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History of earthquake studies in Russia

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Abstract
To evaluate the completeness of modern knowledge on historical seismicity it is necessary to know the general geopolitical and socio-cultural background in the country. It determines the possibility to record the evidence of an earthquake and conserve the record in original form for a long time-period. The potential duration of historical earthquake study in Russia is assessed based on these considerations. Certain stages of earthquake study in Russia have been detected. Specific problems of seismicity studies of low active areas are discussed as an example of Russian platform. The value of each (even moderate magnitude) event becomes crucial for seismic hazard assessment in such territories. A correct identification of event nature (tectonic earthquake or exogenous phenomena – landslides, karsts, etc.) is practically impossible without using primary sources with detailed descriptions. Occurrence of modern earthquakes can be used to assess the accuracy of historical seismicity knowledge.

Key words *earthquakes – historical seismicity – evaluation of completeness and accuracy of knowledge on seismicity*

1. Introduction

Understanding of the completeness of modern knowledge on seismic history is essential for correct seismic hazard assessment. Seismic history is carried in earthquake catalogues and events based on macroseismic data present the most long-term part of it: they have a crucial importance, even if the number of events in instrumental catalogues is much more. Traditionally, completeness of a catalogue is evaluated using magnitude-frequency graphs: it is believed that the data for a given time-period is complete in the linear part of graph (for example, Bune and Gorshkov, 1980). Therefore, the completeness of a sample (earthquake catalogue) is evaluated upon statistics calculated on this sample (together with some *a priori* assumptions). We suspect certain drawbacks in such methodology. For example, the assumption of magnitude-frequency relationship linearity might be wrong for given spatial and temporal frames of study (even if it is true for the seismicity in a whole). In this paper, the potential duration of historical earthquake studies in Russia is assessed analysing the geopolitical and socio-cultural conditions in the country.

History of earthquake study is not simply a sequence of publications of earthquake catalogues; first of all, it is a development of ideas, general approaches and techniques. To understand state-of-the art and future perspectives, the history of macroseismic studies in Russia is analysed.

Macroseismic studies are of special importance for seismic hazard assessment of low active territories, because instrumentally recorded events are very few or absent. Regional seismometric networks usually are far from low active areas and when the network registers small or moderate earthquakes, accurate data processing is very difficult. In platforms, especially near large rivers, the problem is complicated by the presence of active exogenous phenomena (landslides, karsts), which can produce false events in earthquake catalogues.

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The goals of the paper are: i) to evaluate the potential historical duration of earthquake studies in Russia independent from catalogue statistics; ii) to present history, state-of-the-art and perspectives of macroseismology; iii) to discuss specific problems of earthquake studies in low active territories.

2. Potential «duration» of historical earthquake studies in Russia

To be able today to study an earthquake which occurred in the past it is necessary for the information on its effects to have been recorded, conserved in the original form for a long time-period and this information has to be accessible now. Existence of the whole informative chain depends on geopolitical and socio-cultural conditions. For example, the presence of written language, *i.e.* the capability of people of writing and so to leave written records, essentially raises the chances of recording the earthquake. A high cultural level of society provokes interest in natural phenomena: in such society there is a good chance that even moderate earthquakes will be reported as something worth mentioning. Frequent invasions of enemies and damage caused by invaders, dramatically decrease the possibilities of records surviving for a long time.

The summary of territorial changes of the Russian state starting from the time of its foun-

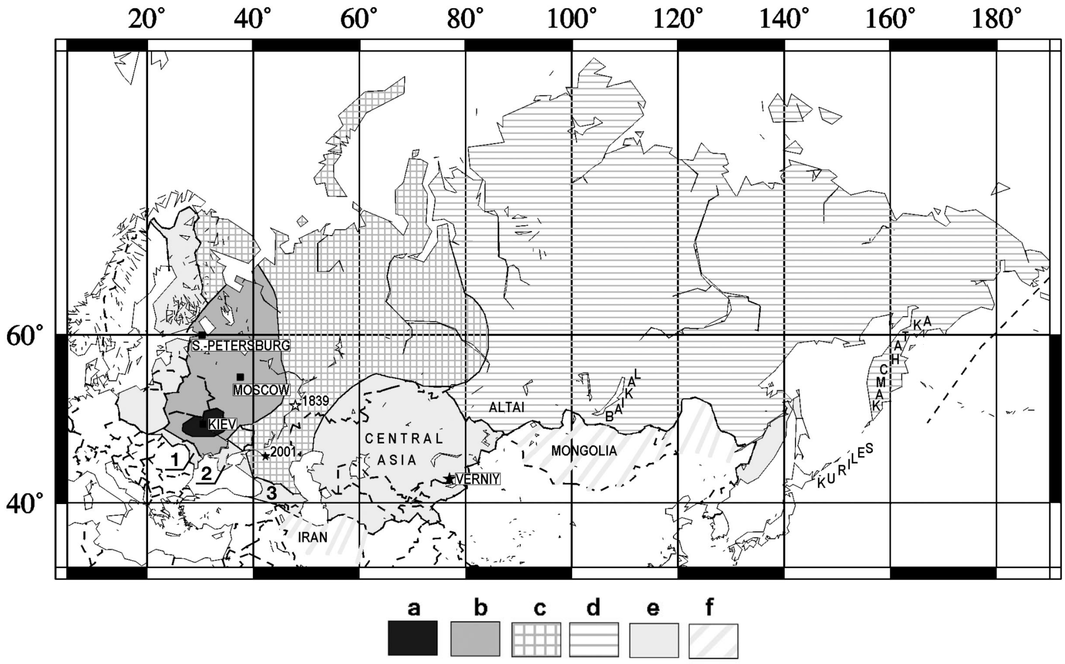

Fig. 1. Territorial expansion of the Russian state: a – the first Russian state formed in the 9th century (Kiev Russia); b – independent Russian princedoms established in the next 300 years (Moscow princedom was founded in 1147); c – Russia after forming the centralised state (beginning of the 17th century); d – territories included in Russia in 17th century (up to 1689); e – Russia before the World War I; f – regions under strong influence of Russia at the beginning 20th century. Dates of two events discussed in this paper are shown: 1839 – a falsequake from Volga River basin; 2001 – a moderate magnitude event on the southern part of Russian platform. Verniy (modern Alma-Ata) is indicated in relation with the earthquake of 1887 presented as example of preinstrumental stage of earthquake studies in Russia. Numbers on map stand for: 1 – Eastern Carpathia; 2 – Crimea; 3 – Eastern Anatolia and Caucasus.

dation up to 20th century is compiled based on information from Schmidt (1998), Volodikhin (1995), Volodikhin (1997) and Zalesskiy *et al.* (2001) (fig. 1). The first Russian state was formed (Kiev Russia, 9th century) on practically aseismic areas of the East-European platform: region of Kiev - Chernigov - Pereslavl. During the following 300 years several independent princedoms appeared on the Russian platform (Smolensk, Novgorod, Vladimir-Suzdal, Ryazan, Murom, Moscow): so the development was toward practically aseismic regions. To the end of this period Russia lost its independence and underwent Mongol-Tatar rule. The next step of its territorial expansion occurred after regaining independence and forming a centralised state (15th-16th centuries). For the first time, Russia occupied some seismoactive lands. As a result of the next expansion seismoactive territories compose its considerable part (Baikal, Kamchatka, Far East), though these areas were very poorly populated. Since that time, Russia permanently expanded its territory and before World War I it became one of the most seismoactive countries in the World. The Russian Empire included such seismoactive regions as Eastern Carpathia, Caucasus, Crimea, Eastern Anatolia, Central Asia, Baikal, Altai, Sayans, Kuril Islands, and Kamchatka; under its influence were Northern Iran and a large part of Mongolia and Northern China. From consideration of spatial changes in Russia more or less regular occurrence of earthquakes on its territory could be expected starting from 1700s. Before that time these territories might also be active, as later on, but they were out of Russia, which gives little chance to have a record of this activity in Russian sources. Spatial changes are not the only important ones. Favourable conditions for recording earthquake macroseismic effects and conserving the record are necessary. Some socio-cultural events in Russia affecting these conditions are listed in table I. The information is extracted from Schmidt (1998), Volodikhin (1995), Volodikhin (1997) and Zalesskiy *et al.* (2001). Compilation of table I stopped at 1862 because of the foundation of the Rumyantsev public library, which was later transformed into the Russian State Library. The library subscribted to all the newspapers and bought a copy of each book published in Russia. Since that time we have a reliable place where written sources are stored.

Table II presents the information directly related to the safety of historical materials. Data on all 14 Federal State Archives of Russia is given: date of archive foundation, time period for which it contains documents and amount of documents is indicated. Information is taken from the website: http://www.rusarchives.ru/federal/list.shtml.

Tables I and II display that starting from 1700s conditions were favourable for regular recording of earthquake reports. At the same time, some events (table I) give evidence that even a century later omissions in catalogues are not excluded because of unrecoverable losses of information, particularly because of fires.

3. Main stages of earthquake studies

History of earthquake study has never been a permanent progressive flow of ideas, methods and achievements. To make the presentation of history of earthquake studies in Russia better structured certain stages are marked out.

3.1. *Preinstrumental / geographical stage (1850-1902)*

In the second half of the 19th century a number of destructive earthquakes occurred in the territory of the Russian Empire and in the vicinity of its borders: Ararat, 1840; Shemakha, 1859; Erzrum, 1859. They attracted professional and public attention, first of all by numerous victims and destruction (Abich, 1862). As an example of earthquake study of this stage we present the publication of Mushketov (1890) on Verniy earthquake, June 9 (May 28 – old style), 1887. The earthquake was so destructive that special plans to move the regional capital city of Verniy (modern Alma-Ata) elsewhere have been prepared. Hardly any modern publication can be compared with the accuracy with which Mushketov collected and presented the materials on the earthquake. Map of Verniy city and a complete list of all buildings (including construction type) with detailed description of damage are presented in the publication.

Today this information could be used for microzoning of Alma-Ata. Descriptions are proved by a number of photos of rather high quality (fig. 2). Data on all localities are summarised in the concluding table, which is reproduced here in table III. This table contains data, which let us to step from seismic hazard to seismic risk assessment. The description of macroseismic effects in full scale (and not only maximal effects extracted from the general context) makes it possible today to apply modern statistical methods of data processing.

With the same accuracy and completeness are documented manifestations of the earthquake in natural environment (fig. 3).

Table I. Social and cultural events in Russia affecting the historical earthquake studies.

Data	Event
10th century	Slavonic written language entered Russia (988-Christening of Russia).
1037	Compilation of first Russian chronicle in Kiev. Total number of known Russian chronicles: 1500; only 35 of them have survived, they are published in the Complete Collection of Russian Chronicles (1841-1982).
1147	Moscow founded; in 1177 fire practically completely destroyed the town. Later on, this happened several times. For example, even 30 years after the fire in 1571, the territory of Moscow was at least two times less and the population was 8 times less than before that. This lasted up to 1820s, when stone/brick buildings started to be built instead of wooden ones.
1408	First All-Russian Chronicle was compiled. It burnt down in fire in 1812 together with the whole collection of manuscripts of Moscow Society of History and Russian Antiquity.
1460 *ca.*	Moscow becomes the capital of Russia. Since that time historical documents and archives have been accumulated there up to the time when new capital was built in 1703.
1 March 1564	First Russian printed book was published.
1621	First hand-written newspaper was published (only a few issues appeared in one copy).
1626	The largest Kremlin archive in Moscow burnt down.
1681	First Russian high educational institution was established.
15 Dec 1702	First issue of a regularly printed newspaper appeared.
16 May 1703	St. Petersburg was founded - future «capital» of Russian Academy of Science, Russian Geographical Society, Permanent Central Seismological Commission.
1714	First public library in St. Petersburg was opened.
1724	First «professional» Russian archive - Archive of Ministry of Foreign Affairs.
27 Dec 1725	Russian Academy of Sciences was founded in St. Petersburg.
1728	First scientific Russian archive - Archive of Academy of Sciences.
1755	University of Moscow was founded; its public library opened in 1756.
1812	Napoleon's occupation of Moscow, which leads to great damage to written sources. From 20.5 thousands of books and manuscripts of the Moscow University library only 51 books and 12 manuscripts survived.
1862	Rumyantsev public library founded in Moscow (today Russian State Library). In 1995 it retained 39 000 000 items.

Table II. Federal archives of Russia (sorted by date of reported materials).

Place	Archive	Foundation year/ Period covered	Amount of documents
Moscow	Russian State Archive of Ancient Acts	1918 11th cent.-1917	3313000
	Russian State Archive of Military History	1925 1520-1918	3428676
	Russian State Archive of Literature and Arts	1941 18th cent.-1994	1101400
	Russian State Archive of Social and Political History	1919 1760-1993	1649647
	State Archive of Russian Federation	1920 1800-2000	5447137
	Russian State Archive of Audio Documents	1932 1898-2001	200000
	Russian State Military Archive	1920 1917-1991	3393110
	Russian State Archive of Economics	1961 1917-1994	4098718
	Russian State Archive of Film and Photo Documents	1918	863569
	Russian State Archive of Modern History	1921 1922-1991	1232000
	Russian State Archive of Science and Technology	1995	?
St. Petersburg	Russian State Archive of Navy	1827 1659-1940	1218103
	Russian State Historical Archive	1922 late 18th cent.-1920	6576620
Vladivostok	Russian State Historical Archive of the Far East	1943 1722-1998	500635

Specialists who studied contemporary earthquakes at such high professional level could not accept that each catastrophic earthquake has to be investigated as some random natural phenomenon. They wanted to find certain regularities in spatial and temporal distribution of earthquakes: for this, it was necessary to build earthquake catalogues, which reflect seismic history for as long a time as possible. In 1893, the first comprehensive catalogue of Russian earthquakes was published (Mushketov and Orlov, 1893); it included events up to 1887. In the Introduction, Mushketov and Orlov explained the reasons why such a catalogue is necessary. These reasons show how little things have been changed since that time. In principle, they might be copied and passed to any applications of seismological project today. Here are the first two sentences of their Introduction:

«Destructive earthquakes recurring from time to time within the Russian boundaries or neighbouring countries often arouse the interest of Russian society and government; each time when such cases happen, expeditions were sent to study

Table III. Summary table of damage and losses report of 1887, Verniy earthquake compiled by Mushketov (1890).

Locality	Population	Number of buildings before the earthquake	Number of destroyed, or heavily damaged buildings	Losses in roubles of	
				Real estate	Moveable property
City of Verniy	21000	1799	1798	1136889	476400
Village B. Almatin-skaya together with M. Almatinskaya	6491	972	347	331930	26225
Lubovniy	1293	232	25	25792	8135
Kazansko-Bogorodskoe	959	120	118	21571	387
Sofiyskaya	3568	576	265	10867	298
Nadezhdinskiy	2239	313	52	800	60
Mikhailovskoe	1352	487	55	331	-
Malovodnoe	242	70	15	331	-
Zaitsevskoe	1393	332	46	637	-
Karasuyskoe	21	16	15	897	-
Kutentaiskoe	102	18	18	375	-
Iliyskiy	275	73	15	1313	-
Sazanovskoe	1111	137	22	3495	-
Uital	178	27	1	290	-
Total	40394	5172	2792	1535518	511505

Fig. 2. Example of documentation of damage in Verniy (photos from Mushketov, 1890). We can clearly see the type of construction and damage.

the destructive consequences of earthquakes, with the idea of establishing permanent seismic observations, even money has been found to alleviate the results of natural calamity. But, alas, regardless of such temporary excitation, earthquake study in Russia did not go forward, and interest toward them gradually subsides, as soon as underground shocks calm down». The goal of the catalogue was formulated by the same authors as follows: «Protection from earthquakes is impossible without knowledge of their geographical distribution». (Note that here and elsewhere citations and descriptions in English are translated from Russian by the author).

It is not by chance that the Imperial Russian Geographical Society became the sponsor and organiser of the seismological studies. So, this period of pre-instrumental stage we can also call the period of geographical seismology.

Mushketov and Orlov (1893) discussed the problem of catalogue completeness. They compiled a table which is reproduced here (table IV). Completeness is evaluated based on analysis of sources of information. Never after that in Russian catalogues of historical seismicity (including recent ones) has such an analysis been presented. Very impressive is also the size of territory for which information on earthquakes was presented. Only 80 years later in the USSR a large team from all seismological institutions all over the country could carry out a project in which spatial frames might be compared with the area covered by the catalogue of Mushketov and Orlov.

The catalogue is descriptive. Sources of each entry are given. This was the first catalogue of Russian Empire earthquakes, so the authors were not able to copy and post entries from other earlier published catalogues (except for earthquakes in boundary regions). As a result, the work is based mainly on primary sources (archive materials, newspapers, etc.).

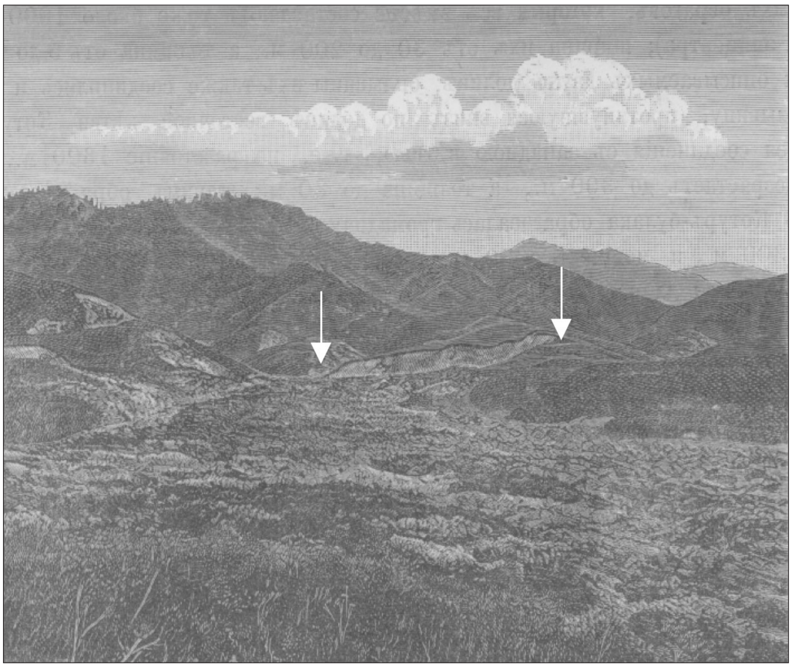

Fig. 3. Example of documenting macroseismic effects on natural environment (photo from Mushketov, 1890). Arrows point the edges of the landslide.

Table IV. Evaluation of data completeness of the earthquake catalogue from Mushketov and Orlov (1893).

Region / Country	Year of first entry	Year from which regular information is available	Total event number	Event number in regular part
China	596 B.C.	1485	710	558
Eastern Siberia	1700	1700	549	549
Western Siberia	1734	1761	36	35
Caucasus	715	1801	590	555
Central Asia together with Bukhara and Khiva	1716	1820	202	200
North of European Russia	1670	1742	27	26
Urals	1788	1788	20	20
European Russia	1000	1807	148	111
Turkish and Persian territories adjacent to Caucasus	1843	1843	121	121

But this was not a special goal of compilers: when it was possible to use information from published catalogues (Abich, 1882; Perrey, 1843; Mallet and Mallet, 1858) they did.

The milestone achievements of this stage are comprehensive studies of contemporary strong earthquakes and compilation of the first descriptive earthquake catalogue of the Russian Empire. It is natural to put the end of the preinstrumental stage in 1902, when in St. Petersburg the Permanent Central Seismological Commission (PCSC) had been established the main goal of which was organisation of instrumental observations.

3.2. *Early instrumental stage (1902-1914)*

Before the foundation of PCSC, the Temporary Seismological Commission acted for one year using as a model the corresponding British service. Since 1902 annual bulletins have been published. The first one included data from five seismic stations (Irkutsk, Nikolaev, Tashkent, Tiflis, Yurev) and from two astronomic observatories where seismological observations were carried out (Kharkov and Pavlovsk) (Levitski, 1902). The instrumental observations were started by specialists who had great experience in macroseismic investigations. Probably because of that, macroseismic and instrumental data were put in bulletins together. This reflects the assumption of the fact, that the object of study – earthquake – is unique, so for its comprehensive understanding it is necessary to describe different manifestations of the events, including macroseismic effects. Alas, such an «integrated» understanding of the problem was soon lost: seismologists had an impression (partly illusionary) that the instrumental data are much more accurate and absolutely sufficient for comprehensive earthquake investigation. When the changes in PCSC administration in 1912 macroseismic information had a supplementary role.

The most important achievement at this stage of earthquake study was in putting the instrumental and macroseismic data collection, systematisation, conservation and distribution on a regular basis. As an end of the stage, the year 1914 could be pointed when the sequence of political and social shocks followed: World War I, Revolutions, Civil War, which practically blocked earthquake studies in Russia up to mid 1920s. We can call the period 1914-1925 as an empty one for Russian seismology.

3.3. *Regional stage (1925-1961)*

Because of hard socio-economic situation (also, probably, because of the absence of a leader) it was impossible to organise large All-Union projects comparable spatially with the Mushketov and Orlov catalogue. But interest in seismic history in mid 1920s was very high. It was warmed by occurrence of such destructive earthquakes as Leninakan (1926) and Crimea (1927). The investigations of that time were on a regional scale. A number of catalogues on the seismic history of Armenia (Stepanyan, 1942), Azerbaijan (Malinovskiy, 1935), Lesser Caucasus (Bius, 1948), Turkmenia (Gorshkov, 1947) and many others had been compiled. As an example of regional catalogue, publication of Bius (1948) is presented.

Bius (1948) is a descriptive catalogue, though it already contains the very first step toward parameterisation. Earthquake parameters are not determined, but for many cases intensities in localities are evaluated in degrees of macroseismic scale. Bius used the MCS intensity scale, a description of which he included in the Introduction. This was the most widely used scale in the 1940s. Macroseismic scales are an important part of quantitative description in earthquake studies; their development is an inherent and essential part of the history of earthquake studies. But this is such a huge and specific problem that requires a special analysis in separate paper: here we will only mention which scales were used in particular studies.

At this stage, investigators met several problems, hard for historical seismology also today. Bius put in the introduction to the catalogue a table of localities, which had been renamed for political reasons (first of all – because of the revolution of 1917). This is another example of how tightly the geopolitical and socio-cultural background in the country is linked to studies of past earthquakes. To give an impression of the problem a table from Bius (1948) is reproduced here (table V). It has to be stressed that these are renamings of localities only in Lesser Caucasus before 1948 (and, as pointed by Bius, the list is not complete even for them). Since that times at least three waves of renamings have passed: today only very few localities carry the same name as is written in column «Modern name» of table V. A lot of names in original sources cannot be identified today.

Sources are given for each entry in the catalogue. Using primary sources was not considered something of special importance. Because the time before 1887 is covered by the Mushketov and Orlov catalogue, it comprises the basic (and often the single) source of information for earthquakes of that time. But for a later time Bius had to work mainly with primary sources (there were no published catalogues, except those of Stepanyan (1942) and Malinovskiy (1935) from where data on Armenian and Azerbaijan earthquakes could be copied).

The main achievement of this stage was compilation of several regional catalogues. They guarantee (as much, as they could) continuity of macroseismic information accumulation, which was started by Mushketov and Orlov in the 1850s. The basis for the next stage of earthquake study was formed. The problem appeared in this stage is related to the scale level of works. In each region, data was collected, systemised and analysed according to different procedures. It leads to accumulation of inhomogeneous materials (though, rather homogeneous within the same region). The end of this stage is marked by publication by Shebalin (1961) of the paper titled «Intensity, magnitude and source depth of earthquakes» in the first issue of «Earthquakes in the USSR» which later on became annual. From this publication started the era of parametric macroseismic catalogues in Russia.

Table V. List of renamed localities in the region of Lesser Caucasus from Bius (1948).

Modern name	Old name/names	Modern name	Old name/names
Agara	Tanatubani	Mikha Tsakhakaya	Akhalsenaki
Alabashly	Karaery	Mikuzani	Dzegani
Aragats	Alagez	Nazarashen	Gaji Nazar Kuli
Arbat	Perekeshkul	Oktomber	Sardarabad
Bogdanovka	Khojabeki	Psirtskha	Noviy Afon
Gavazy Upper	Bezhany	Rozenfeld	Marienfeld
Gashperdy	Akhakhibula	Sabirabad	Petropavlovka
Gegechkori	Martvili; Naogalevi	Sevan	Elenovka
Goris	Gerusy	Stalinir	Tskhinvali
Dmitrovka	Salim	Stepanavan	Jelalogly
Erevan	Erivan'	Stepanakert	Khankendy
Ijevan	Karavansaray	Tabatskuri	Kizilkilisa
Kalinino	Vorontsovka	Tbilisi	Tiflis
Karadonly	Bagramtapa	Tejisi	Minasaskend
Karyagino	Karabukag; Sardar	Khanlar	Elenendorf; Elenino
Kirovabad	Gyanja; Elisavetpol'	Kharagouli	Belogory
Kirovakan	Big Karakilis	Khashuri	Mikhailovo
Krasnye Kolodtsy	Tsarskie Kolodtsy	Khilly	Bozh'i Promysla
Krasnoselsk	Krasnoe Selo; Mikhalovka	Tsalka	Barmaksiz
Kulevi	Redut Kale	Tsebelda	Zalharovka
Maylya	Kumani (island)	Tsulukidzhe	Khoni
Leninakan	Aleksanropol	Chaikend	Mikhailovka
Likhi	Varvatino	Shamkhor	Annenfeld; Annino
Bolnisi	Luksemburg; Ekaterinenfeld	Shorzha	Nadezhdino
Martuni	Khonashen	Shaumyany	Shulavery
Makharadze	Ozurgeti	Shroma	Mikel Gabriel
Mayakovskiy	Bagdadi		

3.4. *Parametric stage (1962-1982)*

The paper by Shebalin (1961) not only suggested a set of formulae (macroseismic field equations) which can be used to determine earthquake parameters based on initial macroseismic information but also formulated ideology of parametric catalogue compilation. The basic principle of the ideology was the following: any communication on an earthquake, regardless to its completeness and reliability, can and must be parameterised into the catalogue entry. The only problem is in a reasonable evaluation of accuracy of parameterisation. The most complete realisation of this principle is found in one of the largest seismological projects in the USSR – (Kondorskaya and Shebalin, 1977). An American version of the catalogue was published in 1982 (Kondorskaya and Shebalin, 1982) which included corrections and addenda to the Russian edition made by catalogue editors. This publication is considered a most prominent achievement of this stage and, at the same time, it marks the end of the stage.

From the previous stage the catalogue inherited the regional principle of organisation: in fact, under one cover page are published 14 catalogues, each of them has its own team of compilers and editors and separate list of sources. Nevertheless, chief editors were able to establish a high level of standardisation in data processing and presentation of results. The catalogue has a general introduction, parametric part, textual descriptions of the most important events, list of sources. As a supporting dataset compilers prepared an «Atlas of isoseismals» (Shebalin, 1974) also compiled according to the regional principle, and never published because of financial and organizational problems. All the intensities in Kondorskaya and Shebalin (1982) and in Shebalin (1974) are given in the MSK64 scale.

Catalogue format and structure are shown for the case of the 31 December 1899 Akhalkalak earthquake. It is the largest seismic event of Javakhet Highland. Information on the Akhalkalak earthquake is presented in the most complete form: its parametric entry and textual description are shown in fig. 4a,b, an isoseismal map is plotted in the above mentioned, unpublished Atlas (fig. 5). Such catalogue format and structure present complete

(a)

Date	Origin Time		Epicenter			Depth of focus		Magnitude		Intensity at epicenter		Zone	Примечания (Remarks)	Источники (Ref.)	Remarks in English
	h m s	Class	N Lat (°)	E Long (°)	Class	h (km)	Class	M	Class	I_0	Class				
I899 окт 5	I3 30 ±IOм	6	(40,0 ±	47,0) I,0	6	(I5) 5–50	6	(4,0) ±0,7	4 0	5 ±I	I I			Бюс,I56	
дек I9	I8 40 ±IOм	6	42,3 ±	46,6 0,5	5	(25) I2–50	5	4,9 ±0,7	4 0	(5–6) ±I	I 4		4–5–(45)(4)	Ан,Н,I6, 24,58,59 I00	
3I	10 50 ±IOм	6	4I,6 ±	43,5 0,I	3	8 6–I0	3	5,4 ±0,3	2 0	8–9 ±0,5	6 67		Ахалкалакское; 8 –6(3) 7 –22(8); 6 –48(8); 5 –96(I8); 4 –I70(24); 3 –(330)(6); по/А/ I_0 =8; по /АБВ/ М = 5 I/4–6 I/4. Большое число слабых афтершоков, в т.ч. з I2ч 30м; I3ч 30м; I8ч I.I I9ч; 3.Ш I7ч с М ≈ 2,5–3,5	А,АБВ,Бюс МО,5,42, 53,54,76 II0,I2I, I22,I69, I73, 224,228, 245, VК	Akhalkalak; Many weak aftershocks, including

(b)

Akhalkalak

1899, 31 December, 10:50

41.6° N, 43.5° E; h = 8 km; M = 5.4; I_0 = 8–9

[A, ABV, Bius, MO, VK, IIb-5, 42, 53, 54, 76, 110, 121, 122, 169, 173, 224, 228, 245]

The following description of this earthquake at the epicenter is given in **[Bius]**:

"Azavreti. The blow struck from the east, then from the opposite direction. The central part of the settlement (on the embankment) suffered slightly, the outskirts (on the weathered and cracked cliff) suffered heavily. The water became turbid in the springs, its flow increased, and only after 15 days did it return to normal.

"Mereniya. There were two shocks--one from the southwest, the other from the opposite direction, and a number of vertical shocks. Everything collapsed during the second shock.

"Malyy Samsar. The blow was from the east to northeast and caused considerable destruction; water in wells became muddy; the stream almost dried up the first day, but the next day its water was turbid."

Based on these reports, the intensity at the epicenter could somewhat exceed 8.

Fig. 4a,b. Information on 31 December 1899, Akhalkalak earthquake in Kondorskaya and Shebalin (1982): a) parametric entry with remarks and b) description of macroseismic effects, referring to Bius (1948) as its source.

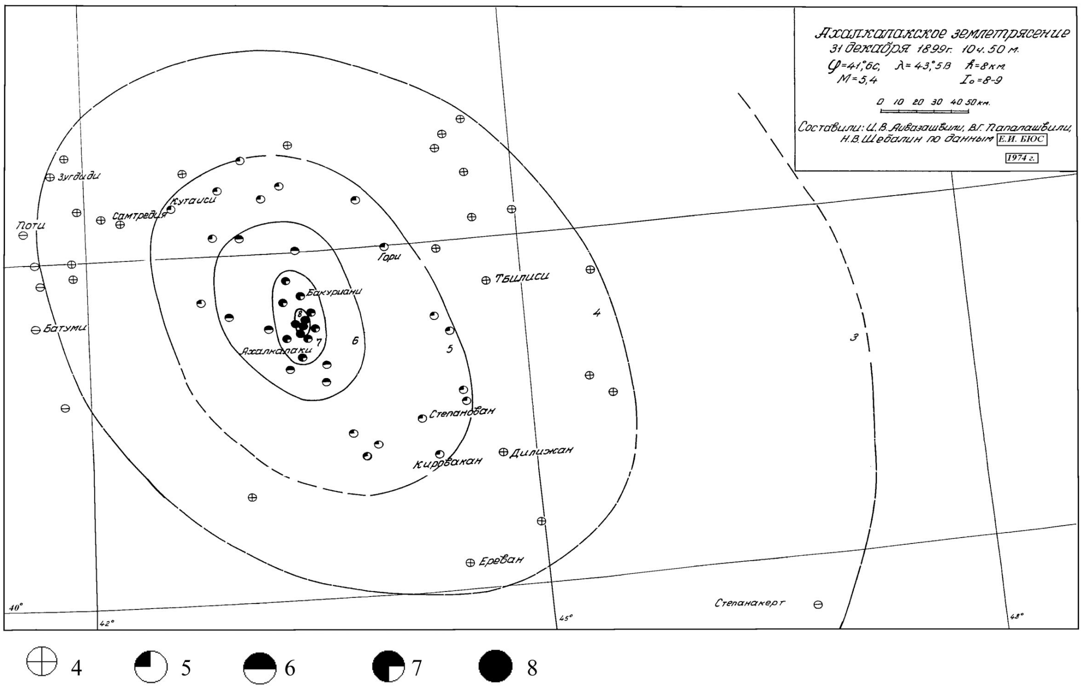

Fig. 5. Isoseismal map of 31 December 1899, Akhalkalak earthquake from unpublished Atlas prepared in 1974 as supporting dataset for Kondorskaya and Shebalin (1982). According to the legend it is based on data from Bius (1948).

information on earthquake and support parameterisation at least for the major events in the given seismotectonic region. The most remarkable achievement of the «total parameterisation principle» was in transformation of macroseismology from a descriptive supplementary seismological discipline into one of the basic methods for quantitative seismic hazard assessment.

3.5. *Modern stage (1982-2002)*

During the modern stage, earthquake studies in the USSR developed in two main directions: extensive (compilation of catalogues for large areas without giving much importance to the study of single entries) and intensive (detailed comprehensive analysis of the major earthquakes). Extensive studies related to large international and Russian projects (Global Seismic Hazard Assessment Program – Shebalin and Tatevossian, 1997; Seismic Zoning of Northern Eurasia – Ulomov, 1993). Any essentially new ideas and methods of catalogue compilation were not developed within the extensive approach. Some corrections of parameters were made; false events excluded and omitted ones added in earlier published catalogues. Usually this was done without referring to newly found original sources of information, so, often it is impossible to guess the reasons for corrections (or, rather, changes). Intensive studies were based on understanding of the crucial importance of quality and reliability of information sources on historical earthquakes. Most remarkably these ideas were formulated within the frames of the international project Basic European Earthquake Catalogue and Database (Stucchi *et al.*, 2001). According to them the procedure of earthquake parameterisation has to start from analysis of sources of information done following rigorous historical methods. Procedure of parameterisation itself must be absolutely clear and transparent. Cited sources in the reference list have to be the ones really used for parameter determination and not just copied and passed from other publications. As an example of study in Russia done according to these standards we will present the paper on the Akhalkalak earthquake (Tatevossian *et al.*, 1997). This demonstrates the problems which can arise from a too active implementation of the total parameterisation principle.

Figure 6 from Tatevossian *et al.* (1997) illustrates the chronology of sources given in Kondorskaya and Shebalin (1982) for the Akhalkalak earthquake. The list of sources includes publications based on field expeditions organised immediately after the earthquake in its epicentral area and several later compilations, many of which do not contain references at all. The list even points to sources published before (!) the occurrence of the Akhalkalak earthquake (obvious misprints). Isoseismal map plotted based on data from primary sources is given in fig. 7 (Tat-

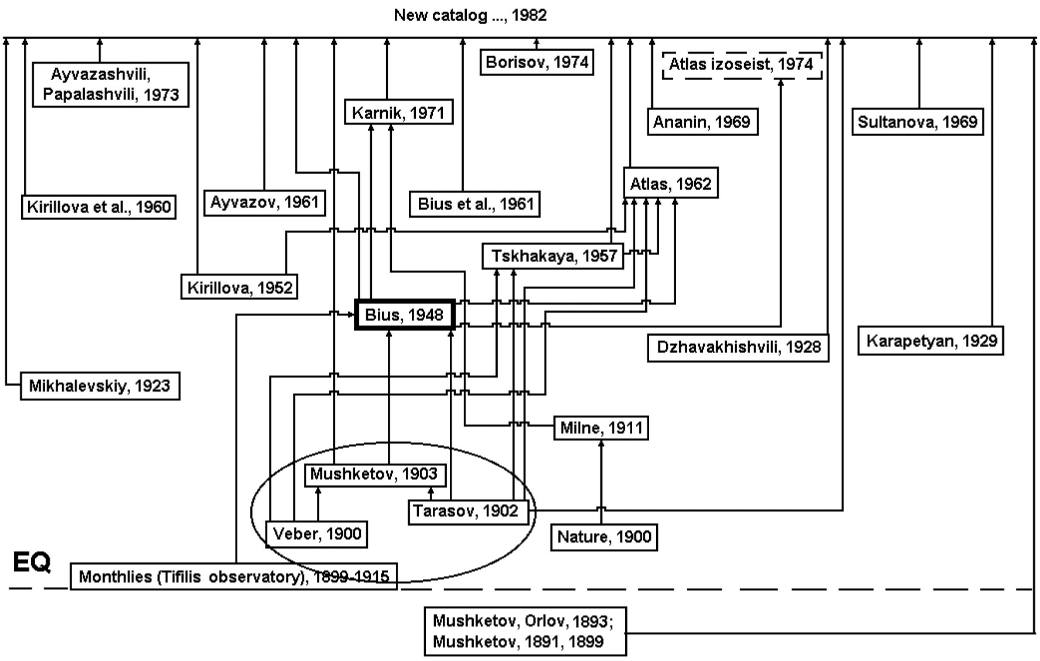

Fig. 6. Chronological scheme (reference-tree) of sources from Kondorskaya and Shebalin (1982) on 31 December 1899, Akhalkalak earthquake compiled in Tatevossian *et al.* (1997). The catalogue of Bius (1948), which was the basic source for isoseismal map compilation, is shown in a bold rectangle; in a dashed rectangle is Shebalin (1974), which is a ghost root for the catalogue entry; EQ indicates the earthquake origin time; in oval are enclosed sources, which represent primary materials.

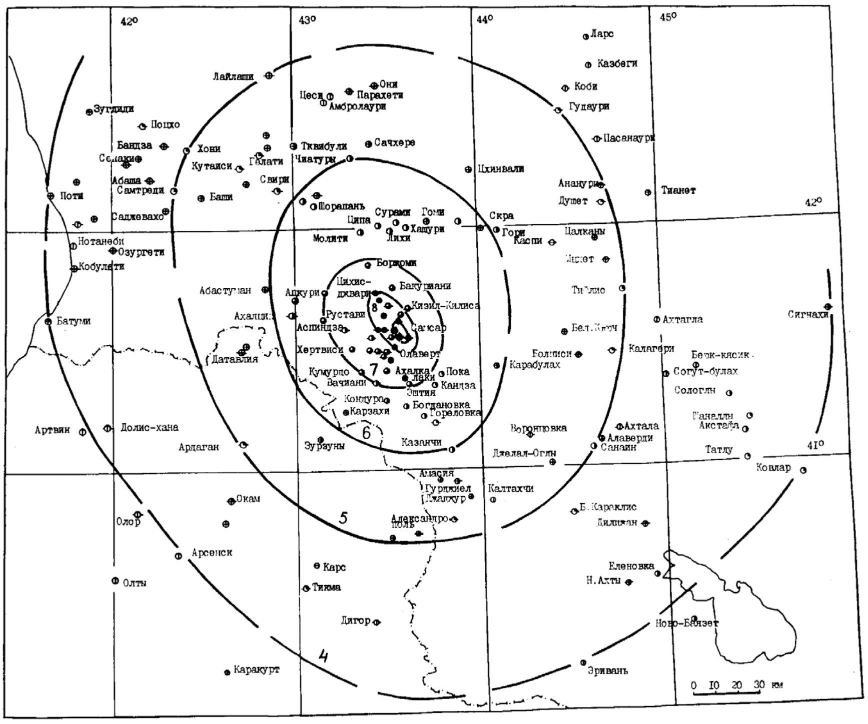

Fig. 7. Isoseismal map of 31 December 1899, Akhalkalak earthquake compiled by N.V. Shebalin and N.G. Mokrushina based on materials from primary sources - see the scheme in fig. 5 (from Tatevossian *et al.*, 1997).

evossian *et al.*, 1997). Comparison with the map in fig. 5 demonstrates that only a small portion of data accessible for this earthquake was used in Kondorskaya and Shebalin (1982), which decreases the accuracy and reliability of parameter assessment.

4. Specific problems of earthquake studies in the Russian platform

In case of low seismic activity, the role of each event in the catalogue becomes crucial for seismic hazard evaluation. This is also true for the Russian platform. The question arises of how accurate and complete is our knowledge on seismicity of this large area where the majority of the Russian population live today.

The Salsk earthquake occurred on 22 May 2001, in the southern part of the Russian platform (M_S = 4.6): it was felt over a relatively large area. The earthquake had the maximum observed magnitude in the region throughout the whole period of historical and instrumental recordings. The seismicity of the epicentral zone before 22 May 2001 was represented only by two shocks with magnitudes 2.7 and 3.2 in 1984 and 1996 correspondingly. A macroseismic survey of the epicentral area of this earthquake was done and its results are published in Tatevossian *et al.* (2002). Instrumental and macroseismic epicentres are in good agreement; the location error is less than 3-5 km. The position of the Salsk earthquake is shown in corresponding seismic (fig. 8) and geotectonic (fig. 9) settings. Usually, earthquake effects in large cities and administrative

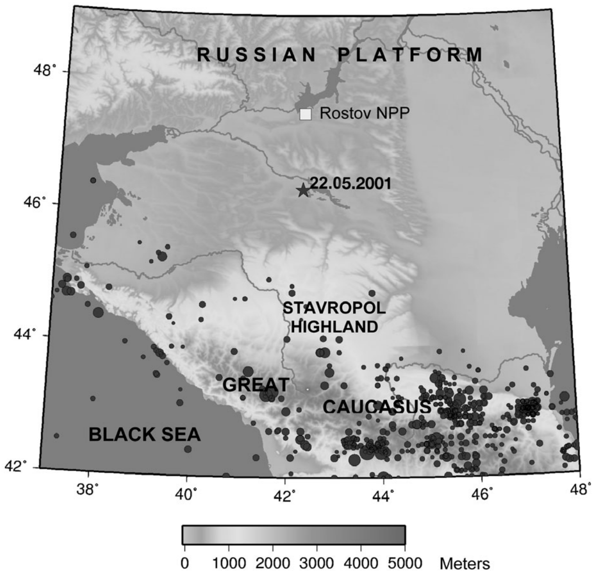

Fig. 8. Seismic setting of the 22 May 2001 Salsk earthquake from Tatevossian *et al.* (2002). Earthquake epicentres are plotted according to the Earthquake catalogue of Northern Eurasia (Ulomov, 1993) (circle size is proportional to earthquake magnitude).

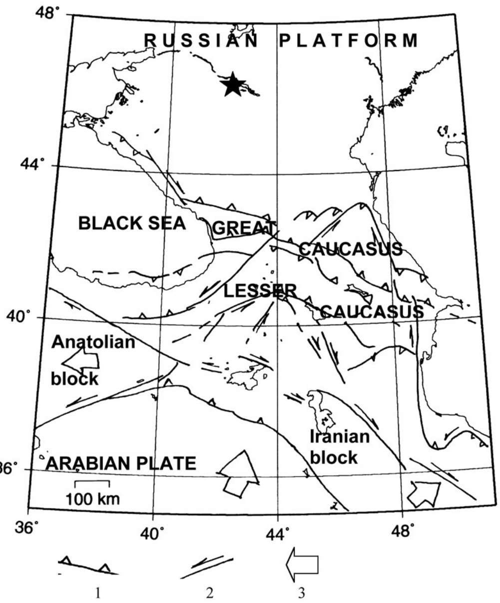

Fig. 9. Tectonic setting of the 22 May 2001 Salsk earthquake from Tatevossian *et al.* (2002). Tectonic scheme from Rebai *et al.* (1993) with simplifications: 1 – reverse faults (triangles point to upthrown wing); 2 – strike-slip faults (arrows show direction of motion); 3 – plate motion direction.

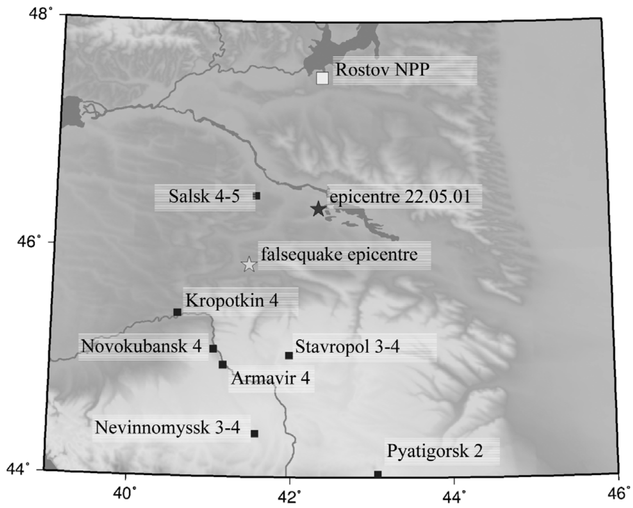

Fig. 10. «Administrative» data filtering. Hypothetical event, which can appear in the regional catalogue after 100 years on the 22 May 2001 Salsk earthquake, if the only information which would survive on that event will be the one collected by Geophysical Service of RAS (Tatevossian *et al.*, 2002). Intensities at the sites are given according to the Geophysical Service, RAS.

centres attract attention in historical sources, though they might be well away from the epicentre and zone of maximum effects. This distorts the figure of spatial distribution of macroseismic effects. Such a distortion because of switching on the «administrative» filter can be found even when we are dealing with modern earthquakes studied by an official seismological body. Immediately after the Salsk earthquake Geophysical Service of RAS rapidly collected information on its felt effects (Geophysical Service of RAS, 2001). The data was acquired from administrative centres. The localities and intensities assessed by the Geophysical Service are shown in fig. 10.

Let us make a mental experiment and assume that the only information which will survive a hundred years after the Salsk earthquake, will be these rapidly collected communications. If the future seismologist processes these data according to the modern standard procedures he will locate the epicentre location 100 km away from its actual site, deeper source (15, instead of 9 km) and magnitude 5.6, which is 1 unit more than it really was! And he will be satisfied with the results obtained because the epicentre will move toward the Stavropol Highland where earthquakes of similar moderate magnitudes are known (fig. 8). The location of a false event is also in better agreement with the general geotectonic scheme (fig. 9). And he will be very happy, because only in a few cases do we have today such a lot of information for historical earthquakes of this area: intensities are reported in seven localities (fig. 10).

Those are the measure of distortions associated with «administrative» filter. Another mental experiment can illustrate the effect of a poorly populated area. Imagine that the Salsk earthquake occurred 200 years before its actual time, in 1801: which localities in this region could have felt this earthquake? Only one – Stavropol, which was founded in 1777! So, this event either will be omitted in the catalogues, or located as a moderate event somewhere near Stavropol.

Another problem complicating historical earthquake studies in Russia can be illustrated in relation to the Salsk earthquake – a problem of toponymy. During field observations of the Salsk earthquake the macroseismic group visit-

Table VI. Different versions of interpretation of the 1839 Fedorovka, event based on different datasets: using complete description from primary source in Tatevossian and Mokrushina (2003) and arbitrary cut out text from secondary compilation in Ogajanov *et al.* (2001). Identical parts of description are marked in bold.

Publication	Ogajanov *et al.* (2001)	Tatevossian and Mokrushina (2003)
Supporting text	**«...rumble,** wave-like oscillations, falling of chimneys, parts of constructions, cracks in the ground, vertical and horizontal dislocations of layers, drying of springs. **70 houses were damaged**. **All the valley, on which major part of the village is located was separated from the hill foot and subsided remarkably and moved to Volga ... Noticeable** oscillations **and moving of the ground lasted 3 days, then everything calmed down and up to 6 July (old style) only subsidence and damages occurred** frequently»	«On large landslide of the right bank of the Volga River in Khvalynsk district with village Fedorovka partly situated on it. State peasants have been waken on night from 16 to 17 July 1839 by sudden **rumble** and movements of the ground after that follow loud crackles of their houses. Without understanding the reasons for that they run out in horror and saw that **all the valley, on which major part of the village is located was separated from the hill foot and subsided remarkably and moved to Volga!** Confusion of the people reached highest level, when all the moving mass started to wave and in some places lifted and in others pulled down houses - in a short while throughout all the subsided area were formed remarkable ground bulging and holes, vast and regular form cracks have build raw of terraces seemed artificially made where were marshes and small lakes, hills grew, in uplifted parts formed holes which as most of the cracks filled with water. The surface appears as an unstable raft. **Noticeable** waving **and moving of the ground lasted 3 days, then everything calmed down and up to July 6 (old style) only subsidence and damage occurred** from time to time. During all the process **70 houses were damaged:** some destroyed completely, many houses were cut into several pieces; barns separated and fell, sheds moved, all cellars were destroyed; destructive forces were most severe in threshing-floors and orchards which are near the hill. This part is considerably higher than the village and during subsidence everything situated on it was completely destroyed. Luckily nobody from the village was a victim. Frightened by the first damage they lived all this time outdoors and only now started to repair houses and come back to live in them. Subsidence of the valley is 11/2 versts long and 250 sazhens(*); how far it entered into the Volga has still not been investigated. Taking into account how far from the bank Volga became shallower in places being deep before, it has to be at least as far as some tens of sazhens. Fedorovka village is situated near the big road from Simbirsk to Saratov 15 versta before Khvalynsk. Above this village are elevated rather high hills, on top of which are constructed from limestone and foot from different types of clays and pieces of silicate and limestone rocks. The valley on which village Fedorovka is situated borders with the hills from the East and permanently washed by Volga River waters. From many speculations concerning this event, the following has to be mentioned: opposite the place of subsidence Volga River is hardly squeezed by its banks and it seems it cannot find a space for its waters and washed out the right bank, over which Fedorovka village is situated; and because this bank is mostly built from alluvial deposits, waters infiltrate between permeable and non-permeable layers of ground make empty spaces which were filled with the described subsidence.»
Source	Card catalogue (1991)	Addenda to «Saratov Regional Gazette», 15 July 1839
Interpretation	$I = 7$-8, $M = 5.3$, $H = 10$ km	Falsequake: landslide

(*) Russian old measure of length, equal to 2.13 m.

ed four localities named Veseliy. Results of query in World map database (Encarta World Atlas 1998) reveal 184 localities named Veseliy, 26 of which are in the Krasnodar region. If we add to this list also localities with slightly altered names (Veselaya, Veseloe) then we will get 280 items. Certainly this does not make earthquake studies an easy task in Russia.

The problem of earthquake identification is also very hard in platform regions, especially near large rivers. Usually, these are regions of active landslides and other exogenous phenomena, which can produce false earthquakes in catalogues. This complex problem becomes even more complicated when data sources are used improperly. Let us consider the event on 29 June (17 June – old style) 1839 near the village Fedorovka (middle flow of the Volga River). Two solutions on this event together with supporting texts and corresponding sources are given in table VI: the first interprets the data as a tectonic earthquake with magnitude 5.3 (Ogajanov *et al.*, 2001), the second, as a landslide (Tatevossian and Mokrushina, 2003). The same words in both descriptions are marked in bold. The present paper is not intended to discuss all the details of the 1839 event, just note how much more complete and detailed is the description in primary source cited in Tatevossian and Mokrushina (2003) without any omissions.

The description clearly tells that we are dealing with a landslide. Meanwhile arbitrarily arranged cut out pieces of text enable us to suggest that the analysing event might be an earthquake. Note also the year of publication (1991) used as an information source of the earthquake in 1839 in Ogajanov *et al.* (2001). This shows how dramatically different conclusions can be drawn concerning the same event when secondary sources and arbitrary filtered descriptions are used.

5. Conclusions

Russia became a seismoactive country starting from 1700s. More or less from the same time socio-cultural conditions developed favourable as a whole for recording earthquake effects and conservation of the records.

Earthquake studies in Russia developed from compilation of descriptive catalogues toward parametric ones. The remarkable achievement of the principle of «total parameterisation» was in transforming macroseismology from a descriptive supplementary seismological discipline into the leading quantitative method of seismic hazard assessment. But uncontrolled implementation of this principle together with insufficient attention paid to the analysis of information sources decreases the reliability of final evaluations. The following corrections and addenda to earlier published catalogues do not change the situation essentially. New perspectives in historical earthquake studies come from more accurate use of primary sources.

Distortions, which come from a different kind of initial data filtering («administrative», «arbitrary cut out») can play a dramatic role in seismic hazard assessment of the Russian platform. This problem has a little chance of being solved without using complete descriptions from primary sources in earthquake studies.

Since the 1960s historical earthquake catalogue compilation was a part of seismic hazard assessment projects. This organisational background is very unfavourable for earthquake studies: permanent work on collecting and processing of macroseismic data is replaced by sporadic activities. At the moment there are no current special projects in Russia for historical earthquake studies. Some investigators are receiving contracts with organisations interested in hazard assessment, such as the Ministry of Atomic Energy. The main interest is related to low active territories. The case of 1839 event illustrates one of the reasons for that. In no seismoactive region could such large uncertainty in data interpretation be met. According to one interpretation, the maximum observed magnitude is 5.3, according to another interpretation, there was no earthquake at all. Taking into account the short potential duration of earthquake studies in Russia together with possible long recurrence times of earthquakes on platforms, we can easily understand the reasons for speculations concerning the historical seismicity of the Russian platform. It has to be stressed that the overwhelming majority of the Russian population live there. From a certain point of view, the Salsk earthquake ($M_s = 4.6$)

having the maximum recorded magnitude in the southern parts of the Russian platform, is more informative for hazard assessment, than, say, magnitude 7.5 in the region of the Kuril Islands, where the largest instrumentally recorded event had $M_s = 8.4$ (Shikotan 1969 earthquake).

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