New opportunities for identification of precursors of sea earthquakes

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Нови възможности за идентификация на предвестници на морски земетресения

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Abstract. In many publications, as well as in media statements, prominent foreign and Bulgarian seismologists admit that seismology still does not have reliable methods and technical means for the identification of earthquake precursors in marine conditions (short-term forecast). Several facts, circumstances, and considerations are presented, motivating the need to immediately start experimental research in this area. A Bulgarian patent of a device for capturing underwater gas sources is offered for transmitting characteristics of the underwater gas source to a receiving device on land, indicating an impending earthquake. A strategy for experimentation and application of the device through the implementation of a new European project, uniting the forces and capabilities of the South European countries, is being proposed.

Keywords: short-term earthquake forecast, underwater gas sources, prediction indicators.

Резюме. В редица публикации, както и в изявления по медиите, видни чужди и наши сеизмолози признават, че науката все още не разполага със сигурни методи и технически средства за идентификация на предвестници на земетресения в морски условия (краткосрочно прогнозиране). Излагат се редица факти, обстоятелства и съображения, мотивиращи необходимостта от стартиране на експериментални изследвания в това направление. Предлага се български патент на устройство за капиране на подводни газови извори с приспособления за предаване на характеристики на подводния газов извор, индикиращи предстоящо земетресение, до приемно устройство на сушата. Предлага се стратегия за експериментиране и внедряване на устройството чрез осъществяването на нов европейски проект, обединяващ силите и възможностите на страните от Южна Европа.

Ключови думи: краткосрочна прогноза на земетресения, подводни газови извори, прогностични индикации.

Introduction

"No one doubts the enormous social, economic, and scientific significance of the problem of predicting earthquake catastrophes. It is no coincidence that since the creation of the science of seismology, this task has been considered the main one. ...

The search for reliable earthquake precursors to predict strong earthquakes is perhaps the most modern stage in the development of seismology” (Rizhikova, 1981, pp. 141).

In the last two decades in several publications (Gufeld, 2007; Hristoskov, Solakov, 2009; Bokov, 2011; Rodkin, 2011, 2017; Vance, 2018, etc.) foreign and our seismologists noted that despite all the efforts and resources spent by the United States, Japan, China and Russia, world seismology is not yet able to make any short-term (most important) earthquake forecast. According to Koronovsky and Naimar (2013), short-term forecasts are impossible due to the fractal structure of the substance in earthquake zones. Progress on this issue was not mentioned and from the ESONET (European Seafloor Observatory Network) project, despite six French-Italian-German-American-Turkish scientific cruises since the 1999 earthquake in the North Anatolian Fault for study fluid emissions from the seabed of the Sea of Marmara (Possemeyer, 2008). Recently, the Japanese geophysicist Kosuke Heki is looking for the first harbingers of an impending earthquake at an altitude of 290 km and the ASL is in the process of testing its hypothesis (Vance, 2018).

According to the authors, the short-term earthquake forecast is possible, and we will disclose the facts, events, circumstances, and considerations that give us this confidence.

There is a new, untested approach to the problem of short-term earthquake forecasting, based on the concept of the special role of gases as the fastest and most adequate harbingers of seismotectonic processes, which Gufeld (2007) proposed a broader and more in-depth interpretation.

Research area

The proximity of the Shabla earthquake zone and the regularly several weak (magnitudes from 2 to 4) earthquakes yearly makes the shallow-water methane seeps area Zelenka (Fig. 1) a suitable testing polygon for marine seismological research and experiments. A large number of active faults have been found in the Bulgarian waters of the Black Sea (Genov, Dimitrov, 2003; Dimitrov, Genov, 2004; Dimitrov, Vasilev, 2016), the most dangerous of which is the Kaliakra fault (Fig. 2). The epicenters of the earthquakes in the Shabla earthquake zone are marked mainly along the Kaliakra deep fault, the eastern wing of which sinks relative to the western. It is a bundle of subparallel faults, well expressed in the seabed relief, a proof of which is the collapse of one of them in a strong earthquake in the Yailata area (Northern Bulgarian Black sea coast) with an early Byzantine fortress (Rogozhin et al., 2019). The Kaliakra fault is traced to Cape Emine, and possibly on land southwest of Burgas (Shanov, 2008). The hypocenters of earthquakes in this area are at relatively shallow depths of 15–30 km (Shanov, 2008). Along the Kaliakra fault and the faults crossing it from the land, a large number of permanently or periodically active gas seeps have been found, expressed as depressions (craters) in the seabed relief, most of which are “informative”, i.e. the gas is coming from a great or considerable depth (Valanginian-Oligocene age) - at Tyulenovo Village from 120–600 mbsf (meters below seafloor) (Stoeva, 2003).

We have several convincing examples of earthquakes that were preceded by activation of gas sources by days or hours, for example at Shabla (*M*7.2, 1901), Crimea (*M*6.7, 1927), Izmit (*M*7.6, 1999), and others, in which in some cases the gases (hydrocarbons) ignited (e.g. Crimean earthquake in 1927). These examples prove that the fractal state of the substance does not prevent the timely abrupt activation (and in some cases calming down) of the emissions from gas sources, which should be considered as indicators of impending earthquakes.

Fig. 1. Satellite image of Cape Kaliakra and the shallow-water methane seeps the Zelenka locality (data source: Google Earth).

Фиг. 1. Спътниково изображение на нос Калиакра и на района на плитки метанови извори Зеленка (по данни на Google Earth)

Instrumentation and results

Based on older data, a seismotectonic model of the Bulgarian sector of the Black Sea has been prepared (Dimitrov et al., 2005), which is constantly supplemented and clarified.

There is a Bulgarian invention patented in the USA under № 6.344.818 from 05.02.2002 "Apparatus and method for detection of materials", successfully experimented in the search for gas emissions at sea and on land near the Tyulenovo gas field. The device has detected a series of gas sources on two parallel faults in the sea in a north-northeast direction, which is consistent with the idea of the Kaliakra deep fault as a bundle of subparallel faults (Stoeva, 2003).

There is a Bulgarian invention № 61997 B1 from 06.01.1994 "Device for capturing underwater gas sources" with the main purpose to transmit signals for changes of emissions from gas sources of the coastal zone and the shelf to receiving devices on land. A variant of the invention captures gas in tanks.

We believe that the device placed above gas seeps in the sea in front of the locality of Zelenka (eastward of Kavarna), will be a useful tool for earthquake precursors study. According to one of the authors – A. Vasilev, the following series of events took place:

- 1) A geophysical expedition is being carried out in the Zelenka locality for registration with a side-scan sonar inspection of the gas seeps and video recording and taking of gas samples;

- 2) Scuba divers find a flat sandy bottom with microcraters from calm gas emissions;

- 3) Then there is an earthquake on August 5, 2009, with magnitude M_d 4.7;

- 4) It occurs exactly on the Batovo fault, on which the gas seeps in the Zelenka locality are situated;

- 5) After some time scuba divers take samples and make a video from the same place;

Fig. 2. Major faults in the Varna-Shabla region (adapted from Oaie et al., 2016).

Legend: KRF: Kemanlar-Ruslar Fault; yellow circles: 710 weak earthquakes of the region from the last 30 years; red star: the strongest for the last 50 years earthquake in the Western Black Sea (M_d 4.7); blue circle: a historical earthquake with tsunamis (M 7.5)

Фиг. 2. Основни разломи в регион Варна-Шабла (по Oaie et al., 2016).

Легенда: KRF: Kemanlar-Ruslar разлом; жълти кръгчета: 710 слаби земетресения в региона от последните 30 години; червена звезда: най-силно земетресение за последните 50 години в западната част на Черно море (M_d 4.7); синьо кръгче: историческо земетресение с цунами (M 7,5).

- 6) During this time (from 2 to 5) the sea is quiet and calm;
- 7) The gas emissions are the same as for 2;
- 8) However, morphological traces of intense gas emissions are registered, which occurred between the two surveys (Vasilev et al., 2021).

Discussion

There is a team of specialists ready to build the device, install and test it. The probability for a successful earthquake data acquisition would increase with the simultaneous use of several devices on several gas areas on different seismogenic faults.

An ideal test polygon for the device is the North Anatolian Fault, 30 km south of City of Istanbul (along the Gulf of Izmit). because the Turkish geophysicists fear a new major earthquake in the sea part of this most dangerous for Turkey fault (Fig. 3. according to Dimitrov, Rangelov, 2020¹).

¹ Dimitrov, O., B. Rangelov. 2020. Report 1 under the agreement DNTS/Russia 02/20, June 25, 2018, IO-BAN library (in Bulgarian).

Fig. 3. Map of earthquake epicenters for the period 1965-2018 (data source: USGS)

Фиг. 3. Карта на епицентрите на земетресенията за периода 1965-2018 г. (по данни на USGS)

The interest of the team working on the issue is dictated by the fact that the peculiarities of the relief of the coast and the littoral of the Black Sea, especially north of Bourgas, put their residents in an extremely dangerous or hopeless situation in the case of earthquake or tsunami. This circumstance dictates the need for urgent preventive monitoring in the coastal zone for possible earthquakes and tsunamis. The implementation of the MARINEGEOHAZARD project is an activity in this direction (Rangelov et al., 2011).

This situation in many parts of the coast is further aggravated by the fact that each earthquake plays the role of a trigger mechanism for gravitational processes along the coast (the phenomenon of "vibrogenesis", according to Agafonov, 1998), which may be more dangerous than the earthquake and even tsunami in the Black Sea.

Due to our lag in the development of this cardinal problem, it is high time to start systematic observations and research on the regime and other characteristics at least for some of the gas seeps in various sections of our Black Sea coast, to obtain more complete information about its "degassing" (Gufeld, 2007). They are a prerequisite for future short-term earthquake forecasts study, which are possible to be realized through the device in question.

The immediate tests of the device will allow its adaptation to the conditions of the land, which will be facilitated by the already experimented and long-established Bulgarian patent in the USA № 6.344.818/05.02.2002.

Earthquake forecasting requires determining the time, place, and strength of the earthquake. The capture device will only tell us that we have to expect an earthquake in days. And also the place of the quake - on the fault on which it is mounted. The strength of the earthquake will be judged by the magnitude and speed of changes in the characteristics of the gas emissions. Over time we will receive more complete information about the individual characteristics of each seismogenic fault and we will learn to make more accurate forecasts of the location and strength of the earthquakes.

Another opportunity to apply this method is to test its compatibility with landslide hazard research along the Black Sea coast. The latest data on the Zelenka locality, where engineering-geological surveys are conducted, show the presence of faults, which may be associated with sea-side landslides in the region (Ivanov et al., 2019; Nankin, Ivanov, 2019).

As far as the issue of short-term earthquake forecasts affects not only Bulgaria, and it is about preventing many casualties, losses, and destruction of society, settlements, and cultural heritage, it is unacceptable to wait for the results of our experiment, which may last decades. There are two Bulgarian inventions that with increased effectiveness for revealing previously unsuspected possibilities. The point is to provide them immediately, first to the countries of Southern Europe most affected by frequent and severe earthquakes, to start in each, at least in a few points of its waters, the research and experimental work, which will shorten the time until the first short-term earthquake forecast tests. At the same time, attempts must be made to adapt the forecasting device to onshore conditions, which will allow addressing successfully this global problem in the next decade. We already have the instructive experience of ESONET in implementing projects of this type.

Conclusion

This paper presents facts that some significant earthquakes were preceded by a sharp change in underwater methane emissions. These facts underlie the authors' belief that monitoring of these emissions is a promising stage in the search for earthquake precursors. This conviction is further supported by: i) the registration of such processes in front of the northern Bulgarian coast (one of the most endangered areas of the Black Sea with earthquakes with $M > 7$, sunken ports, and registered 710 weak earthquakes in the last 30 years); ii) the presence of suitable Bulgarian areas for research polygons (eg., Zelenka methane seeps - near the coast and on an active fault connected with the Shabla seismic zone); iii) the existence of various tools for monitoring gas emissions, including a device patented 28 years ago in Bulgaria.

The authors recommend the accelerated development of these studies, which can save valuable infrastructure and human lives.

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