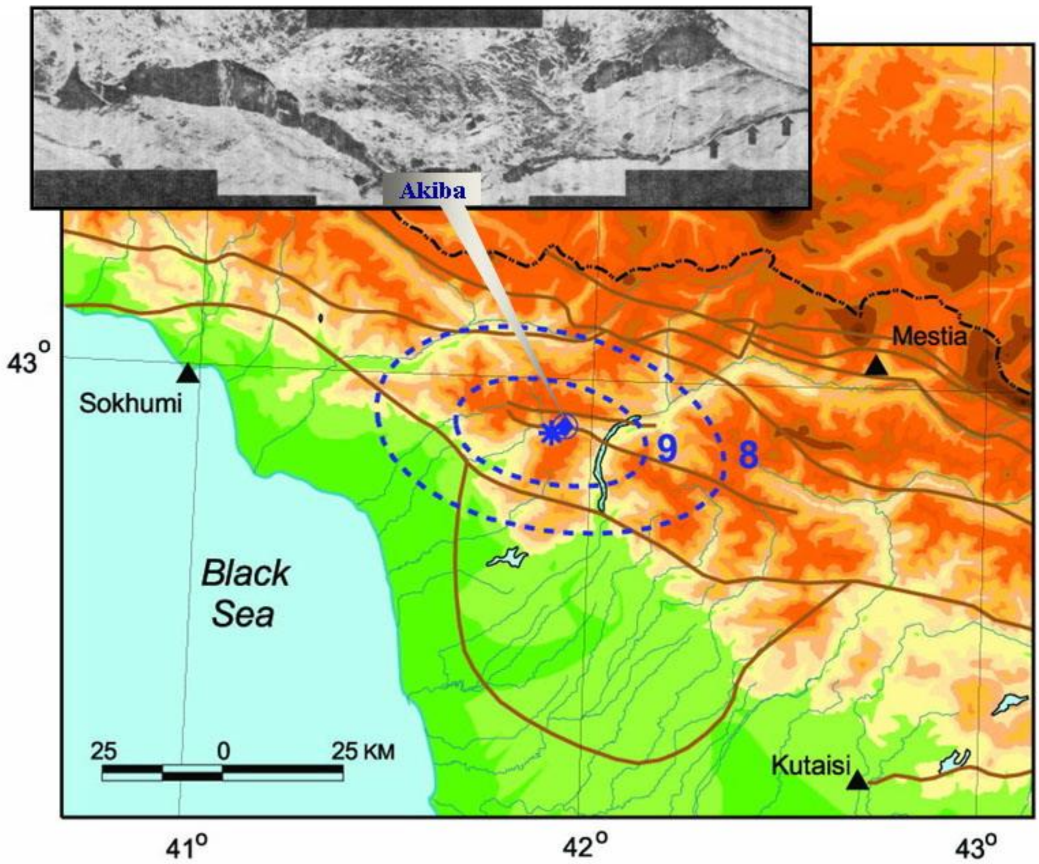

Fig. 28. Map of intensity distribution for the Akiba Earthquake, 1750.

1750 Labaskaldi-Tseri EQ

"The seismogenic structure of Labaskaldi was formed in the watershed part of the Labaskaldi Ridge in 10-12 km from Mestia. Its faults are connected with the depth fault junction. As a whole the structure appears a mountainous graben (600×150 m) surrounded by terrace-like normal dip-slips with the length of 2 km and the amplitude of vertical dislocation – 1.5-7 m that break the covering slates alongside their dislocation. Some certain normal dip-slips, as they cross the riverbeds, form 1.5 m tectonic dams on their thalwegs which on their part entirely cover the erosive ravines. On the thalwegs of the ditches and in the central part of the graben there are many open fissures (20 m width) and waterless holes (12 m in diameter and 10 m in depth) that absorb the clastic material.

The ascended wings of the fault have preserved the sliding mirrors with shadings and gutters indicating that the pointed top of the mountain has sunk within the Labaskaldi Ridge. The top has shortened by 12-15 m that could have caused by an earthquake with intensity 9. In the 8-10 m radius the explored landslides cover the area of 2 million m^3.

The structure Tseri, which combines another seismodislocations fields, is situated on the divide of the rivers Tseri and Chalaburi, 12-15 km south-east from Mestia. Its faults have deformed one of the northern branches of the Svaneti Ridge (height – 2982 m) and crossed the sandstone-slate layer and the relief horizons. The structure covers the area of approximate length 3.5 km, maximum width 200 m.

The plane top of the mountain has crashed into the open cavity formed by the normal dip-slips. A watershed crest of 200 m width and 1.5 m length has literally collapsed to 20 m depth. The normal dip-slips surrounding the collapse area form some steep terraces of 18 m height. Taking into consideration their size they must have originated due to an earthquake of intensity not less than 9" (Khromovskikh, Nikonov, 1984; Khromovskikh et al., 1979).

The huge landslides of Tvibra and Shavi-Ghele are situated on the right slopes of the gorge of the river Enguri, on the highway relatively in 114 km and 115 km from town Zugdidi.

The upper part of the gorge, within the sub-latitudinal cavity of upper Svaneti is completely changed due to the Pleistocene glaciation and later significantly complicated by large-scale and deep deformational seismogenic landslide phenomena among which the deep and slowly displacing ones of Tvibra and Shavi-Ghele are mostly distinguished. These landslides systematically damage the single highway linking Zugdidi and Mestia.

The Tvibra landslide is located on the territory of village Parri. The landslide has developed in the tectonically destructed suite of Jurrasisc slates. In the landslide area the argillaceous slates suite is so much destructed, entangled and disintegrated by the tectonic processes that is has transformed into clay. The landslide body covers a 900 m long area from the upper slope in the tectonic fault zone and frontally extends on the slope. The slope morphologically is divided in three generation terraces. The two upper terraces are stabile and the lower one is dynamically active, this terrace with the volume over 7 200 m^3 extends along the slope by 200 m length and constitutes danger for the highway.

The Shavi-Ghele landslide continues the Tvibra landslide. It is characterized with typical seismogravitation phenomena and has developed in the tectonically destructed zone. Its volume exceeds 54 million m^3 and covers a 1200 m long territory on the right slope of the gorge of the river Enguri. The morphology of the slope above the highway is presented by broken terraces and a hill relief with 3-4 terraces of different origin and age. The average declination of the relief surface is 35-45º, though it reaches 50-70º in the terrace transformation zone (Oniani, Tsereteli, 1984; Tsereteli, Gaprindashvili, 2008).

The analysis of the above material shows that both paleoseismodislocation structures of Labaskaldi and Tseri distanced by 15 km from each other are located in the fault zone of the southern frontal part of the eastern flysch formation of the south slope of the Caucasus. They originated simultaneously (1600-1900) in the same earthquake epicenteral zone (Fig. 29). The discovery of two huge seismogenic landslides near the structure Labaskaldi also confirms the seismic activity of these territories. Thus, the parameters of the earthquake identified on the basis of the paleoseismodislocations Labaskaldi and Tseri (according to the above evaluations) are as follows: date – 1750 (Δt=±100 year); epicentre coordinates – φ=43.00°, λ=42.70° (ΔE=±0.2°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=6.9 (ΔM=±0.5); intensity in the epicentre – I_o=9-10 (ΔI_o=±1).

Sources:

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, pp. 114-115 (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 92-95 (in Russian).

Oniani, M. E., Tsereteli, E. D. 1984. Geological report on the engineering-geological survey a scale of 1:50 000 in Upper Svaneti. Tbilisi, 240 pp. (in Russian).

Tsereteli, E., Gaprindashvili, M. 2008. Estimation of an engineering-geodynamic condition and geomorphological features of a site of highway Khaishi-Mestia. Tbilisi, 28 pp. (in Georgian).

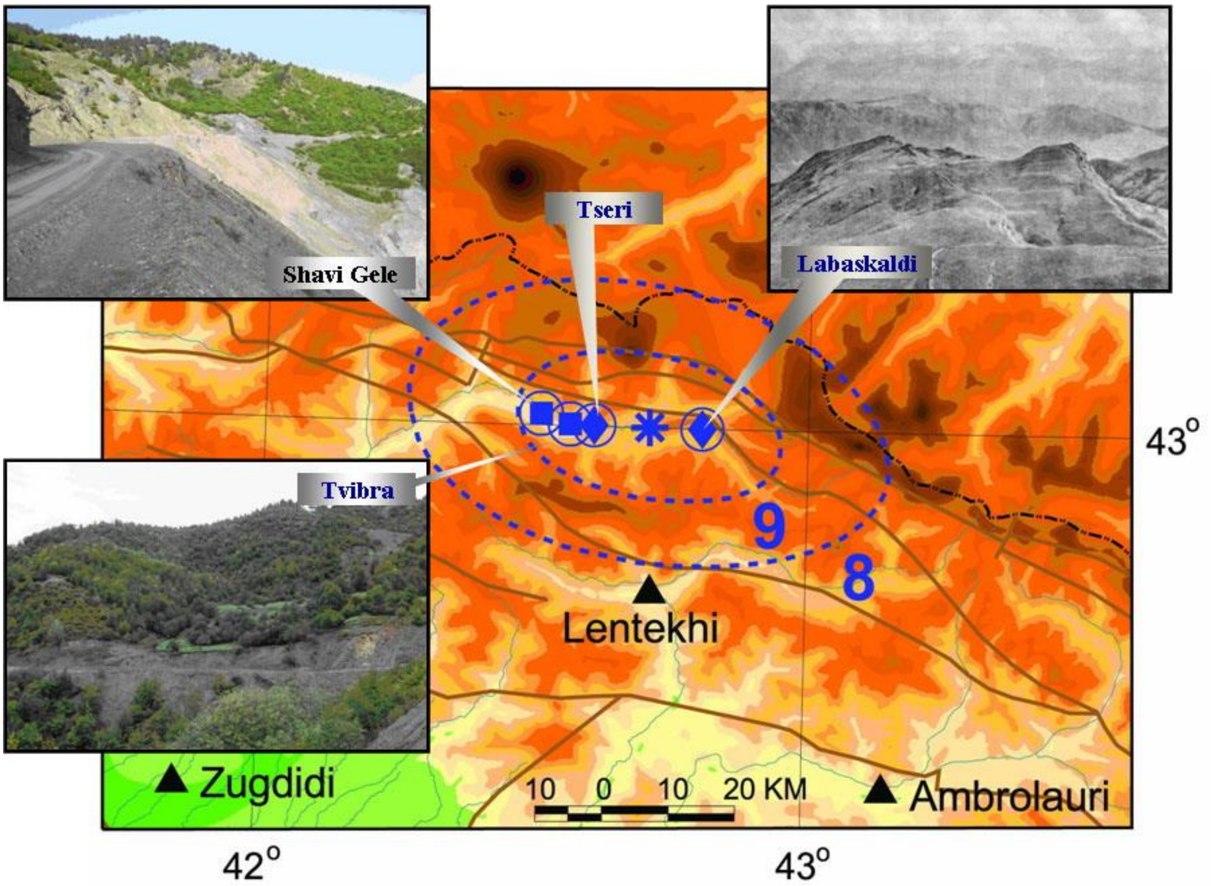

Fig. 29. Map of intensity distribution for the Labaskaldi-Tseri Earthquake, 1750.

1756 Kakheti EQ

"1756. The devastating earthquake in Kakheti" (Bius, 1948; Stepanyan, 1942).

"1756. The destruction in Kakheti" (New Catalog…, 1982).

In case of few and unspecified data as above to parametrize an earthquake is possible only by means of logical analysis, analogies and isoseismal models. In particular, we suppose that the earthquake was of a moderate strength (M~5, I~7), other wise more information would have been survived about a strong earthquake in densely populated Kakheti of the XVIII century. In the resent past such a phenomenon took place in 1981 alongside the extremely active Alazani faults zone in Kakheti. This was an earthquake in village Gavazi (h=9 km, M_S=4.9, I_o=7) and it caused some destructions and human damages. We suppose that the 1756 historical earthquake in the central part of Kakheti must have occurred in this faults zone (Fig. 30). The figure shows the probable distribution of the macroseismic effects of the earthquake accepted after choosing isoseismal models. Thus, the main parameters of the earthquake are: date – 1756 (Δt=±1 year); epicentre coordinates – φ=41.90º, λ=45.70º (ΔE=±0.5º); depth – h=10 km (Δh=5-20 km); magnitude – M_S=4.7 (ΔM=±0.7); intensity in the epicentre – I_o=7 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 26 (in Russian).

Stepanyan, V. A. 1942. Short Chronology of the most important earthquakes in Armenia and neighboring regions. Armenian Acad. Scf. USSR, Yerevan (in Armenian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.76.

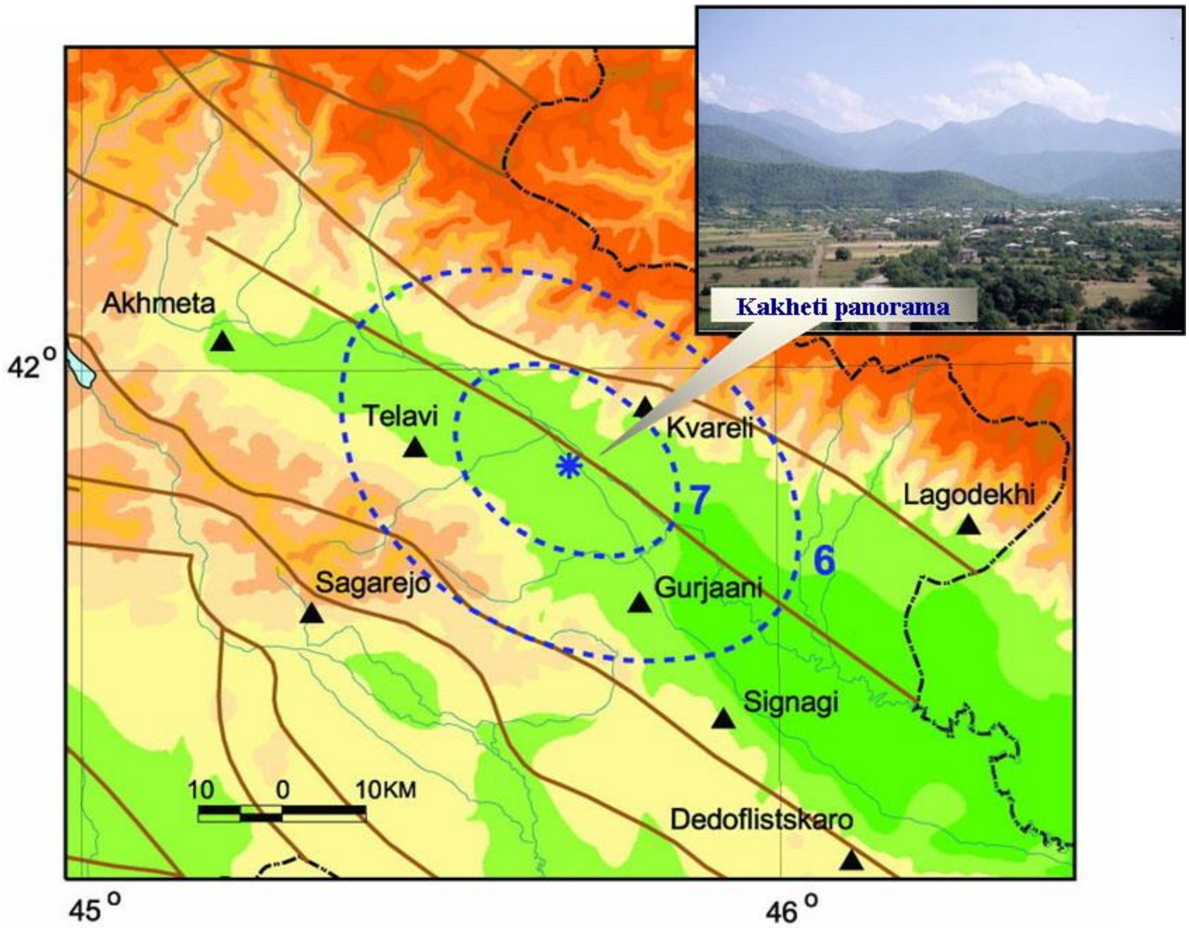

Fig. 30. Map of intensity distribution for Kakheti I 1756 earthquake.

1785.05 Shemomkmedi EQ

The Shemomkmedi chronicle ends with the year 1753. A local priest gave the data about this chronicle to Dimitri Bakradze. In D. Bakradze's opinion the author of the chronicle was Giorgi Dumbadze. In the Institute of Manuscripts another chronicle was found that was similar to the Shemomkmedi chronicle. But the latter had a postscript – Gabriel Makharadze (the author). "Undoubtedly the chronicle has been written in Guria". It is possible that Gabriel Makharadze continued the previous chronicle of Shemomkmedi. In his chronicle G. Makharadze reports: "May of 1785. There was a terrible earthquake and houses were ruined" (Zhordania, 1967).

"As a result of this earthquake many buildings in Guria were ruined, among them the temple in village Shemomkmedi (Zhordania, 1967). The Monastery Complex of Shemomkmedi is situated on the right of the river Bzhuzhi in the area of village Shemomkmedi (Ozurgeti area). The main parts of the complex are built on 150 high hill, on the rock basement (tufogenic rocks). After the earthquake the temple was restored. The fact of restoration is revealed by the filled cracks and the changed order of the blocks in the walls. There are 1 and 3 cm wide cracks in the south-western wall of the attachment of the main building. Some similar cracks are found in the opposite wall. They are directed upwards and disappear in the masonry of the dome, though some wider cracks are found even there. It seems as if they separate the building in two parts from south-west to north-east. By the nature of deformations the earthquake intensity must have been not less than 8" (Khromovskikh et. al., 1979).

According to the analysis of the above sources we defined the parameters of this strong historical earthquake (Fig. 31): date – May of 1785 (Δt=±1 month); epicentre coordinates – φ=41.90°, λ=42.10° (ΔE=±0.2°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=5.5 (ΔM=±0.5); intensity in the epicentre – I_o=8 (ΔI_o=±1).

Sources:

Zhordania, T. 1967. Chronicle. Book 3. Metsniereba Publ. House, Tbilisi (in Georgian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, p. 37 (in Russian).

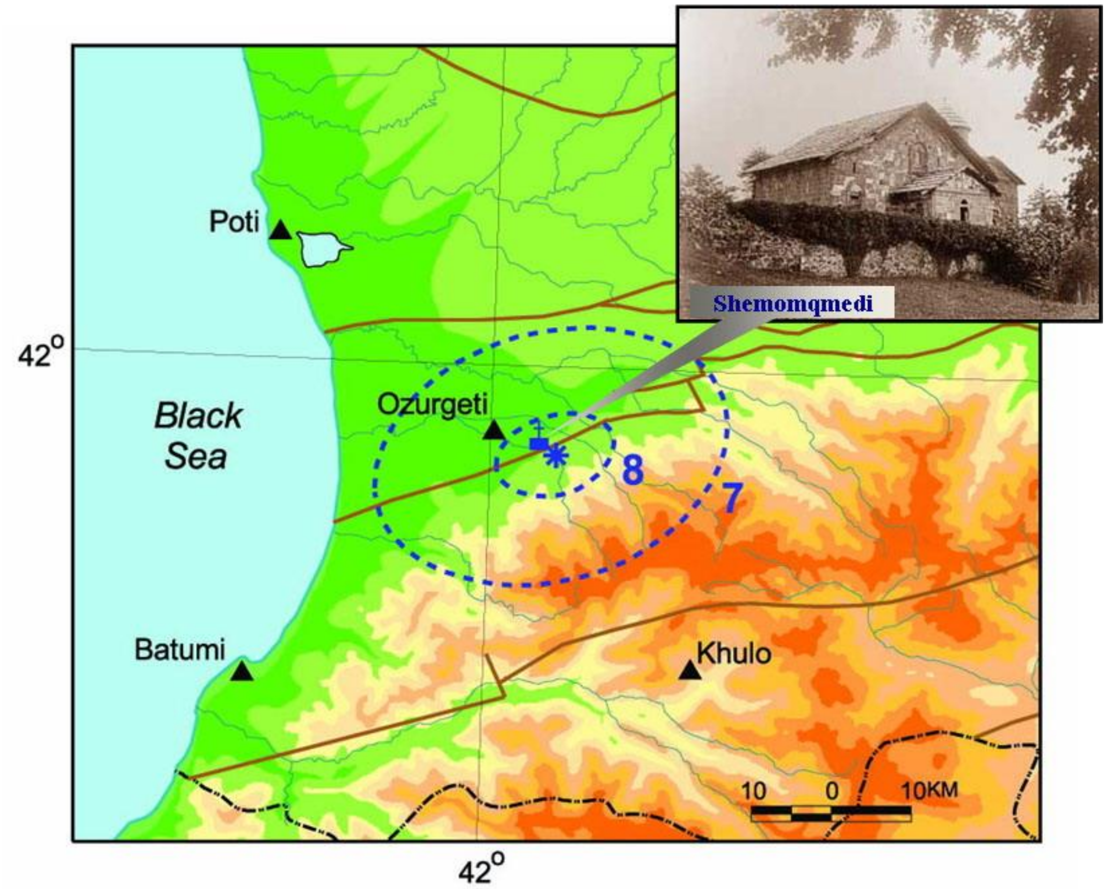

Fig. 31. Map of intensity distribution for the Shemomkmedi Earthquake, May, 1785.

1803.10.29 Tbilisi EQ

"In Tbilisi there was an earthquake; the walls of houses were cracked" (Bius, 1948).

Despite of laconism of the above source (Bius, 1948) we may make some significant conclusions on its basis. Firstly, this earthquake was a local one and probably, like the 2002 Tbilisi earthquake it occurred within the city (Fig. 32). Secondly, it was quite weak and had intensity ~6 just within the city. If taken in account that the average depth of the seismically active layer under Tbilisi (by the analogy of the 2002 earthquake) is 7 km (Varazanashvili et al., 2008) than it is possible to evalauete all the parameters of this earthquake: date – 29 October, 1803 (Δt=±1 day); epicentre coordinates – φ=41.70°, λ=44.80° (ΔE=±0.2°); depth – h=7 km (Δh=3-14 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicentre – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 26 (in Russian).

Varazanashvili, O., Tsereteli, N., Adamia, Sh., Butikashvili, N., Mukhadze, T. 2008. Seismotectonic Features of the April 25, 2002 Tbilisi, Georgia, Earthquake (M_S=4.6). Journal of Georgian Geophysical Society (A), vol. 12, pp. 33-45.

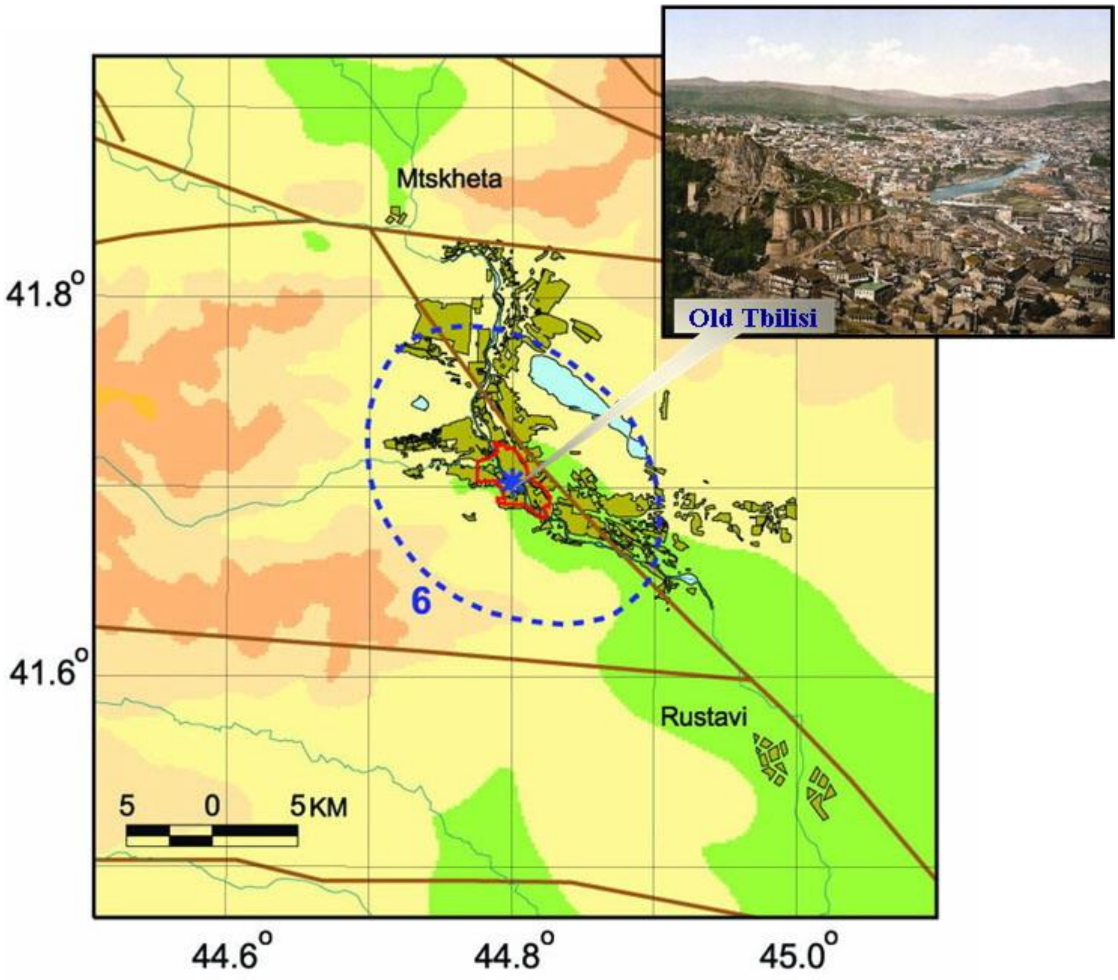

Fig. 32. Map of intensity distribution for the Tbilisi Earthquake II, October 29, 1803.

1804.10.11 Tbilisi

"Throughout the night of 11 to 12 October in Tbilisi some undulation in the ground took place without causing any harm, but in the suburbs of Avlabari the ancient wall collapsed and an old uninhabited house ruined" (Bius, 1948).

After the 1803 earthquake this earthquake is the second significant seismic phenomenon connected with seismic activation of Tbilisi and its surrounding territories that was observed in the beginning of the XVIII century. According to the locality and the little strength of the earthquake (Fig. 33) its probable parameters of the earthquake are as follows: date – 11 October, 1804; 17:00 (Δt=±1 hour); epicentre coordinates – φ=41.70°, λ=44.80° (ΔE=±0.2°); depth – h=9 km (Δh=4-18 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicentre – I_o=5-6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 27 (in Russian).

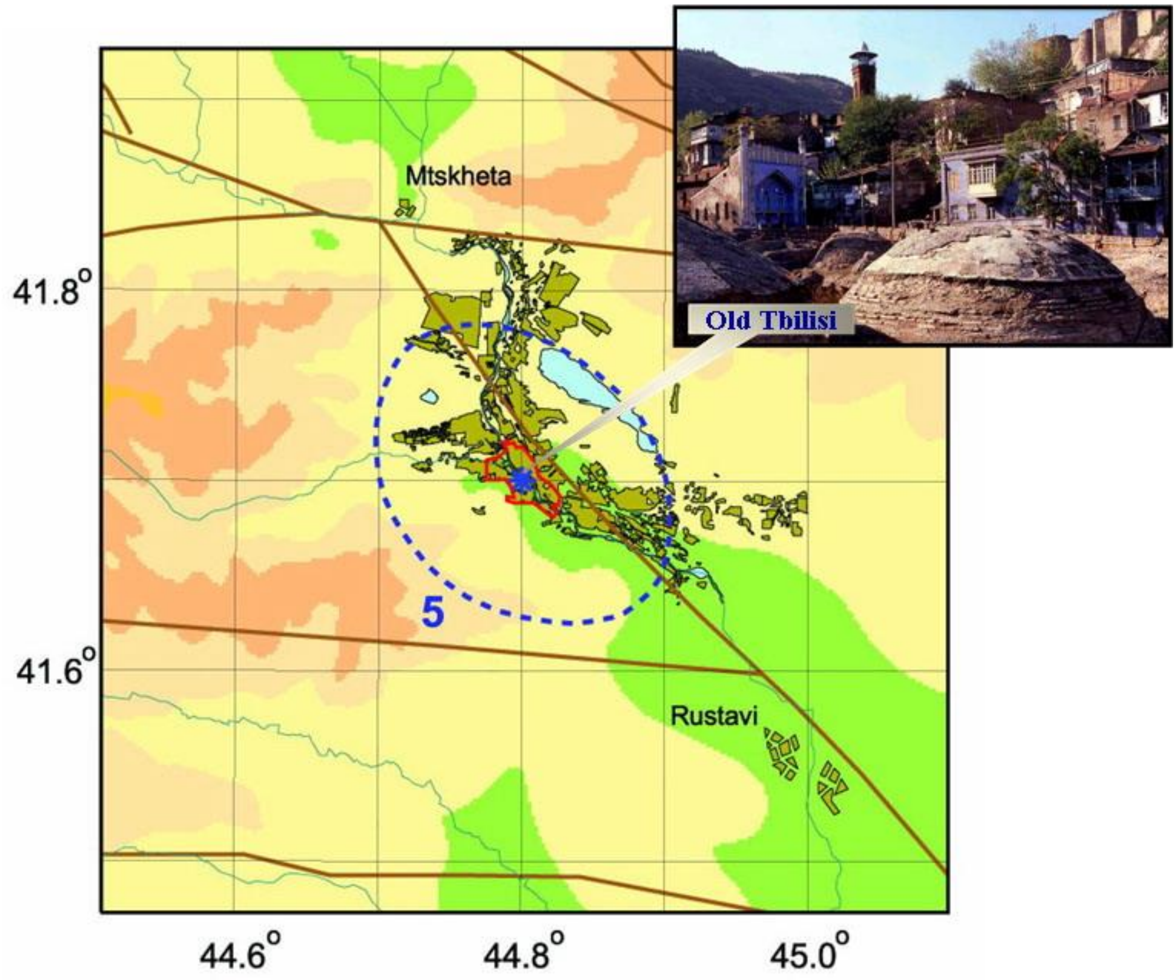

Fig. 33. Map of intensity distribution for the Tbilisi Earthquake III, October 11, 1804.

1805.02.21 Gori Area EQ

"In Gori a strong earthquake occurred but did not cause any damage. A weak underground quake was felt in Tbilisi" (Bius, 1948).

This earthquake is classified as a local (Gori area) seismic phenomenon (Fig. 34) and its parameters are evaluated as: date – 21 February, 1805; 19:00 (Δt=±1 hour); epicentre coordinates – φ=41.90°, λ=43.90° (ΔE=±0.5°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=4.4 (ΔM=±0.5); intensity in the epicentre – I_o=5-6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 27 (in Russian).

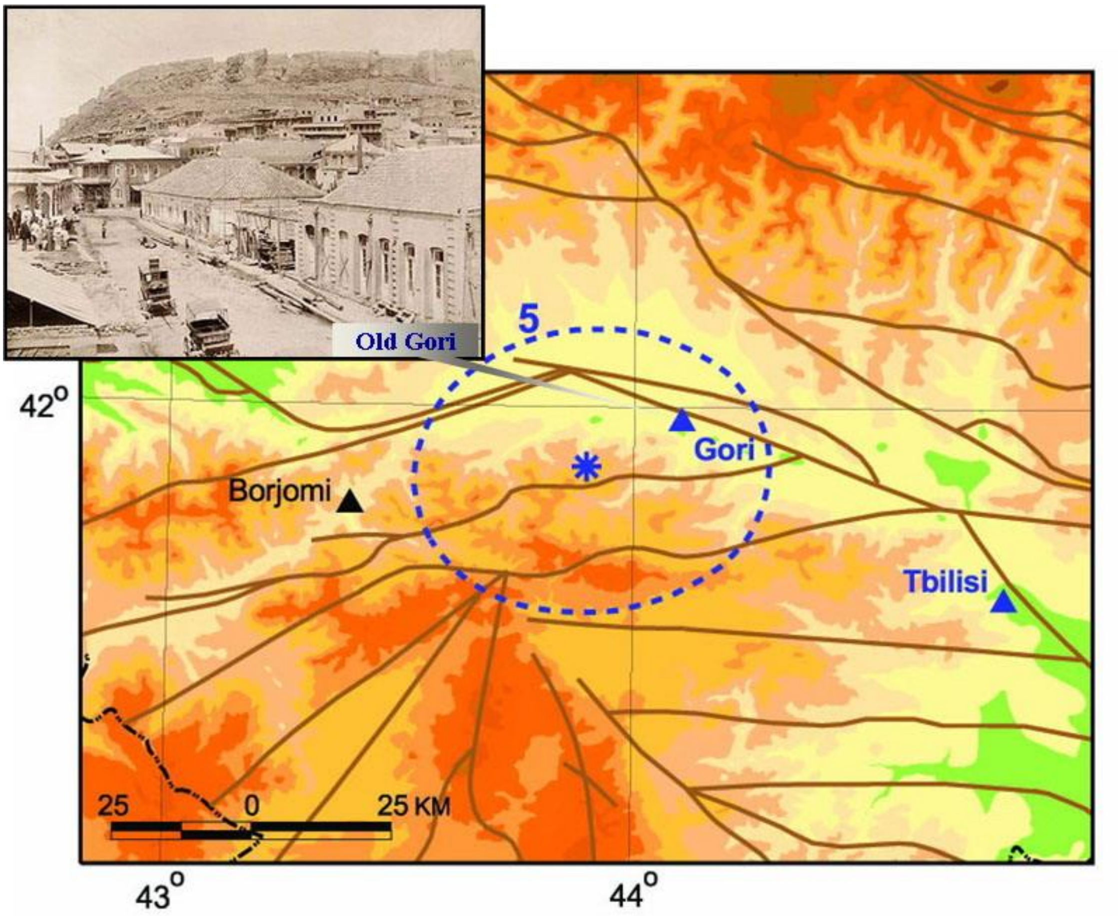

Fig. 34. Map of intensity distribution for the Gori Area Earthquake, February 21, 1805.

1811.01.01 Kakheti EQ

"1811. "A devastating earthquake in Kakheti" (Bius, 1948),

"1 January, 1811; 05:00 (17:00). In Tbilisi there occurred two earthquakes following one after another with direction from the South to the North" (Bius, 1948).

φ = 41°58' , λ= 45°30' , 1811. (7-8) (Bius, 1952).

"1 January, 1811; 05:00. A devastating earthquake in Kakheti. 4 – (50) (1)" (New Catalog…, 1982).

The analysis of the above data shows that in Tbilisi the macroseismic intensity of this earthquake was not more than 4 (Bius, 1948). According to Bius (1952) the epicentre of this earthquake was in 65 km from Tbilisi near town Telavi in the active Alazani faults zone and had intensity 7-8 in the epicentre. In New Catalogue the epicentre is considered in 35 km distance from Tbilisi near town Sagaredjo and its intensity is evaluated as 7 (New Catalog…, 1982). We suppose that Bius' interpretation is more precise (Fig. 35) and evaluate the main parameters of the earthquake as follows: date – 1 January, 1811; 05:00 (Δt=±1 hour); epicentre coordinates – φ=42.00°, λ=45.50° (ΔE=±0.5°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=5.0 (ΔM=±0.7); intensity in the epicentre – I_o=7-8 (ΔI_o=±1).

Sources:
Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 27 (in Russian).
Bius, Ye. I. 1952. Seismic conditions of the Trans-Caucasus, part II. Acad. Scf. GSSR, Tbilisi, pp. 141, 157 (in Russian).
New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.77.

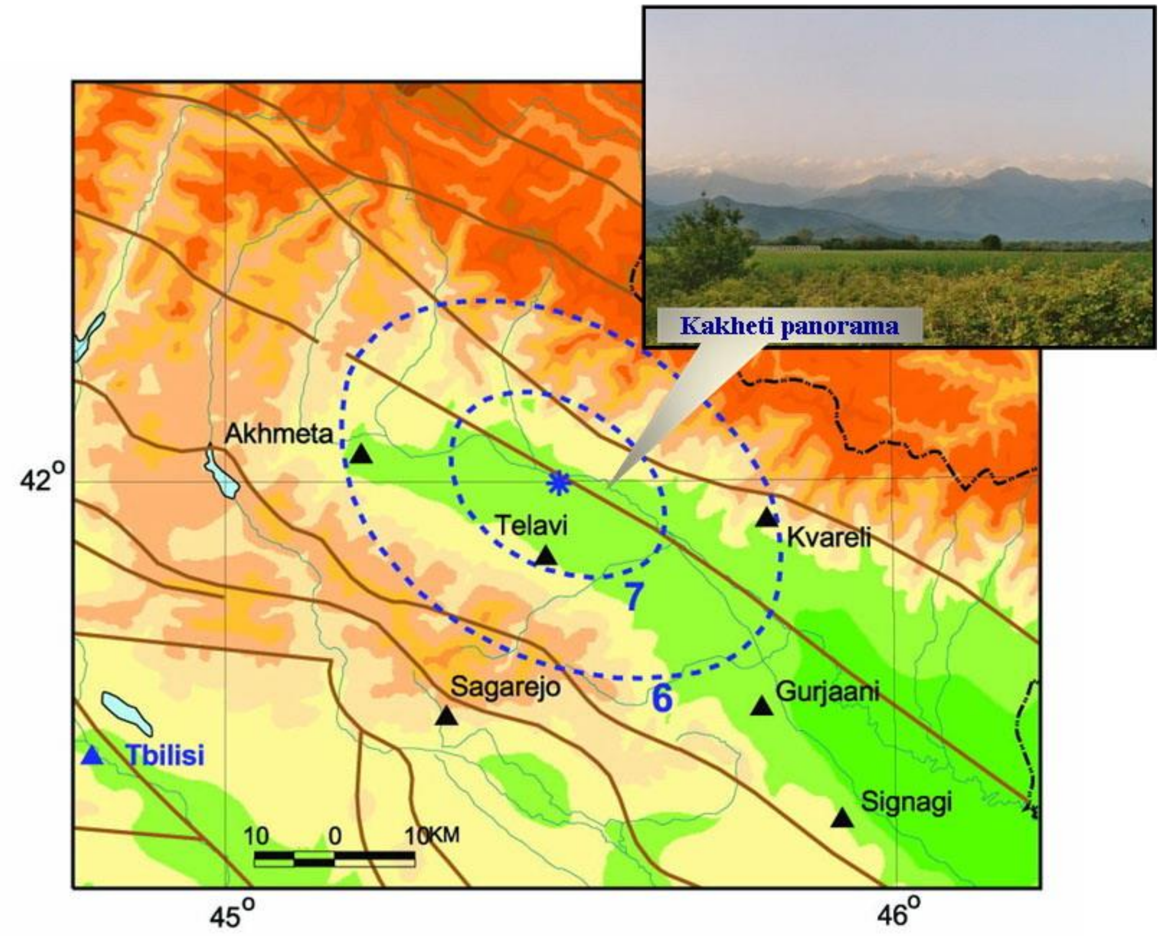

Fig. 35. Map of intensity distribution for the Kakheti Earthquake II, January 1, 1811.

1819.02.28 Tbilisi EQ

"29 January, 1819; 19:00. Tbilisi. Underground shocks repeatedly struck with great force and caused fear among the population. The ground vibrated and quaked twice. It damaged some few old buildings" (Bius, 1948).

This seismic phenomenon is to be classified as a local earthquake. It occurred in Tbilisi on February 28, 1819 (M_S=4.5, I=7). In accordance with the work of I. Mushketov and A. Orlov (Mushketov, Orlov, 1893) Ye. Bius describes this event as: "In Tbilisi there were numerous underground shocks that were preceded by a rumble. Some of the houses were quite crashed" (Bius, 1948). This data confirm that in some areas of Tbilisi the earthquake had intensity 7 (Varazanashvili, Kupradze, 2005).

"Probably the dates 29.I and 28.II belong to the same quake" (New Catalog…, 1982).

We may evaluate the parameters of this local earthquake (Fig. 36) of Tbilisi as following: date –28 February, 1819 (Δt=±1 day) ; epicentre coordinates – φ=41.70°, λ=44.80° (ΔE=±0.2°); depth – h=7 km (Δh=3-14 km); magnitude – M_S=4.5 (ΔM=±0.5); intensity in the epicentre – I_o=7 (ΔI_o=±0.5).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 28 (in Russian).
Mushketov, I. V., Orlov, A. P., 1893. Catalog of earthquakes in the Russian Empire. Notes, Russian Geog. Soc., St. Petersburg, vol. 26 (in Russian).
Varazanashvili, O., Kupradze, M. 2005. Seismic history and seismic risk of Tbilisi. Journal of Georgian Geophysical Society (A), vol. 8, pp. 63-69.
New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 77.

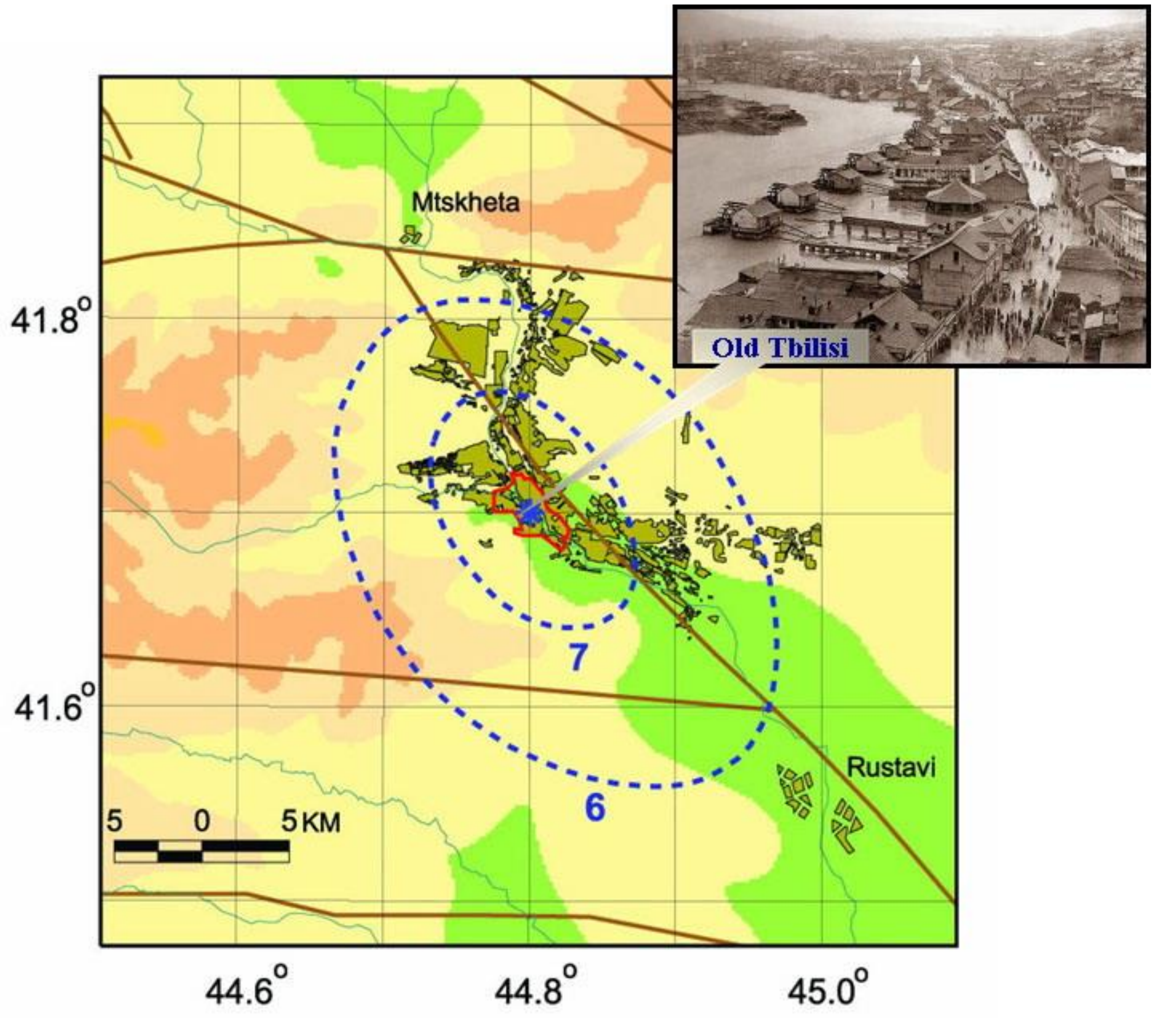

Fig. 36. Map of intensity distribution for the Tbilisi Earthquake IV, February 28, 1819.

1845.05.24 Javakheti EQ

"24 May, 1845. At night. District of Akhaltsikhe. Within half a minute there occurred three underground shocks. The first was strong that caused cracks in the walls of many houses. In the settlement of Bolshaya Kondura (Didi Gondrio) the earthquake ruined a house and crushed 4 people" (Bius, 1948).

It seems that the epicenter of the earthquake was in the Javakheti highland, near village Didi Gondrio (Ninotsminda administrative area). In New Catalogue the epicenter is considered in the northern part of Akhalkalaki administrative area in 35 km distance from village Didi Gondrio, but this evaluation is incorrect (New Catalog…, 1982). Thus, the probable parameters of this earthquake (Fig. 37) are: date – 24 May, 1845; 01:00 (Δt=±6 hour); epicentre coordinates – φ=41.30°, λ=43.50° (ΔE=±0.2°); depth – h=8 km (Δh=4-16 km); magnitude – M_S=4.6 (ΔM=±0.5); intensity in the epicentre – I_o=7 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 34 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 80.

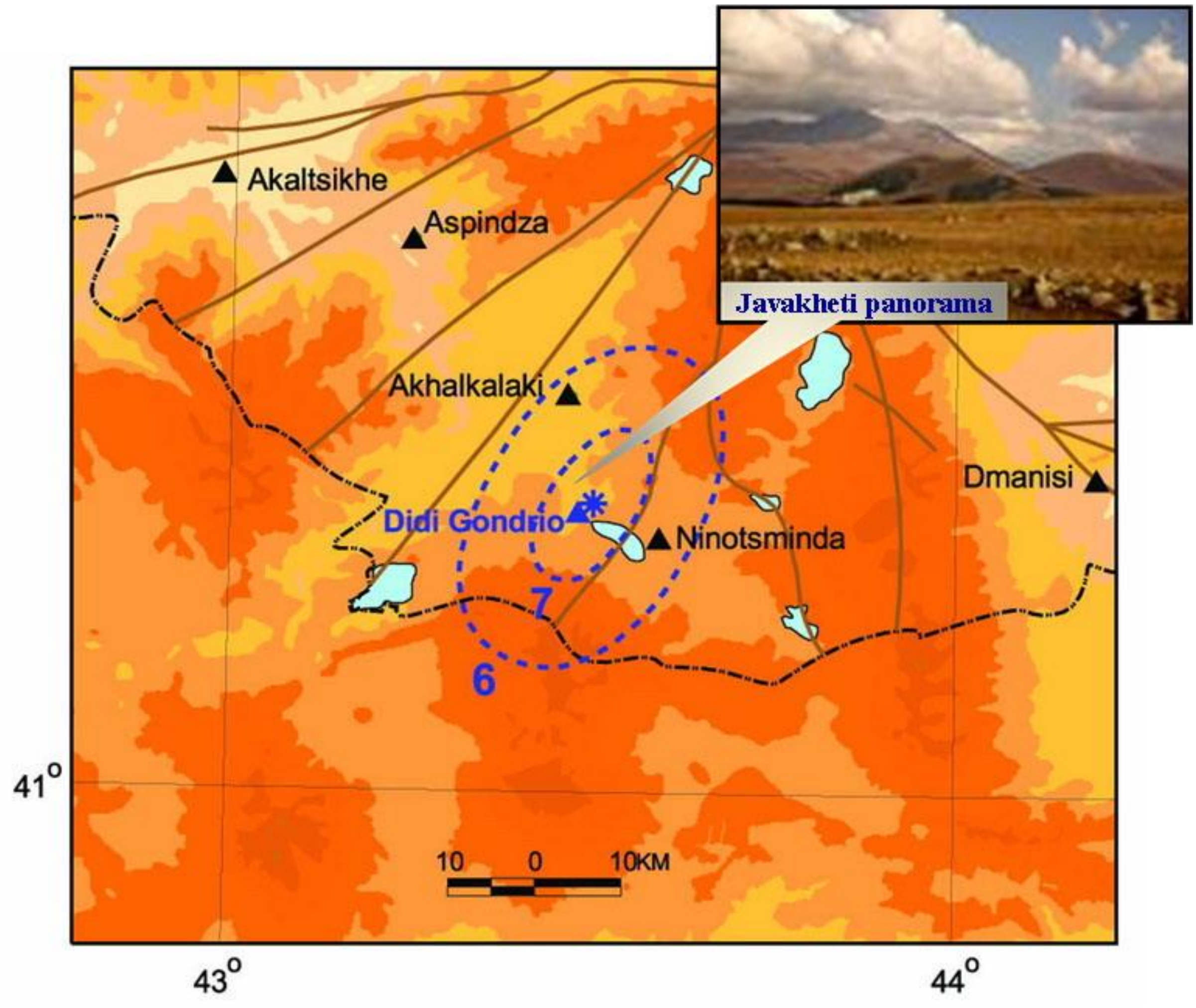

Fig. 37. Map of intensity distribution for the Javakheti Earthquake I, May 24, 1845.

1846.04.23 Jvarisa EQ

"April, 1846. 21:00. Djavrisi (Jvarisa). There occurred an earthquake after which a large section of the land began to move slowly downslope towards the river Rioni. On 28 April half of the village that was a space of 4 km^2 entirely moved and was displaced along 125 m distance. There were formed a small lake and 2 m high mounds on the landslide site" (Bius, 1948).

There are two villages by name Jvarisa. One of them is in Ambrolauri and the other – in Tkibuli administrative area. But only the one in Ambrolauri administrative area is located on the bank of the river Rioni in the hazardous landslide zone. We suppose that the epicenter of this earthquake must be on this site (Fig. 38). Thus, the epicenter coordinates of the earthquake in New Catalogue (New Catalog…, 1982) that locates them near village Jvarisa in Tkibuli administrative area are incorrect. The probable parameters of the earthquake are: date – 23 April, 1846; 21:00 (Δt=±1 hour); epicenter coordinates – φ=42.60°, λ=43.00° (ΔE=±0.2°); depth – h=7 km (Δh=3-14 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicenter – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, pp. 34-35 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 80.

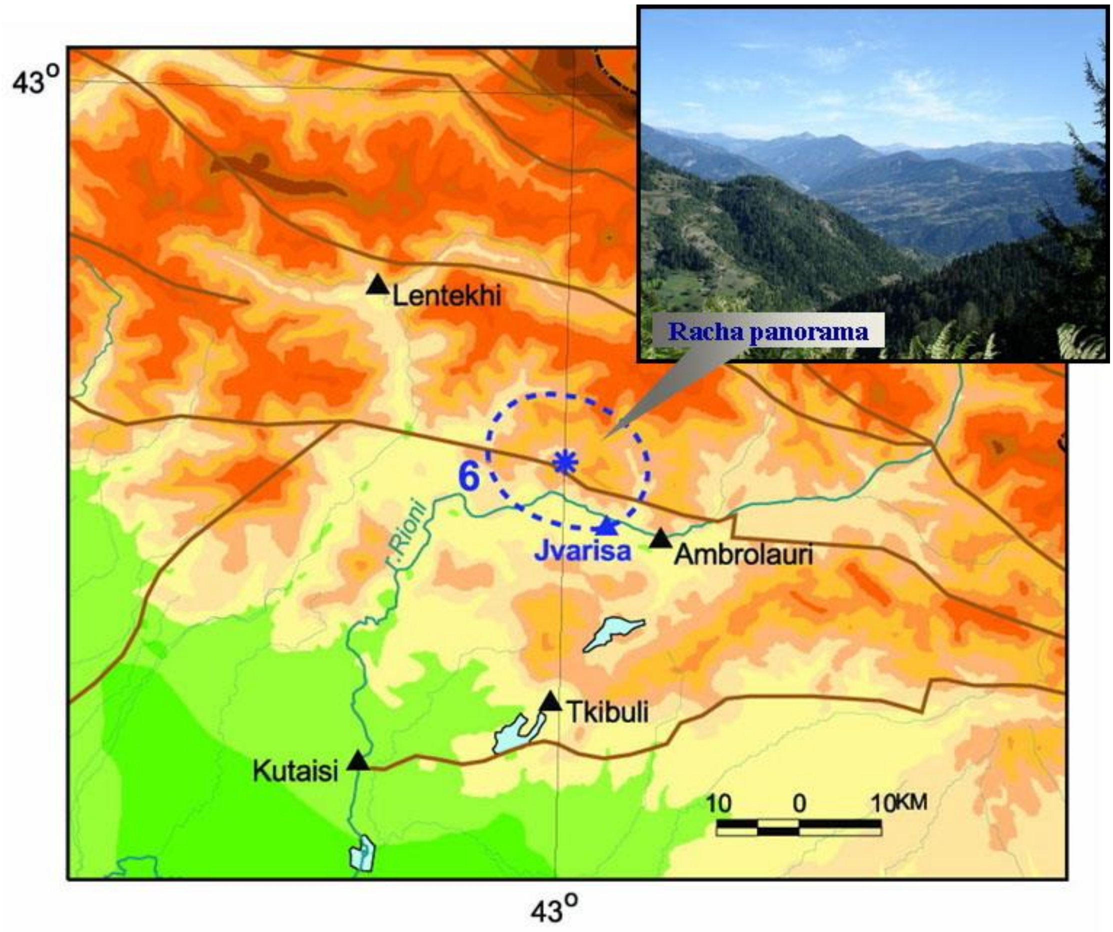

Fig. 38. Map of intensity distribution for the Jvarisa Earthquake, April 23, 1846.

1853.03.18 Kakheti EQ

"18 March, 1853; 05:00. An earthquake in Kakheti. At Sighnaghi – the earthquake lasted no longer than 15 seconds. Walls of houses noticeably oscillated, hanging cradles swung, those who were asleep woke up, some residents ran from homes to streets, the Earth vibrated. At Sabue – plaster crumbled in many stone houses, sleeping peopele woke up, dogs began to bark and birds – to scream; the earthquake lasted no longer than 50 seconds. The earthquake was felt in Tsarskie Kolodtsi, in Bejani and in Zakatala. In Tbilisi the earthquake was accompanied by rumbling, no damage was followed. The earthquake was felt in Telavi as well" (Bius, 1948).

According to the isoseismals map (Fig. 39) constructed by us on the basis of the above data of Bius (1948), the parameters of the earthquake are: date – 18 March, 1853; 00:30 (Δt=±1 hour); epicenter coordinates – φ=41.80°, λ=45.80° (ΔE=±0.2°); depth – h=10 km (Δh=7-15 km); magnitude – M_S=4.2 (ΔM=±0.5); intensity in the epicenter – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 37 (in Russian).

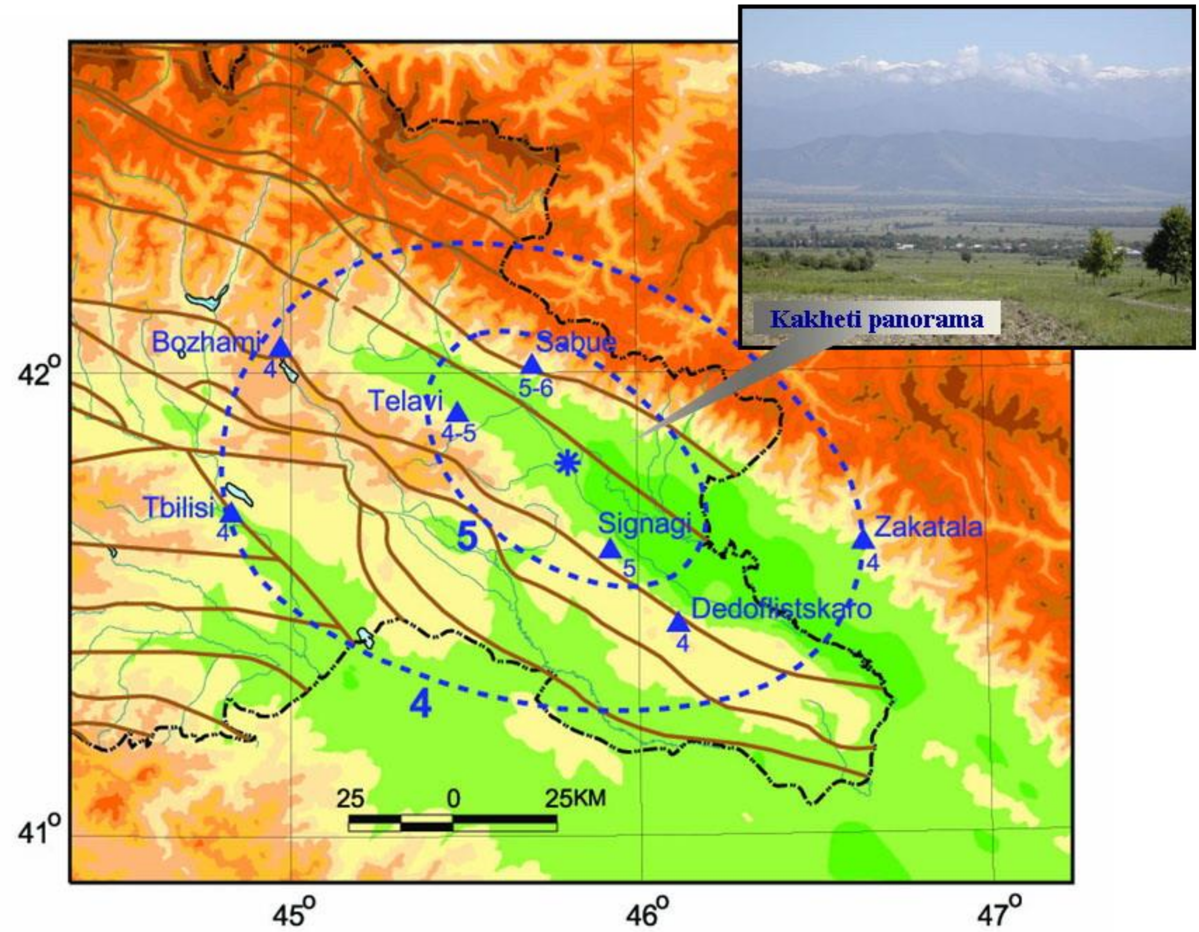

Fig. 39. Map of intensity distribution for the Kakheti Earthquake, March 13, 1853.

1856.02.13 Gori EQ

"13 February, 1856; 04:00. Gori. Firsts there were weak quakes that were followed by stronger ones. They lasted for several seconds. The residents woke up of the noise. The earthquake did not cause harm, except broken glass in the windows" (Bius, 1948).

The main parameters of the earthquake (Fig. 40) near town Gori may be considered as (New Catalog…, 1982): date – 13 February, 1856; 04:00 (Δt=±1 hour); epicenter coordinates – φ=42.00°, λ=44.00° (ΔE=±0.2°); depth – h=12 km (Δh=8-18 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicenter – I_o=5 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 38 (in Russian).
New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 81.

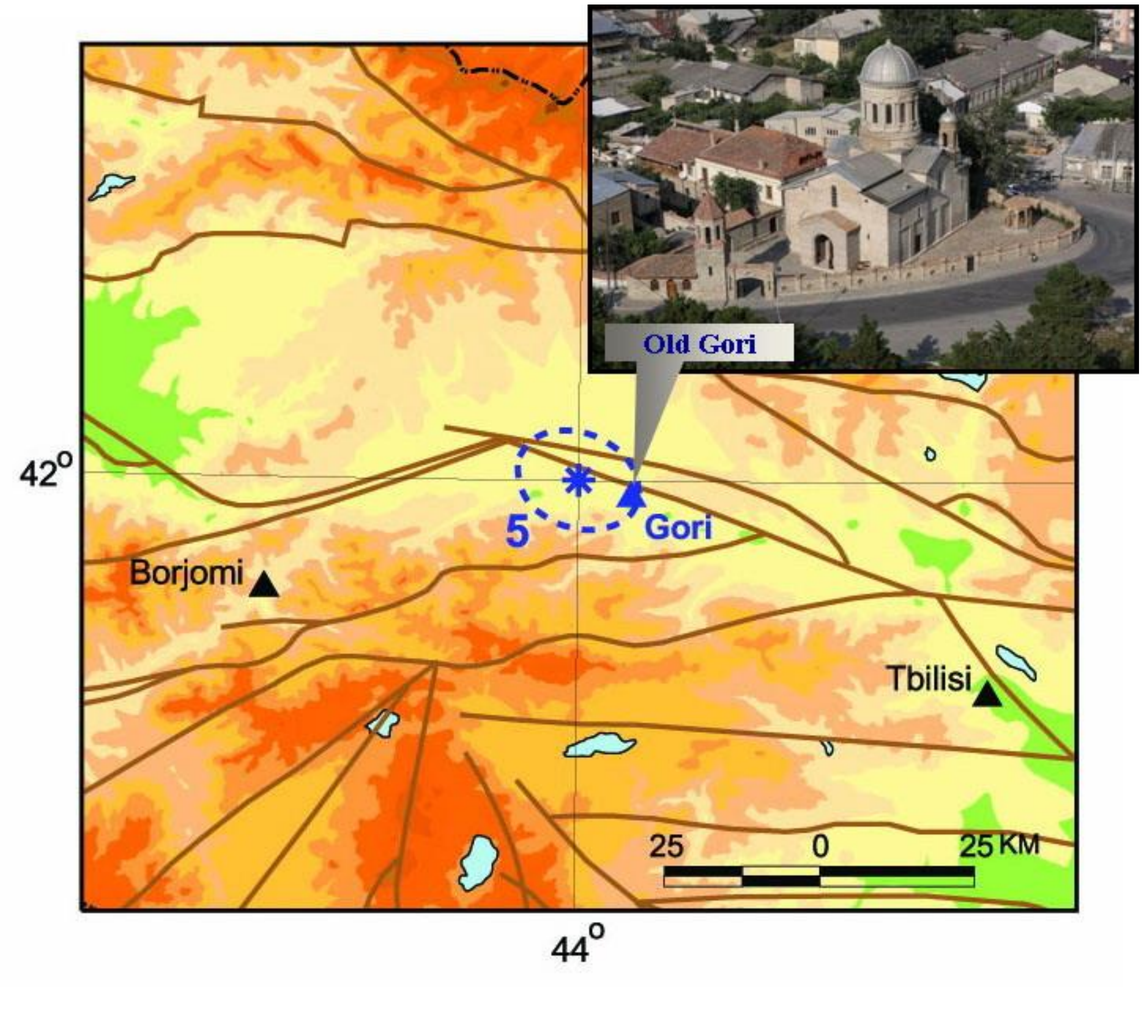

Fig. 40. Map of intensity distribution for the Gori Earthquake, February 13, 1856.

1868.02.18 Javakheti EQ

"18 February, 1868. 17:00. There occurred an earthquake mainly in Alexandropol and Akhaltsikhe district, it spread (through Tbilisi) to Telavi and Zurnabad. There is some information about the earthquake: in Alexandropol the earthquake was felt strongly in the direction of N-S, hanging objects swung strongly, small cracks were formed in the vaults, glass was broken; within two hours the earth quaked again; in Akhaltsikhe the earthquake was felt quite strongly. It was felt near Lake Toparavani and Kvirili (very strongly) and lasted for 6 seconds. In Akhalkalaki shocks spread from the South, a few poorly constructed buildings collapsed, the earthquake lasted 7 days. In Chatakh frequent quakes were observed. In Tbilisi there was a moderate earthquake, and during one minute five amplifications and attenuations were observed in underground rumble and crackle, the direction of the shock – NNE-SSW; 5 or 6 weak shocks were felt at night and in the morning of 19 February. In Manglisi three shocks were felt during one minute. In Shorapani the earthquake was felt. In Zurnabad – some instant vibration of the soil from E to W. In Telavi – hardly noticeable undulation, duration – 1 second. In Gori – a weak quake. In Surami – an unnoticeable quake. In Borjomi – on the left bank of the river Borjomi the earthquake was felt significantly, on the right bank of the river and its gorge it was not observed. There were changes in the regimes of the sources. In Kars – quite strong underground shocks. In Atskuri – the earthquake was observed. In Ardagan – a strong earthquake. At the post stations between Atskuri and Tbilisi earthquake was not observed and neither was it felt at points of Yerevan, Shemakha and farther to the east… The soil in the Akhaltsikhe district has seldom been calm. A few poorly constructed houses were destroyed, but there were no disastrous consequences for residents (of Akhalkalaki). Village Spasskoe situated not far from the probable focus of this earthquake was too much affected" (Bius, 1948).

"Destruction in village Spasskoe" (New Catalog…, 1982).

By means of the newly constructed map (Fig. 41) of this earthquake in Javakheti we accept its parameters as: date – 18 February, 1868; 17:00 (Δt=±1 hour) ; epicenter coordinates – φ=41.20°, λ=43.50° (ΔE=±0.2°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=4.9 (ΔM=±0.5); intensity in the epicenter – I_o=6-7 (ΔI_o=±0.5).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, pp. 45-46 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 83.

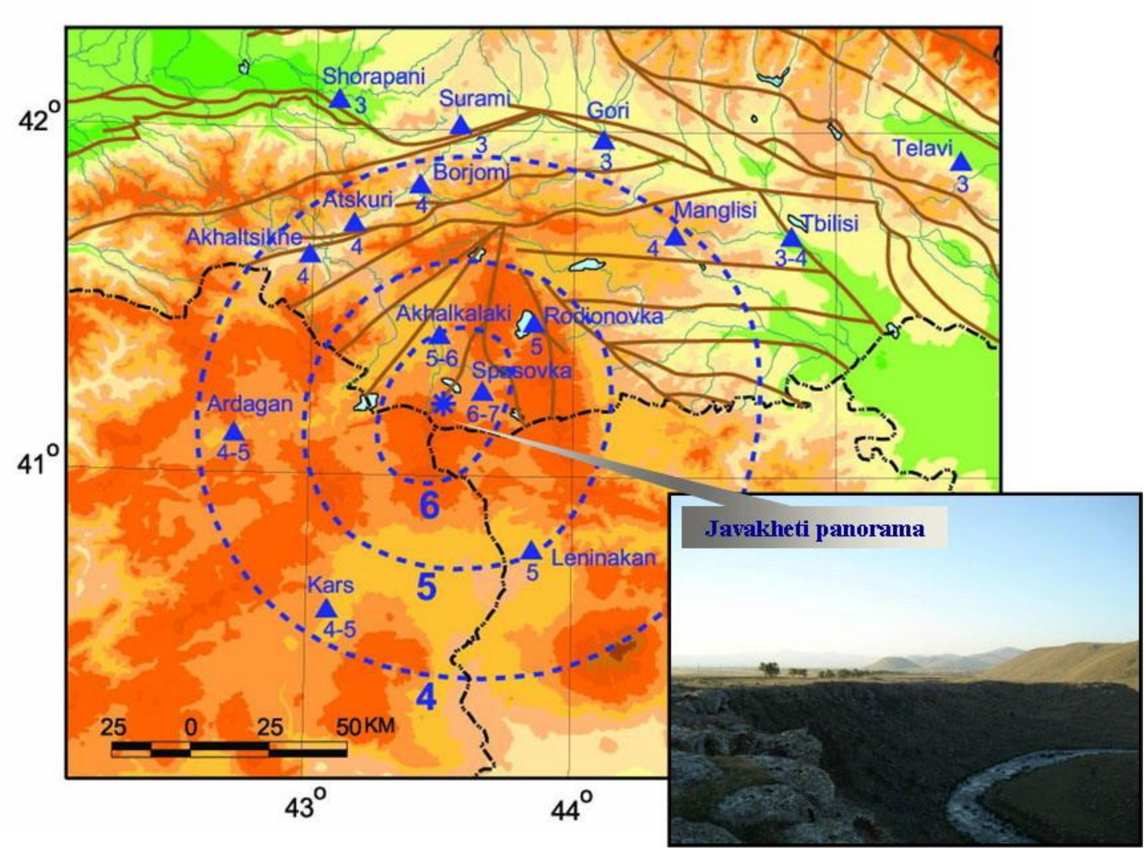

Fig. 41. Map of intensity distribution for the Javakheti Earthquake II, February 18, 1868.

1868.12.09 Pasanauri EQ

"9 December, 1868. 16:00. Kobi, Dusheti, Kvishkheti. Two quakes with an interval of 20 minutes. Gudamakari gorge, Pasanauri. The earthquake was directed from E to W. Some parts of buildings and furniture began to tremble" (Bius, 1948).

The main parameters of this earthquake (Fig. 42) are: date – 9 December, 1868; 16:00 (Δt=±1 hour); epicenter coordinates – φ=42.30º, λ=44.70º (ΔE=±0.2º); depth – h=25 km (Δh=16-38 km); magnitude – M_S=4.0 (ΔM=±0.5); intensity in the epicenter – I_o=4-5 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 50 (in Russian).

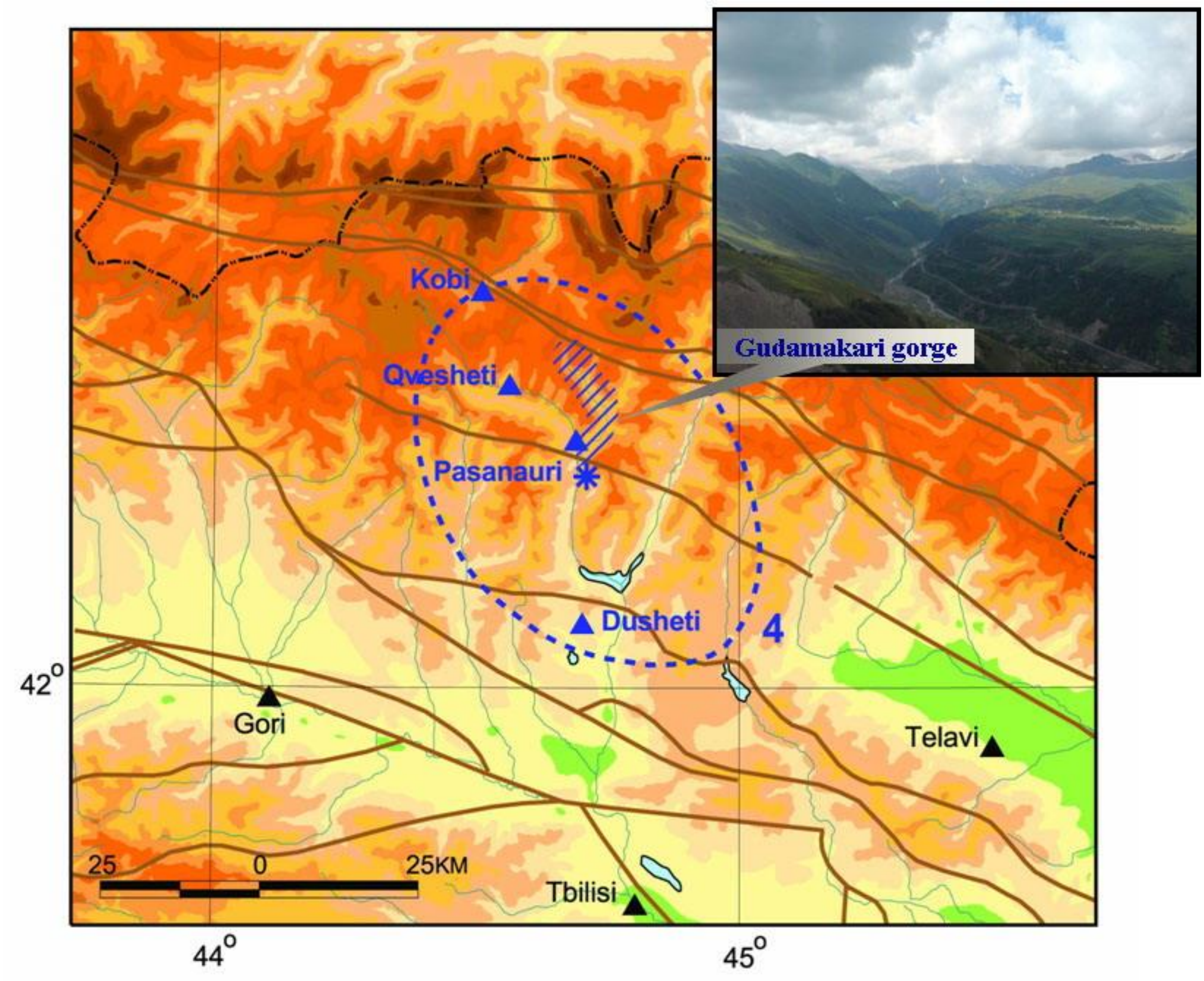

Fig. 42. Map of intensity distribution for the Pasanauri Earthquake, December 09, 1868.

1870.07.19 Ozurgeti EQ

"19 July, 1870. 14:30. Ozurgeti. A strong underground shock lasted 4 seconds. It was followed by a weak one which lasted 2 seconds. Prior to the earthquake and after it some rumbling was heard. Such earthquakes seldom occur in this area" (Bius, 1948).

As it seems this earthquake (Fig. 43) is to be classifies as a local one. Its parameters are approximately as following: date – 19 July, 1870; 14:30 (Δt=±10 minutes); epicenter coordinates – φ=41.90°, λ=42.10° (ΔE=±0.2°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=4.2 (ΔM=±0.7); intensity in the epicenter – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 53 (in Russian).

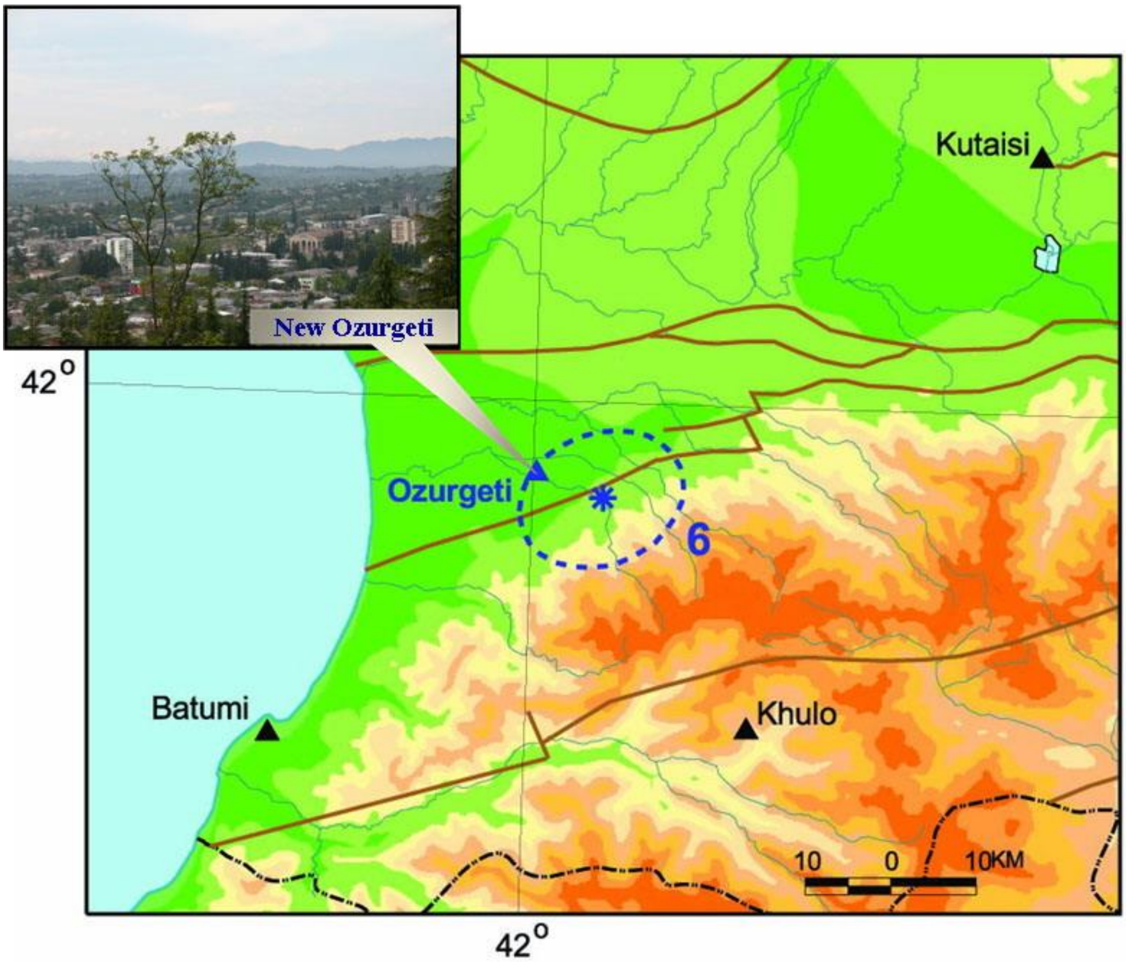

Fig. 43. Map of intensity distribution for the Ozurgeti Earthquake, July 19, 1870.

1874.02.25 Borjomi EQ

"25 February, 1874. 19:30. At Akhaltsikhe – an earthquake was felt, its direction was NW-SE. In Borjomi – a weak underground shock" (Bius, 1948).

"25 February, 1874. 20:00. Borjomi. A strong underground shock, chairs and light things shifted from their places; approximately after 0.5 hour another weak shock followed" (Bius, 1948).

For this local earthquake (Fig. 44) that was preceded by a foreshock we accept the following parameters: date – 25 February, 1874; 20:30 (Δt=±1 hour); epicenter coordinates – φ=41.80°, λ=43.40° (ΔE=±0.2°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicenter – I_o=5-6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 55 (in Russian).
New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 85.

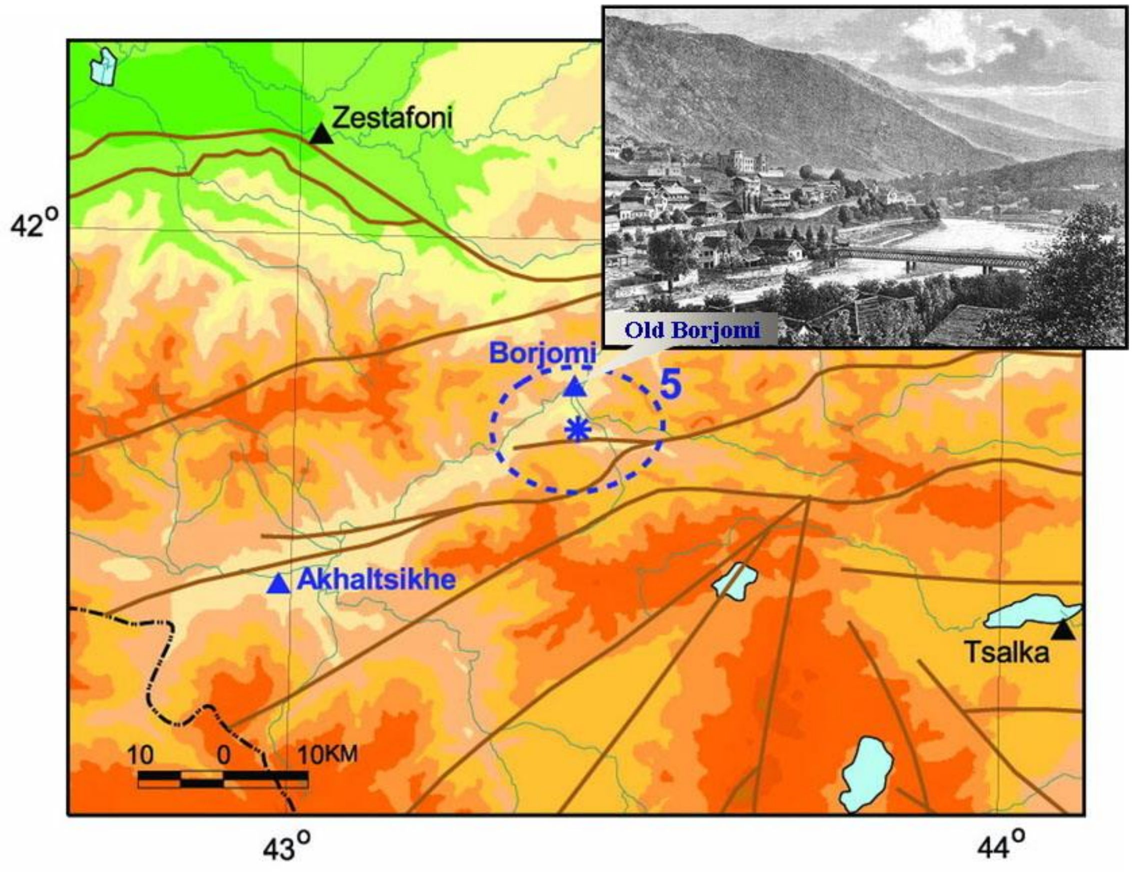

Fig. 44. Map of intensity distribution for the
Borjomi Earthquake, February 25, 1874.

1877.08.08 Utsera EQ

"8 August, 1877. 06:30 (18:30). Quite a strong earthquake was felt in the vicinity of 15 km from town Oni. It lasted for 3-4 seconds; furniture, houseware, walls of wooden houses staggered; unfastened clapboard fell from the roof. The quake spread on both sides of the river Rioni downstream more than 50 km. In Utsera the earthquake struck several walls of stone houses. Earthquakes have not been observed for a long time here" (Bius, 1948).

The main parameters of this earthquake (Fig. 45) are: date – 8 August, 1877; 19:30 (Δt=±10 minutes); epicenter coordinates – φ=42.60°, λ=43.60° (ΔE=±0.5°); depth – h=5 km (Δh=2-10 km); magnitude – M_S=3.8 (ΔM=±0.5); intensity in the epicenter – I_o=6-7 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 56 (in Russian).

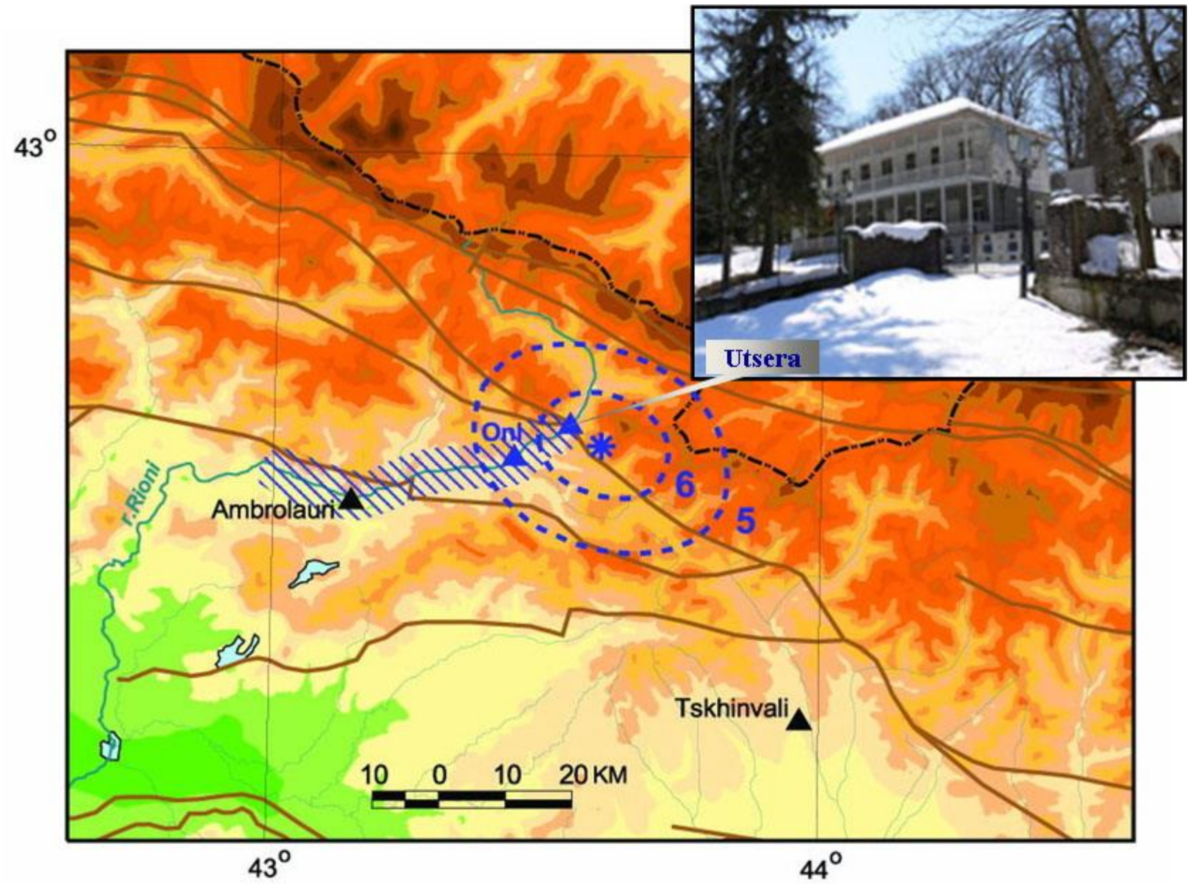

Fig. 45. Map of intensity distribution for the
Utsera Earthquake, August 8, 1877.

1878.11.26 Borjomi area EQ

"26 November, 1878. 23:00. In Borjomi – a strong earthquake accompanied by frightful subterranean rumble. Houses cracked, sleeping people fell off their beds. Old people do not remember anything like this. In Surami – the same situation" (Bius, 1948).

The parameters of this local earthquake (Fig. 46) are as follows: date – 26 November, 1878. 23:00 (Δt=±1 hour); epicenter coordinates – φ=41.90°, λ=43.50° (ΔE=±0.2°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=4.3 (ΔM=±0.5); intensity in the epicenter – I_o=5-6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, pp. 56-57 (in Russian).

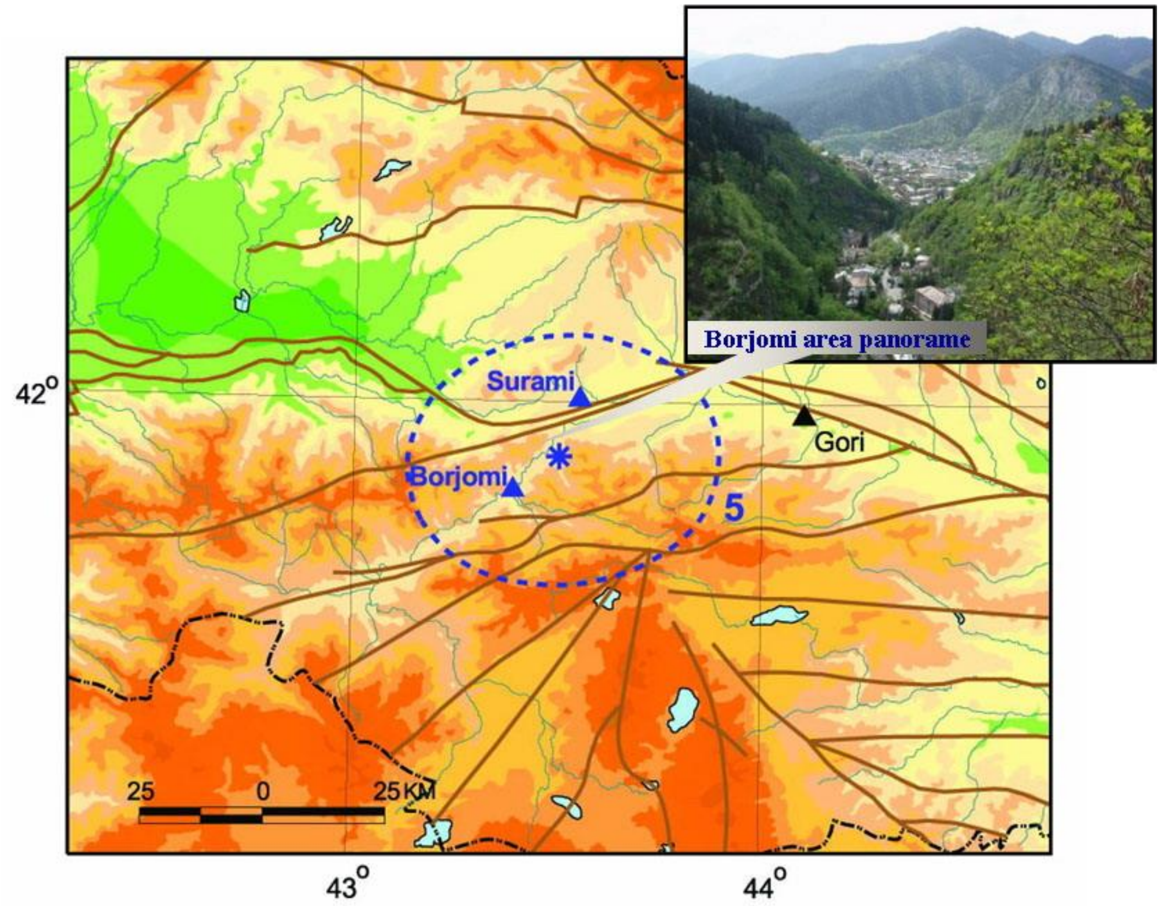

Fig. 46. Map of intensity distribution for the Borjomi Area Earthquake, November 26, 1878.

1881.08.24 Kartli EQ

"24 August, 1881. 20:00. There are following reports on the earthquake: In Dzevera – quite a strong earthquake distributing from SW to NE, not all the asleep awakened, lasted 3 seconds. In village Gomi the undulation in the soil lasted 15-20 seconds. There was a rumble, dish rattled, pictures twisted on walls. In Kobi the earthquake distributed from NW to SE and lasted for one minute. In Kutaisi a strong rumble was heard prior to the earthquake, then followed a quake from E to W. In Tbilisi three shocks were felt From NE to SW " (Bius, 1948).

On the bases of the above data and the map (Fig. 47) of isoseismals constructed by us we evaluated the parameters of the earthquake in Kartli as follows: date – 24 August, 1881. 20:00 (Δt=±1 hour); epicenter coordinates – φ=42.00°, λ=44.00° (ΔE=±0.2°); depth – h=17 km (Δh=8-34 km); magnitude – M_S=4.0 (ΔM=±0.5); intensity in the epicenter – I_o=5 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 58 (in Russian).

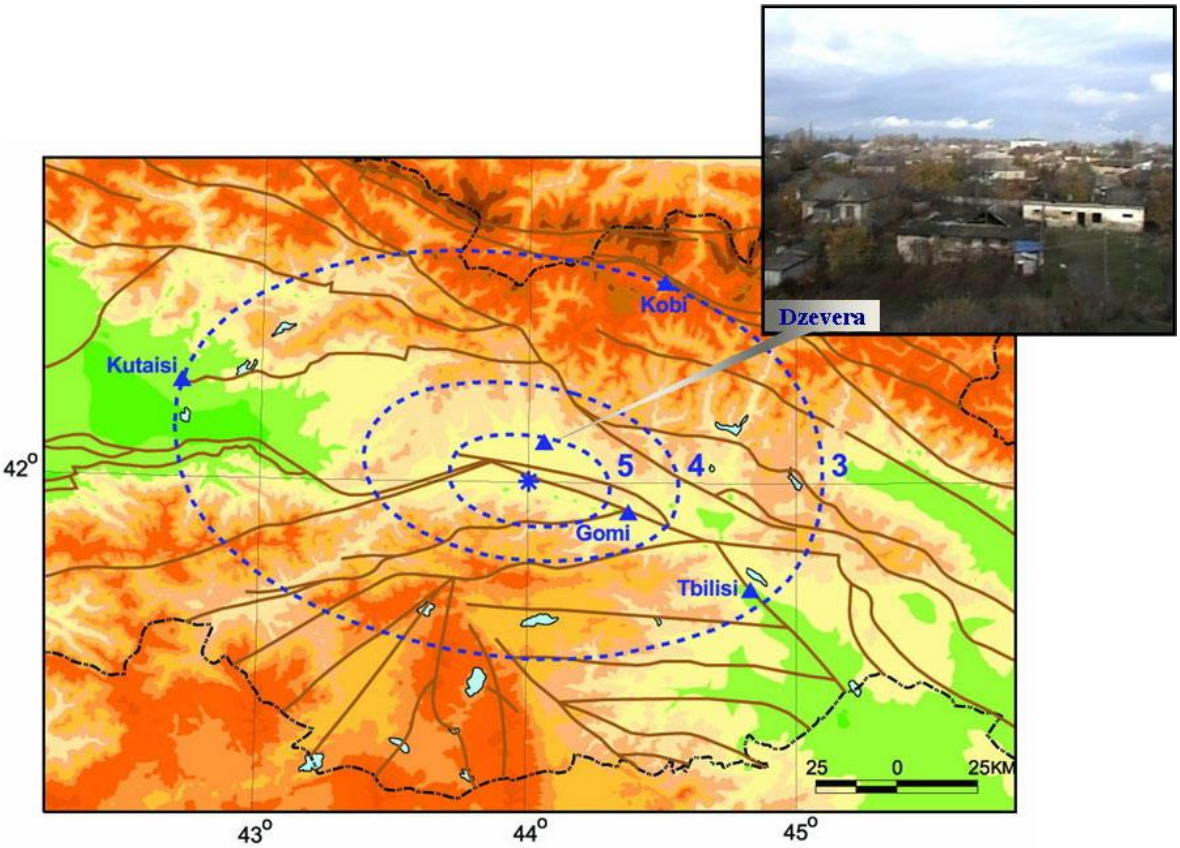

Fig. 47. Map of intensity distribution for the
Kartli Earthquake, August 24, 1881.

1887.07.16 Lanchkhuti EQ

"16 July, 1887. 17:30. An earthquake in the western Georgia. It was followed by a weaker quake after a quarter of an hour. Data from the locations: in Batumi the earthquake was felt along the coast; some part of the population ran from their homes and for some time did not dare to go back. The direction of the earthquake was E-W. In Poti – an earthquake with the E-W direction. In Senaki – there was an earthquake. The soil vibrated in the E-W direction. In Ozurgeti – the earthquake was felt. In Chaladidi – three quakes were felt. In village Nigoiti – there was an earthquake. In Kutaisi – the earthquake was stronger here than in other regions" (Bius, 1948).

"17 July, 1887. 19:00. The earthquake reoccurred. It lasted 8-10 seconds. In Poti – there was an earthquake. In Lanchkhuti – there were two shocks. The second one followed after 2 seconds and caused damage; carriages bumped into one another. In Supsa the building of the station was damaged. The earthquake was most strongly felt near the stations of Supsa and Sadjavakho. The Natanebi-Supsa train had to stop because its carriages began to swing from side to side. In Sadjavakho the earthquake was strongly felt. Roofs collapsed. In Senaki, Kutaisi, Ochamchire, Churuksi, Nigoiti – there was an earthquake" (Bius, 1948).

"…According to the work (Mushketov, Orlov, 1893), probably there were two shocks at 17:45 and 18:50; the second (probable) shock (Bius, 1948) dated 17. VII is incorrect…" (New Catalog…, 1982).

According to the work (1893) of I. Mushketov and A. Orlov and after correcting Ye. Bius' data (New Catalog…, 1982) it became possible to construct the isoseismal map of this earthquake (Fig. 48) and define its parameters: date – 16 July, 1887. 17:45 (Δt=±1 hour); epicenter coordinates – φ=41.05°, λ=44.05° (ΔE=±0.1°); depth – h=12 km (Δh=6-24 km); magnitude – M_S=4.9 (ΔM=±0.5); intensity in the epicenter – I_o=7 (ΔI_o=±0.5).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 60 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 88.

Mushketov, I. V., Orlov, A. P., 1893. Catalog of earthquakes in the Russian Empire. Notes, Russian Geog. Soc., St. Petersburg, vol. 26 (in Russian).

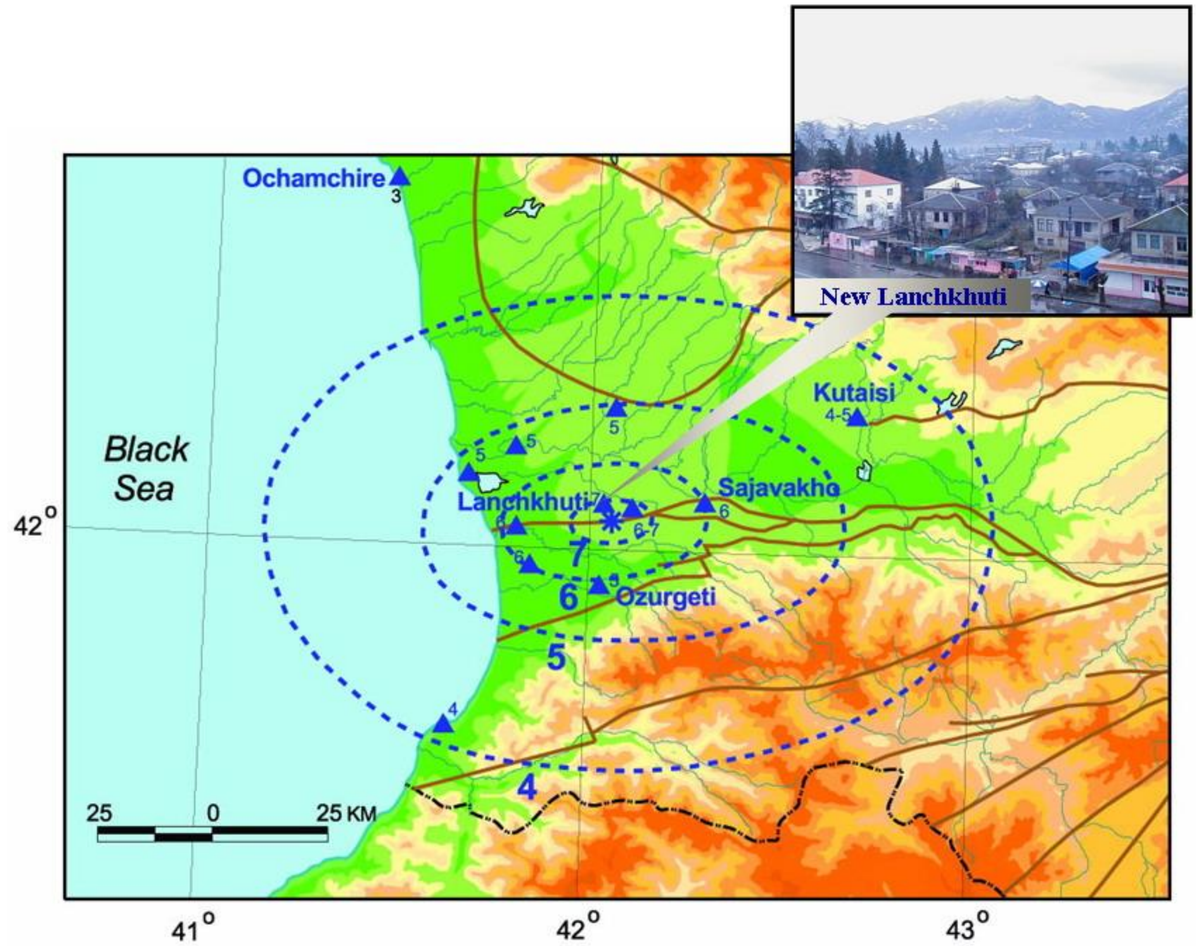

Fig. 48. Map of intensity distribution for the Lanchkhuti Earthquake, July 16, 1887.

1890.10.28 Mtskheta Area EQ

"28 October, 1890. 19:00. The earthquake lasted for 20 seconds, distributed over a large territory of Provinces of Tbilisi, part of Kutaisi province, Elizavetpolsk, Yerevan and Baku provinces. In Ksanka – heavily damaged railway buildings; between the stations of Ksanka and Mtskheta five guard booths were damaged. In Borjomi after the third underground shock many buildings were cracked; more dilapidated buildings were destroyed. In Tbilisi the shocks were spread from the South. On the right bank of the river Mtkvari, where the earthquake was felt strongly, some rumble was heard. In Gori – an earthquake was felt. In Kazakh the vibration of the soil was direction from E to W and had no consequences. In the area of Lake Sevan the earthquake was not noticed" (Bius, 1948).

There are quite controversial data on this earthquake. In particular, high macroseismic effect is noticed in two inhabited areas – village Ksani and town Borjomi that are distanced from each other by 100 km. The isoseismal map (Fig. 49) constructed by us shows that the epicenter of the earthquake was located near village Ksani and the intensity increased in Borjomi due to the local soil effects. Consequently, we accept the parameters of the earthquake as follows: date – 28 October, 1890. 19:00 (Δt=±1 hour); epicenter coordinates – φ=41.85°, λ=44.60° (ΔE=±0.5°); depth – h=15 km (Δh=7-30 km); magnitude – M_S=5.2 (ΔM=±0.5); intensity in the epicenter – I_o=7 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 62 (in Russian).

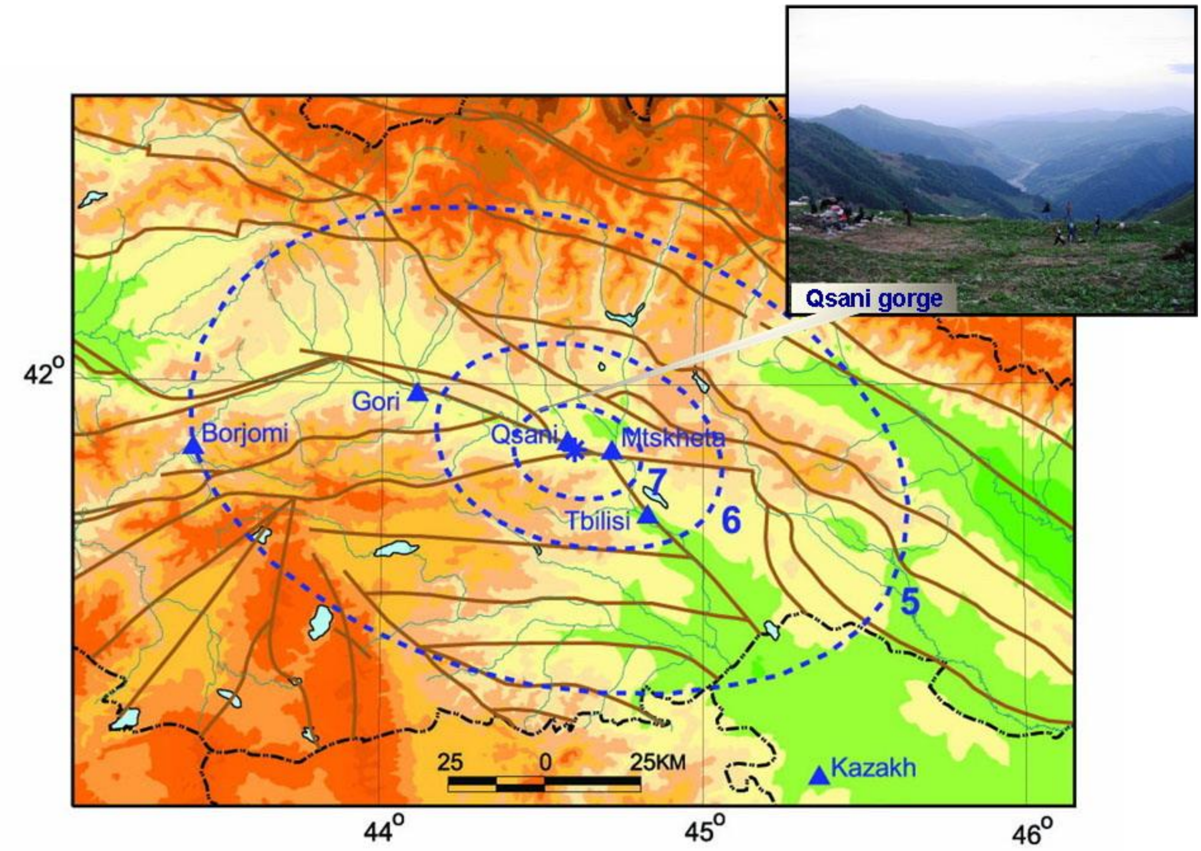

Fig. 49. Map of intensity distribution for the Mtskheta Area Earthquake I, October 28, 1890.

1891 Amtkheli EQ

"The Amtkheli structure is located on 25-27 km north-east from Sokhumi city and is presented as a landslide (of approx. 100 million m³). The landslide has cut the river Amtkeli and formed a lake (Machavariani, 1891). …The possibility of strong earthquakes in the basin of the river Amtkheli, besides the 1891 shocks, is confirmed by the paleodislocation (explored aero-visually) in the pass with the same name. It is presented as a short tectonic terrace in granitoids near the huge landslide. Moreover, on the slopes of the Amtkheli area there are some displacements, possibly stimulated by some earthquake" (Khromovskikh et al., 1979).

“The biggest landslides were discovered in the mountains of the Great Caucasus. These are 100 million m³ seismogravitational displacements of dolomites, sandstones and slates in the basins of the rivers Galidzga and Amtkheli. The landslides are situated near the real or probable seismodislocations” (Khromovskikh, Nikonov, 1984).

“Lake Amtkeli or Azanta is located in Gulripshi region (Georgia, Abkhazia). It was formed on 3 October, 1891 when the river Amtkeli was blocked after the collapse of the mountain Patara-Shkhapacha” (http://ka.wikipedia.org).

Despite no mention of earthquake in the above sources we suppose that the collapse of a large segment of the cliff was caused by an earthquake. Thus, the parameters of the earthquake (Fig. 50) identified on the basis of the seismogravitational structure Amtkeli are the following: date – 1891 (Δt=±1 year); epicenter coordinates – φ=43.05º, λ=41.30º (ΔE=±0.2º); depth – h=15 km (Δh=7-30 km); magnitude – M_S=6.0 (ΔM=±0.5); intensity in the epicenter – I_o=8 (ΔI_o=±1).

Sources:

Machavariani, K. 1891. Rockslide of Tsebelda. Newspaper Caucasus, № 273.

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, pp. 96-99 (in Russian).

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, p. 118 (in Russian).

http://ka.wikipedia.org

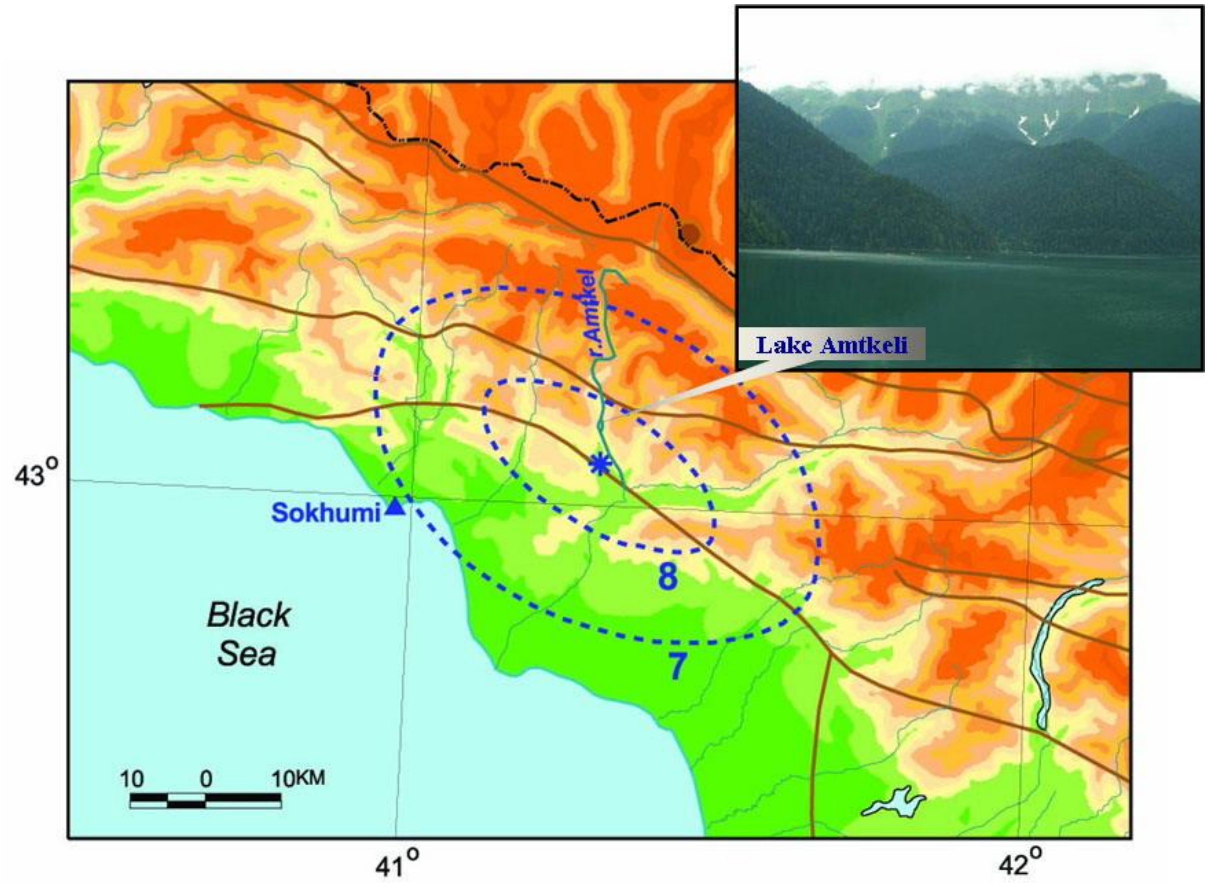

Fig. 50. Map of intensity distribution for the Amtkeli Earthquake, 1891.

1891.03.27 Kareli area EQ

"27 March, 1891. 18:30. In Tsipa quite a strong earthquake lasted for 6 seconds. Glasses of windows rattled and cracks appeared in walls. In Tbilisi within 15 seconds two underground shocks were felt from NNW to SSE. In Telavi out of two shocks the first one was stronger than the other. The earthquake was felt on the Georgian Military Highway in Mleti, Ananuri and Pasanauri (Bius, 1948).

The large scales of macroseismic effects of this earthquake in Kareli area (Fig. 51) indicates to its deeper focus than usual. Taking into consideration this fact we defined the parameters of the earthquake as: date – 27 March, 1891. 18:30 (Δt=±10 minutes) ; epicenter coordinates – φ=42.10°, λ=43.90° (ΔE=±0.5°); depth – h=22 km (Δh=14-33 km); magnitude – M_S=4.5 (ΔM=±0.5); intensity in the epicenter – I_o=5-6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 62 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 89.

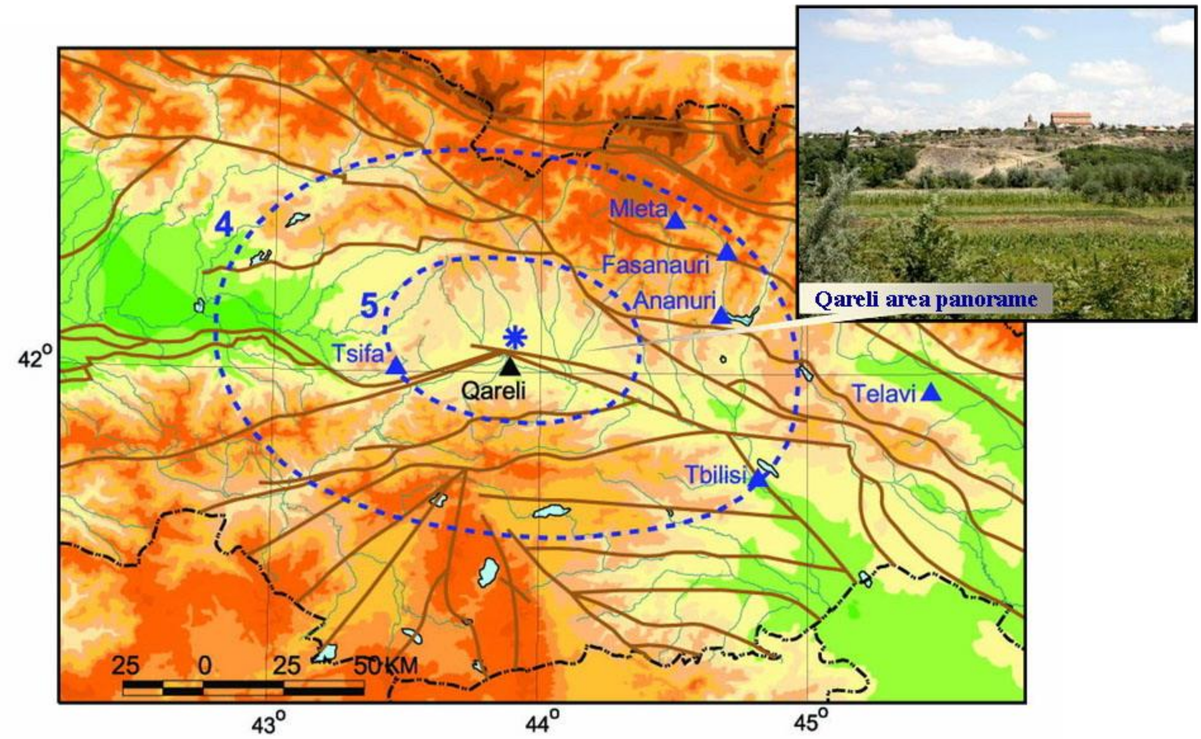

Fig. 51. Map of intensity distribution for the Kareli area Earthquake, March 27,1891.

1894.11.29 Mtskheta area EQ

"29 November, 1894. 10:30. In Tbilisi there were two underground shocks within two seconds. The second one was stronger. The earthquake had direction from ESE-WNW. Some of the houses became cracked, walls noticeably vibrated, many people on the street did not notice the earthquake. It was much stronger felt in upper floors. In Manglisi at the telephone station the earthquake broke glasses and crumbled the plaster. In Dusheti – there were three underground shocks from E to W, which damaged houses. In Shulaveri the earthquake was felt" (Bius, 1948).

According to these data the earthquake of the same maximal intensity occurred in three inhabited points located in different areas and the epicenter is to be searched between these points (Fig. 52). The main parameters of the earthquake in Mtskheta area are: date – 29 November, 1894; 10:30 (Δt=±10 minutes); epicenter coordinates – φ=41.90°, λ=44.60° (ΔE=±0.2°); depth – h=24 km (Δh=18-36 km); magnitude – M_S=5.0 (ΔM=±0.5); intensity in the epicenter – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 63 (in Russian).

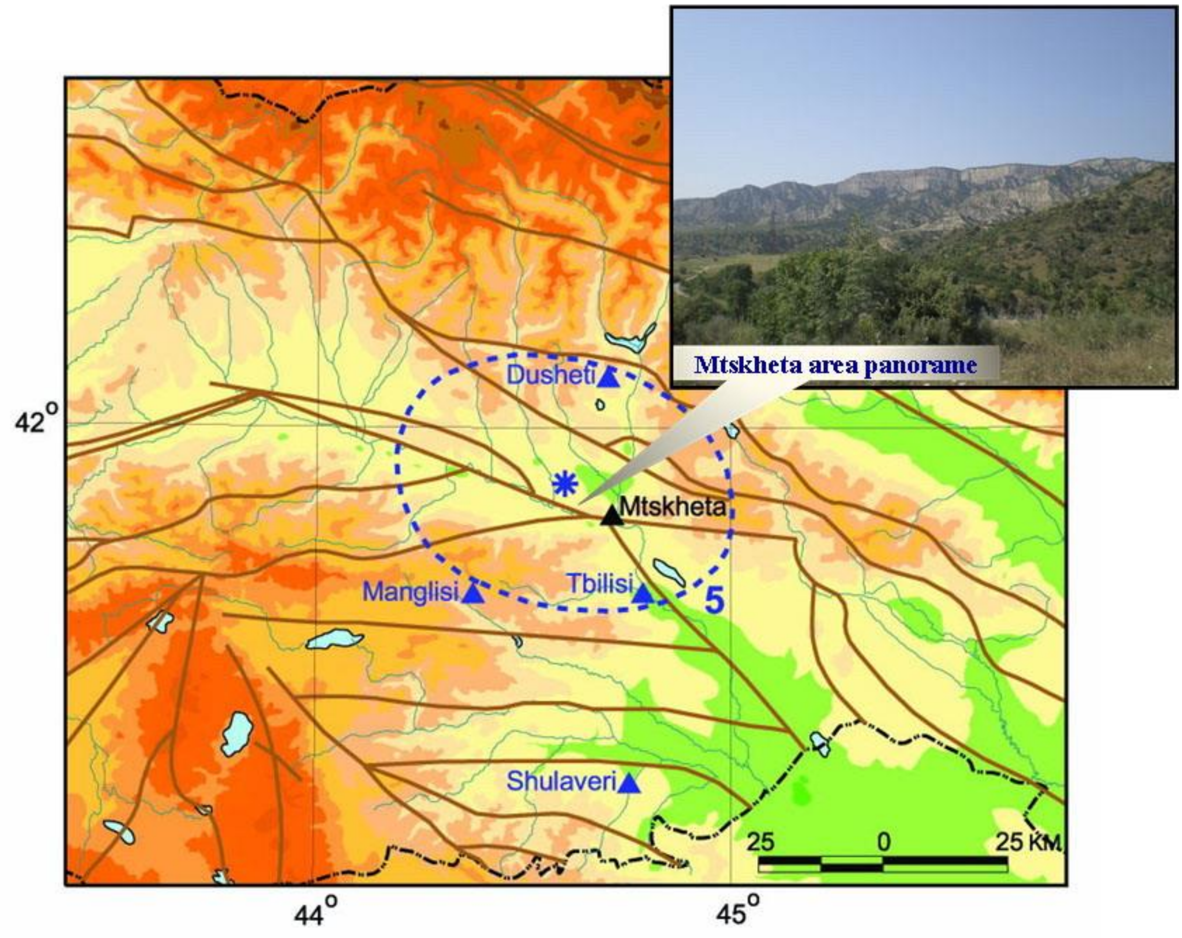

Fig. 52. Map of intensity distribution for the Mtskheta area Earthquake II, November 29, 1894.

1896.09.22 Tbilisi area EQ

"22 September, 1896. 05:30. Earthquake seized quite a large area. It was more strongly felt on the territory from Kvirila (west) to Evlakh (east), weaker – from Samtredia and village Rioni to Lyak and Adjikabul. It was strong in the mountains north of Tbilisi in Mleta, Pasanauri, Gudauri, Kobi; some relatively slight vibration was felt in Kazbegi, Lars and Vladikavkaz; to the south strong shocks were observed in Dilijan, weaker – towards the cities of Yerevan and Kars. In Tbilisi there was a strong underground shock, a minute later there was another which was stronger than the first one. The first shock lasted 10 seconds, the other – 15 seconds. There was a third one as well. The shocks were accompanied by subterranean rumble. The second and third shocks were so strong that the asleep fell off their beds, plaster burst, crockery broke down, chimneys crumbled. There was panic. In Kojori the strong earthquake cracked walls of houses. In Yelizavetpol within 3 seconds there occurred two quakes accompanied by the noise on the similarity of some thunder. Ceilings cracked, lamps swung, dishes rattled, pictures fell down, one of the old building settled and cracked. In Gvarebi a fairly strong wave-like earthquake was felt from E to W. There was panic, from the mountains some huge stones rolled down. In Gombori – there was a thunder-like rumble and after a few seconds a sharp vibration of soil began. The earthquake lasted 1 minute, it was difficult to stand on feet, houses cracked, walls shook, dish and window panes rattled. The quake distributed from NE. In Salogly strong shocks lasted about one minute, walls of the station building were damaged, clocks stopped. In Telavi the shocks distributed from W, the walls of the college cracked, the ceiling of the top floor noticeably moved off the encasement, inkpots fell from the tables. The earthquake was felt quite strongly in the points: Borjomi, Sighnaghi, Alexandropol, Akhalkalaki, Kutaisi and other areas of the Transcaucasus" (Bius, 1948).

"1896 IX 22; φ=41.58, λ=45.17" (Bius, 1952).

"1896, September 22. 05:00.; Lat(°)=41.6, Long(°)=45.2; h=18km; M=5.2; I_o=7" (New Catalog…, 1982).

"1896 9 22 3 53; φ=41.6, λ=45.0; h=30 km; M=6.3; I_o=7.5" (Shebalin, Tatevossian, 1997).

On the basis of the new isoseimal map (Fig. 53) constructed by us and the equations of macroseismic field defined for the territory of Georgia and the corresponding nomograms – φ=41.65°, λ=45.00°; h=20 км; M_S=6.0; I_o=7.5 and taking into consideration that the work (Abe, 1994) gives the instrumental magnitude of the earthquake its main parameters must be determined as follows: date – 22 September, 1896; 03:53 (Δt=±10 minutes); epicenter coordinates – φ=41.65°, λ=45.00° (ΔE=±0.2°); depth – h=25 km (Δh=12-37 km); magnitude – M_S=6.3 (ΔM=±0.5); intensity in the epicenter – I_o=7.5 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 65 (in Russian).

Bius, Ye. I. 1952. Seismic conditions of the Trans-Caucasus, part II. Acad. Scf. GSSR, Tbilisi, p. 78 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p.157.

Shebalin, N. V., Tatevossian, R. E. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and Prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers, Netherland, pp. 201-232.

Abe, K. 1994. Instrumental magnitudes of historical earthquakes, 1892-1898. BSSA, 84, 2, 415-425.

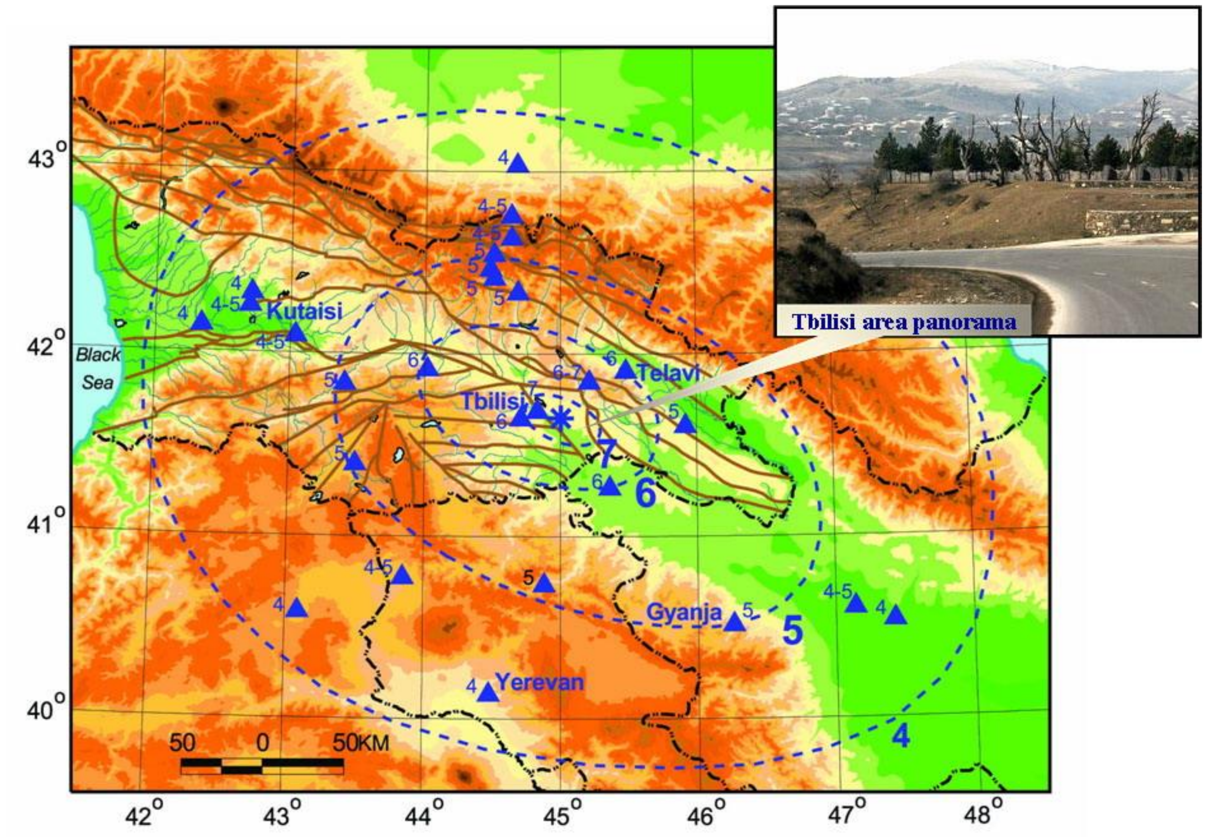

Fig. 53. Map of intensity distribution for the Tbilisi area Earthquake, September 22, 1896.

1897.01.22 Lagodekhi area EQ

Catalogue of earthquakes occurred in the North Caucasus with intensity VI and more:
"...22.1.1897 5^h**.** Lagodekhi, intensity V-VI" (Ananin, I.V. 1968).

"3 February, 1897. 02:00. Lagodekhi. There was a strong earthquake. The shocks struck twice within one hour. The residents became scared (intensity V)" (Bius, 1948, 952).

"4 February, 1897. 23:00. Lagodekhi. The earthquake reoccurred" (Bius, 1948).

"22 January, 1897. 05:00; Lat(°)=41.4, Long(°)=46.3; h=10 km; M=3.8; I_0=5-6 " (New Catalog…, 1982).

The analysis of the above data shows that the earthquake interpretation in New Catalogue (New Catalog…, 1982) is based on I. Ananin's material (Ananin, I.V. 1968). In its part this material is similar to Ye. Bius' data (Bius, 1948, 952) by the viewpoint of maximal intensity and the site badly affected by the earthquake. These two sources are differentiated by the date and time of origination of the earthquake. As a rule, Ye. Bius gives the date by the Gregorian calendar while I. Ananin probably indicates it by the Julian calendar, though there is difference in the times (hour) of the earthquake occurrence. In spite of this fact the both sources indicate to town Lagodekhi as the point mostly affected by this earthquake. In New Catalogue the epicenter of this earthquake is considered in 50 km from Lagodekhi, in outer Kakheti, in Dedoplistskaro region that is probably incorrect (Fig. 54). Thus, according to the short analysis the parameters of the earthquake are as follows: date – 3

February, 1897. 02:00 (Δt=±6 hours); epicenter coordinates – φ=41.80°, λ=46.30° (ΔE=±0.2°); depth – h=10 km (Δh=5-20 km); magnitude – M_S=3.8 (ΔM=±0.7); intensity in the epicenter – I_o=5.5 (ΔI_o=±1).

Sources:

Ananin, I. V. 1968. North Caucasus. In: Seismic zoning of the USSR. Red.: S.V. Medvedev, Nauka Publ. House, Moscow, p. 266 (in Russian).

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 65 (in Russian).

Bius, Ye. I. 1952. Seismic conditions of the Trans-Caucasus, part II. Acad. Scf. GSSR, Tbilisi, p. 78 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 90.

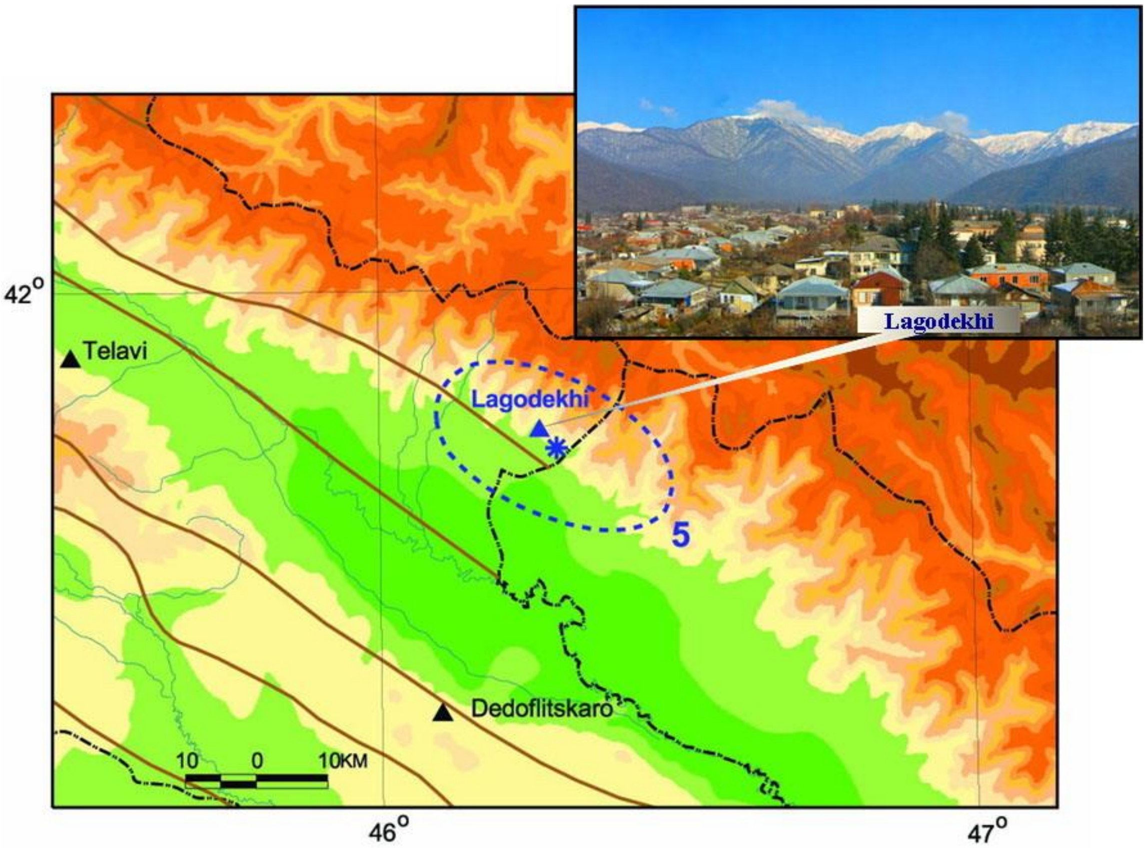

Fig. 54. Map of intensity distribution for the Lagodekhi Area Earthquake, January 22, 1897.

1898.08.13 Javakheti area EQ

"13 August, 1898. 00:00. Aleksandropol. There was a brief underground shock in the direction NW-SE and then – vibration of the soil for a few seconds. Some rumble was heard before the earthquake. There are reports that the earthquake was observed in the district of Telavi, Akhalkalaki, Akhaltsikhe, in Tbilisi, Gudauri, Borjomi, Abastumani, Baraleti, Akhalkalaki, in Eshtia springs gave murky water during a week. A new source in Hosta (3 km from Akhalkalaki); Kanza, Saghamo, Sakhta, Bogdanovka, Bolshaya Kondura, Vachiani, Sulda, Karzaki, Tambovka, Ronionovka, Gorelovka, Atskuri and Ikalto are too damaged. In general, the earthquake was felt in Provinces of Tbilisi and Yerevan. The focus of the earthquake is located near village Eshtia" (Bius, 1948).

The coordinates of this earthquake in Bius' work (Bius, 1948, 952) are φ=41.30°, λ=43.55°; In New Catalogue (New Catalog…, 1982) the coordinates are considered as φ=41.60°, λ=43.40°, but the latter is incorrect; according to the isoseismal maps constructed by us we consider the parameters as φ=41.30°, λ=43.50° (Fig. 55) that are approximately similar to Ye. Bius' data. Thus, the main parameters of the earthquake in Javakheti are: date – 13 August, 1898; 00:00 (Δt=±1 hour); epicenter coordinates – φ=41.30°, λ=43.50° (ΔE=±0.2°); depth – h=10 km (Δh=7-15 km); magnitude – M_S=4.2 (ΔM=±0.5); intensity in the epicenter – I_o=6 (ΔI_o=±1).

Sources:

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, p. 66 (in Russian).

Bius, Ye. I. 1952. Seismic conditions of the Trans-Caucasus, part II. Acad. Scf. GSSR, Tbilisi, p. 150 (in Russian).

New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, p. 90.

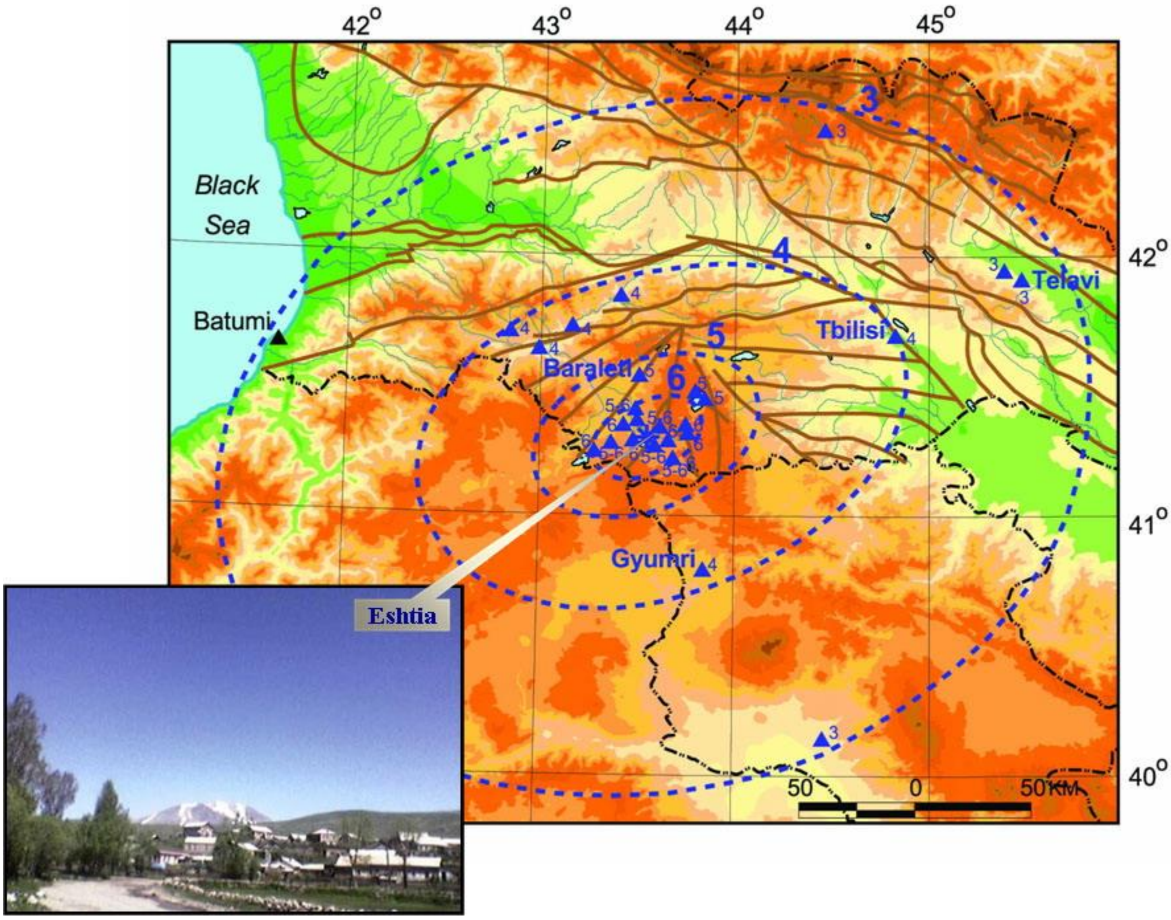

Fig. 55. Map of intensity distribution for the Javakheti Earthquake III, August 13, 1898.

1899.12.31 Akhalkalaki EQ

The revision and new interpretation of the data of the Akhalkalaki earthquake described in details in the primary sources (Mushketov, 1903; Bius, 1948) were made in the research (Tatevossian et al., 1997) published in 1997. It contains a new isoseismal map of this earthquake and its main parameters (among them the instrumental magnitude M_S=6.1 defined by 7 stations data) (Ambraseys, Adams, 1989; Abe, 1994). According to the total information in this work we, in our part, constructed isoseismal maps for the entire distribution area and the epicenter zone of this earthquake (Fig. 56, 57). Unlike the research (Tatevossian et al., 1997) where isoseismals are mainly oriented in NW-SE in our case the isoseismals have meridian orientation that better corresponds to the existing geologic environment. Thus, we accept the parameters of the Akhalkalaki earthquake as the following: date – 12 December, 1899; 10:50 (Δt=±10 minutes); epicenter coordinates – φ=41.55°, λ=43.55° (ΔE=±0.1°); depth – h=9 km (Δh=4-18 km); magnitude – M_S=6.1 (ΔM=±0.2); intensity in the epicenter – I_o=9 (ΔI_o=±0.5).

Sources:

Mushketov, I. 1903. Materials on Akhalkalaki earthquake on December 19, 1899. Proceedings of the Geological Committee, new series, issue 1 (in Russian).

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, pp. 66-74 (in Russian).

Tatevossian, R. E., Albini, P., Camassi, R., Mokrushina, N.G., Shebalin, N.V., Petrossian, A.E. 1997. Analysing and improving supporting data set of the Akhalkalak, december 31, 1899, earthquake. Historical and prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers. Netherland. pp. 383-400.

Ambraseys, N. N., Adams, R. D. 1989. Long-term seimicity of North Armenia. EOS, March 7, 152-154.

Abe, K. 1994. Instrumental magnitudes of historical earthquakes, 1892-1898. BSSA, 84, 2, 415-425.

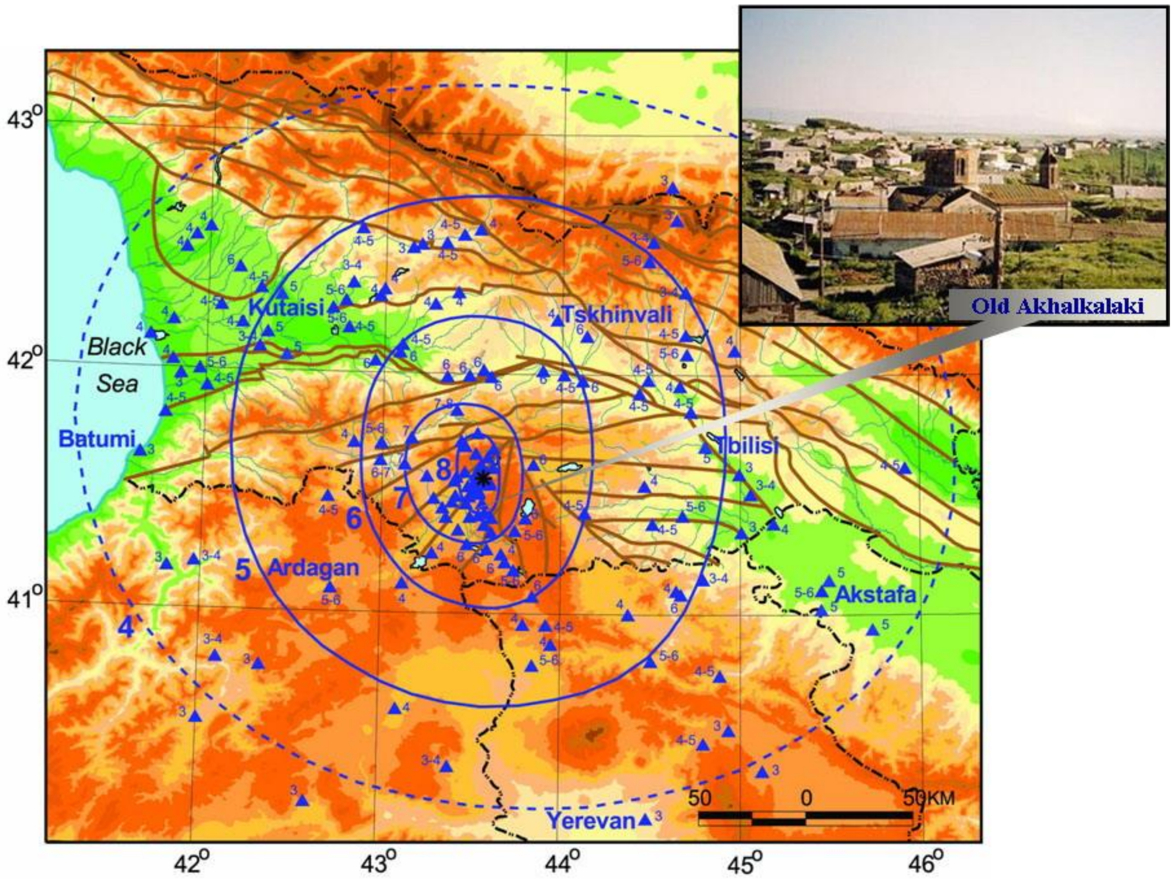

Fig. 56. Map of intensity distribution for the Akhalkalaki Earthquake, December 31, 1899.

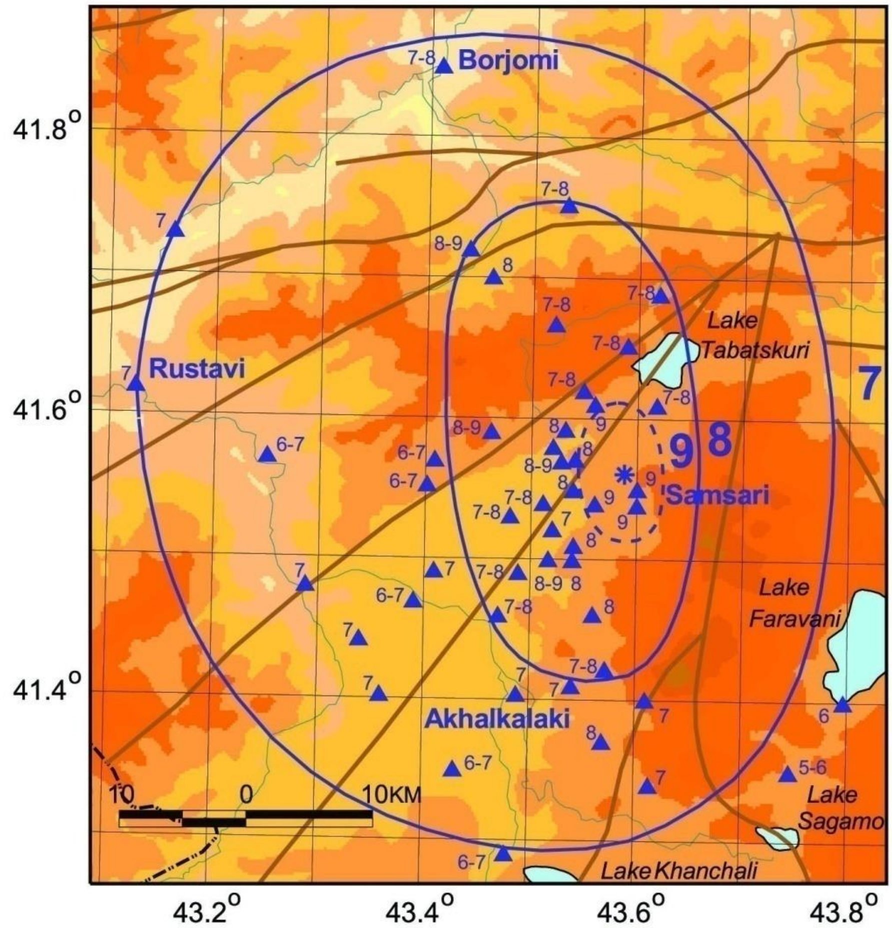

Fig. 57. Map of intensity distribution in the epicenter zone of the Akhalkalaki Earthquake, December 31, 1899.

8 Conclusion

Long-term seismic history is an important foundation for reliable assessment of seismic hazard and risk. Therefore, completeness of earthquake catalogues in the longest historical part is very important. Survived historical sources, as well as special researches from the institutes, museums, libraries and archives in Georgia, the Caucasus and the Middle East indicate to high level of seismicity which entailed numerous human casualties and destruction on the territory of Georgia during the historical period. The study and detailed analysis of these original documents and researches have allowed us to create a new catalogue of historical earthquakes of Georgia from 1250 BC to 1900 AD. The method of the study is based on a multidisciplinary approach, i.e. on the joint use of methods of history and paleoseismology, archeoseismology, seismotectonics, geomorphology, etc. We present here a new parametric catalogue of 44 historic earthquakes of Georgia (Table 2) and a full "descriptor" of all the phenomena described in it. Constructed on its basis, the summarized map of the distribution of maximum damage in the historical period (before 1900) on the territory of Georgia (Fig. 11) clearly shows the main features of the seismic field during this period. In particular, in the axial part and the southern slope of the Greater Caucasus there is a seismic gap, which was filled in 1991 by the strongest earthquake and its aftershocks in Racha. In addition, it is also obvious that very high seismic activity in the central and eastern parts of the Javakheti highland is not described in historical materials and this fact requires further searches of various kinds of sources that contain data about historical earthquakes. We hope that this catalogue will enable to create a new joint (instrumental and historical) parametric earthquake catalogue of Georgia and will serve to assess the real seismic hazard and risk in the country.

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References

Adamia, Sh., Mumladze, N., Sadradze, N., Tsereteli, E., Tsereteli, N., Varazanashvili, O. 2008. Late Cenozoic tectonics and geodynamics of Georgia (SW Caucasus). Georgian International Journal of Science and Technology ISSN 1939-5825. Nova Science Publishers, vol. 1, issue 1, USA, pp. 77-107.

Allen, M., Jackson, J., Walker, R. 2004. Late Cenozoic reorganization of the Arabia-Eurasia collision and the comparison of short-term and long-term deformation rates. J. Tectonics, vol. 23, 1-16.

Bius, Ye. I. 1948. Seismic conditions of the Trans-Caucasus, part I. Acad. Scf. GSSR, Tbilisi, 304 pp. (in Russian)

Bius, Ye.I. 1952, 1955. Seismic conditions of the Trans-Caucasus, part II, III. Acad. Scf. GSSR, Tbilisi, 175, 131 pp. (in Russian).

DeMets, C., Gordon, R., Argus, D., Stein, S. 1990. Current plate motions. Geoph. J. Int., 101, 425-478.

Jackson, J., Ambraseys, N. 1997. Convergence between Eurasia and Arabia in eastern Turkey and the Caucasus. Historical and Prehistorical Earthquakes in the Caucasus. Kluwer Academic Publishers, pp. 79-90.

Javakhishvili, Z., Varazanashvili, O., Butikashvili N. 1998. Interpretation of the macroseismic field of Georgia. Journal of Georgian Geophysical Society (A). vol. 3, pp. 85-88.

Khromovskikh, V. S., Nikonov, A. A. 1984. Following strong earthquakes. Nauka Publ. House, Moscow, 145 pp. (in Russian).

Khromovskikh, V. S., Solonenko, V. P., Semenov, R. M., Zhilkin, V. N. 1979. Paleoseismogeology of the Great Caucasus. Nauka Publ. House, Moscow, 188 pp. (in Russian).

Macroseismic data with the parameters of the focus and isoseismals shtrong earthquakes on the territory of the GSSR. 1984. Tbilisi, 78 pp. (in Russian).

Malinovskiy, N. V. 1935. Catalog of earthquakes in the AzSSR. Proceeding, Az section, branch of the Acad. Scf. USSR, 10 (in Russian).

Makrushina, N. G., Shebalin, N V. 1982. Estimation of the Quality of strong Shakings sites in seismic zoning maps in the USSR, Problems of engineering sesismology 23, 97-113 (in Russian).
Mushketov, I. V., Orlov, A. P., 1893. Catalog of earthquakes in the Russian Empire. Notes, Russian Geog. Soc., St. Petersburg (in Russian).
New Catalogue of Strong Earthquakes in the USSR. 1977. Nauka Publ. House, Moscow, 535 pp. (in Russian).
New Catalog of Strong Earthquakes in the USSR. 1982. NOAA, USA, 608 pp.
Reilinger, R. 2006. Kinematics and dynamics of active rifting of the Northern and Central Red Sea. RKL, EAR 03-05480.
Shebalin, N. V., Tatevossian, R. E. 1997. Catalogue of large historical earthquakes of the Caucasus. Historical and Prehistorical earthquakes in the Caucasus. Kluwer Academic Publishers. Netherland. pp. 201-232.
Shebalin, N. V. 1968. Metods of aplication of seismic enginering data for regional seismity. Regional seismity in the USSR, Nauka Publ. House, Moscow, pp. 95-111 (in Russian).
Shebalin, N. V., Aivazishvili I. V., Varazanashvili, O. Sh., Papalashvili, V. G. 1976. Equations of the macroseismic field for the Greater Caucasus and the Transcaucasus. Seismic Bulletin of the Caucasus for 1974. Metsniereba Publ. House, Tbilisi, pp. 113-126 (in Russian).
Stepanyan, V. A. 1942. Short Chronology of the most important earthquakes in Armenia and neighboring regions. Armenian Acad. Scf. USSR, Yerevan (in Armenian).
Tsereteli, E. D., Varazashvili, L. I. 1986. Character of seismicity in the development of slope gravitational processes in the Caucasus. Geol. e. idrogeol. Italy, ISSN 0435-3870, 21, N2, pp. 57-63.
Tsereteli, E. D., Chelidze, T. L., Adamia, Sh. A., Varazanashvili, O. Sh., Tsereteli, N. S. 2008. The large landslide-gravitational events, as an affirmative phenomenon of an area of possible occurrence of strong earthquakes. Mikheil Nodia Institute of Geophysics proceedings, vol. 60, pp. 11-23 (in Russian).
Tskhakaya, A. D., Papalashvili, V. G. 1973. Seismic conditions of the Caucasus. Metsniereba Publ. House, Tbilisi, p.114 (in Russian).
Varazanashvili, O. 1998. Papalashvili V. Reconstruction of strong earthquake parameters by historical data of XI-XIV cc. in Georgia. Journal of Georgian Geophysical Society (A), vol. 3, pp.77-84.
Varazanashvili, O. 1999. Seismic hazard assessment of Georgia by deterministic and probabilistic methods. Journal of Georgian Geophysical Society (A). vol. 4, pp. 35-45.
Varazanashvili, O., Tsereteli, N., Sumbadze, B., Muchadze, T. 2006. Seismotectonic conditions and Seismic Risk in Gori. Bulletin of the Georgian Academy of Sciences, vol. 174 (3), pp. 423-426.