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# GeoInt: the first macroseismic intensity database for the Republic of Georgia

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**Abstract** Our work is intended to present the new macroseismic intensity database for the Republic of Georgia—hereby named GeoInt—which includes earthquakes from the historical (from 1250 B.C. onwards) to the instrumental era. Such database is composed of 111 selected earthquakes and related 3944 intensity data points (IDPs) for 1509 different localities, reported in the Medvedev-Sponheuer-Karnik scale (MSK). Regarding the earthquakes, the $M_S$ is in the 3.3–7 range and the depth is in the 2–36 km range. The entire set of IDPs is characterized by intensities ranging from 2–3 to 9–10 and covers an area spanning from 39.508° N to 45.043° N in a N-S direction and from 37.324° E to 48.500° E in an E-W direction, with some of the IDPs located outside the Georgian border, in the (i) Republic of Armenia, (ii) Russian Federation, (iii) Republic of Turkey, and (iv) Republic of Azerbaijan. We have revised each single IDP and have reevaluated and homogenized intensity values to the MSK scale. In particular, regarding the whole set of 3944 IDPs, 348 belong to the Historical era (pre-1900) and 3596 belong to the instrumental era (post-1900). With particular regard to the 3596 IDPs, 105 are brand new (3%), whereas the intensity values for 804 IDPs have been reevaluated (22%); for 2687 IDPs (75%), intensities have been confirmed from previous interpretations. We introduce this database as a key input for further improvements in seismic hazard modeling and seismic risk calculation for this region, based on macroseismic intensity; we report all the 111 earthquakes with available macroseismic information. The GeoInt database is also accessible online at *http://www.enguriproject.unimib.it* and will be kept updated in the future.

**Keywords** Seismic hazard · Macroseismic intensity · Database · Historical earthquake · Instrumental earthquake

**Electronic supplementary material** The online version of this article (https://doi.org/10.1007/s10950-017-9726-5) contains supplementary material, which is available to authorized users.

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## 1 Introduction

In present-day practice, seismic hazard studies are conducted in terms of peak ground acceleration (PGA), spectral acceleration (SA), peak ground velocity (PGV), and other recorded parameters (e.g., Stromeyer and Grünthal 2009; Norouzi et al. 2015; Shoushtari et al. 2016). Nevertheless, seismic hazard

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assessment is also required to take into account macroseismic intensity (e.g., Grünthal 1998; Garcia-Mayordomo et al. 2004; Grünthal et al. 2006; Tyagunov et al. 2006; Capera et al. 2010; Cua et al. 2010; Zare 2017). Macroseismic intensity databases are used in seismic hazard assessment because they represent a fundamental input for calibrating intensity prediction equations, spanning over a longer time window (e.g., Stromeyer and Grünthal 2009; Bindi et al. 2011). Particularly, such equations are used worldwide and are based on post-1900 catalogs, especially where parameters based on recorded data are not available (Cua et al. 2010). Furthermore, macroseismic intensity can provide information about damage caused by historical (and recent) events, which is useful for reconstructing shaking distributions; this, in turn, can enable performing analyses of ground motion levels over a longer time window than it would be possible by considering only events that occurred during the instrumental era (e.g., Capera et al. 2010; Cua et al. 2010; Asadi and Zare 2014). In addition, such data are abundant, whereas strong motion recordings are sparse for such events (Cua et al. 2010). Finally, several authors used macroseismic intensity data to estimate the location and magnitude of earthquakes that occurred recently as well as prior to the instrumental era. This approach has been successfully applied worldwide, for instance in the United States (e.g., Bakun and Wentworth 1997; Bakun et al. 2003; Bakun and Hopper 2004a 2004b; Bakun 2006a 2006b; Doser 2009), in Central America (Hough 2013), in Japan (Bakun 2005), in Europe (Levret et al. 1994; Hinzen and Oemisch 2001; Bakun and Scotti 2006), and in Central Asia (Bindi et al. 2014). Moreover, a huge amount of macroseismic intensity data are available online for events that happened in South America and North America (Askew and Algermissen 1985a b; Tavera et al. 2002; Tavera et al. 2007; Onemi 2010).

The foothills of the Caucasus are regarded as one of the most tectonically active areas of the world (Tan and Taymaz, 2006): In fact, the Republic of Georgia is cut by several active faults, which strike mostly parallel to the mountain range and which can be as long as several tens of kilometers (Fig. 1) (Tsereteli et al. 2016a). The observed seismicity in the Republic of Georgia is characterized by 1783 independent earthquakes with $M_S$ comprised between 2.8 and 7, which took place between 1250 B.C. and 2016 A.D. along the main fault systems of the Greater and Lesser Caucasus intermountain depressions, as well as along active fault-propagation folds (Fig. 1) (Tsereteli et al. 2016a b; Tibaldi et al. 2017a b). In the present work, we consider 111 of those earthquakes, shown in Fig. 1 as squares, which represent a subset of the seismic catalog of the Republic of Georgia (Tsereteli et al. 2016a, b), in order to compile the first new macroseismic intensity database (here named *GeoInt*). The most famous earthquake included in our database is the $M_S$ 6.9 Racha earthquake that struck on April 29, 1991, causing about 270 fatalities and 100,000 evacuees. Direct loss in terms of damage was estimated in the order of 10 billion Rubles (approximately 5.5 billion USD by commercial course and 16 billion USD by official course for that period) (Varazanashvili et al. 2012). Furthermore, about 20,000 earthquake-induced landslides hit the affected region (Tatashidze et al. 2000; Varazanashvili et al. 2012). Since instrumental data are not sufficient to provide PGA or PGV models for the Republic of Georgia, the macroseismic intensity database is a key input for any further calibration of intensity prediction equations (IPEs) and/or the elaboration of a new probabilistic seismic hazard model. The Republic of Georgia has a well-documented history and a wide array of available archeological, historical, and geological data. The analysis of this descriptive information regarding the impacts of past earthquakes since 1250 B.C. in Georgia can be crucial to assessing seismic hazard and elaborating damage scenarios for possible future earthquakes. In order to carry out the present work, we revised all available macroseismic information and collected new data from different sources. Such data and sources are stored in the library of the Institute of Geophysics in Tbilisi (Georgia) and are in Georgian and Russian language.

## 2 Seismotectonic settings

The Republic of Georgia (Sakartvelo) lies between the Russian Federation to the north, the Republic of Turkey and the Republic of Armenia to the south, and the Republic of Azerbaijan to the east (Fig. 1). The main morphological units in this country are the Greater and Lesser Caucasus mountain ranges, separated by the Black Sea-Rioni and Kura (Mtkvari)-South Caspian intermountain troughs. The tectonics and geological evolution of Georgia and the Caucasus, or of the Black Sea-Caspian Sea region as a whole, are mostly influenced by the region's location between the still-

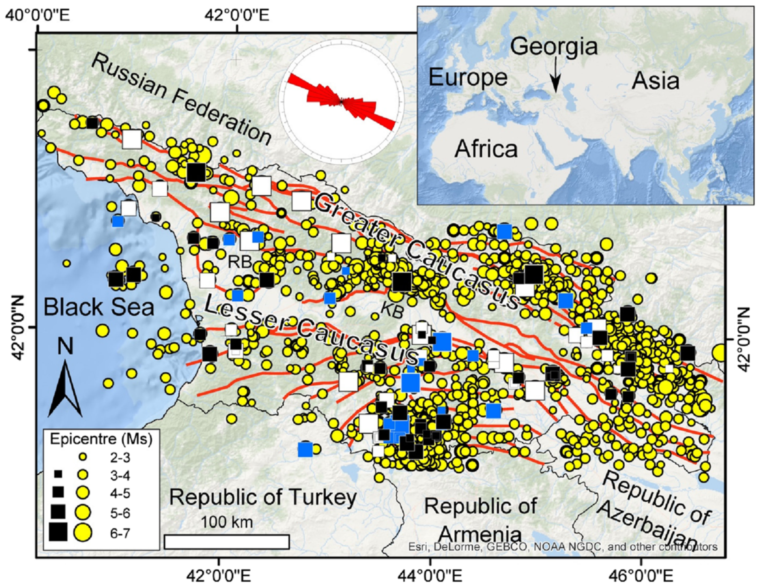


**Fig. 1** Active tectonic faults and seismicity within the Republic of Georgia and its surroundings (modified after Tsereteli et al. 2016a). The entire Georgian seismic catalog is shown as yellow dots scaled with magnitude ($M_S$). Squares represent the earthquakes listed in GeoInt, which are a subset of the whole Georgian seismic catalog, scaled with magnitude as well; white squares belong to the historical period (pre-1900 A.D.), blue squares to the early instrumental period (1900–1955 A.D.) and black squares to the late instrumental period (1956 A.D.–today). Active faults are shown as red lines and have been derived from the EMME Project (Gülen and Team 2010, Gülen et al. 2014). The inset in the upper right corner shows the location of Georgia. RB, Rioni Basin; KB, Kura Basin. Rose diagram represents strike of active faults. Digital elevation model and ocean base are from Esri Base Map

converging Eurasian and Africa-Arabian lithosphere plates, within the wide zone of a continent-continent collision. According to geodetic data, the convergence rate is ~ 20–30 mm/year, some 2/3 of which are likely to be absorbed south of the Lesser Caucasian (Sevan-Akera) ophiolitic suture, mainly in south Armenia, Nakhchivan, northwest Iran, and Eastern Turkey (Reilinger et al. 2006).

Most of the faults in the region strike in the WNW-ESE to E-W range, thus roughly parallel to Caucasus mountains, and correspond to compressional thrust faults (see rose diagram in Fig. 1). In the depression between the Greater Caucasus and the Lesser Caucasus (Rioni and Kura foreland basins), E-W to WNW-ESE structures dominate. In the Kura foreland basin and in the southeastern Lesser Caucasus, there are NW-SE to WNW-ESE faults with reverse kinematics and possible strike-slip components. In part of the Rioni Basin, the possible active faults have a characteristic horse-shoe shape in plan view with a southward convex side. This shape might have resulted from the interconnection of different faults segments linked with an oblique asymmetric indentation of an upper crustal blocks moving towards the SSW (Tibaldi et al. 2017c). Faults have been outlined according to the distribution of seismicity, to the general morphology of the mountain front and to the offset of lithostratigraphic units (Zare et al. 2014b). Analysis of the focal mechanism solutions of some strong earthquakes in Georgia shows that the crustal blocks located west of the line stretching in the submeridional direction across the Javakheti volcanic highland—located in the SW part of the Lesser Caucasus near the Tabatskuri Lake (Georgia) at (41.621° N, 43.745° E)—have experienced westward lateral escape, 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. 2017; Tsereteli, et al. 2016a).

## 3 Introduction to the Georgian seismic database

Seismic observations from the territory of Georgia date back to 1250 years B.C. (e.g., Varazanashvili et al. 2011; Tsereteli et al. 2016a). This long-term seismic history is divided into several periods of observation: (i) historical period (HP, from 1250 B.C. to 1900 A.D.); (ii) early instrumental period (EIP, 1900–1955), which is subdivided into two stages (1900–1935 and 1936–1955); and (iii) late instrumental period (LIP, from 1956 until the present), which has three stages (1956–1995, 1996–2005, and 2016–present). The stages that compose the instrumental periods are linked to the development of both instrumental unification of seismic network and political and socio-economic changes that affected the Republic of Georgia in the XX century. As a result, the seismic catalog for the Republic of Georgia is characterized by 1783 earthquakes with $M_S$ comprised between 2.8 and 7, which occurred along the main fault systems of the Greater and Lesser Caucasus and inter-mountain depressions, between 1250 B.C. and 2016 A.D. (Fig. 1). A total of 44 earthquakes belong to the HP, whereas 285 belong to the EIP and 1454 to the LIP; the Georgian seismic catalog will be kept updated.

Due to the lack of instrumental data, particularly for the first half of the XX century (EIP), the location of some epicenters has been improved also by considering macroseismic information; the resulting improved epicenters are already listed in the official Georgian catalog (e.g., Tsereteli et al. 2016a). As a consequence of this, in the present work, we have not further revised any epicentral locations; all earthquake information for the HP are taken from Varazanashvili et al. (2011). Magnitudes have been categorized in terms of surface waves ($M_S$); in a few instances, whenever the direct determination of $M_S$ was impossible, the size of the events has been estimated through the energy class ($K$), according to the $K = 1.8\ M_S + 4$ relationship, based on Rautian (1964). Following Rautian and Khalturin (1978), it is accepted that $M_S \cong M_C$, where $M_C$ is the magnitude estimated from coda waves. As defined in the above-cited paper, an earthquake with $M_S > 3.5$ was estimated directly by using the regional calibration curve for $M_S$. Sometimes $M_b \cong M_{PV}$ (magnitude estimated from the vertical component of P waves) was also assumed. There is an empirical correlation formula between $M_{PV}$ and $M_S$ for the hereby considered region: $M_{PV} = 2.5 + 0.63M_S$. Since 2004, because of the reorganization of the Georgian seismic network, only local magnitude values *($M_L$)* were calculated for recorded earthquakes (and hardly ever $M_d$ and $M_b$ values*)*. In this case, the conversion to $M_S$ magnitude was carried out through the relationship provided by Kalafat et al. (2009), whereby $M_L = 1.0553 + 0.7782\ M_S$. The $M_S$ version of the Georgian seismic catalog is part of the new Earthquake Model of the Middle East (EMME), until 2006 A.D., in the framework of the Global Earth Model (GEM) (Zare et al. 2014a, b).

## 4 The first Georgian macroseismic database (GeoInt)

In this work, we present data related to the HP, EIP, and LIP, placing more emphasis on earthquakes that occurred during the instrumental period (post-1900 A.D.) because they are associated with 91% of IDPs. We selected 111 earthquakes characterized by defined $M_S$, location and depth (Table 1). Obviously, earthquake parameters are better defined for the EIP and LIP than for the HP; in particular, the focal depth for earthquakes belonging to the HP has been assigned by using the Blake (1941)'s formula, the Shebalin (1968)'s equation and also taking into account the average focal depth of earthquakes in the area during instrumental period; for further details of historical parameters, see Varazanashvili et al. (2011). The accuracy of earthquake parameters belonging to EIP and LIP periods has been already discussed in Kondorskaya and Shebalin (1982), Tsereteli et al. (2012) and Tsereteli et al. (2016a); therefore, we prefer avoiding any duplications of already published work.

For each earthquake, we reported (in Table 1) (i) earthquake ID, date, and UTC time (whenever available); (ii) number of intensity data points (IDPs); (iii) maximum and minimum intensity value (MSK); (iv) link to the online version of IDPs distribution; and (v) number of IDPs from the literature, revised and new ones. Furthermore, references and sources for earthquake IDPs information are reported. Earthquake IDs are composed of the year (first four numbers followed by a dot), month (two numbers), day (two numbers), hour (two numbers) and minutes (two numbers); this was done with the purpose of giving a unique ID to each event (e.g., Albini et al. 2013 2014).

### 4.1 Dataset description

The compiled database includes 3944 IDPs, related to 111 earthquakes (from 1250 B.C. to 2012 A.D.). This subset of earthquakes is represented in Fig. 1 (epicenters are shown as squares): The events are mostly located within the Georgian border (with the exception of one seismic event, located in Turkey) and are characterized

**Table 1** Lis of earthquakes provided in GeoInt, subdivided into (i) historical period, (ii) early instrumental period, and (iii) late instrumental period. For each, the following details are provided: (i) earthquake ID; (ii) epicentral location, depth, and magnitude (both $M_S$ and $M_W$); (iii) UTC time and date; (iv) reference for earthquake information; (v) number of IDPs; (vi) online map of IDPs distribution; (vii) number of IDPs which have been checked and revised from previous works and number of new IDPs as a result of the present work; (viii) references for IDPs. Further details in regard to references are reported in Table 2

| | Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|---|
| Historical period | − 1250,00000000 | 42.70 | 42.20 | 10 | 6.6 | 6.6 | 1250 B.C. | Kvira (Nenskra-Abakura) | Varazanashvili et al. 2011 |
| | 50,00000000 | 42.90 | 41.00 | 10 | 5.5 | 5.8 | 50 | Dioskuria | Varazanashvili et al. 2011 |
| | 85,00000000 | 42.05 | 43.90 | 15 | 7.0 | 7.0 | 85 | Bebnisi | Varazanashvili et al. 2011 |
| | 400,00000000 | 42.90 | 41.00 | 10 | 5.5 | 5.8 | 400 | Sebastopolisi | Varazanashvili et al. 2011 |
| | 742,00000000 | 42.40 | 44.90 | 18 | 6.4 | 6.4 | 742 | Jvari Pass (Jvris Gadasaavleli) | Varazanashvili et al. 2011 |
| | 1088,04220000 | 41.40 | 43.40 | 15 | 6.5 | 6.5 | 1088-04-22 | Tmovgi | Varazanashvili et al. 2011 |
| | 1100,00000000 | 43.10 | 42.30 | 15 | 7.0 | 7.0 | 1100 | Nenskra-Abakura | Varazanashvili et al. 2011 |
| | 1275,00000000 | 41.85 | 44.70 | 15 | 6.5 | 6.5 | 1275 | Mtskheta | Varazanashvili et al. 2011 |
| | 1283,00000000 | 41.70 | 43.20 | 15 | 7.0 | 7.0 | 1283 | Samtskhe | Varazanashvili et al. 2011 |
| | 1350,00000000 | 42.70 | 43.10 | 15 | 7.0 | 7.0 | 1350 | Lechkumi-Svaneti | Varazanashvili et al. 2011 |
| | 1530,00000000 | 42.05 | 45.40 | 15 | 5.7 | 5.9 | 1530 | Alaverdi I | Varazanashvili et al. 2011 |
| | 1600,00000000 | 43.40 | 41.00 | 15 | 7.0 | 7.0 | 1600 | Bzipi | Varazanashvili et al. 2011 |
| | 1614,00000000 | 42.40 | 41.80 | 10 | 6.0 | 6.1 | 1614 | Tsaishi | Varazanashvili et al. 2011 |
| | 1682,06132230 | 41.70 | 44.80 | 07 | 4.2 | 4.9 | 1682-06-13 22:30:00 UTC | Tbilisi I | Varazanashvili et al. 2011 |
| | 1742,08050000 | 42.10 | 45.60 | 20 | 7.0 | 7.0 | 1742-08-05 | Alaverdi II | Varazanashvili et al. 2011 |
| | 1750,00000000 | 42.90 | 41.90 | 15 | 7.0 | 7.0 | 1750 | Akiba | Varazanashvili et al. 2011 |
| | 1750,00000001 | 43.00 | 42.70 | 15 | 6.9 | 6.9 | 1750 | Labaskaldi-Tseri | Varazanashvili et al. 2011 |
| | 1756,00000000 | 41.90 | 45.70 | 10 | 4.7 | 5.2 | 1756 | Kacheti I | Varazanashvili et al. 2011 |
| | 1785,05000000 | 41.90 | 42.10 | 10 | 5.5 | 5.8 | 1785-05 | Shemomqmedi | Varazanashvili et al. 2011 |
| | 1803,10290000 | 41.70 | 44.80 | 07 | 3.8 | 4.6 | 1803-10-29 | Tbilisi II | Varazanashvili et al. 2011 |
| | 1804,10111700 | 41.70 | 44.80 | 07 | 3.5 | 4.4 | 1804-10-11 17:00:00 UTC | Tbilisi III | Varazanashvili et al. 2011 |
| | 1805,02211900 | 41.90 | 43.90 | 10 | 4.4 | 5.0 | 1805-02-21 19:00:00 UTC | Gori area | Varazanashvili et al. 2011 |
| | 1811,01010500 | 42.00 | 45.50 | 10 | 5.0 | 5.4 | 1811-01-01 05:00:00 UTC | Kakheti II | Varazanashvili et al. 2011 |
| | 1819,02280000 | 41.70 | 44.80 | 07 | 4.5 | 5.1 | 1819-02-28 | Tbilisi IV | Varazanashvili et al. 2011 |
| | 1845,05240100 | 41.30 | 43.50 | 08 | 4.6 | 5.2 | 1845-05-24 01:00:00 UTC | Javakheti I | Varazanashvili et al. 2011 |
| | 1846,04232100 | 42.60 | 43.00 | 06 | 3.7 | 4.5 | 1846-04-23 21:00:00 UTC | Jvarisa | Varazanashvili et al. 2011 |
| | 1853,03180030 | 41.80 | 45.80 | 10 | 4.2 | 4.9 | | Kakheti III | Varazanashvili et al. 2011 |

**Table 1** (continued)

| | Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1853-03-18 00:30:00 UTC | | |
| | 1856,02130400 | 42.00 | 44.00 | 10 | 3.5 | 4.4 | 1856-02-13 04:00:00 UTC | Gori | Varazanashvili et al. 2011 |
| | 1868,02181700 | 41.20 | 43.50 | 15 | 4.9 | 5.4 | 1868-02-18 17:00:00 UTC | Javakheti II | Varazanashvili et al. 2011 |
| | 1868,12091630 | 42.30 | 44.70 | 25 | 4.0 | 4.8 | 1868-12-09 16:30:00 UTC | Pasanauri | Varazanashvili et al. 2011 |
| | 1870,07191430 | 41.90 | 42.10 | 10 | 4.2 | 4.9 | 1870-07-19 14:30:00 UTC | Ozurgeti | Varazanashvili et al. 2011 |
| | 1874,02251930 | 41.80 | 43.40 | 12 | 3.5 | 4.4 | 1874-02-25 19:30:00 UTC | Borjomi | Varazanashvili et al. 2011 |
| | 1877,08080630 | 42.60 | 43.60 | 05 | 3.8 | 4.6 | 1877-08-08 06:30:00 UTC | Utsera | Varazanashvili et al. 2011 |
| | 1878,11262300 | 41.90 | 43.50 | 15 | 4.3 | 5.0 | 1878-11-26 23:00:00 UTC | Borjomi area | Varazanashvili et al. 2011 |
| | 1881,08242000 | 42.00 | 44.00 | 17 | 4.0 | 4.8 | 1881-08-24 20:00:00 UTC | Kartili I | Varazanashvili et al. 2011 |
| | 1887,07161745 | 42.05 | 42.05 | 12 | 4.9 | 5.4 | 1887-07-16 17:45:00 UTC | Lancukhuti | Varazanashvili et al. 2011 |
| | 1890,10281900 | 41.85 | 44.60 | 20 | 5.2 | 5.6 | 1890-10-28 19:00:00 UTC | Mtskheta | Varazanashvili et al. 2011 |
| | 1891,00000000 | 43.05 | 41.30 | 15 | 6.0 | 6.1 | 1891 | Amtkeli | Varazanashvili et al. 2011 |
| | 1891,03271830 | 42.10 | 43.90 | 22 | 4.5 | 5.1 | 1891-03-27 18:30:00 UTC | Kareli | Varazanashvili et al. 2011 |
| | 1894,11291030 | 41.90 | 44.60 | 24 | 5.0 | 5.4 | 1894-11-29 10:30:00 UTC | Mtskheta | Varazanashvili et al. 2011 |
| | 1896,09220353 | 41.65 | 45.00 | 25 | 6.3 | 6.3 | 1896-09-22 03:53:00 UTC | Tbilisi area | Varazanashvili et al. 2011 |
| | 1897,02030200 | 41.80 | 46.30 | 10 | 3.8 | 4.6 | 1897-02-03 02:00:00 UTC | Lagodekhi | Varazanashvili et al. 2011 |
| | 1898,08130000 | 41.30 | 43.50 | 10 | 4.2 | 4.9 | 1898-08-13 | Javakheti III | Varazanashvili et al. 2011 |
| | 1899,12311050 | 41.57 | 43.57 | 09 | 6.1 | 6.2 | 1899-12-31 10:50:00 UTC | Akhalkalaki | Varazanashvili et al. 2011 |
| Early instrumental period | 1908,12100439 | 42.30 | 43.00 | 12 | 4.8 | 5.3 | 1908-12-10 04:39:00 UTC | Tkibuli | Kondorskaya and Shebalin 1982 |
| | 1912,10121948 | 41.40 | 43.70 | 28 | 6.3 | 6.3 | 1912-10-12 19:48:57 UTC | Tskhratskaro | Kondorskaya and Shebalin 1982 |
| | 1913,04200313 | 41.50 | 44.60 | 36 | 5.6 | 5.8 | 1913-04-20 03:13:34 UTC | – | Kondorskaya and Shebalin 1982 |

**Table 1** (continued)

| Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|
| 1915,01140509 | 42.80 | 44.70 | 19 | 5.4 | 5.7 | 1915-01-14 05:09:43 UTC | Dariali | Kondorskaya and Shebalin 1982 |
| 1920,02201144 | 42.00 | 44.10 | 11 | 6.2 | 6.2 | 1920-02-20 11:44:25 UTC | Kartili II | Kondorskaya and Shebalin 1982 |
| 1925,01091738 | 41.20 | 42.80 | 11 | 5.8 | 6.0 | 1925-01-09 17:38:24 UTC | Ardahani | Kondorskaya and Shebalin 1982 |
| 1925,05132251 | 41.30 | 43.60 | 18 | 5.1 | 5.5 | 1925-05-13 22:51:17 UTC | – | Kondorskaya and Shebalin 1982 |
| 1928,04200816 | 42.10 | 45.50 | 14 | 4.6 | 5.2 | 1928-04-20 08:16:00 UTC | – | Kondorskaya and Shebalin 1982 |
| 1930,11070556 | 42.70 | 42.00 | 17 | 4.8 | 5.3 | 1930-11-07 05:56:52 UTC | Samegrelo-Svaneti | Kondorskaya and Shebalin 1982 |
| 1935,01190049 | 42.80 | 40.90 | 22 | 4.7 | 5.2 | 1935-01-19 00:49:25 UTC | Shavi Zghva-Sokhumu | Kondorskaya and Shebalin 1982 |
| 1936,05091024 | 41.50 | 44.10 | 13 | 3.6 | 4.5 | 1936-05-09 10:24:31 UTC | – | Kondorskaya and Shebalin 1982 |
| 1940,03092008 | 41.40 | 43.60 | 17 | 4.9 | 5.4 | 1940-03-09 20:08:43 UTC | – | Kondorskaya and Shebalin 1982 |
| 1940,05072223 | 41.70 | 43.80 | 16 | 6.0 | 6.1 | 1940-05-07 22:23:18 UTC | Tabatskuri | Kondorskaya and Shebalin 1982 |
| 1940,05231910 | 41.80 | 43.80 | 09 | 4.0 | 4.8 | 1940-05-23 19:10:00 UTC | Tabatskuri | Kondorskaya and Shebalin 1982 |
| 1940,07101310 | 41.30 | 43.70 | 18 | 5.1 | 5.5 | 1940-07-10 13:10:48 UTC | Tabatskuri | Kondorskaya and Shebalin 1982 |
| 1940,09260218 | 42.50 | 43.15 | 02 | 3.5 | 4.4 | 1940-09-26 02:18:14 UTC | Ambrolauri | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1941,06150128 | 42.30 | 42.10 | 09 | 4.7 | 5.2 | 1941-06-15 01:28:24 UTC | Menji | Kondorskaya and Shebalin 1982 |
| 1947,08150411 | 42.50 | 45.00 | 25 | 5.5 | 5.8 | 1947-08-15 04:11:03 UTC | Gudamakari | Kondorskaya and Shebalin 1982 |
| 1948,09130055 | 42.40 | 42.40 | 15 | 4.3 | 5.0 | 1948-09-13 00:55:07 UTC | Dasavlet | Kondorskaya and Shebalin 1982 |
| 1951,01170021 | 41.30 | 43.70 | 16 | 4.2 | 4.9 | 1951-01-17 00:21:30 UTC | – | Kondorskaya and Shebalin 1982 |
| 1951,03032141 | 41.90 | 44.40 | 14 | 4.6 | 5.2 | 1951-03-03 21:41:23 UTC | – | Varazanashvili 2017 |
| 1951,11022155 | 42.30 | 45.30 | 16 | 5.3 | 5.6 | 1951-11-02 21:55:42 UTC | Mtatusheti | Kondorskaya and Shebalin 1982 |
| 1953,02120746 | 41.85 | 43.90 | 07 | 4.0 | 4.8 | | Kvemo Boshuri I | Kondorskaya and Shebalin 1982 |

Table 1 (continued)

| | Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1953-02-12 07:46:52 UTC | | |
| | 1954,06111125 | 41.40 | 44.10 | 12 | 4.6 | 5.2 | 1954-06-11 11:25:36 UTC | Gomareti | Kondorskaya and Shebalin 1982 |
| | 1955,12251843 | 42.73 | 42.28 | 10 | 4.8 | 5.3 | 1955-12-25 18:43:30 UTC | Zemo Samegrelo | Kondorskaya and Shebalin 1982 |
| Late instrumental period | 1957,01291521 | 42.42 | 42.38 | 11 | 5.3 | 5.6 | 1957-01-29 15:21:26 UTC | Gegechkori | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1958,05310350 | 41.40 | 43.90 | 17 | 4.7 | 5.2 | 1958-05-31 03:50:07 UTC | – | Kondorskaya and Shebalin 1982 |
| | 1958,07050205 | 42.70 | 41.65 | 06 | 4.6 | 5.2 | 1958-07-05 02:05:57 UTC | Achigvara | Kondorskaya and Shebalin 1982 |
| | 1958,11260012 | 41.60 | 45.90 | 19 | 4.6 | 5.2 | 1958-11-26 00:12:07 UTC | Sighnaghi | Kondorskaya and Shebalin 1982 |
| | 1959,05201949 | 41.87 | 41.85 | 09 | 5.1 | 5.5 | 1959-05-20 19:49:16 UTC | Adzhara-Guria | Kondorskaya and Shebalin 1982 |
| | 1959,12081333 | 41.20 | 43.86 | 10 | 5.4 | 5.7 | 1959-12-08 13:33:58 UTC | Madatapa | Kondorskaya and Shebalin 1982 |
| | 1963,07161827 | 43.18 | 41.65 | 10 | 6.4 | 6.4 | 1963-07-16 18:27:14 UTC | Chkhalta | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1964,03110008 | 42.46 | 44.84 | 14 | 4.5 | 5.1 | 1964-03-11 00:08:59 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1967,06170956 | 41.75 | 45.15 | 07 | 4.0 | 4.8 | 1967-06-17 09:59:05 UTC | Khashmi I | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1967,06290822 | 41.37 | 43.90 | 10 | 4.4 | 5.0 | 1967-06-29 08:22:44 UTC | Paravani I | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1968,03060301 | 42.01 | 44.00 | 24 | 3.7 | 4.6 | 1968-03-06 03:01:01 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1968,05130246 | 43.50 | 40.60 | 15 | 4.5 | 5.1 | 1968-05-13 02:46:34 UTC | Bzipi | Kondorskaya and Shebalin 1982 |
| | 1968,06191503 | 41.33 | 43.96 | 10 | 4.0 | 4.8 | 1968-06-19 15:03:34 UTC | – | Kondorskaya and Shebalin 1982 |
| | 1969,06141744 | 41.32 | 43.55 | 12 | 4.6 | 5.2 | 1969-06-14 17:44:57 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1970,01030654 | 41.80 | 43.50 | 05 | 4.7 | 5.2 | 1970-01-03 06:54:41 UTC | Borjomi | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1971,06281953 | 42.60 | 43.50 | 07 | 4.0 | 4.8 | 1971-06-28 19:53:41 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1971,09082235 | 41.29 | 43.98 | 12 | 4.5 | 5.1 | 1971-09-08 22:35:08 UTC | Dmanisi I | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |

**Table 1** (continued)

| Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|
| 1974,08041506 | 42.20 | 45.90 | 18 | 5.1 | 5.5 | 1974:08:04 15:06:12 UTC | Bezhta | Kondorskaya and Shebalin 1982 |
| 1978,01020631 | 41.42 | 44.12 | 16 | 5.3 | 5.6 | 1978-01-02 06:31:26 UTC | Dmanisi II | Kondorskaya and Shebalin 1982 |
| 1978,05261343 | 41.91 | 46.48 | 16 | 5.3 | 5.6 | 1978-05-26 13:43:38 UTC | Tlyarata | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1978,08222248 | 41.82 | 43.98 | 10 | 4.3 | 5.0 | 1978-08-22 22:48:17 UTC | Kvemo Boshuri II | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1979,12272116 | 42.67 | 41.84 | 08 | 4.3 | 5.0 | 1979-12-27 21:16:51 UTC | Rechkhi | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1981,02230406 | 41.80 | 45.90 | 10 | 4.9 | 5.4 | 1981-02-23 04:06:36 UTC | Gavazi | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1982,01240203 | 41.99 | 43.37 | 11 | 4.0 | 4.8 | 1982-01-24 02:03:50 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1984,01190921 | 41.30 | 43.80 | 10 | 4.0 | 4.8 | 1984-01-19 09:21:31 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1984,07042125 | 42.84 | 41.27 | 16 | 4.0 | 4.8 | 1984-07-04 21:25:53 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1985,07040508 | 42.03 | 45.63 | 30 | 5.1 | 5.5 | 1985-07-04 05:08:28 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1986,05130844 | 41.48 | 43.70 | 12 | 5.6 | 5.8 | 1986-05-13 08:44:01 UTC | Paravani II | Gotsadze and Tutberidze 1986 |
| 1986,09030928 | 41.52 | 43.52 | 16 | 4.4 | 5.0 | 1986-09-03 09:28:17 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1988,09061916 | 42.01 | 41.75 | 13 | 4.6 | 5.2 | 1988-09-06 19:16:38 UTC | Kobuleti | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1988,09090102 | 42.05 | 43.90 | 05 | 3.3 | 4.3 | 1988-09-09 01:02:19 UTC | – | Varazanashvili 2017 |
| 1989,04130749 | 41.62 | 45.73 | 16 | 4.5 | 5.1 | 1989-04-13 07:49:19 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1990,09220246 | 41.89 | 45.93 | 09 | 4.1 | 4.8 | 1990-09-22 02:46:01 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1990,12161545 | 41.26 | 43.77 | 14 | 5.1 | 5.5 | 1990-12-16 15:45:36 UTC | – | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1991,04290912 | 42.43 | 43.70 | 12 | 6.9 | 6.9 | 1991-04-29 09:12:45 UTC | Racha | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1992,10232319 | 42.49 | 44.99 | 19 | 6.3 | 6.3 | 1992-10-23 23:19:44 UTC | Barisakho | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| 1994,03042308 | 41.76 | 45.19 | 06 | 3.9 | 4.7 | 1994-03-04 23:08:13 UTC | Khsami II | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |

**Table 1** (continued)

| | Earthquake ID | Lat (°) | Lon (°) | Depth (km) | $M_S$ | $M_W$ | Date and UTC time | Name of earthquake | Reference for earthquake information |
|---|---|---|---|---|---|---|---|---|---|
| | 1996,05280450 | 41.95 | 42.10 | 06 | 4.3 | 5.0 | 1996-05-28 04:50:10 UTC | Askana | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1997,02092149 | 41.32 | 44.05 | 34 | 4.1 | 4.8 | 1997-02-09 21:49:08 UTC | Paravani III | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 1997,11271734 | 41.77 | 45.17 | 20 | 5.3 | 5.6 | 1997-11-27 17:34:26 UTC | Khasmi III | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 2002,04251741 | 41.74 | 44.84 | 06 | 4.6 | 5.2 | 2002-04-25 17:41:21 UTC | Tbilisi V | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. |
| | 2012,12231331 | 42.42 | 41.08 | 15 | 5.6 | 5.8 | 2012-12-23 13:31:40 UTC | Shavi Zghva I | Varazanashvili 2017 |

| | Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|---|
| Historical period | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3019 | 9–10 | 9–10 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 17–18 |
| | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3018 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 19 |
| | Varazanashvili et al. 2011 | 6 | http://www.enguriproject.unimib.it/?page_id=3017 | 9–10 | 8 | 6 | 0 | 0 | Varazanashvili et al. 2011, pp. 20–21 |
| | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3016 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 22 |
| | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3015 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 23 |
| | Varazanashvili et al. 2011 | 3 | http://www.enguriproject.unimib.it/?page_id=3014 | 9 | 9 | 3 | 0 | 0 | Varazanashvili et al. 2011, pp. 24–26 |
| | Varazanashvili et al. 2011 | 2 | http://www.enguriproject.unimib.it/?page_id=3013 | 9–10 | 9–10 | 2 | 0 | 0 | Varazanashvili et al. 2011, pp. 26–28 |
| | Varazanashvili et al. 2011 | 4 | http://www.enguriproject.unimib.it/?page_id=3012 | 8–9 | 8 | 4 | 0 | 0 | Varazanashvili et al. 2011, pp. 28–30 |

**Table 1** (continued)

| Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|
| Varazanashvili et al. 2011 | 4 | http://www.enguriproject.unimib.it/?page_id=3011 | 9 | 7 | 4 | 0 | 0 | Varazanashvili et al. 2011, pp. 30–33 |
| Varazanashvili et al. 2011 | 10 | http://www.enguriproject.unimib.it/?page_id=3010 | 9 | 7 | 10 | 0 | 0 | Varazanashvili et al. 2011, pp. 33–36 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3009 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 36–37 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3008 | 9–10 | 9–10 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 37–38 |
| Varazanashvili et al. 2011 | 4 | http://www.enguriproject.unimib.it/?page_id=3007 | 8 | 6–7 | 4 | 0 | 0 | Varazanashvili et al. 2011, pp. 39–40 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3006 | 6–7 | 6–7 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 40–41 |
| Varazanashvili et al. 2011 | 8 | http://www.enguriproject.unimib.it/?page_id=3005 | 9 | 7 | 8 | 0 | 0 | Varazanashvili et al. 2011, pp. 41–43 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3004 | 9–10 | 9–10 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 44 |
| Varazanashvili et al. 2011 | 3 | http://www.enguriproject.unimib.it/?page_id=3003 | 9 | 9 | 3 | 0 | 0 | Varazanashvili et al. 2011, pp. 45–46 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3002 | 7 | 7 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 47 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3001 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 48–49 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=3000 | 6 | 6 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 49–50 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2999 | 5–6 | 5–6 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 50–51 |

Table 1 (continued)

| Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|
| Varazanashvili et al. 2011 | 2 | http://www.enguriproject.unimib.it/?page_id=2998 | 5 | 3 | 2 | 0 | 0 | Varazanashvili et al. 2011, pp. 51–52 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2995 | 7 | 7 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 52–53 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2994 | 7 | 7 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 53–54 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2993 | 7 | 7 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 55 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2992 | 6 | 6 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 56 |
| Varazanashvili et al. 2011 | 7 | http://www.enguriproject.unimib.it/?page_id=2991 | 5–6 | 4 | 7 | 0 | 0 | Varazanashvili et al. 2011, p. 57 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2990 | 5 | 5 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 58 |
| Varazanashvili et al. 2011 | 17 | http://www.enguriproject.unimib.it/?page_id=2989 | 6–7 | 2–3 | 17 | 0 | 0 | Varazanashvili et al. 2011, pp. 58–59 |
| Varazanashvili et al. 2011 | 5 | http://www.enguriproject.unimib.it/?page_id=2988 | 4–5 | 4 | 5 | 0 | 0 | Varazanashvili et al. 2011, p. 60 |
| Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2987 | 6 | 6 | 1 | 0 | 0 | Varazanashvili et al. 2011, pp. 60–61 |
| Varazanashvili et al. 2011 | 2 | http://www.enguriproject.unimib.it/?page_id=2986 | 5 | 3 | 2 | 0 | 0 | Varazanashvili et al. 2011, pp. 61–62 |
| Varazanashvili et al. 2011 | 2 | http://www.enguriproject.unimib.it/?page_id=2985 | 6–7 | 5–6 | 2 | 0 | 0 | Varazanashvili et al. 2011, pp. 62–63 |
| Varazanashvili et al. 2011 | 2 | http://www.enguriproject.unimib.it/?page_id=2984 | 5 | 5 | 2 | 0 | 0 | Varazanashvili et al. 2011, pp. 63–64 |

**Table 1** (continued)

| | Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|---|
| | Varazanashvili et al. 2011 | 5 | http://www.enguriproject.unimib.it/?page_id=2983 | 5 | 3 | 5 | 0 | 0 | Varazanashvili et al. 2011, pp. 64–65 |
| | Varazanashvili et al. 2011 | 12 | http://www.enguriproject.unimib.it/?page_id=2982 | 7 | 3 | 12 | 0 | 0 | Varazanashvili et al. 2011, pp. 65–66 |
| | Varazanashvili et al. 2011 | 5 | http://www.enguriproject.unimib.it/?page_id=2981 | 6–7 | 4 | 5 | 0 | 0 | Varazanashvili et al. 2011, pp. 66–67 |
| | Varazanashvili et al. 2011 | 6 | http://www.enguriproject.unimib.it/?page_id=2980 | 8 | 8 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 69 |
| | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2979 | 5–6 | 3–4 | 6 | 0 | 0 | Varazanashvili et al. 2011, pp. 67–68 |
| | Varazanashvili et al. 2011 | 4 | http://www.enguriproject.unimib.it/?page_id=2978 | 5–6 | 3–4 | 4 | 0 | 0 | Varazanashvili et al. 2011, pp. 69–70 |
| | Varazanashvili et al. 2011 | 27 | http://www.enguriproject.unimib.it/?page_id=2977 | 7 | 4 | 27 | 0 | 0 | Varazanashvili et al. 2011, pp. 70–71 |
| | Varazanashvili et al. 2011 | 1 | http://www.enguriproject.unimib.it/?page_id=2976 | 5–6 | 5–6 | 1 | 0 | 0 | Varazanashvili et al. 2011, p. 72 |
| | Varazanashvili et al. 2011 | 25 | http://www.enguriproject.unimib.it/?page_id=2973 | 6 | 3 | 25 | 0 | 0 | Varazanashvili et al. 2011, p. 73 |
| | Varazanashvili et al. 2011 | 163 | http://www.enguriproject.unimib.it/?page_id=2972 | 9 | 3 | 163 | 0 | 0 | Varazanashvili et al. 2011, pp. 74–75 |
| Early instru-mental period | Kondorskaya and Shebalin 1982 | 26 | http://www.enguriproject.unimib.it/?page_id=2233 | 7 | 3 | 23 | 6 | 3 | Byus 1948, pp. 107–108 |
| | Kondorskaya and Shebalin 1982 | 62 | http://www.enguriproject.unimib.it/?page_id=2232 | 7 | 3 | 52 | 27 | 10 | Byus 1948, pp. 121–123 |
| | Kondorskaya and Shebalin 1982 | 36 | http://www.enguriproject.unimib.it/?page_id=2231 | 6 | 3 | 25 | 10 | 11 | Byus 1948, pp. 128–129. |

**Table 1** (continued)

| Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|
| Kondorskaya and Shebalin 1982 | 33 | http://www.enguriproject.unimib.it/?page_id=2230 | 7 | 3 | 25 | 6 | 8 | Byus 1948, pp. 134 |
| Kondorskaya and Shebalin 1982 | 112 | http://www.enguriproject.unimib.it/?page_id=2229 | 8–9 | 3–4 | 104 | 30 | 8 | Byus 1948, pp. 145–152 |
| Kondorskaya and Shebalin 1982 | 31 | http://www.enguriproject.unimib.it/?page_id=2228 | 8–9 | 3–4 | 25 | 14 | 6 | Byus 1948, pp. 166–167 |
| Kondorskaya and Shebalin 1982 | 20 | http://www.enguriproject.unimib.it/?page_id=2227 | 7 | 3 | 5 | 4 | 15 | Byus 1948, p. 170 |
| Kondorskaya and Shebalin 1982 | 13 | http://www.enguriproject.unimib.it/?page_id=2226 | 6–7 | 3 | 12 | 7 | 1 | Byus 1948, pp. 186–187 |
| Kondorskaya and Shebalin 1982 | 66 | http://www.enguriproject.unimib.it/?page_id=2225 | 6 | 3 | 66 | 12 | 0 | Byus 1948, 200–204 |
| Kondorskaya and Shebalin 1982 | 59 | http://www.enguriproject.unimib.it/?page_id=2224 | 6 | 3 | 55 | 11 | 4 | Byus 1948, pp. 223–226 |
| Kondorskaya and Shebalin 1982 | 15 | http://www.enguriproject.unimib.it/?page_id=2223 | 5–6 | 3 | 14 | 5 | 1 | Byus, 1948, p. 237 |
| Kondorskaya and Shebalin 1982 | 32 | http://www.enguriproject.unimib.it/?page_id=2222 | 6 | 3–4 | 32 | 10 | 0 | Byus 1948, pp. 259–261 |
| Kondorskaya and Shebalin 1982 | 370 | http://www.enguriproject.unimib.it/?page_id=2221 | 8 | 3–4 | 366 | 135 | 4 | Byus 1948, pp. 262–280 |
| Kondorskaya and Shebalin 1982 | 33 | http://www.enguriproject.unimib.it/?page_id=2220 | 6 | 3 | 33 | 14 | 0 | Byus 1948, pp. 282–284 |
| Kondorskaya and Shebalin 1982 | 43 | http://www.enguriproject.unimib.it/?page_id=2219 | 6 | 3 | 43 | 19 | 0 | Byus 1948, pp. 286–288 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 30 | http://www.enguriproject.unimib.it/?page_id=2218 | 7 | 3–4 | 30 | 14 | 0 | Byus 1948, pp. 288–291 |

**Table 1** (continued)

| | Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|---|
| | Kondorskaya and Shebalin 1982 | 24 | http://www.enguriproject.unimib.it/?page_id=2217 | 6–7 | 3 | 22 | 7 | 2 | Byus 1948, pp. 296–298 |
| | Kondorskaya and Shebalin 1982 | 110 | http://www.enguriproject.unimib.it/?page_id=2216 | 7–8 | 3–4 | 110 | 14 | 0 | Byus 1952, pp. 13–18; Tskhakaia, 1949 |
| | Kondorskaya and Shebalin 1982 | 51 | http://www.enguriproject.unimib.it/?page_id=2215 | 6 | 4 | 51 | 4 | 0 | Byus 1952, pp. 27–30 |
| | Kondorskaya and Shebalin 1982 | 24 | http://www.enguriproject.unimib.it/?page_id=2064 | 6 | 3–4 | 24 | 4 | 0 | Tskhakaya and Papalashvili 1973, p.7 |
| | Varazanashvili 2017 | 49 | http://www.enguriproject.unimib.it/?page_id=2063 | 6 | 3 | 49 | 16 | 0 | Tskhakaya and Papalashvili 1973, pp.7–8 |
| | Kondorskaya and Shebalin 1982 | 89 | http://www.enguriproject.unimib.it/?page_id=2062 | 7 | 3–4 | 89 | 15 | 0 | Tskhakaya and Papalashvili 1973, pp.8–9; |
| | Kondorskaya and Shebalin 1982 | 14 | http://www.enguriproject.unimib.it/?page_id=2061 | 6–7 | 3–4 | 14 | 5 | 0 | Tskhakaya and Papalashvili, 1973, pp.10 |
| | Kondorskaya and Shebalin 1982 | 63 | http://www.enguriproject.unimib.it/?page_id=2060 | 7 | 4 | 63 | 11 | 0 | Pataraya 1957, pp. 129–133 |
| | Kondorskaya and Shebalin 1982 | 36 | http://www.enguriproject.unimib.it/?page_id=2059 | 6–7 | 3 | 36 | 8 | 0 | Tskhakaya and Papalashvili 1973, pp.16–18 |
| Late instru-mental period | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 14 | http://www.enguriproject.unimib.it/?page_id=2058 | 8 | 3–4 | 14 | 3 | 0 | Tskhakaya 1973, pp.990–999 |
| | Kondorskaya and Shebalin 1982 | 28 | http://www.enguriproject.unimib.it/?page_id=2057 | 6 | 3 | 28 | 8 | 0 | Tskhakaya and Papalashvili 1973, p. 27 |
| | Kondorskaya and Shebalin 1982 | 35 | http://www.enguriproject.unimib.it/?page_id=2201 | 7 | 3–4 | 35 | 8 | 0 | Tskhakaya and Papalashvili 1973, p. 27 |
| | Kondorskaya and Shebalin 1982 | 15 | http://www.enguriproject.unimib.it/?page_id=2029 | 6 | 3 | 15 | 0 | 0 | Tskhakaya and Papalashvili 1973, p. 28 |

**Table 1** (continued)

| Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|
| Kondorskaya and Shebalin 1982 | 84 | http://www.enguriproject.unimib.it/?page_id=2028 | 7–8 | 3 | 84 | 9 | 0 | Tskhakaya and Papalashvili 1973, p. 29 |
| Kondorskaya and Shebalin 1982 | 59 | http://www.enguriproject.unimib.it/?page_id=2027 | 7–8 | 3 | 59 | 18 | 0 | Tskhakaya and Papalashvili 1973, p. 31 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 51 | http://www.enguriproject.unimib.it/?page_id=2026 | 9 | 3 | 51 | 9 | 0 | Tskhakaya et al. 1967, p.10 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 25 | http://www.enguriproject.unimib.it/?page_id=2025 | 6 | 3 | 25 | 16 | 0 | Tskhakaya and Papalashvili, 1973, p. 46 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 21 | http://www.enguriproject.unimib.it/?page_id=2024 | 6 | 2–3 | 21 | 4 | 0 | Akhalbedashvili 1970, pp. 31–33 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 31 | http://www.enguriproject.unimib.it/?page_id=2023 | 6–7 | 2–3 | 31 | 11 | 0 | Lebedeva et al. 1970, pp. 34–35 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 24 | http://www.enguriproject.unimib.it/?page_id=2022 | 5 | 3 | 24 | 7 | 0 | Tskhakaya and Papalashvili 1973, p. 55 |
| Kondorskaya and Shebalin 1982 | 21 | http://www.enguriproject.unimib.it/?page_id=2203 | 6–7 | 3 | 20 | 2 | 1 | Tskhakaya and Papalashvili 1972, pp. 56–67 |
| Kondorskaya and Shebalin 1982 | 16 | http://www.enguriproject.unimib.it/?page_id=2021 | 4–5 | 3 | 13 | 5 | 3 | Tskhakaya and Papalashvili 1973, pp. 56–67 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 20 | http://www.enguriproject.unimib.it/?page_id=2020 | 5–6 | 3–4 | 20 | 1 | 0 | Tskhakaya and Dzhibladze 1973, pp. 19–28 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 81 | http://www.enguriproject.unimib.it/?page_id=2019 | 7 | 2–3 | 81 | 27 | 0 | Ayvazishvili et al. 1973, p.17 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 19 | http://www.enguriproject.unimib.it/?page_id=2018 | 6 | 3 | 19 | 1 | 0 | Papalashvili 1997, p. 6 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 64 | http://www.enguriproject.unimib.it/?page_id=2017 | 6 | 3 | 64 | 2 | 0 | Papalashvili 1997, p. 7 |

**Table 1** (continued)

| | Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|---|
| | Kondorskaya and Shebalin 1982 | 58 | http://www.enguriproject.unimib.it/?page_id=2016 | 6–7 | 3 | 58 | 0 | 0 | Papalashvili 1997, p. 23 |
| | Kondorskaya and Shebalin 1982 | 132 | http://www.enguriproject.unimib.it/?page_id=2015 | 8 | 3 | 132 | 30 | 0 | Papalashvili et al. 1982 pp. 11–19 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 102 | http://www.enguriproject.unimib.it/?page_id=2014 | 6 | 3 | 102 | 32 | 0 | Papalashvil et al. 1982, pp. 11–19; Papalashvili 1997, pp. 51–53 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 73 | http://www.enguriproject.unimib.it/?page_id=2013 | 6 | 3 | 73 | 5 | 0 | Papalashvili et al. 1982, pp. 11–19; Papalashvili, 1997, pp. 53–54 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 18 | http://www.enguriproject.unimib.it/?page_id=2012 | 7 | 3–4 | 18 | 8 | 0 | Kalinin et al. 1982, pp. 27–31 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 58 | http://www.enguriproject.unimib.it/?page_id=2190 | 7 | 3 | 58 | 8 | 0 | Napetvaridze (Eds.) 1984, p. 7 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 23 | http://www.enguriproject.unimib.it/?page_id=2189 | 5 | 3 | 23 | 5 | 0 | Agalarova et al. 1985, pp. 12–19; Papalashvil 1997, p. 76 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 38 | http://www.enguriproject.unimib.it/?page_id=2192 | 5–6 | 3 | 38 | 0 | 0 | Agalarova et al. 1987, pp. 19–35; Papalashvil 1997, pp. 87–88 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 27 | http://www.enguriproject.unimib.it/?page_id=2011 | 5 | 3 | 27 | 0 | 0 | Agalarova et al. 1987, pp. 19–35; Papalashvil 1997, pp. 95–96 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 33 | http://www.enguriproject.unimib.it/?page_id=2010 | 5–6 | 2–3 | 33 | 10 | 0 | Agalarova et al. 1988, pp. 60–75; Papalashvil 1997, pp. 107–108 |
| | Gotsadze and Tutberidze 1986 | 154 | http://www.enguriproject.unimib.it/?page_id=2009 | 7–8 | 3 | 152 | 14 | 2 | Balavadze and Chichinadze (Eds.) 1986, pp. 50–51 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 29 | http://www.enguriproject.unimib.it/?page_id=2007 | 5–6 | 3 | 29 | 9 | 0 | Varazanashvili et al. 1989, pp. 78–86; Papalashvili 1997, pp. 124–127 |
| | Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 78 | http://www.enguriproject.unimib.it/?page_id=1957 | 7 | 3 | 78 | 21 | 0 | Papalashvili et al. 1991, pp.53–59; Papalashvili 1997, pp. 127–128 |

**Table 1** (continued)

| Reference for earthquake information | No. of IDPs | Link to the online version | I (max) | I (min) | Checked | Revised | New | Reference for IDPs |
|---|---|---|---|---|---|---|---|---|
| Varazanashvili 2017 | 44 | http://www.enguriproject.unimib.it/?page_id=2211 | 5–6 | 3–4 | 44 | 6 | 0 | Papalashvili et al. 1991, pp. 40–48; Papalashvili 1997, pp. 127–128 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 51 | http://www.enguriproject.unimib.it/?page_id=1908 | 4–5 | 2–3 | 51 | 0 | 0 | Papalashvili and Agalarova 1993, pp. 24–31; Papalashvili 1997, p. 131 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 13 | http://www.enguriproject.unimib.it/?page_id=1907 | 5–6 | 3–4 | 12 | 3 | 1 | Papalashvili and Butikashvili 1996, pp. 24–26 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 77 | http://www.enguriproject.unimib.it/?page_id=1906 | 7 | 3–4 | 77 | 16 | 0 | Makhatadze et al. 1996, pp. 28–32 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 313 | http://www.enguriproject.unimib.it/?page_id=1905 | 9 | 2–3 | 313 | 59 | 0 | Papalashvili et al., 1997, pp. 18–25 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 74 | http://www.enguriproject.unimib.it/?page_id=1904 | 7 | 3 | 73 | 13 | 1 | Makhatadze et al. 1997, pp. 219–221 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 13 | http://www.enguriproject.unimib.it/?page_id=1903 | 6–7 | 2–3 | 12 | 6 | 1 | Papalashvili et al. 2000, p. 19 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 42 | http://www.enguriproject.unimib.it/?page_id=1902 | 6–7 | 3 | 42 | 7 | 0 | Papalashvili et al. 2002, pp. 176–180 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 34 | http://www.enguriproject.unimib.it/?page_id=1900 | 5 | 3–4 | 34 | 3 | 0 | Papalashvili and Butikashvili 2003, pp. 219–221 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 11 | http://www.enguriproject.unimib.it/?page_id=1881 | 6–7 | 3–4 | 11 | 5 | 0 | Mukhadze and Papalashvili 2003, pp. 244–250 |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics. | 29 | http://www.enguriproject.unimib.it/?page_id=1880 | 7 | 2–3 | 29 | 5 | 0 | Akhalbedashvili et al. 2006, p. 29 |
| Varazanashvili 2017 | 23 | http://www.enguriproject.unimib.it/?page_id=1876 | 6–7 | 3 | 0 | 0 | 23 | Macroseismic data. Archives of the TSU M. Nodia Institute of Geophysics. (in Georgian) |

by depths in the 2 to 36 km range; magnitude values range from $M_S$ 3.3 to 7 (Table 1). The entire set of IDPs (with intensity values ranging from 2–3 to 9–10) is reported in Fig. 2a; it is also available as additional files or downloadable at *http://www.enguriproject.unimib.it*, whereby epicentral and hypocentral distances, together with IDPs locations, are also reported. IDPs are reported in the Medvedev-Sponheuer-Karnik intensity scale (MSK) (e.g., Musson et al. 2010). The areal coverage of the whole set of IDPs extends from 39.508° N to 45.043° N and from 37.324° E to 48.500° E, with some IDPs outside the Georgian border, particularly in Armenia, Russia, and Azerbaijan (Fig. 2a). IDPs spatial distribution for the HP, EIP, and LIP are represented in Figs. 2b and 3a, b, respectively.

The selected events that are part of GeoInt have magnitude values ($M_S$) ranging from 3.3 to 7; the most represented ones are between $M_S$ classes 4.5–5.0 and 4.0–4.5 (Fig. 4a). Each class contains the lowest number but the highest one is part of the upper class. Intensity values range from 2 to 3 to 9–10 (Fig. 4b); the most represented class is 4 (characterized by the highest frequency (> 1000)), followed by 5, 3, and 6. Classes 7 and 8 are less represented, and classes 2 and 9 are the least

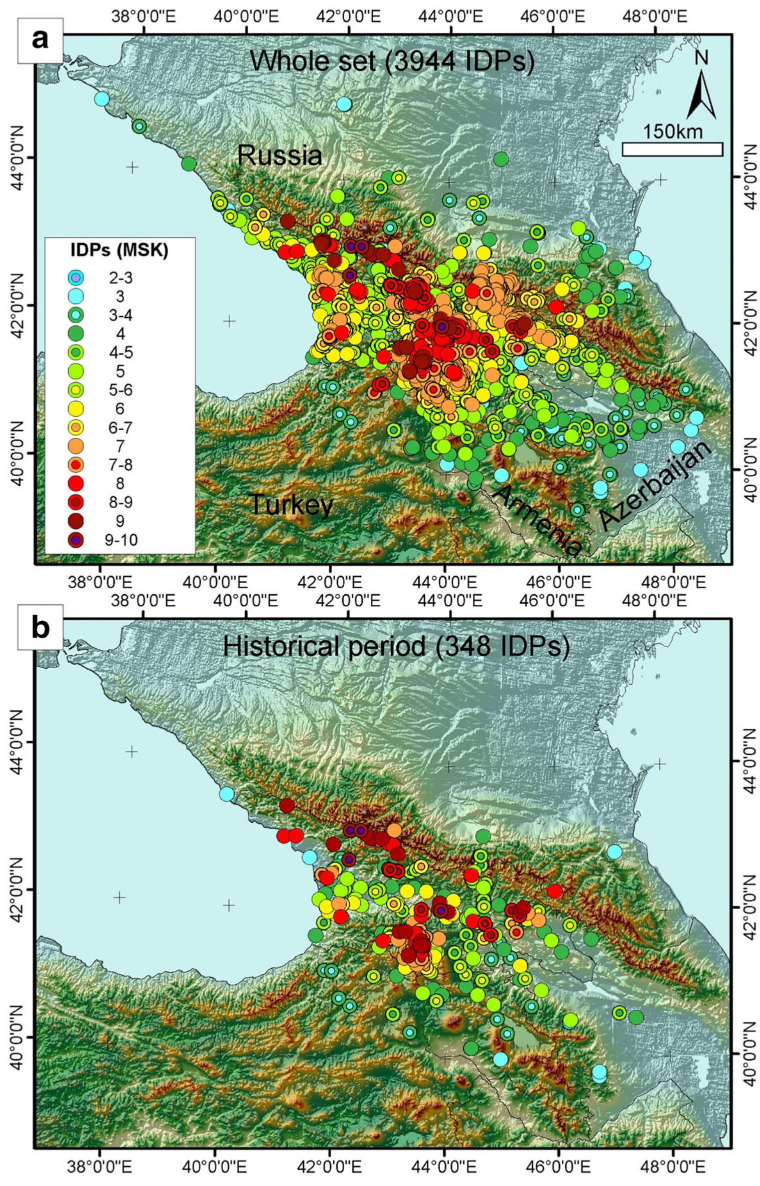


**Fig. 2** **a** Distribution of the 3944 IDPs associated with the 111 earthquakes relative to our study, considering the temporal window between 1250 B.C. and 2012 A.D. **b** Distribution of the 348 IDPs (out of 3944) associated with the 44 earthquakes belonging to the historical period (between 1250 B.C. and 1900 A.D.). Filled circles represent the collected intensity data points (IDPs). Color code for IDPs is from Locati et al. (2014)

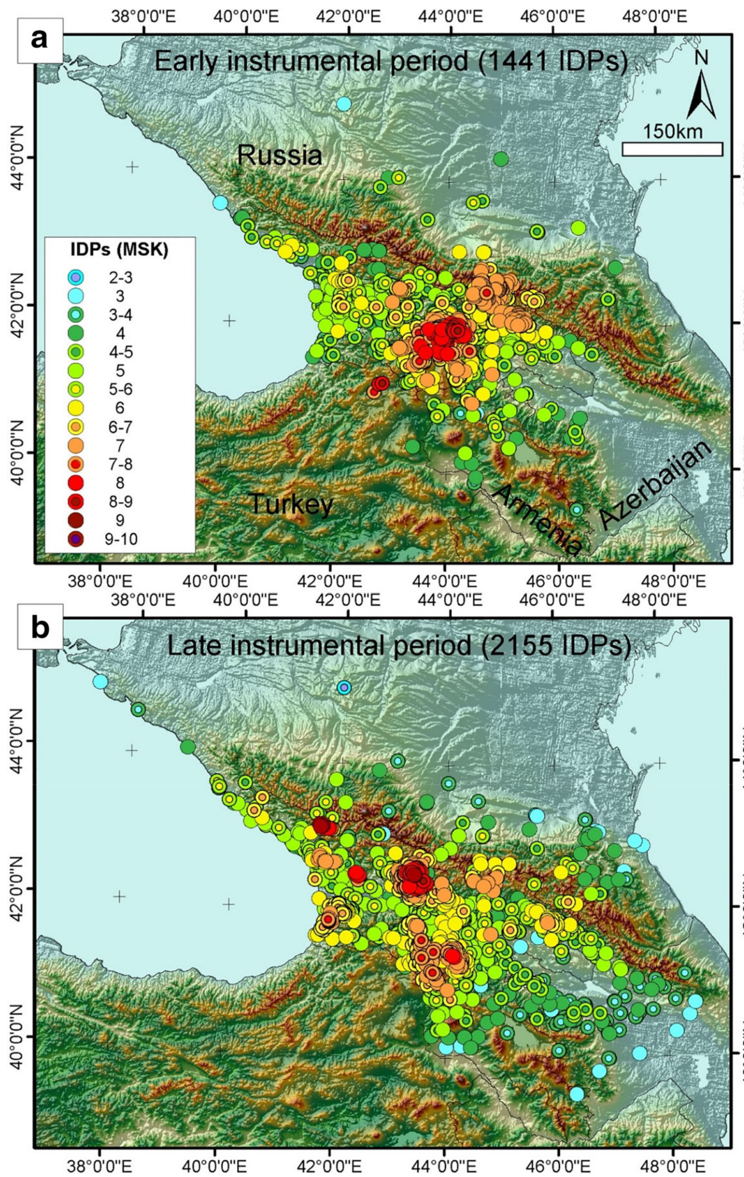


**Fig. 3** Distribution of the 3596 IDPs belonging to the instrumental period (post-1900 A.D.), filled circles represent the collected intensity data points (IDPs). **a** Distribution of the 1441 IDPs (out of 3596) associated with the 25 earthquakes considered in our study, taking into account the time window between 1900 A.C. and 1955 A.D.—early instrumental period. **b** Distribution of the 2155 IDPs (out of 3596) associated with the 42 earthquakes belonging to the late instrumental period (between 1956 A.D. and 2012 A.D.). Color code for IDPs is from Locati et al. (2014)

represented ones. Considering the same dataset but from another point of view, we have plotted the frequency of IDPs in terms of magnitude values (Fig. 4c). The most represented magnitude is 4.5–5.0, followed by 6.0–6.5, 5.0–5.5, 4.0–4.5, 5.5–6.0, and 6.5–7.0. It is worth noting that magnitude values 3.0–3.5, 3.5–4.0, and 7.0–7.5 are the least represented ones.

The rose plot in Fig. 4d represents the azimuthal distribution of each IDP with respect to the corresponding epicenter (as listed in the Georgian Seismic Database, Varazanashvili et al. 2011; Tsereteli et al. 2016a). The most represented azimuths are W, WNW, ESE, and SE respectively. Another observation derived from database analysis is that the greater is the magnitude, the wider is the interval of intensities, as shown in Fig. 4e. Since the GeoInt database is composed of earthquakes belonging to different periods, we present a further analysis focused on the HP and IP (EIP + LIP) in the following paragraphs.

## 4.2 Dataset description for the historical period

A total of 44 out of 111 earthquakes listed in GeoInt belong to the HP (epicenters are represented as white

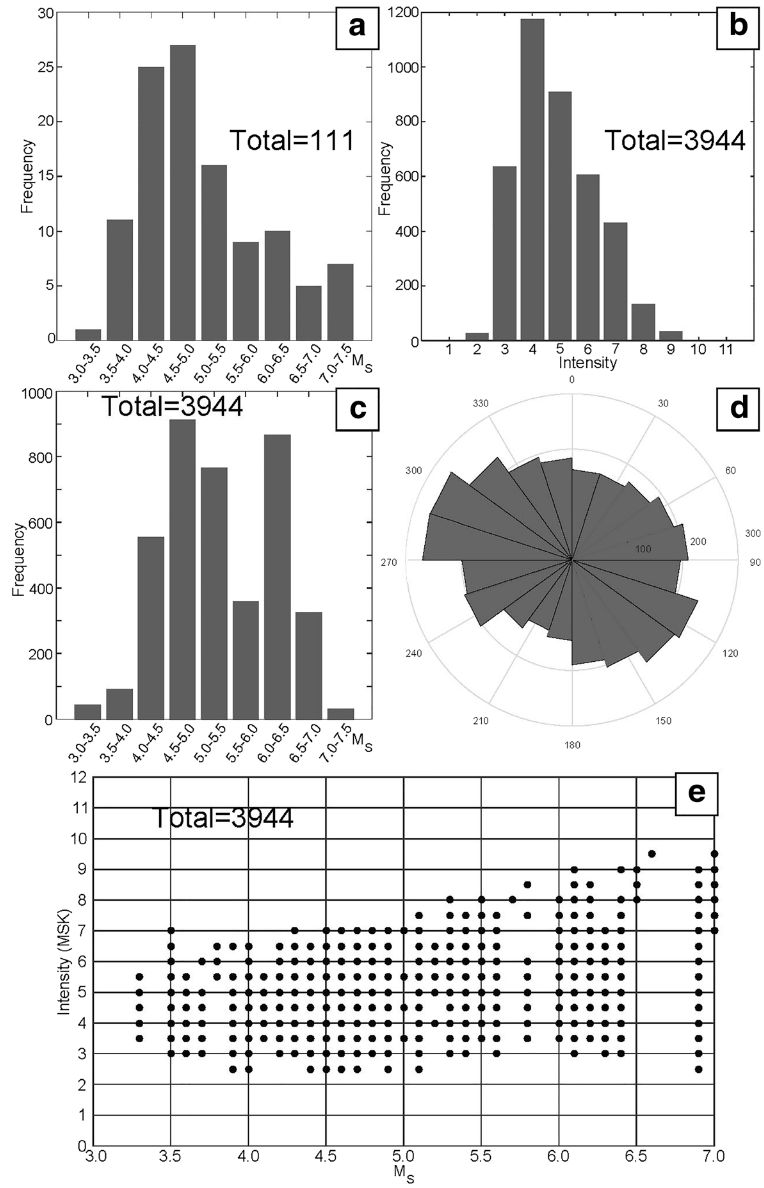


**Fig. 4** **a** Magnitude ($M_S$) frequency for the 111 events belonging to GeoInt database. **b** Intensity frequency for the entire macroseismic dataset. **c** Frequency of magnitude ($M_S$) for the 3944 IDPs. **d** Rose plot shows the azimuthal distribution of the whole set of IDPs. For each IDP, we have calculated the azimuth between the intensity data point and the corresponding epicenter. **e** Plot of intensity range vs. magnitude

squares in Fig. 1); they are all located within the Georgian borders and are characterized by a given depth comprised between 5 and 25 km and $M_S$ values between 3.5 and 7 (Varazanashvili et al. 2011) (Table 1). The 348 IDPs related to such subset of events are plotted in Fig. 2b. The areal coverage of the whole set of IDPs related to the HP extends from 39.758° N to 43.515° N and from 39.868° E to 47.430° E, with some IDPs located outside the Georgian border, in Armenia, Russia, and Azerbaijan. Intensity values are in the 3 to 9–10 range, and IDPs with values higher than 8 are mainly located along the western part of the Greater Caucasus (Fig. 2b).

Figure 5a shows the frequency of magnitude values ($M_S$) for the 44 earthquakes: It is worth highlighting that the most represented values are $M_S$ 4.0–4.5 and 7.0–7.5, followed by 3.5–4.0, 4.5–5.0, and 6.0–6.5. The intensity frequency shown in Fig. 5b is characterized by the predominance of intensity values equal to 4, which comprises more than 80 IDPs. Figure 5c shows that a clear majority of IDPs is characterized by $M_S$ 6.0–6.5, while the rose plot in Fig. 5D shows that the whole set of IDPs has a predominantly ESE, WNW, and N-S trending azimuthal distribution with respect to the corresponding epicenter. The plot of intensity ranges vs.

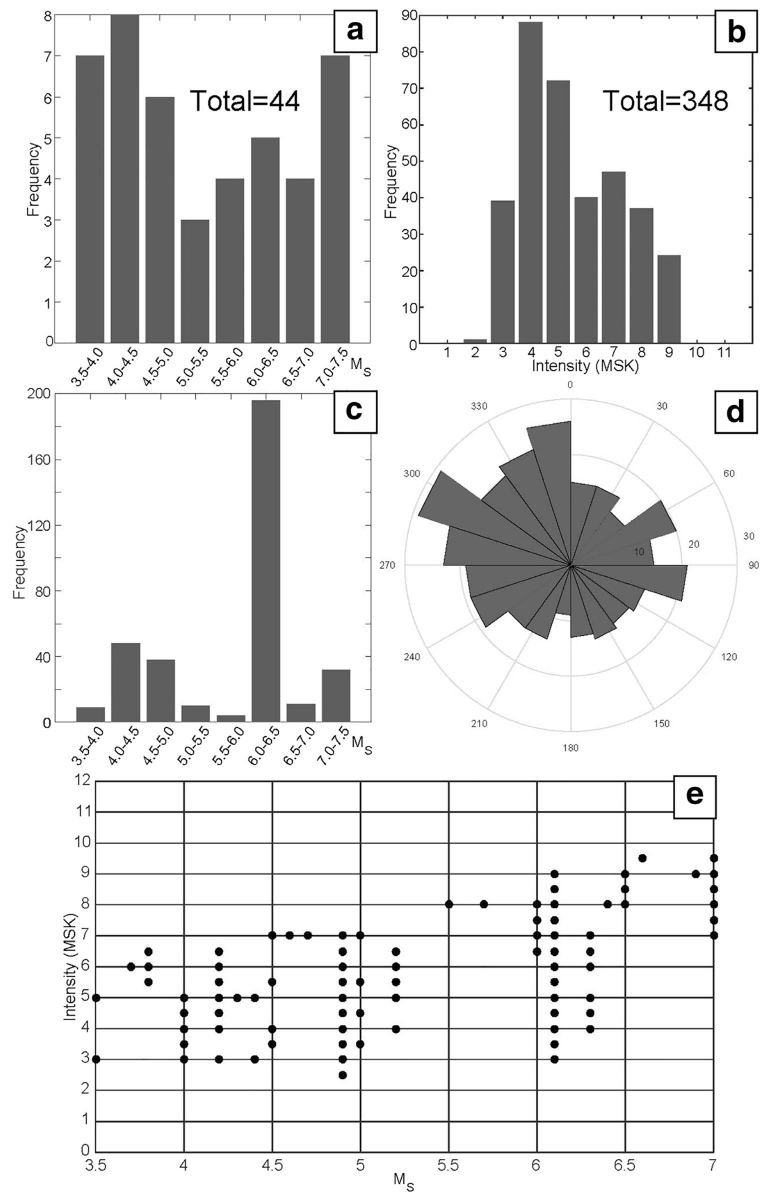


**Fig. 5** **a** Magnitude ($M_S$) frequency of the 44 events belonging to the HP. **b** Intensity frequency of the entire IDPs dataset belonging to the HP. **c** Frequency of magnitude ($M_S$) for the 348 IDPs. **d** Rose plot shows the azimuthal distribution for the whole set of IDPs. For each IDP, we calculated the azimuth between the intensity data point and the corresponding epicenter. **e** Plot of intensity range vs. magnitude

magnitude values in Fig. 5e shows a clear discontinuity in terms of intensity values with respect to the whole set that includes also the IP (Fig. 4e) and does not show a clear increase in the range of intensities as magnitude increases.

### 4.3 Description for the dataset belonging to the instrumental period

The instrumental period subset includes 3596 IDPs, related to 67 earthquakes (from 1908 to 2012 A.D.). Such subset of earthquakes is represented in Fig. 1 (blue and black squares for EIP and LIP, respectively): They are mostly located within the Georgian border (with the exception of one event, located in Turkey) and are characterized by depths between 2 and 36 km and magnitude values ranging from $M_S$ 3.3 to 6.9 (Table 1).

The set of IDPs belonging to the IP (intensity ranging from 2–3 to 9) is reported in Fig. 3: the areal coverage extends from 39.508° N to 45.043° N and from 37.324° E to 48.500° E, with some IDPs outside the Georgian border, in Armenia, Russia, and Azerbaijan. Figure 3a shows IDP distribution for the EIP, with a total number of 1441 IDPs related to 25 earthquakes, and Fig. 3b shows IDPs distribution for the LIP, with a total number of 2155 IDPs related to 42 earthquakes.

The EIP is characterized by IDPs with an aerial coverage that extends from 39.513° N to 45.043° N and from 39.726° E to 47.117° E. These IDPs are located mainly within the Georgian territory; some are scattered between Russia, Turkey, Armenia, and Azerbaijan (Fig. 3a). The highest intensity values are concentrated in a cluster, centered within the topographic depression that lies between the Greater and Lesser Caucasus, in the central sector of the country. The whole set of IDPs belonging to the LIP extends from 39.508° N to 45.033° N and from 37.324° E to 48.500° E (Fig. 3b). Some IDPs are located outside the Georgian border between Russia, Turkey, Azerbaijan, and Armenia. The IDPs with the highest intensity values are concentrated in four clusters, located along the front of the Greater Caucasus and Lesser Caucasus.

The events that belong to the instrumental period and are part of GeoInt have magnitudes ($M_S$) ranging from 3.3 to 6.9; the most represented magnitude values are the $M_S$ classes 4.5–5.0, 4.0–4.5, and 5.0–5.5 (Fig. 6a). Intensity values range from 2–3 to 9 (Fig. 6b); the most represented class is 4 (characterized by the highest

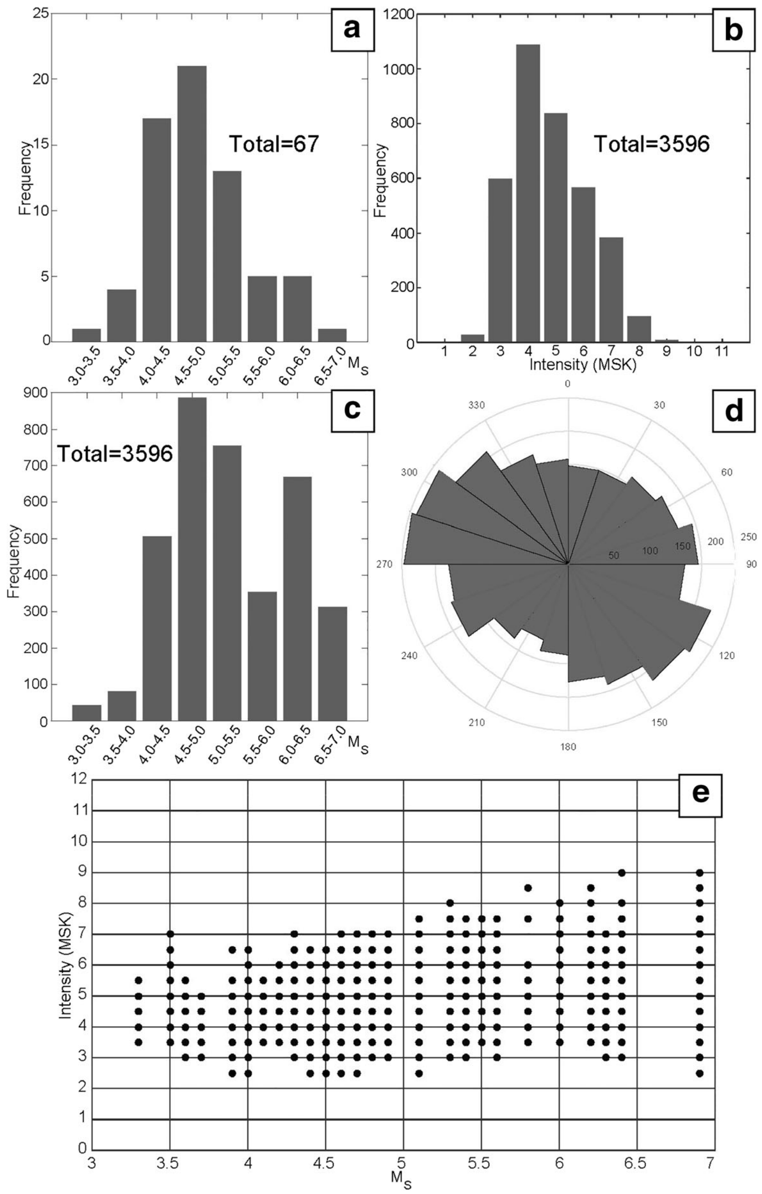


**Fig. 6** **a** Magnitude ($M_S$) frequency for the 67 events belonging to the instrumental period (IP). **b** Intensity frequency for the macroseismic dataset (IP). **c** Frequency of magnitude ($M_S$) for the 3596 IDPs. **d** Rose plot shows the azimuthal distribution for the whole set of IDPs. For each IDP, we have calculated the azimuth between the intensity data point and the corresponding epicenter. **e** Plot of intensity range vs. magnitude

frequency (> 1000)), followed by 5, 3, and 6. Classes 7 and 8 are less represented, and classes 2 and 9 are the least represented ones. In Fig. 6c, we show the frequency of IDPs in terms of magnitude values. The most represented magnitude is 4.5–5.0, followed by 5.0–5.5, 6.0–6.5, 4.0–4.5, 5.5–6.0, and 6.5–7.0. Furthermore, magnitude values 3.0–3.5 and 3.5–4.0 are the least represented ones.

The rose plot in Fig. 6D represents the azimuthal distribution of each IDP with respect to the corresponding epicenter. The most represented azimuths are W, WNW, ESE, and SE, respectively. Another observation derived from the database analysis is that the greater is the magnitude, the wider is the interval of intensities, as shown in Fig. 6e.

Owing to the huge amount of data belonging to the IP, the distribution of the collected IDPs is mapped for each entire value of MSK intensity (Fig. 7). As we can observe, IDPs with intensity values (MSK) of 2 and 2–3 (thus, not entirely 3) are mainly concentrated in the eastern sector of Georgia, with some IDPs located outside the border, mainly in Armenia and Azerbaijan, and just one in Russia (Fig. 7a). IDPs with intensity values of 3 and 3–4 mostly cover the whole Republic of Georgia, though some data are located in Russia (to the north), Azerbaijan (to the east) and Armenia (to the

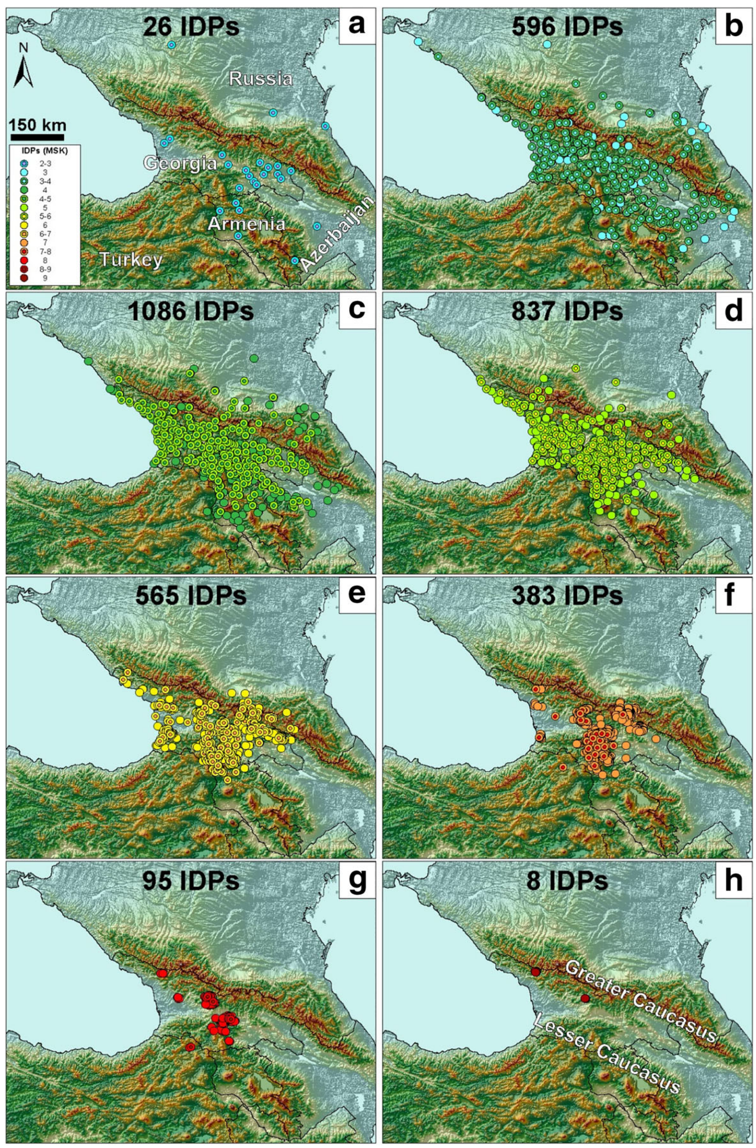


**Fig. 7** Distribution of IDPs belonging to the instrumental era, classified for each value of MSK intensity, from 2 to 9 (**a**–**h**, respectively). Values that are not entirely related to the upper class are represented in the lower class; for example, values between 8 and 9 (8–9) belong to class 8 (**g**). For each class, the number of IDPs is reported. Color code for IDPs is from Locati et al. (2014)

south) (Fig. 7b). The above observations are also valid for intensities 4 and 4–5, 5, and 5–6 (Fig. 7c, d). On the other hand, intensity values of 6 and 6–7, 7, and 7–8 are mainly located within Georgian borders (Fig. 7e, f). More in detail, intensities belonging to class 6 (Fig. 7e) show two main areas of data clustering, respectively, along the western coast and in the central-eastern part of the country. In the latter, it is possible to clearly observe three different concentrations, two of which located along the Lesser and Greater Caucasus and one within the Kura Basin area. Intensities belonging to class 7 show two clusters, one located in the central part of the Lesser Caucasus and one in the central part of the Greater Caucasus (Fig. 7f). Some data are also present within the western Greater Caucasus and at its foothills.

Intensities 8 and 8–9 are located in western and central Georgia, in the Greater and Lesser Caucasus, respectively, as well as at their foothills (Fig. 7g). The greatest intensity (9) is represented by points entirely located along the Greater Caucasus, in the central and western part of Georgia (Fig. 7h).

A further consideration for the IDPs related to the IP is relative to their distance from the earthquake focal source: Each intensity value was plotted versus the hypocentral distance, whose values range between 2 and 446 km (Fig. 8a). At a general level, the graph shows an attenuation of intensities with increasing distance. Furthermore, the intensity values (20 km binned) are represented by classes and related to the hypocentral distance (Fig. 8b). Apart from the 0–20 km class, it is possible to notice that all intensities decrease in frequency with distance: Intensity 9 is represented within 40 km, and so is intensity 8; class 7 is represented up to 60 km. Intensity 6 is present up to 160 km, intensity 5 is present as far as 200 km. At greater distances, only intensities 4 and 3 are present: intensity 4 disappears as far as 280 km whereas class 3 reaches the maximum distance but

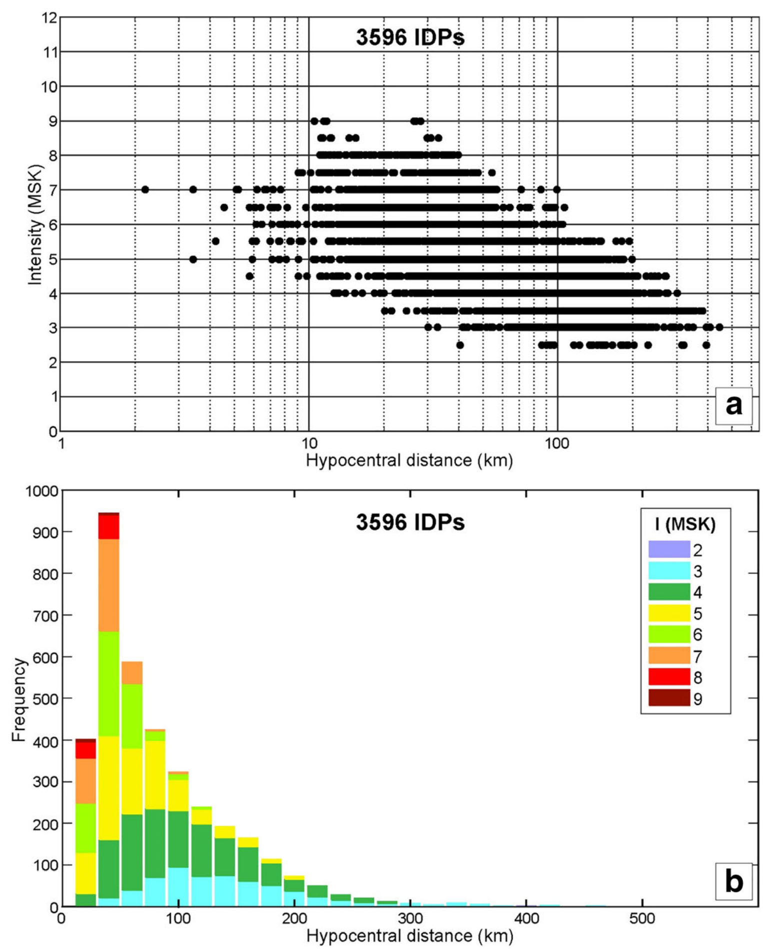


**Fig. 8** **a** Distribution of the 3596 IDPs (belonging to the IP) plotted versus hypocentral distance. **b** Frequency distribution of hypocentral distances (20 km bins) for the entire dataset; intensity values are color-coded. Values that are not entirely related to the upper class are represented in the lower class: for example, values between 8 and 9 (8–9) belong to class 8. Color code for IDPs is modified after Locati et al. (2014)

is not represented within the first 20 km from the hypocenter. Intensity 2 is poorly represented.

### 4.4 Time window observations

The magnitude values ($M_S$) of all the earthquakes comprised in GeoInt, thus including both the HP and the IP, are represented versus the date of earthquake occurrence in Fig. 9a. Moreover, Fig. 9b shows the relation between earthquake occurrence and the number of IDPs. As we can observe, the number of IDPs, as well as the $M_S$ range, has dramatically increased during the IP, which includes the majority of earthquakes in our database. Moreover, the number of earthquakes in GeoInt has increased over the late instrumental period (LIP, Fig. 10a)—42 out of 67—as well as the number of corresponding IDPs (Fig. 10b)—1441 and 2155 for the early and late instrumental periods, respectively. Furthermore, the most powerful earthquakes during the instrumental period are the 1991, $M_S$ 6.9 event, known as Racha earthquake, and the 1963, $M_S$ 6.4 event, known as Chkhalta earthquake (Fig. 10a and Table 1). In total, for the IP, six earthquakes have $M_S \geq 6$, 18 events are between $M_S$ 5 and 6 and the remaining 43 have $M_S < 5$. We have not observed any relation between date of occurrence and earthquake magnitude. Regarding the number of IDPs per earthquake, the two most represented seismic events are the 1991 Racha earthquake and 1940 Tabatskuri earthquake (Table 1), with 313 and 370 IDPs, respectively (Fig. 10b). Also in this case, there is no relation between the number of IDPs and the date of occurrence of the earthquakes.

From another point of view, by considering the localities that are listed in the database, we noticed that some cities were struck by a large number of earthquakes (Fig. 11a). Such cities are represented as red and yellow circles, hit by more than 50 and 40–50

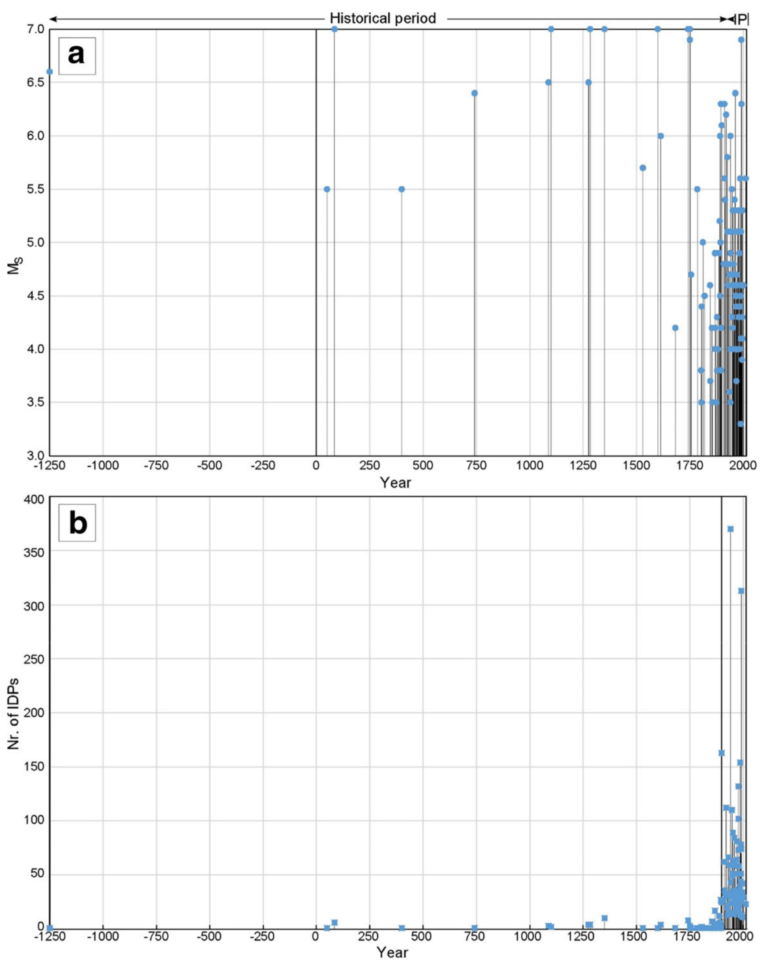


**Fig. 9** **a** Plot of earthquake magnitudes ($M_S$) vs. date of earthquake occurrence, representing each event in the database. **b** Number of IDPs vs. date of earthquake occurrence, representing each event. Events have been divided into historical period (HP) and instrumental period (IP)

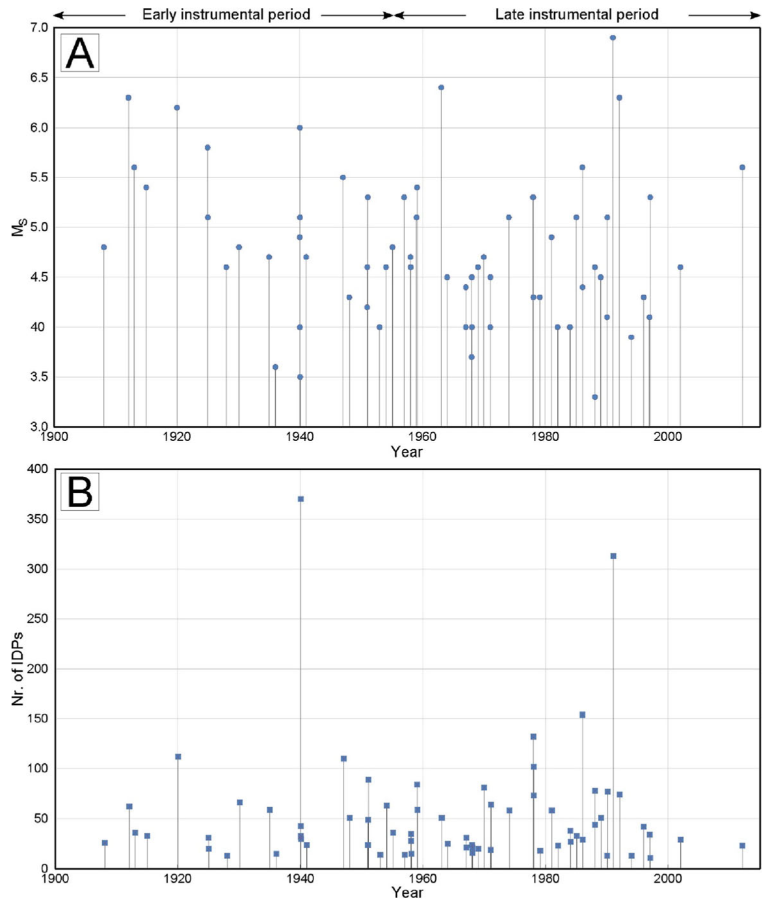


**Fig. 10** **a** Plot of earthquake magnitudes ($M_S$) vs. date of earthquake occurrence, representing each event belonging to the instrumental era. **b** Plot of number of IDPs vs. date of earthquake occurrence, representing each event. Events have been divided into early instrumental period (EIP) and late instrumental period (LIP)

earthquakes respectively. In particular, the three cities with the highest frequency of events are Tbilisi (hit 53 times), Gori (hit by 47 earthquakes), and Borjomi (hit by 41 earthquakes).

Furthermore, the sites characterized by the highest cumulated intensity values (with minimum intensity values greater or equal to 6) are represented in Fig. 11b. Those are (i) Tbilisi, with a cumulated value of 221; (ii) Gori, with a cumulated value of 198; (iii) Borjomi and Akhalkalaki, with a cumulated value of 176 and 175; and (iv) Bakuriani, with a cumulated value of 174.

Since Tbilisi and Gori are the two Georgian cities that have been the most affected by earthquakes (hit 53 and 47 times, respectively, and characterized by cumulated intensity values of 221 and 198, respectively), we plotted the maximum intensity value (MSK) for each earthquake (Fig. 12a, b), considering all the events that hit them from their foundation until present days. Both cities have been subjected to a maximum intensity value of 8–9 (1275 M 6.5 Mtskheta earthquake for Tbilisi and 1920 M 6.2 Kartli earthquake for Gori), and in both cases, we noticed a lack of information in the time intervals spanning from 450 (year of foundation) to 1682 for Tbilisi and from 1100 (year of foundation) to 1805 for Gori. The red line shows the limit above which damage to buildings is reported, according to Medvedev et al. (1965), showing that both cities suffered from damage in the past.

## 4.5 Macroseismic data collection and revision

In this section, we describe the procedures related to the collection and selection of macroseismic information: We looked through all available sources reporting original description of macroseismic observations, most of which are books (listed in Table 2). In these books are listed: (i) IDPs with assigned intensity and coordinates; (ii) localities with description but without any assigned intensity value; (iii) localities with description and

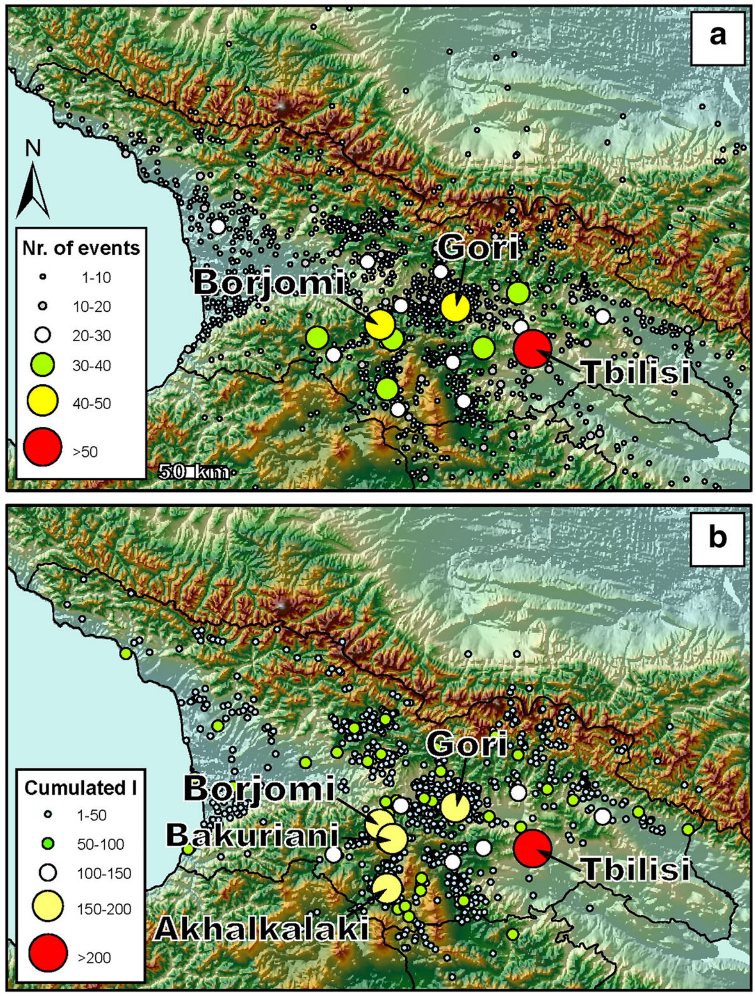


**Fig. 11** **a** Localities listed in GeoInt, sized and colored according to the number of earthquakes that hit them. Tbilisi was struck 53 times, Gori 47 times, and Borjomi 41 times. **b** Localities with minimum intensity greater than 5, sized and colored with cumulated intensity values. Tbilisi cumulated a value of 221, Gori 198, Borjomi 176 and Akhalkalaki 175, and Bakuriani 174

assigned intensity value but without coordinates; and (iv) IDPs with assigned intensity and locality but with wrong name. The latter is due to the fact that many settlements were renamed several times during the former Soviet Union. As a result, names of old settlements were often misinterpreted because of the difficulty to find their present name. Furthermore, in the former Soviet Union the exact geographical coordinates of some settlements were kept secret. Thus, it was difficult to find the exact geographical coordinates in previous works. We revised all intensity values by (i) reading original descriptions and assigning new intensity values and (ii) finding missing (secret) and wrong localities (in terms of geographic coordinates). The reevaluation of IDP values from MCS to MSK scale of intensity has been performed for only two sources: Byus (1948) and Byus (1952). As is known, those scales are somehow different, but anyway they yield almost the same intensity estimation (Shebalin 1975). In order to avoid any possible inaccuracy, we read all descriptions associated with each intensity value and assigned values in MSK scale. Finally, during the process of intensity revision, we did not notice any tendency regarding the over-/underestimation of intensity values.

The 111 earthquakes we analyzed are characterized in terms of their location, magnitude, and focal depth (Fig. 1 and Table 1), and at least one IDP. The IDPs listed in GeoInt are characterized by a defined location and intensity assignment (Fig. 2a).

The histogram in Fig. 13a shows that the information about the earthquakes belonging to the HP has been acquired from a previous work (Varazanashvili et al. 2011), which presents both the methodology for estimating macroseismic intensity as well as

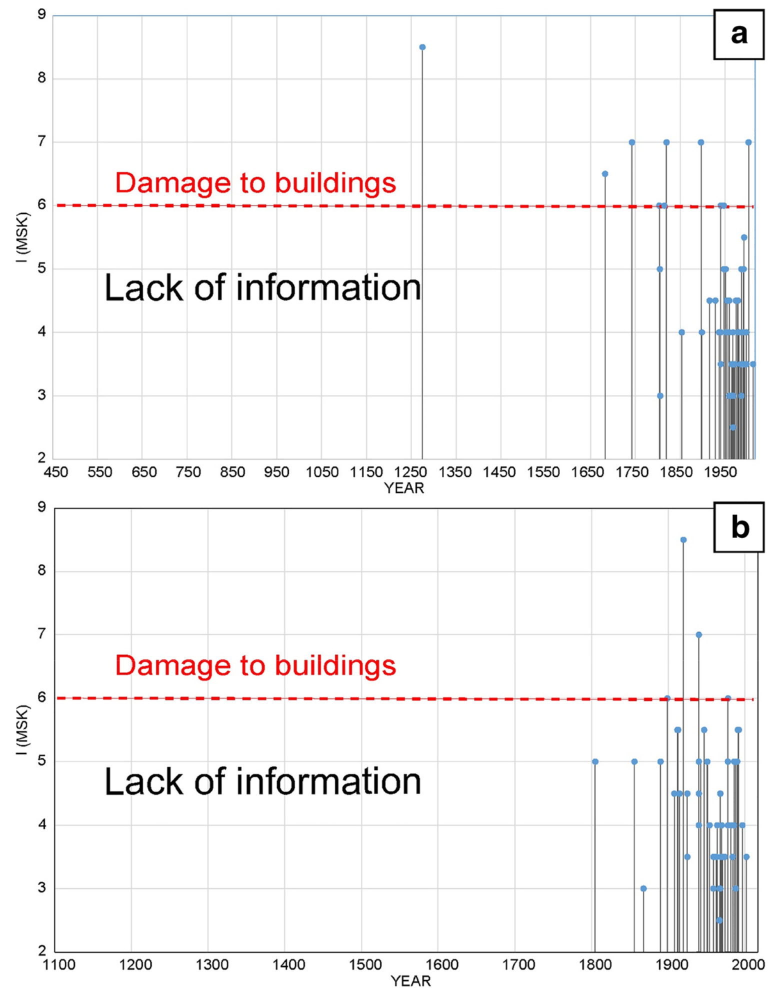


**Fig. 12** Plot of maximum intensity value vs. the date of earthquake occurrence for Tbilisi (**a**) and Gori (**b**). The time window represented for both cities spans from their foundation up to today

earthquake parameters (location, magnitude). Sources used in the book are as follows: Malinovskiy (1935), Stepanyan (1942), Byus 1948 1952), Shebalin (1968), Tskhakaia and Papalashvili (1973), Shebalin et al. (1976), Jackson et al. (1997), New Catalog of Strong Earthquakes in the USSR (1977), Shebalin and Tatevosian (1997), Mushketov and Orlov (1893), Khromovskikh, and Nikonov (1984), Khromovskikh et al. (1979, 1984), Makrushina and Shebalin (1982), Papalashvili and Makhatadze (1984), Varazanashvili and Papalashvili (1998), and Varazanashvili et al. (2011). A brief description of the above references is given in Table 2.

Varazanashvili et al. (2011) focused on the following: (i) the compilation of all available sources of information; (ii) the parameterization of historical earthquakes based on macroseismic field equations; (iii) the evaluation of the quality and accuracy of the received parameters; (iv) the use of isoseismal models for earthquakes with various magnitudes elaborated for Georgia over the instrumental period; (v) the reconstruction of historical earthquakes with few macroseismic data; and (vi) a thorough analysis of macroseismic, archeological, seismotectonic, geomorphological, and other types of data. We need to underscore that, for 61 out of 67 earthquakes belonging to the IP, intensity values have been revised and newly assigned (Fig. 13a).

Regarding the whole set of IDPs, Fig. 13b shows that 3035 (77%) intensity values have been checked and confirmed, and 804 (20%) have been revised (changed); moreover, 105 (3%) intensity values are totally new.

The earthquakes belonging to the IP have been selected based on the presence of complete and reliable descriptions of their macroseismic effects and have been revised. For such earthquakes, comprised between 1900

**Table 2** Source list of references used in building up the GeoInt database. Most are in Russian language; a brief description is provided, as well as the indication of the site where they are available

| Reference | Type | Title | Description | Language | Availability |
|---|---|---|---|---|---|
| Agalarova et al. 1985 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1982 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Agalarova et al. 1987 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1984 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Agalarova et al. 1988 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1985 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Akhalbedashvili 1970 | Book | Khashmskoe zemletryasenie v iyune 1967 goda | Macroseismic information for the 1967 the Khashmi earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Akhalbedashvili et al. 2006 | Book | Tbilisis seismurobis shesakheb | Seismicity of Tbilisi | Georgian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Ayvazishvili et al. 1973 | Book | Zemletryasenie 3 yanvarya 1970 goda v Borzhomskom payone | Macroseismic information for the 3 January 1970 earthquake occurred in the Borjomi area | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Byus 1948 | Book | Seysmicheskye usloviya Zakavkaz'ya | Macroseismic information | Russian | Georgian Technical University Library. Tbilisi (Georgia) http://opac.gtu.ge/cgi-bin/koha/opac-detail.pl?biblionumber=21203 |
| Byus 1952 | Book | Seysmicheskye usloviya Zakavkaz'ya | Macroseismic information | Russian | Georgian Technical University Library. Tbilisi (Georgia) http://opac.gtu.ge/cgi-bin/koha/opac-detail.pl?biblionumber=21203 |
| Gotsadze and Tutberidze 1986 | Book | Coordinaty ochagov glavnogo i posleduyshchikh zemletryaseniy | Coordinates of hypocenters of the main and subsequent earthquakes | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Kalinin et al. 1982 | Book | Makroseysmicheskoe obsledovanie zemletryaseniya v rayone Inguri GES 27 dekabrya | Macroseismic investigation of the 1979 earthquake occurred at the Enguri Dam Area | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Kondorskaya and Shebalin 1982 | Book | New catalog of strong earthquakes in the USSR from Ancient Times through 1977 | Earthquake catalog with some macroseismic information (for specific earthquake) | English | Online at ftp://ftp.ngdc.noaa.gov/hazards/publications/Wdcse-31.pdf |
| Lebedeva et al. 1970 | Book | Paravanskoe zemletryasenie 29 iyunya 1967 goda | Description of the 29 June 1967 Paravani earthquake | Russian | Description of the 29 June 1967 Paravani earthquake |
| Macroseismic data from archives of the TSU M. Nodia Institute of Geophysics | Report | – | Unpublished macroseismic data | Georgian | Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Makhatadze et al. 1996 | Book | Zemletryasenie 16 dekabrya 1990 goda na Djhavakhetskom nagorye v rayone oz. Sagamo | Description of the 16 December 1900 earthquake (Javakheti Highlands, area of Lake Sagamo) | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |

**Table 2** (continued)

| Reference | Type | Title | Description | Language | Availability |
|---|---|---|---|---|---|
| Makhatadze et al. 1997 | Book | Zemletryasenie 23 oktyabrya 1992 goda v Gudamakarskom ushchelie | Description of the 23 October 1992 Gudamakari | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Mukhadze and Papalashvili 2003 | Book | Khashminskoe-IV zemletryasenie 27 noyabrya 1997 goda c $M_W = 5.3$, $Io = 7$ (Gruziya) | Description of the 27 November 1997 Khashmi earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Napetvaridze 1984 | Book | Gavazskoe zemletryasenie 23 fevralya 1981 goda | Description of 1991 earthquake occurred in Gavaszi area, Georgia | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili 1997 | Book | Seysmicheskie usloviya Kavkaza | Seismic conditions of Caucasus | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili and Butikashvili 1996 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1990 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili and Butikashvili 2003 | Book | Paravanskoe-II zemletryasenie 9 fevralya 1997 goda c MLH = 4.5, $Io = 5–6$ (Gruziya) | Description of 9 February 1997 Paravani II | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili et al. 1991 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1988 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili et al. 1982 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1978 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili and Agalarova 1993 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1989 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili et al. (1991) | Book | Zemletryasenie 6 sentyabrya v Kobuletskom rayone Adzharskoy ASSR | Description of the 6 September 1988 earthquake (Kobuleti area) | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili 1997 | Book | Racha-Javskoe zemletryasenie 29 aprelya 1991 goda | Description of the 29 April 1900 Racha-Java earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili et al. (2000) | Book | Gruziya | – | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Papalashvili et al. (2002) | Book | Askanskoe zemletryasenie 28 maya 1996 goda c Kp = 11.7, $Io = 6–7$ | Description of the 28 May 1996 Askana earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Pataraya 1957 | Book | Gomaretskoe zemletryasenie 11 yunya 1954 goda | Description of the 11 June 1954 Gomareti earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Tskhakaia 1949 | Book | Gudamakarskoe zemletryasenie 15 avgusta 1947 g | Description of the 15 August 1947 Gudamakari earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Tskhakaya 1973 | Journal | Gegechkorskoe zemletryasenie v yanvare 1957 g | Description of the 1957 Gegechkori earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Tskhakaya and Dzhibladze 1972 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1968 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |

**Table 2** (continued)

| Reference | Type | Title | Description | Language | Availability |
|---|---|---|---|---|---|
| Tskhakaya and Dzhibladze 1973 | Book | Zemletryaseniya Kavkaza | Earthquakes occurred in Caucasus region during the 1969 A.D. | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Tskhakaya and Papalashvili 1973 | Book | Seysmicheskye usloviya Kavkaza | Seismic conditions of Caucasus | Russian | Georgian Technical University Library, Tbilisi (Georgia) http://opac.gtu.ge/cgi-bin/koha/opac-detail.pl?biblionumber=21203 |
| Tsakaya et al. 1967 | Book | Chkhaltinskoe zemletryasenie | Description of the 1963 Chkhalta earthquake | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Unpublished instrumental data. Archives of the TSU M. Nodia Institute of Geophysics | Report | – | Unpublished instrumental data | Georgian | Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Varazanashvili 2017 | Report | – | Unpublished macroseismic data | Georgian | Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Varazanashvili et al. 1989 | Book | Paravanskoe (Abul-Samsarskoe) zemletryasenie 13 maya | Description of the Paravani (Abul-Samsari) earthquake occurred on 13 May, 1986 | Russian | Library at the TSU M. Nodia Institute of Geophysics, Tbilisi (Georgia) |
| Varazanashvili et al. 2011 | Book | Historical earthquakes in Georgia (up to 1900): source analysis and catalog compilation | Description of Historical earthquakes occurred in the Georgian territories | English | On site, at the University of Milano-Bicocca (Italy) and the Nodia Institute of Geophysics, Tbilisi (Georgia) |

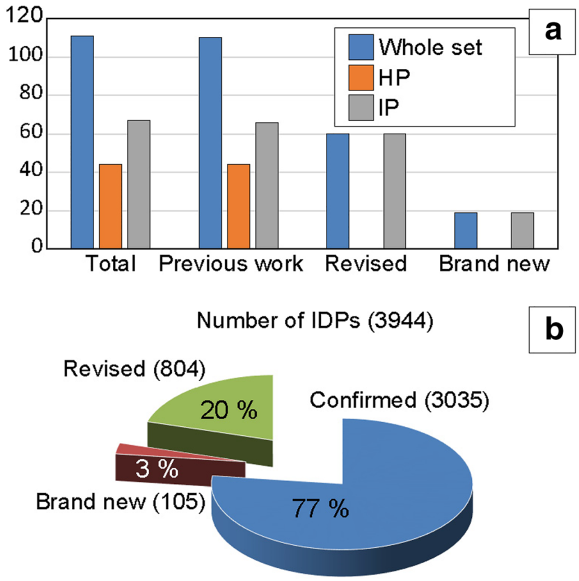


**Fig. 13** **a** Histogram showing (i) the total number of earthquakes listed in GeoInt (111); (ii) the number of earthquakes reporting IDPs from previous works (110); (iii) the number of earthquakes reporting revised IDPs (60); and (iv) the number of earthquakes with brand new IDPs (19). **b** Pie chart showing the number of intensity values which have been confirmed in the present work as well as IDPs that are brand new or revised, belonging to the whole catalog

and 2012 A.D., the macroseismic intensity was revised and new IDPs have been identified, totaling 3596 places with associated intensity values. In regard to earthquakes: (i) for 66 events, IDPs were already present in the literature; (ii) for 60 events, intensity values have been revised (and changed); and (iii) for 19 events, brand new IDPs have been identified and added to the list (Fig. 14a). By considering the EIP and LIP respectively, the number of earthquakes is greater for the LIP; moreover, there is a greater number of previous works that focused on the study of macroseismic effects in Georgia. On the contrary, the number of earthquakes with brand new IDPs is greater for the EIP (Fig. 14a).

At a general level, considering the whole set of IDPs for the instrumental era, 105 are new (3%), whereas the intensity values of 804 IDPs have been reevaluated (22%); furthermore, for 2155 IDPs (75%), intensity values have been confirmed from previous interpretations (Fig. 14b). By distinguishing the IDPs set in EIP (Fig. 14c) and LIP (Fig. 14d) respectively, we have been able to notice that (i) 1727 (80%) IDPs for the LIP and 960 (70%) IDPs for the EIP have been confirmed, whereas (ii) 396 IDPs for the LIP (18%) and 408 IDPs for the EIP (28%) have been revised. In both cases, new IDPs are present: 73 (5%) for the EIP and 32 (2%) for the LIP. We wish to emphasize that, in percentage, the revision process has resulted in a greater number of revised IDPs for the EIP.

In the process of revision of macroseismic material, we have carefully analyzed all sources of information and the quality of the relevant data. The final changes in the intensity estimates have been performed taking into account the entire set of available data as well as the accuracy in the determination of the intensity. The date and time of occurrence of earthquakes have been checked and refined, mainly based on early, primary sources that are fully listed and described in Table 2 (description, original language, hosting site).

For the HP, all IDPs (348) are from Varazanashvili et al. (2011). For the EIP, a first set of IDPs (932) was proposed by Byus (1948) who studied earthquakes until 1943 A.D. (Table 1) and reported intensity values using the Mercalli-Cancani-Sieberg scale (MCS). We have reevaluated 331 out of these 932 intensity values (IVs) and have identified 71 new IDPs.

A total of 161 IDPs are from Byus (1952) and Tskhakaia, (1949), for the time window 1947–1948 A.D.; for 18 of these, IVs have been reevaluated. For the time interval 1951 to 1955 A.D., another 262 IDPs are from Pataraya (1957), Tskhakaya, and Papalashvili (1973); for 59 of these, intensity values have been revised.

In regard to the LIP, 2123 IDPs are from previous works; IVs for 396 IDPs have been revised and 9 new IDPs have been identified, based on Tsakaya et al. (1967), Akhalbedashvili (1970), Lebedeva et al. (1970), Tskhakaya and Papalashvili (1973), Tskhakaya (1973), Tskhakaya and Dzhibladze (1972), Tskhakaya, and Papalashvili (1973), Papalashvili et al. (1982), Kalinin et al. (1982), Napetvaridze (1984), Agalarova et al. (1985 1987 1988)Varazanashvili et al. (1989), Balavadze and Chichinadze 1991 Papalashvili et al. (1991), Papalashvili (1997), Papalashvili and Agalarova (1993), Makhatadze et al. (1996), Papalashvili and Butikashvili (1996), Papalashvili (1997), Papalashvili et al. (2000), Mukhadze and Papalashvili (2003), Papalashvili and Butikashvili (2003), and Akhalbedashvili et al. (2006). Only the 23 IDPs related to the 2012 earthquakes are based on information from

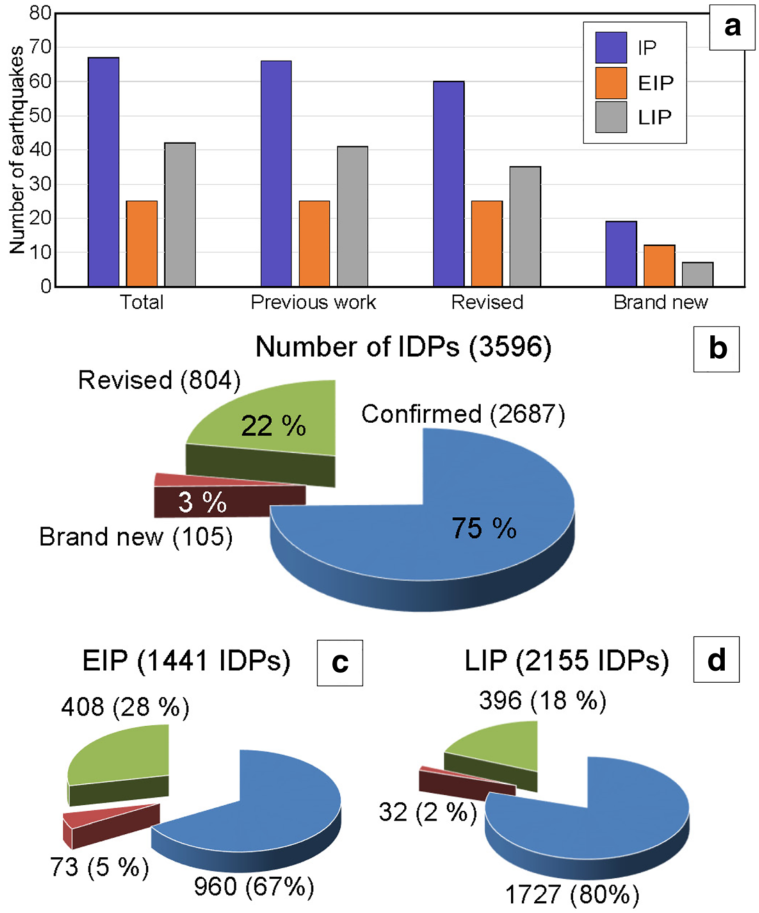


**Fig. 14** **a** Histogram showing (i) the total number of earthquakes listed in the database and belonging to the instrumental period (IP) (67); (ii) the number of earthquakes reporting IDPs from previous work (66); (iii) the number of earthquakes reporting revised IDPs (60); and (iv) the number of earthquakes with brand new IDPs (19). **b** Pie chart showing the number of intensity values that have been confirmed in the present work as well as IDPs that are brand new or revised, belonging the IP. **c**, **d** Same statistics as in **b** but with IDPs belonging to the early and late instrumental era, respectively (EIP and LIP)

newspapers and online interviews (Macroseismic data. Archives of the TSU M. Nodia Institute of Geophysics).

We hereby illustrate two examples: (i) the 1940 Tabatskuri earthquake (ID: 1940.05072223) ($M_S$ = 6.0, *Io* = 8 MSK), belonging to the EIP (Fig. 15) and (ii) the 1970 Borjomi earthquake (ID: 1970.01030654) ($M_S$ = 4.7, *Io* = 7 MSK), belonging to the LIP (Fig. 16). The old distribution of macroseismic intensity for the 1940 Tabatskuri earthquake, given by Papalashvili and Makhatadze (1984), is shown in Fig. 15a. The new IDPs set, presented here, stems from the revision of the main data source (Byus 1948) and is shown in Fig. 15b. Papalashvili and Makhatadze (1984) reported only 149 IDPs out of 380 described in the main source (Byus 1948). As a result of our revision process, we are now able to present a total of 370 IDPs (after Byus 1948); moreover, we determined 4 new IDPs and revised another 135 IDPs; in the Geoint database, intensity values for this earthquake range from 3 to 4 to 8.

The revision of the original macroseismic sources (Ayvazishvili et al. 1973) relative to the 1970 Borjomi earthquake, shown in Fig. 16a, has enabled us to find out that three IDPs, located 10 km east of the epicenter, are characterized by a greater intensity (now reaching 7 MSK) than previously identified (Fig. 16b). In our work, 27 out of 81 IDPs have been revised, and the remaining ones have been confirmed; in Geoint, intensity values for this earthquake range from 2 to 3 to 7.

## 5 The online version of GeoInt

The GeoInt database can be accessed through a user-friendly web interface, which grants free access to all IDPs (http://www.enguriproject.unimib.it/, Fig. 17). On the right hand side of the page, a menu titled "*GeoInt*

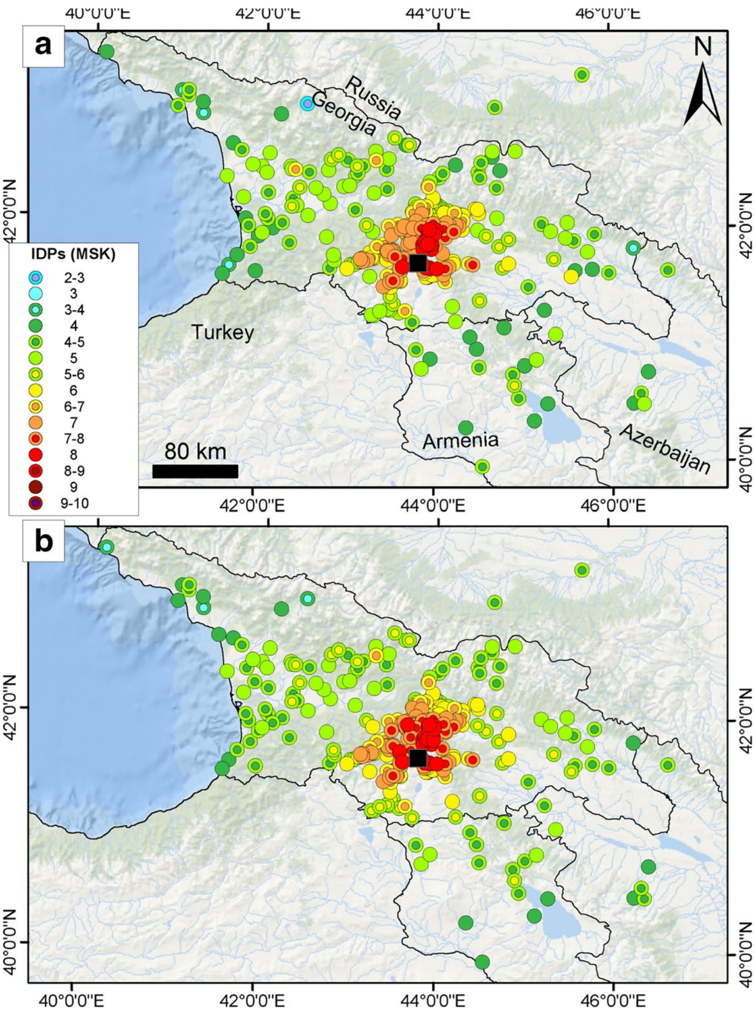


**Fig. 15** **a** Older IDPs distribution related to the 1940 Tabatskuri earthquake, based on Papalashvili and Makhatadze (1984). **b** Our revised IDPs distribution, after Byus (1948). The epicenter is represented as a black square. Color code from Locati et al. (2014)

*Database*" allows the user to get access to different pages. In the "*Introduction*" page there is a brief explanation of the content of the database.

In the page entitled "*Download Data*," the users can access all IDPs for free, upon registration; the IDPs, including epicenters, will automatically be sent by email. In the "*References*" page, a full list of references for earthquakes and IDPs is reported. In the "*Online Catalog*" page, the user can access an interactive map of the 111 selected earthquakes that took place during the historical and instrumental era, from 1250 B.C. to 2012 A.D. Epicenters are shown as squares, scaled as a function of magnitude. The users may access IDPs data in two different ways: either by clicking on the corresponding epicenter on the map, which can be zoomed and panned, or by clicking on the chosen earthquake from the list that can be found below the map. Whenever the user clicks on a given epicenter on the map, a table pops up, bearing the following information: name of the earthquake, ID, latitude, longitude, depth of the hypocenter, magnitude in terms of $M_S$ and $M_W$, date and time of occurrence, as well as a link to access the dedicated webpage and the relevant references. Below the map, all earthquakes are listed in chronological order, from the most recent (2012 A.D., Black Sea earthquake) to the oldest one (1250 B.C., Kvira earthquake): Each link on the list provides the date and time of occurrence of the earthquake, the magnitude ($M_S$), the area, the highest intensity (MSK) value and the ID. Epicenters are from Kondorskaya and Shebalin (1982), Gotsadze and Tutberidze (1986), Varazanashvili

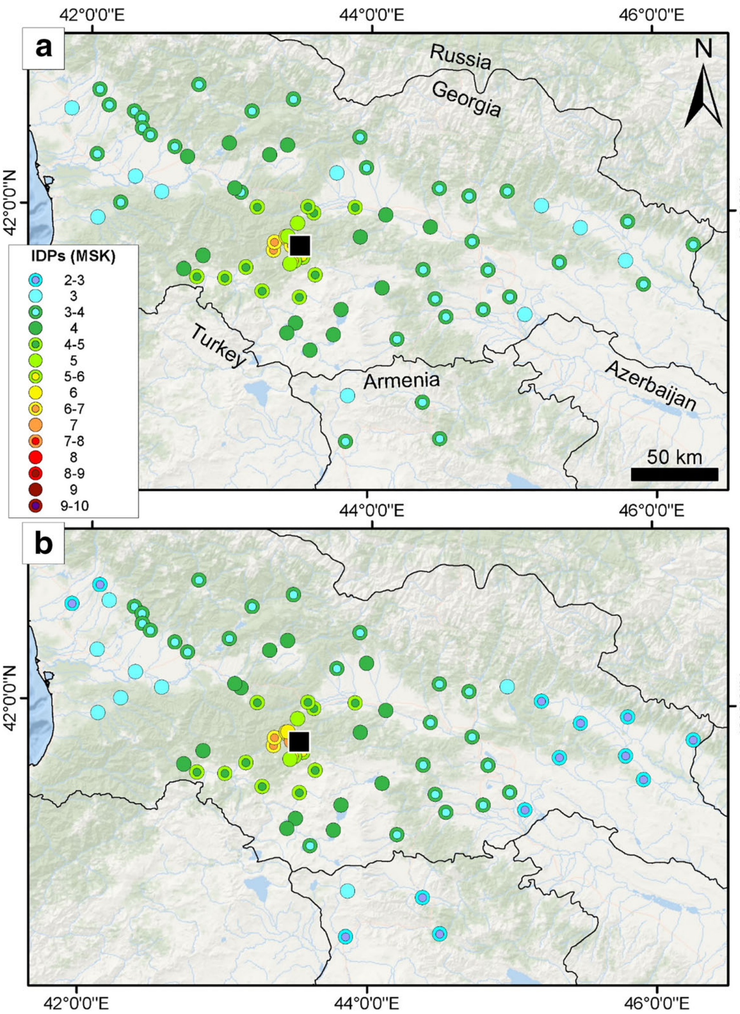


**Fig. 16** **a** Older IDPs distribution related to the 1970 Borjomi earthquake, based on Papalashvili and Makhatadze, (1984). **b** Our revised IDPs distribution, after Ayvazishvili et al. (1973). The epicenter is represented as a black square. Color code is from Locati et al. (2014)

(2017) and unpublished data (Archives of the TSU M. Nodia Institute of Geophysics).

In order to further illustrate our approach, we provide, as an example, details on the 1991 $M_S$ 6.9 Racha earthquake (Fig. 18). Once the earthquake is selected, a separate page opens up, featuring all the available information. The top of the webpage showcases a brief description of the earthquake, including the hypocentral depth, the name of the associated fault, the IDPs range and the location. Below, an interactive map contains the epicenter together with all the collected IDPs: by clicking on each IDP, a table shows the name of the place, latitude and longitude, intensity (MSK) value and source of the data. Further below, some statistics associated with the earthquake are provided, including IDPs number, areal extent and the range of hypocentral distances. At the bottom of the page, a set of graphs enable providing a more in-depth analysis of the earthquake (Fig. 19): (i) top left, intensity frequency for the selected seismic event; (ii) frequency distribution of hypocentral distances (20 km bins); (iii) bottom left, rose plot showing the azimuthal distribution of IDPs with respect to the epicenter; and (iv) bottom right, distribution of the IDPs plotted versus hypocentral distance.

## 6 Discussion and conclusions

As a result of our work, we have been able to set up the first reliable macroseismic database for the Republic of Georgia, hereby entitled "GeoInt." The

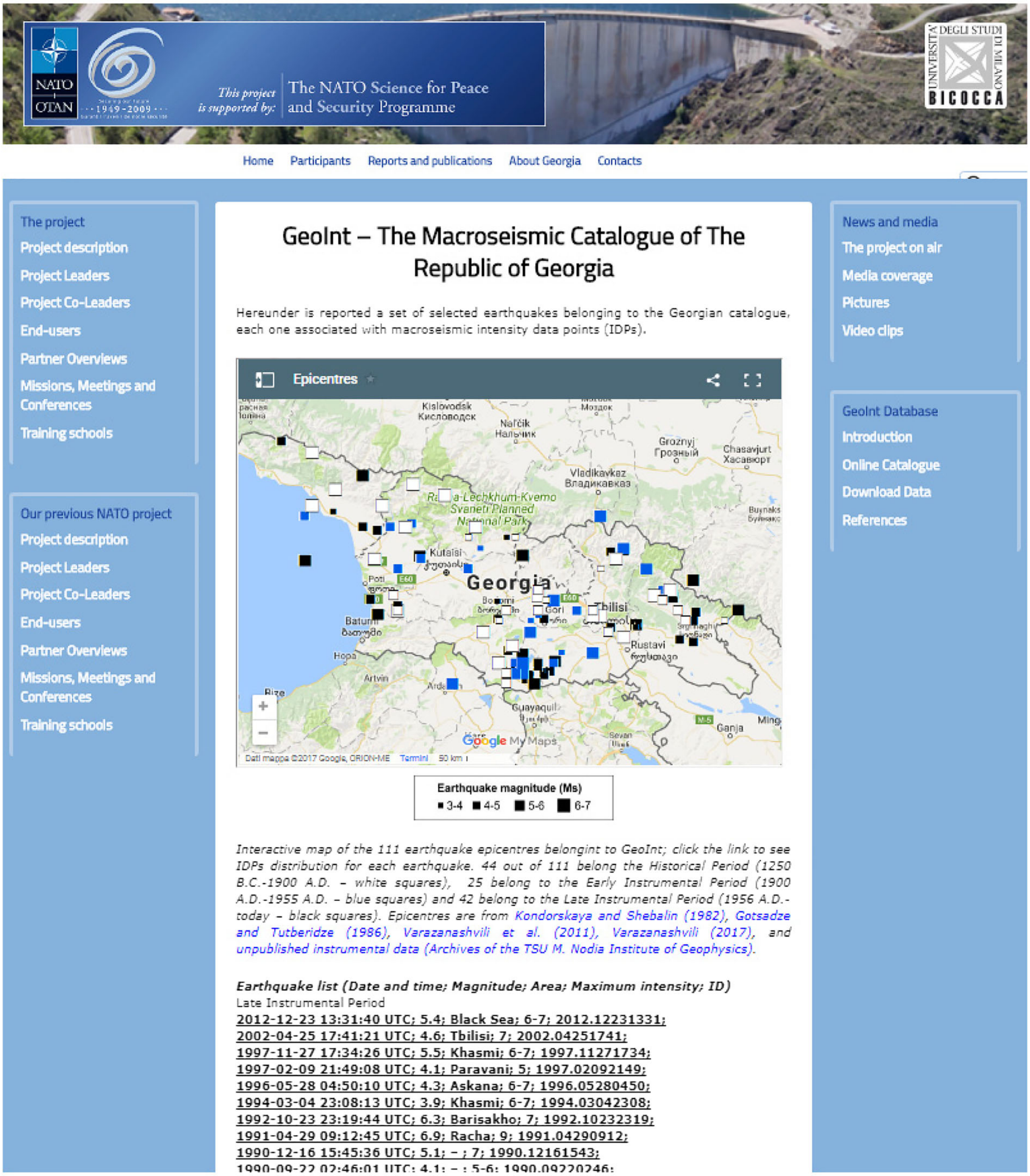


**Fig. 17** GeoInt webpage (http://www.enguriproject.unimib.it/), with the interactive map showing earthquake epicenters as squares (belonging to the HP, LIP, and EIP), and scaled according to magnitude. White squares represent earthquakes from the HP, blue squares are earthquakes from the EIP, and black squares are from the LIP. Below is the interactive list of the earthquakes, in chronological order. From this page, users can access a detailed page about each earthquake and IDPs distribution

GeoInt database is also available online at *http://www.enguriproject.unimib.it* and will be kept updated in the future. This database represents the key input for further improvements in seismic hazard

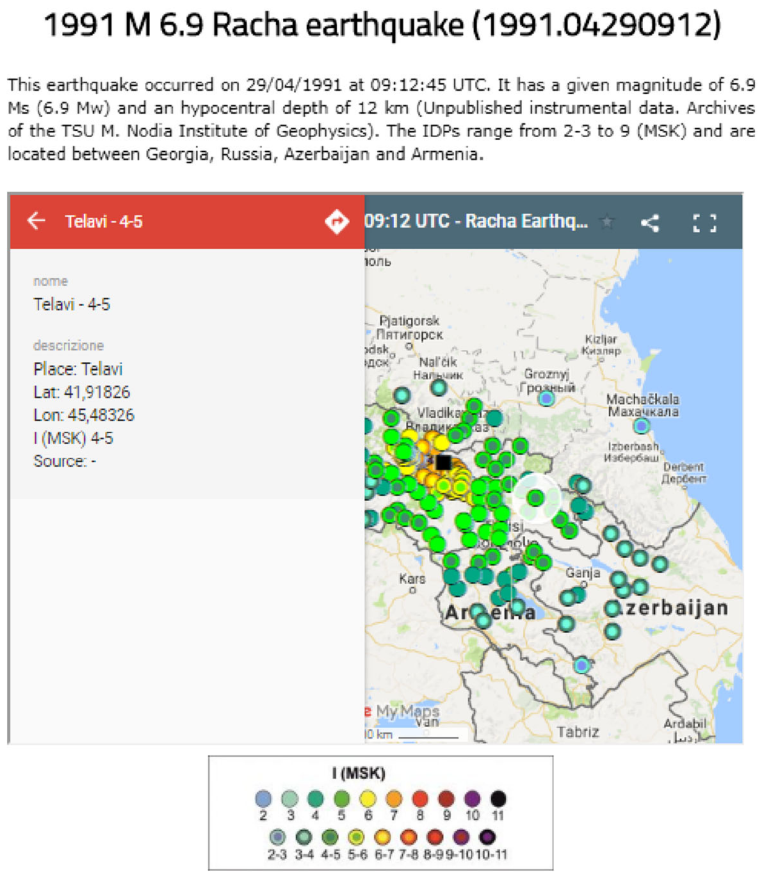


**Fig. 18** Example of the webpage that illustrates the 1991 $M_S$ 6.9 Racha earthquake. The interactive map shows the earthquake epicenter, together with the IDPs. Color code is from Locati et al. (2014)

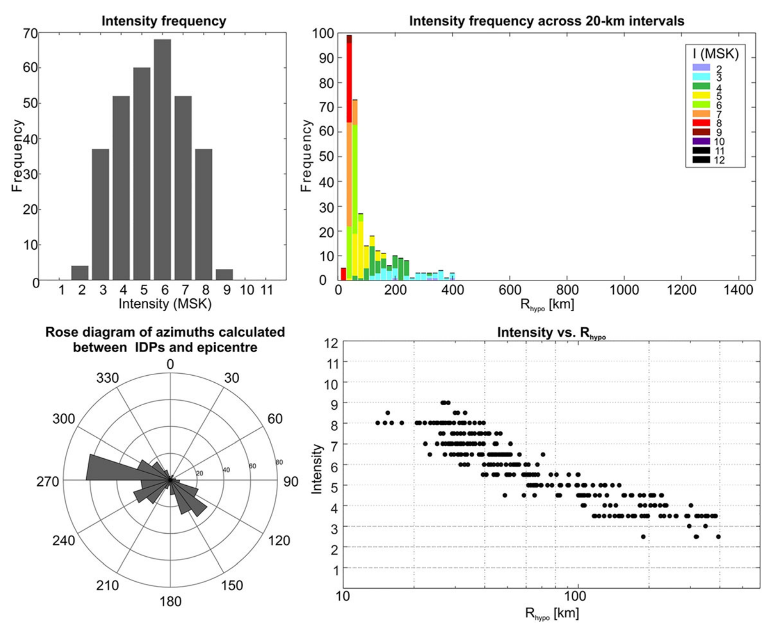


**Fig. 19** Statistics for the 1991, $M_S$ 6.9 Racha earthquake. The graphs can be found at the bottom of each webpage relative to each earthquake

modeling and seismic risk assessment in the country, thanks to:

i. The calibration of new intensity prediction equations (IPEs), made possible by taking into account different sets of data (e.g., belonging to the EIP and LIP) and different distances from the seismic source, such as (a) hypocentral-epicentral distance (e.g., Bakun and Wentworth 1997; Bakun et al. 2003; Doser 2009; Szeliga et al. 2010); *(b)* Joyner-Boore distance; and (c) fault rupture distance (e.g., Sørensen et al. 2010; Ameri et al. 2011)
ii. The calibration of new relationships between ground motion prediction equation (GMPE) and intensity (e.g., Wu et al. 2003; Wald et al. 1999; Zare 2017)
iii. The calculation of probabilistic seismic hazard based on macroseismic intensity (e.g., Papaioannou and Papazachos 2000; Albarello and D'Amico 2004; Brink et al. 2011)
iv. A new investigation of intensity dependence vulnerability curve for Georgian building codes (e.g., Dolce et al. 2006; Polese et al. 2013)
v. The calculation of new scenarios, both in terms of peak ground acceleration (PGA) and macroseismic effects, using a new hybrid-empirical ground motion model that has been recently developed for Georgia (Tsereteli et al. 2016b)
vi. The development of new theoretical correlations between PGA and intensity for this specific region
vii. The reevaluation of seismic events that affected the region before the instrumental era (e.g., Bakun et al. 2002; Bakun 2005; Albini and Rovida 2016)

Apart from the implications regarding seismic hazard assessment for the Republic of Georgia, we would like to underscore that the creation of a database for the whole Caucasus region (including Armenia, Azerbaijan, Turkey, and Russia) should be of international relevance, because this whole area is seismically active (e.g., Farahani et al. 2014; Zare et al. 2014a b; Babayev et al. 2014; Telesca et al. 2017). At present, information is sparse and not easily accessible (Ambraseys and Adams 1989; Balassanian et al. 1997; Noji et al. 1990; Babayev 2006; Gregersen et al. 2007; Albini et al. 2013; Babayev and Telesca 2014). Furthermore, several key infrastructures are present in the area of interest, such as the Armenian Nuclear Power Plant (Nadirov and Rzayev 2017), the Enguri Hydroelectric Power Plant in Georgia (Telesca et al. 2012; Tibaldi and Tsereteli 2017), and the Trans-Caspian Gas pipeline (Soligo Jaffe 2002; Cornell and Ismailzade 2005; Pasquaré et al. 2011; Maggio 2017). All these structures are subjected to major seismic hazard, whose assessment should be considerably improved through the creation of a new seismic hazard model (based on IDPs) that should date back as far as historical time and be focused on an area affected by the same geodynamic forces.

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