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RESEARCH ARTICLE

Earthquake "doublets"-case studies for Kresna-Kroupnik (Bulgaria-M7.8) and Gaziantep–Kahramanmaraş (Turkey-M7.8)

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ABSTRACT

This paper presents a comparative study for two couples of very strong seismic events-Bulgarian Kresna-Kroupnic seismic source activated during 4th April, 1904 (magnitudes 7.2 and 7.8) and those in Turkey 6th February 2023, Gaziantep and Kahramanmaraş seismic source (magnitudes 7.8 and 7.5) called "doublets". The comparison includes main geophysical and seismological parameters and some social and post events consequences and characteristics. The study reveals similarities in the power and huge differences in the consequences of these seismic events occurred in different geodynamic and environmental conditions. Other studies are considered[20, 21] related to strong seismic events and their consequences in other seismic active regions. Comparative tables are developed for easier and visual following of the similarities and differences, and detailed comparison and explanations are given in discussion to try to explain why these differences existed. Conclusions about the effects (social and practical issues) are derived and they could be useful in case of actual retrospective analysis for seismic zoning and for the future assessment of seismic hazard and risk.

Keywords: earthquake doublets (M7.8); comparative study; Bulgaria (1904); Turkey (2023).

1. Introduction

The devastating earthquakes (M7.8 and M7.5) on 6th February 2023 demonstrate the power of the nature and weakness and fragility of the human society. Affecting more than 20 million people in Turkey, the death poll reached about 60,000 deaths and about three times more injured, 120,000 buildings destroyed and more than 60 billion US$ economic losses in Turkey and Syria. This tremendous seismic event at the same time gave the possibility to study and extract the lessons learned and to prevent heavy consequences when next similar event occurs. Following the context of the specific behavior of the seismic process this event can be attributed to the terminology using the word "doublet" of such a combination of two very strong earthquakes occurred in close space and time window-near Gaziantep and Kahramanmaraş. The two strong earthquakes of 6th February demonstrated all peculiarities of the seismic process and its geophysical, seismological and social consequences. The similar effects have been observed also in 1904 in Bulgaria. On 4th of April, 1904 two very strong earthquakes (M7.2 and M7.8) occurred in a very close time and space domain. These seismic events can also be classified as a "doublet". So the comparative analysis of such strong earthquakes can help to understand better the seismic process and the following risks for the population, infrastructure and the affected

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countries as a whole. This paper is targeted to the comparison of the case studies to the seismic doublets in Bulgaria and Turkey and their peculiarities with a focus on the seismic process, destructions, negative social consequences and the specifics if they exist. This is the first attempt to compare two doublets simila in power and very different to the consequences. To extract knowledge which can be useful for the prevention of all possible negatives is another purpose. The results obtained suggest that similar seismic events in power might have very different geophysical, seismological and social consequences due to the resilience and environmental peculiarities of the specifically affected sites.

2. Geology and tectonic settings

The investigated areas-Krasna-Kroupnik seismic source (Bulgaria-BG) and Gazientep-Kahramanmaraş (Turkey-TR) seismic zones are located in SW Bulgaria and SW Turkey respectively-as presented on **Figure 1**[1,2]. The tectonic positions of both seismic events are similar in some issues and different from another point of view:

- Similar, because both are located on the block structures' boundaries separating them.
- Different because the Kresna-Kroupnic event is in extensive geodynamic regime (dominated by normal faulting) but the Gazientep-Kahramanmaraş event is in the compressive one (dominated by strike-slip movements).

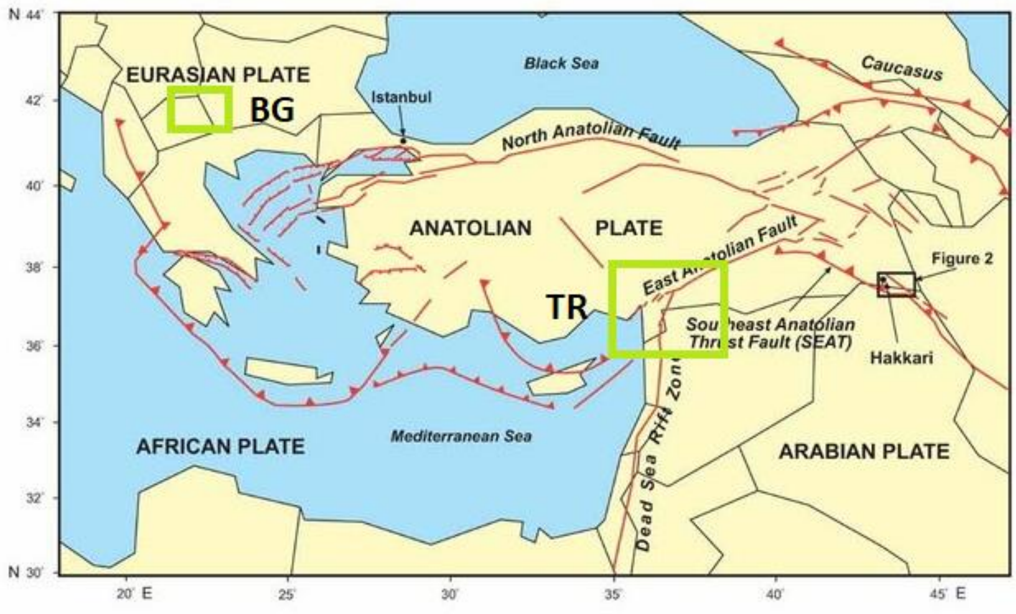

Figure 1. Location of the investigated sites (green quadrangles) in Bulgaria (BG) and Turkey (TR).

2.1. Gazientep-Kahramanmaraş, Turkey earthquakes

The East Anatolian Fault (EAF) is positioned to the NE of Iskenderun bay of Aegean Sea and has more than 700 km long major strike-slip fault zone running from eastern to south-central Turkey. It forms the transform type tectonic boundary between the Anatolian Plate and the northward-moving Arabian Plate. The difference in the relative motions of the two plates is manifest in the left-lateral motion along the fault. The East and North Anatolian faults together accommodate the westward motion of the Anatolian Plate as it is squeezed out by the ongoing collision with the Eurasian Plate.

The East Anatolian Fault runs in a northeasterly direction, starting from the Maras Triple Junction at the northern end of the Dead Sea Transform, and ending at the Karlıova Triple Junction where it meets the North Anatolian Fault (NAF).

Triassic and cretaceous old metamorphic rocks, covered by Eocene limestones and younger sediments and an ophiolite belt of the ancient obduction of the continental crust over the oceanic of Thetis are the main geologic units developed in the area. The fault zone produced several large M~7 earthquakes during the last centuries. The average rate is about a large earthquake in every 20-25 years. This means very high seismic activity and the EAF is recognized as a primary unit dominating the seismic hazard in Turkey, together with the North Anatolian fault. Both fault zones are under compression and the dominant mechanisms of earthquakes are the strike-slip type. The Anatolian microplate surrounded by the both main fault zones is squeezed and moved in general to the west[6].

Aftershock activity is another parameter outlining the source zones of both events. Just for the statistics is important to mention that the aftershock process is not yet finished and will continue at least several years. This is a process of relaxation of the earth’s crust substance generated the strong events.

The aftershocks documented rather well by the seismological network of Turkey, show intensive aftershock series (typical for the shallow strike-slip events).

Up to now, the strongest aftershock M6.7 was registered near the active faults was this one to the Iskenderun bay also generated small (about 1 m) tsunami several days after the main event.

The importance of the investigation of these earthquakes provides knowledge about the seismic process, secondary effects, geophysical properties and the consequences to the population and the infrastructure. Due to the modern seismological equipment, geodetic and satellite displacements measurements, aerial and remote sensing and space imaginary, the study of these seismic events brings very valuable information from different points of view. The lessons learned can be useful for prevention and safety measures. It can be useful not only for Turkey and Syria, but also worldwide. The comparative study of Turkey and Bulgaria similar doublets could be very provocative to recognize the similarities and differences and to try to explain scientifically them.

2.2. Kresna-Kroupnik, Bulgaria earthquakes

The geology of the Kresna-Kroupnik seismic zone (the most recently active area in Bulgaria) is dominated by Late Cretaceous intrusive rocks and Neogene sediments[4]. The tectonics is formed by the recent extension geodynamic regime due to the protrusion of the north branches of NAF. The area of the Kresna-Kroupnic earthquakes (M7.1 and M7.8) is located at the triple junction of the main three tectonic units-Rila-Rhodopean and Pirin, Ograzden and Struma, **Figure** 2. They outlined typical block structures limited by grabens and faults sometimes seismically active. As the main geodynamic regime is extension, the most mechanisms of the stronger events are normal type. Due to the complicated structure and the earth’s crust fragmentation in the area, frequently the low magnitude seismic events demonstrate variety of mechanisms and combinations of strike-slip, normal and trust type. The general neotectonic setting in the area is the block structure. This means that the Earth’s crust is consistent with different sizes of blocks separated by vertical (large) and listric (mostly smaller) faults inclining to horizontal lineaments. The active faults have sparse distribution and demonstrate intensive and/or moderate seismic activity, creep and sliding effects, **Figure** 3.

Figure 2. Tectonic sketch (according[4]) and main tectonic units in Bulgaria.
Red polygon indicated the area of 4th April, 1904 earthquakes.

3. Data and methodology

3.1. Gazientep and Kahramanmaraş (Turkey) earthquakes

The strongest earthquakes (M7.8 and M7.5) shaken Turkey and Syria on 6th February 2023 are rather well studied and documented with all recent possibilities of the different sciences-seismology, geodynamics, geodesy, social sciences, remote sensing and space technologies, etc. Data about the earthquakes, mechanisms and geodynamics of the shocks, co-seismic displacements, surface deformations, aftershock distributions, landslides and rock falls, tsunami and other primary and secondary effects are collected and published widely[3]. The intensive collapses and destructions of buildings, roads, dams, infrastructure, deaths, injured and homeless people, all these data are much more exact and correct in comparison with previous earthquakes, affected this area. The EAF produced many very strong seismic events in the past times. They were historically described and documented in the catalogues of the local and regional seismicity[3, 6]. Recent technologies permit us to use remote sensing, satellite interferometry and other techniques which were not available in the previous times. These approaches enrich our possibilities to study and investigate the processes and consequences of events with rather higher efficiency.

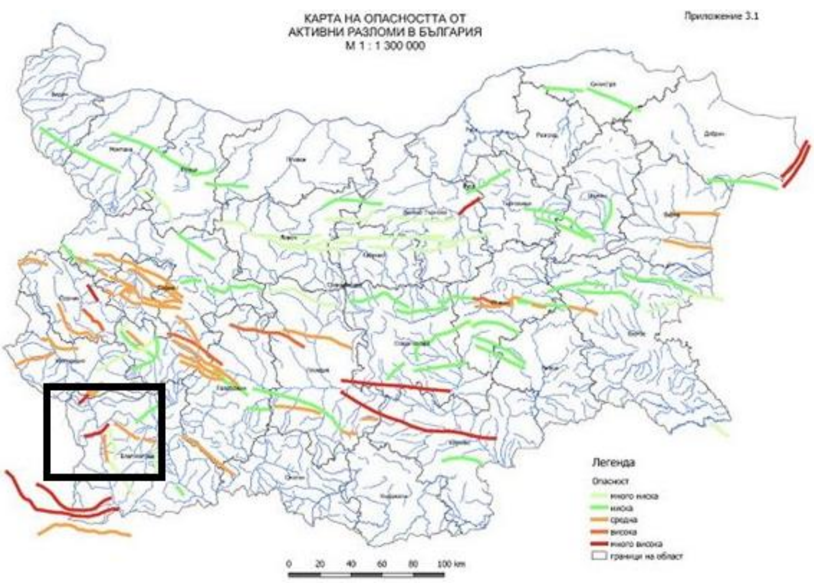

Figure 3. Active faults map of Bulgaria and area of 4th April 1904 earthquakes (black polygon)[5]

Only for illustration two pictures are presented. **Figure** 4a. shows the developments of the aftershock process after the first (M7.8) and prior the second (M7.5) earthquakes and fig.4b. presented approximately same time interval after the second seismic event. It is clearly visible that the aftershock sequence of the M7.8 event is strictly linked to the EAF, but the source of the M7.5 outlined by its aftershocks has mainly E-W direction[6].

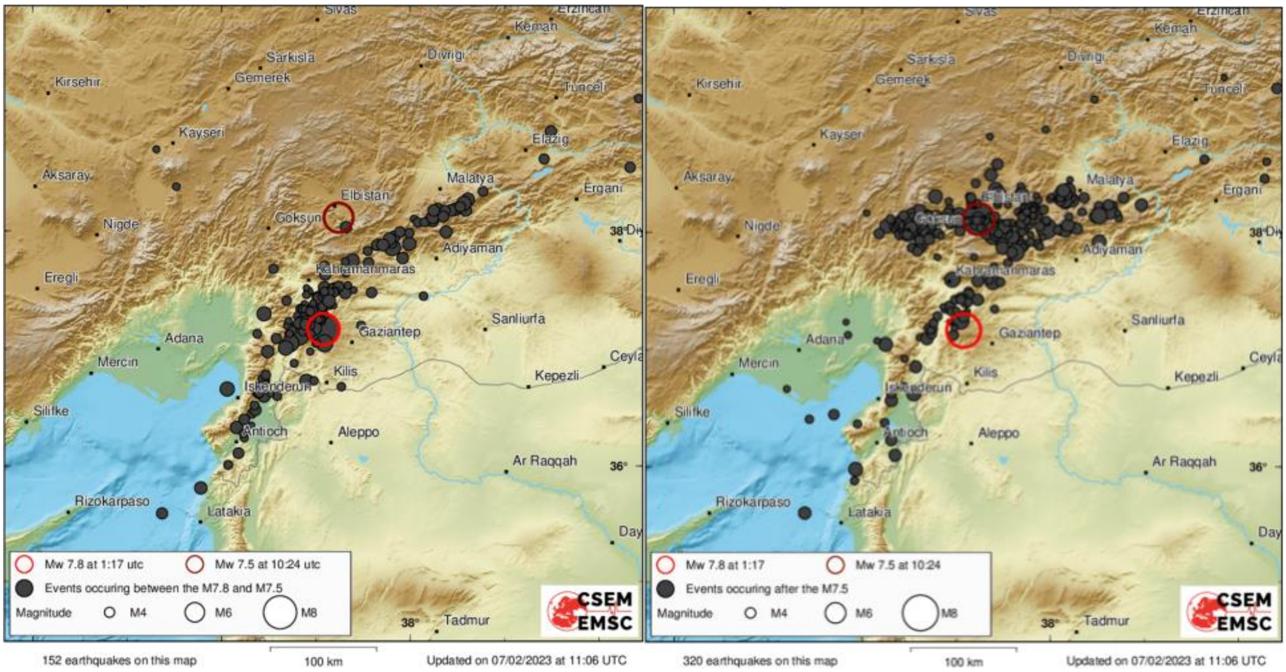

Figure 4a (left) and 4b (right). Aftershocks after first (a) and second (b) shocks-6th Feb.2023[7].

3.2. Kresna-Kroupnik (Bulgaria) earthquakes

The strongest earthquakes occurred on 4th April, 1904. M7.1 (considered foreshock) and M7.8 (main event) occurred in a time domain of about 20 minutes during the day time-around 10 o'clock AM. Most people were outdoor that's why the number of victims and injured were surprisingly low-several tens. The destructed buildings are estimated about several hundreds. It is important to mention that the epicenter was in a low populated mountain region. The felt aftershocks reported between the two strong shocks are about 20 (the strongest ones-two with magnitudes around 5.0)[8]. The immediate strongest aftershock of the sequence was reported about 8 hours later with magnitude 5.5 (intensity VII) and 1.5 year later the strongest aftershock of the whole sequence with magnitude 6.4. A set of more than fifty updated macroseismic maps related to these strong seismic events and their aftershocks have been prepared and published in 2001[8]. A catalogue of historical earthquakes in the area (more than 100 events-years 890-1899) and more than 3,000 seismic events (1900-1975) has been created. All catalogue parameters of the investigated seismic events are extracted from the local reports and estimated magnitudes from the macroseismic information. A facsimile presented the macroseismic map of the M7.8 earthquake of 4th April, 1904[8]. Twenty five macroseismic maps related to these strong events and their aftershocks have been created and published in 2001[8]. For the transformation of the macroseismic map to Peak Ground Acceleration (PGA) specialized seismic hazard modelling was performed[9]. The results might be useful for the comparative analysis. The obtained PGA values of the model are compatible with the macroseismic observations. The important issue is the partial location of the village Kroupnik on the trace of the observed fault dislocation due to the M7.8 earthquake [SRTI]. The modelled values of the PGA reach 0.5-0.55g[9].

To be able to study and compare both-Bulgaria and Turkey doublets several tables were created reflecting the main parameters (similarities and differences) of these earthquakes. The methodology includes comparative analysis of both" doublets" with their peculiarities and consequences by creation tables, comparing and investigating similarities and differences. In **Table 1**. main seismological parameters and conditions of occurrence are presented.

Table 1. General parameters of the investigated main seismic events.
("doublets") in Bulgaria (4th April, 1904) and Turkey (6th February, 2023)

Earthquake "doublet"	Time	Coordinates	Magnitude	Intensity (max)	Depth [km]	Time difference	Distance difference
Bulgaria (BG-Kresna-Kroupnik)	Day				In Earth's crust	~20 min	~20 km
First event- BG1- (foreshock)	10h 02 min	41.78N 22.98E	7.2	IX-X EMS (MSC)	15		
Second event- BG2 (main)	10h 26 min	41.80N 23.10E	7.8	X EMS (MSC)	18		
Turkey (TR- Gaziantep - Kahramanmaraș	Night/ Day				In Earth's crust	~9 hours	~100 km
First event - TR1- (main)	01h 17 min	37.22N 37.02E	7.8	XI-XII EMS	10		
Second event- TR2(aftershock)	10h 24min	38.02N37.20 E	7.5	X-XI EMS	15		

Table 1. shows both doublets and their parameters (similar magnitudes of the main shocks and the seismic peculiarities-such as foreshock for BG1 and aftershock of TR2). All events developed their rupture process in the earth crust with similar depths. The time intervals are significantly different-about 20 min between BG1 and BG2 and about 9 hours between TR1 and TR2. The distances between the both events are very small for BG1 and BG2 events (20km) and much larger for TR1 and TR2 (100km) seismic events. This means that if the BG events emitted the energy in a single shock, the magnitude might increase dramatically. For TR1 and TR2 the distance is significant so the single shock with increased magnitude is less probable. But if it occurred at once the effect might be expected tremendous. The impressive pictures are the observed: intensities IX-X and X for BG events and XI-XII and X-XI for Turkish earthquakes. This might be due to the relative shallower depths and the mechanisms (normal faulting for BG events) and strike-slip for the TR doublet. Another factor influencing these observations could be the effect of the collision of plates (in Turkish case) and the movements of blocks (Bulgarian case).The seismic hazard map of Turkey delineates the NAF and EAF as the most hazardous zones in Turkey[10]. To compare characteristic parameters of the seismic events **Table 2** is presented.

Table 2. Characteristic parameters, secondary effects and geodynamic environment for the investigated doublets.

Events	BG1	TR1	BG2	TR2
Secondary effects:				
Faults	Normal	Strike-slip	Normal	Strike-slip
Geodynamic environment	Extension	Compression	Extension	Compression
Co-seismic deformations	Vertical displacement up to 1-2m	Extremely large deformations up to 30m width and 10^2 – 10^3m	Large displacement (~5-10m), 40km (E-W) length of rupture	Large deformations up to 10m width and 10^2-10^3 m length. (~5m) horizontal

		length – fig. 10. 7m horizontal displacement (-5 to +4 m)		displacement. (-4 to +4 m)-vertical.
Cracks	Many cracks –Up to 1m width.	400 km surface ruptures. Tens of meters width (Fig.5)	Many cracks, 1 perpendicular to the river bed. Length ~40 km.	60-80 km total surface ruptured cracks
Liquefaction areas	No data	~800 km^2 (Fig.6.)	~90 km^2	~430 km^2
Landslides	Landslides and rock falls activated.	Huge landslides, rock falls.	Landslides and rock falls activated intensively.	Many landslides, rock falls.
Foreshocks	3 felt (M~3)	1 felt (M~5)	n/a	n/a
Aftershocks	10^2-10^3 (7 years)	10^3-10^4 (expected)	10^2-10^3(7 years)	10^3-10^4 (expected)
Tsunamis	River flow	(1-2m Alexandreta)	River flow	n/a
Intensity areas	60,000 km^2 – felt 100 km^2 –IX-EMC	200,000 km^2-felt 3,000 km^2 – X EMC	80,000 km^2-felt 300 km^2- X EMC	150,000 km^2 – felt 2,000 km^2- X EMC
Max felt distance	More than 200 km	More than 2000km	More than 300 km	More than 1000km
Max acceleration:	No records	Very rich collection of records ~150	No records	Very rich collection of records ~160
measured	No data	0.5-1.2(2.2)g	No data	0.6g
calculated	0.45-0.5 (model)	1-1.2 modelled	0.5-0.55(model)	0.7-0.8g
“Unusual” observations	Rumbling, 5 m water rise	Strong sounds. Lack of destructions in Erzin (30-50 km from the fault-Intensity IX) Earthquake prediction by Frank Hoogerbeets-NL	Mineral water temperature rise, Lake formed on Struma river bed (tsunami ?). Highest harvest reported by farmers.	Strong sounds. Lack of destructions in Erzin (50-80 km from the fault – Intensity IX-VIII). Earthquake prediction by Frank Hoogerbeets -NL

Figure 5. Surfaces deformations and dislocations TR1 event.

Figure 6. Different types of liquefaction-sand volcanoes and areal flooding (TR1 and TR2 events).

4. Geodetic and remote sensing studies

The geodetic and satellite imaginary are not applicable for the Bulgarian doublet of 1904, because they did not exists that time. For the Turkish earthquake all innovative methods of geodetic measurements were studied including surface geodesy, satellite InSAR methods, remote sensing in broad spectrum, etc.[11]. The GPS measurements in the area before and after M7.8 earthquake in Turkey show the active slow movements at the regional scale considering plate boundaries. **Figure 7**.

The local area of the strong shocks is presented at **Figure 8**. The deviation of the displacements and their high values shows that the whole area is under the influence of the movements and pressure from the south. Slow rotational direction is clearly outlined during the calm seismic regime. The registered displacements are certain indicator of the stress accumulation. Usually such behavior leads to the destruction of the earth crust in a geodynamic regime of compression. Usually it takes time until the stress accumulation reaches the strength of the resisting blocks contacting by faults in our case (EAF). When it happened, the strong energy release produced strong earthquake. The geodesy studies not only the stress regime prior the quake, but also the stress redistribution after the shocks occurred. This information is important when different models of the seismic generation process are investigated and can show the seismic process in its dynamics.

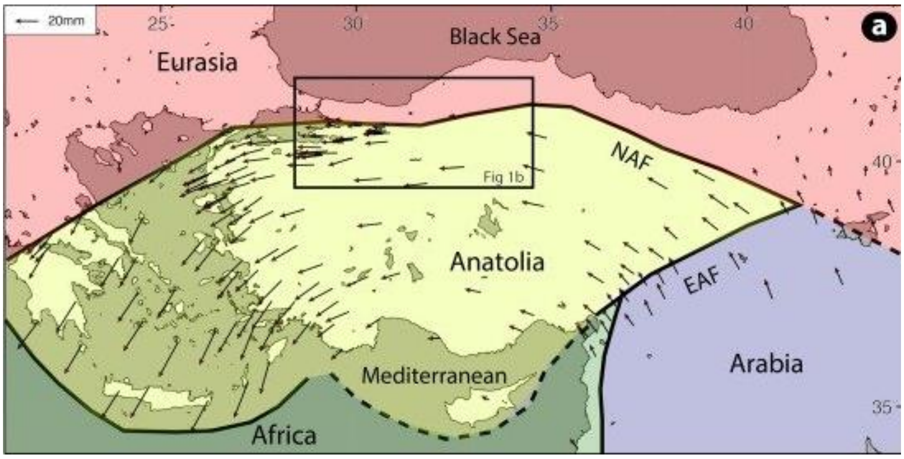

Figure 7. GPS measurements and main tectonic elements.

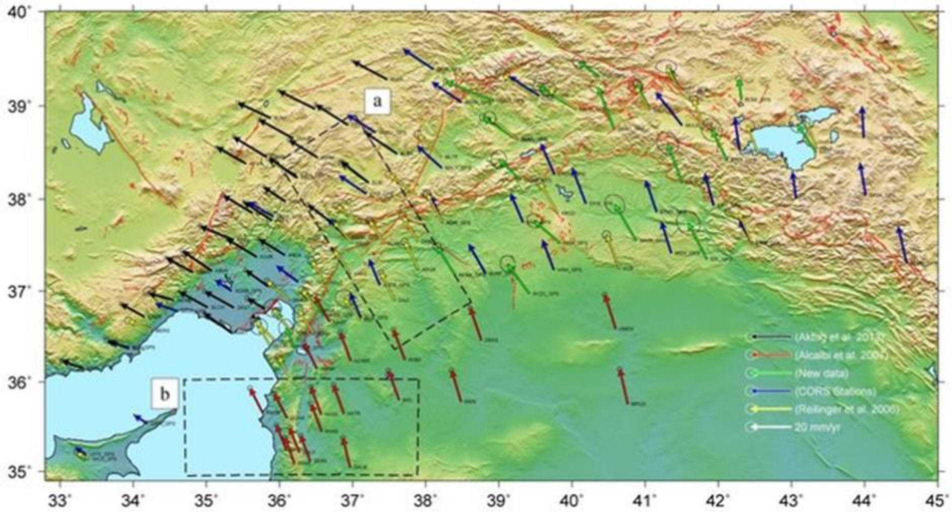

Figure 8. GPS measurements before the shocks of 6th February, 2023.

The useful application of the InSAR data and satellite remote sensing are demonstrated by reconstruction of the co-seismic deformation study, stress redistribution and modeling the destructive seismic process during its dynamics. For the investigated cases the modeled results are very close to the field observations, which support the correctness of the methodology and software used by a Chinese team[12]. Similar results are also obtained by a Bulgarian group[13] making their modeling using similar methodology, but different software, thus confirming the correctness of the study. The complicated displacements produced by the two strong seismic events are visible on **Figure 9**. They show offsets of more than hundreds of centimeters.

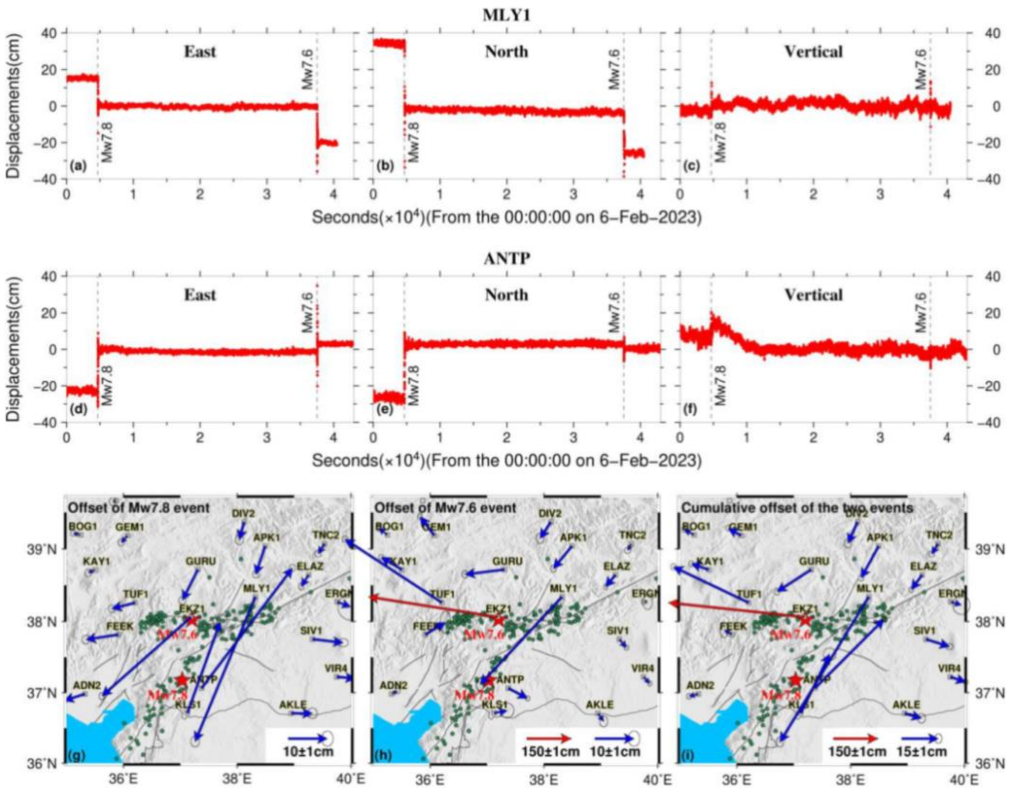

Figure 9. Field observations in two GNSS stations located in the area of the shocks (red asterisks)-up. Low panel-left side-displacements produced by the first shock (M7.8), the center-by the M7.6 event and the right-the cumulative offset by both events.

5. Discussion and conclusions

The observed peculiarities in the geodynamic environment, density population, size of affected areas and the following consequences, are presented in Table 3. It is a table showing the social effects of the investigated seismic events-human deaths and injured, houses affected collapsed and with destructions, economical losses.

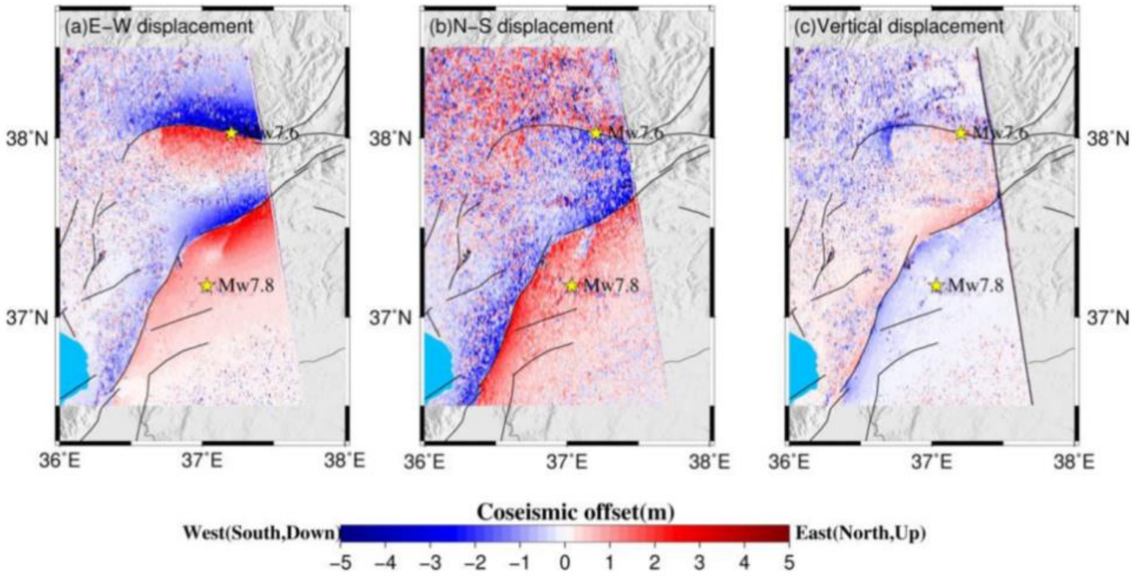

Figure 10. Vertical and horizontal (E-W and N-S) co-seismic displacements produced by both shocks (yellow asterisks) in meters, derived by the remote sensing imaginary.

Table 3. Social effects of the "doublets" earthquakes in Bulgaria (1904) and Turkey (2023).

Doublets	Human losses: Fatalities (Injured)	Buildings collapsed	Buildings no habitable	Economical losses (direct)	People affected
Bulgaria 1904	10-10^2 (10^2)	10-10^2	10^2-10^3	Less than 200 000$	Several thousands
Turkey 2023	~60,000 (~100,000)	105,000	830,000	~30 billion US$	23 millions

Two similar in their magnitudes (M7.8-main shocks) doublets in Bulgaria (1904) and in Turkey (2023) occurred and created significantly different social consequences. What might be the reasons of so drastic discrepancies of consequences of the similar doublets in their power?

5.1. Time of occurrence

- Bulgarian shocks occurred during the day time of a nice spring day (4th April). Most people were on the filed for farmers work. Foreshocks warned in some way people to be more careful. After the strong foreshock (M7.2) all people in the area were warned, scared and did not enter the houses. Pupils were out of schools.
- Turkish shocks occurred during the night and day time. Usually this increases fatalities 2-3 times. Many people entered their homes after the sunrise. The aftershock was very strong and destroyed many affected by the first shock buildings.

5.2. Registration (completeness of data)

- More than 40 seismic stations all over the world registered the foreshock (M7.2), the farthest one at more than 10000km of the Bulgarian case[17, 19]. The main shock registered in more than 60 stations, the farthest one at more than 13 000km. The strongest aftershock is assessed with M6.4 and documented on 8th October 1905. The reevaluation of magnitudes took place some years ago[14].
- The Turkish case was registered at all over the world by modern broadband and short period high sensitive seismographs. The strongest aftershock up to now is with M6.7 on the shore and generated small tsunami-1-1.5 meters[7].

5.3. Macroseismic information and its influence

- The macroseismic information about the earthquakes and aftershocks sequences of the Bulgarian case was collected by the first established seismic networks of volunteer reporters in Bulgaria organized in 1881 by Spass Watzof[16]. The monks especially in Rila monastery (about 30 km from the epicenter), teachers and other people collected nonstop the felt information than transformed into intensities and macroseismic maps. The foreshock was documented by more than 110 observational points which gives the possibility to create high quality macroseismic map. The main shock (m7.8) was documented macroseismicaly with detailed descriptions of the macroseismic effects by more than 230 observational points and transformed into reliable macroseismic map[17]. Something more-even some aftershocks between the strong events (M7.2 and M7.8) were reported and several macroseismic maps constructed[8].

5.4. Historical data (memories of past events)

- The historical review of the past Turkish earthquakes associated with the EAF is well done in[6], and the historical review related to the seismic activity in Kresna-Kroupnik zone in Bulgaria with the catalogue and macroseismic maps is compiled in Ranguelov et al, 2001[8].

5.5. Density of populations is very important

- In Bulgaria affected area belongs that time to the Turkish Empire. There were no big cities or towns. The major settlements affected were: Kroupnik (less than 1000 inhabitants) and Pehchevo (about 2-3,000 inhabitants). No international support was asked.
- In Turkey high populated area was affected (about 20 millions). Many big cities and smaller towns were destroyed, a lot (thousands) of villages were strongly affected and roads to them interrupted. Big amount of buildings (habitable and industrial facilities) were destroyed. This increased dramatically the numbers of fatalities and injured. The hospitals have not enough potential to accommodate injured. International support was provided by 90 countries. Rescue squads and heavy machinery helped.

5.6. Way of building construction-crucial point-Figure 11 and Figure 12

- Extremely important factor for the Bulgaria seismic events negative consequences which were minimized. The buildings in their majority were wooden one store flexible constructions, resistant to the horizontal shear movements. Relatively small numbers of collapses were reported mainly for the animals' shelters. In Turkey very bad behavior of the different constructions were documented. This means a lot of collapses. Impressive fact was the view of similar buildings located very near-some fully collapsed, some-standing firmly. So, a lot of buildings were documented as badly executed by the constructors and builders. Many of them were arrested for law prosecution. A lot of secondary effects (fires, gas leaks, electricity shortages, etc.) were observed. These hazards added their negative effects to the population.

5.7. Development of the infrastructure in past and modern times

- Bulgarian infrastructure had low level development. Some roads were affected, bridges and land cracks appeared, but due to the lack of electric power, gas and other energy centralized sources the affection of the infrastructure was negligible.
- As some of the big cities have industrial facilities, ports, dams, power stations even NPP, military bases, tourist complexes, etc. the infrastructure prior the seismic events was considered high developed. This factor also increased the economic losses together with the victims and injured.

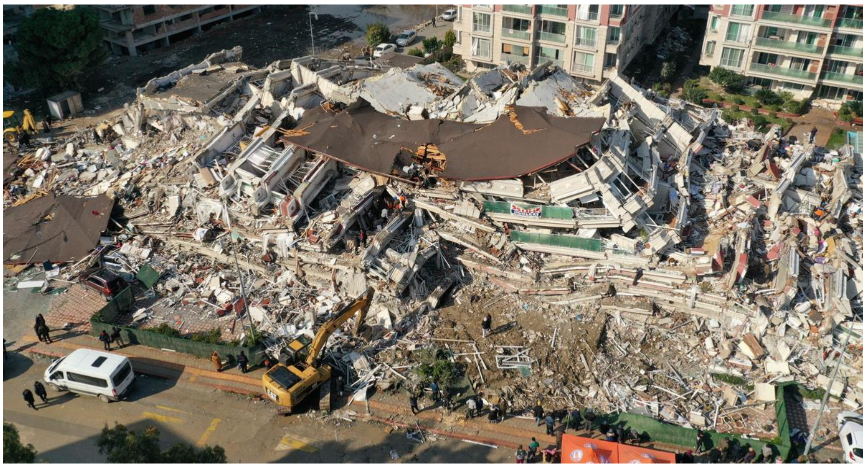

Figure 11. Multistore building collapse [BBC-public domain].

Figure 12. Same type buildings-one collapsed; another-stable [BBC-public domain].

5.8. The earthquake mechanism and area of highest intensities

- The previous studies for Bulgarian doublet confirmed several indicators for the highest magnitude to be assessed as 7.8 for the main earthquake. The normal faulting, observed vertical displacement of about 12 meters and the size of the macroseismic observed intensities are in favor of the greater magnitude. The small length of the ruptured zone, relatively small area of liquefaction and doubtful information about previous historically and paleoseismic evidences for strong shocks are disputable about the M7.8 derived by macroseismic field distribution and the very few records of the poor seismograph network that time.
- The Turkey active fault zone (EAF) producing regularly very strong earthquakes (documented historically pretty well) due to the collision of relatively huge continental plates, the strike-slip mechanism and the shallow depth of the seismic source are supporting the strong negative effects produced by the Turkish doublet. The tremendous and huge surface deformations, co-seismic cracks and activated landslides and rock falls, added their negative effects as well as to the flooding, liquefaction huge area and tsunami as well.

5.9. Aftershocks

- For Bulgaria case more than 1600 felt aftershocks have been reported. The aftershock's sequence was estimated lasts until the end of 1907 (about 4 years[8]). The highest one is assessed of with M6.4 and documented on 8th October 1905. The foreshock and the main event influenced strongly the buildings' construction.
- For the Turkish doublet more than 20,000 aftershocks were registered and the relaxation process is far from its end. The most important fact is that the main shock was strongest one and affected strongly the buildings 'constructions-mostly multi stores homes. The following aftershock even with much smaller magnitudes also triggered the collapses of some weakened constructions.

5.10. Quality of design and building constructions

- The predominant part of the buildings in Bulgaria that time was one (mostly) and two stores (minimal number) wooden flexible construction resistant to the local high frequency vibrations. Low density of populations-affected area covered mostly mountainous regions also is a factor decreasing the fatalities and injured.
- The bad design and the bad execution in SE Turkey and Syria (low quality materials-sand and cement, steel, etc.), as well as low quality of builders and non-regulated building permissions (very frequently missing) are the most important factors for the large destructions and huge amount of fatalities and injured. Important is also the density of population and extended industrial facilities, roads, pipe-lines, electricity lines which frequently triggered fires, etc. The large liquefaction area also adds its negative effects on the stability of the constructions.

5.11. Strange social effects.

Some strange social effects have been reported for Bulgaria and Turkey doublets.

- In Bulgaria, lake formation at the river bed of Struma has been observed due to the huge vertical crack. It took time to be fulfilled and then emptied (about two-three days) according the witnesses and covered by water more than 200m2. This water was used for watering the farmers' lands and then gave richest harvest ever seen.

Much more interesting facts have been reported for the Turkish doublets:

- a) In the city of Erzin, located less than 40-50km far from the most devastating surface ruptures there were NOT any victims and destructions of the buildings. To try to explain this phenomenon with stable construction and good building regulations looks not very serious on the background of the huge collapses at even larger distances. So probably unknown nonlinear effects took place in this case[15].
- b) The Dutch astrologist Frank Hoogerbeets[18] announced that he predicted the shocks and can predict future earthquakes all over the world based on the positions of the space objects in the Solar system and outside. This was like a shock to the serious scientists and many started to fight his predictions. The careful study of his methods of prediction shows that all ‘predicted’ events are pure coincidence and there are not reliable indicators for the impending shocks.

It is very important to mention that the separation in time and space of the strongest shocks (in Bulgaria M7.2 and M7.8) and in Turkey (M7.8 and M7.6) decreased their destructive potential. If these events emitted their energy at once the consequences might be much more dramatic and negative.

6. Conclusions

A comparative study of the very strong earthquakes in Kresna-Kroupnik (Bulgaria, 1904) and Gazientep-Kahramanmaraş (Turkey, 2013) called doublets in this paper has been executed considering the geophysical, seismological and social parameters and sequences in the context of the geological and tectonic environment of the shocks.

The comparison shows that these similar in power doublets have very significant differences in many aspects. Even their seismological parameters are close (power, time of occurrence, for/aftershock of the double event, time and space domain) the produced effects are completely incompatible:

Larger macroseismic surface, huge co-seismic displacements, larger liquefaction area, space-time aftershocks distributions, higher population density, buildings and infrastructure development (with or without constructive control), generated tsunami, dams and river flooding, larger landslide area, etc. are elements characterizing the Gazientep-Kahramanmaraş main events.

On the other side-Bulgaria case-low density of population, day time of occurrence, much smaller area of high intensities, stable wood flexible constructions of the buildings and lack of industries leads to extremely low number of victims, destructions and economic losses.

Another conclusion is related to the seismic energy release. Two strong shocks (“doublets”) is much better issue from energy emission point of view. If the energy was released in one single shock-the consequences could be worst. This is important to have in mind when assessing the destructive potential of such powerful seismic sources in future, when seismic hazards and zoning maps are in preparation.

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Conflict of interest

Author declare no conflict of interest.

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