GIS-Based Software for Monitoring the Earthquake Preparation Process

Armen Kazarian
Institute of Geological Sciences, NAS RA
Fresno California
e-mail: geosurpher@gmail.com

Vahan Davtyan
Geosurpher scientific research company
Yerevan, Armenia
e-mail: davtyanv@gmail.com

Haik Kazarian
Institute of Geological Sciences, NAS RA
Yerevan, Armenia
e-mail: kazarianhaik@gmail.com

***Abstract* — Prediction of earthquakes has long been one of the unsolved problems in seismology. The significance of this issue for the local population cannot be overstated. The entire republic is located within a high seismic risk zone. According to a recent study, strong earthquakes in this territory have a close relationship to planetary cycles. Using histograms of seismic event distribution, these connections are revealed for diurnal and lunar periods.**

To investigate the link, a method and tool for spatial and temporal monitoring of these processes was developed, integrating GIS data for active tectonic faults, seismic events, and planetary positions of the Sun and Moon. According to the study, most of the strongest earthquakes in the region occur during full or new moon periods. The nature of this phenomenon, however, is unclear.

A study of the chemical composition of underground water during the Spitak 1988 earthquake reveals that it changes 4.5 months before the earthquake. The same thing happens before all the region's strong earthquakes. This phenomenon has been named "geochemical quiescence," and it has resulted in the discovery of stable earthquake precursors in the region. The time series of water chemical composition data obtained during the study shows that the mean of the series remains constant, but the standard deviation of the data changes. The study also found that different earthquake preparation processes have the same impact on water chemical composition changes. Surprisingly, post-earthquake changes during aftershock activity time were also comparable. This observation leads to the conclusion that different earthquake preparation processes share some similarities.

A more in-depth statistical analysis of the data revealed that earthquake focal mechanisms are also closely related to planetary cycles. A comparison of seismic data from Greece and Italy revealed that planetary cycles play a critical role in determining the nature of geodynamic activity in the region. The use of daily histograms reveals that existing local and regional seismic catalogs require filtration to exclude the effects of local mining activities.

However, more sophisticated software is required to obtain a more accurate picture of seismic fault activation and its reliance on planetary cycles. More accurate solar system modeling, including the ability to switch between Geocentric and Heliocentric planetary systems, as well as visualization of tectonic fault position at any given time, will aid in understanding earthquake focal mechanism dependencies on planetary forces.

***Keywords* -- earthquake, informatics, information technology.**

Currently, earthquake prediction is regarded as a non-achievable task according to many scientists. The reason for that is a proclaimed elastic rebound theory suggested by Raid at the beginning of the last century [1]. The earthquake was believed to be a process of long-term accumulation of mechanical stress released an abrupt movement of the tectonic block. Monitoring the stress accumulation process is complicated because it is believed to be ongoing deep in the crust. Numerous dynamometers established by different tectonic faults show no or very little stress prior to the main strike. However, the study is going on with the intention of catching the possible earthquake preparation process. The collected information in the form of observed time series is the main source of data for this monitoring. Time series analysis software (Polygraph) was developed to investigate these processes.

The collected information in the form of time series is usually connected to some observation point and it reflects not only the preparation process but also other ongoing issues, such as seasonal changes, etc. Additionally, the preparation process for several earthquakes can go at the same time making tasks of recognition process even more complicated. Overcoming these complications and challenges was a major difficulty during the data analysis. We also assume that the preparation process for a strong earthquake has to be a dominant one. Anticipated earthquakes can be located at different distances from observation points and be at different stages of evolution. Different adjusting calculations were used to overcome this issue for earthquakes located far away from observation points.

As a result, a stable precursor for strong earthquakes in the region was discovered in the form of geochemical quiescence [2,3,4]. Despite the expectation that the precursor should come in the form of an anomaly prior to the seismic shock, it came as a quiescence prior to the storm. It starts 135 days prior to the main shock and allows us to assume the presence of different preparation stages for the entire process (fig. 1).

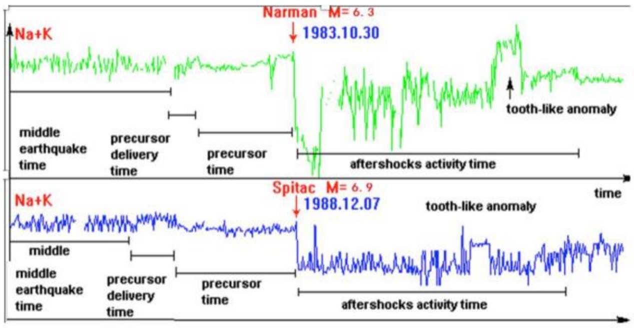

Fig. 1. Geochemical precursor for Narman M=6.3 1983, and Spitak M=6.9, 1988 M=6.9 earthquakes. Water sampling of from the observation point was carried out daily.

Further investigation shows the same precursor for the Rudbar 1990 and Racha earthquakes. The match of this precursor shows that the earthquake precursor occurred at the same time prior to the strike (fig. 2). Hydrogeochemical precursors reflected the tiny movement of tectonic micro-blocks at the same time prior to strong earthquakes, regardless of their magnitude.

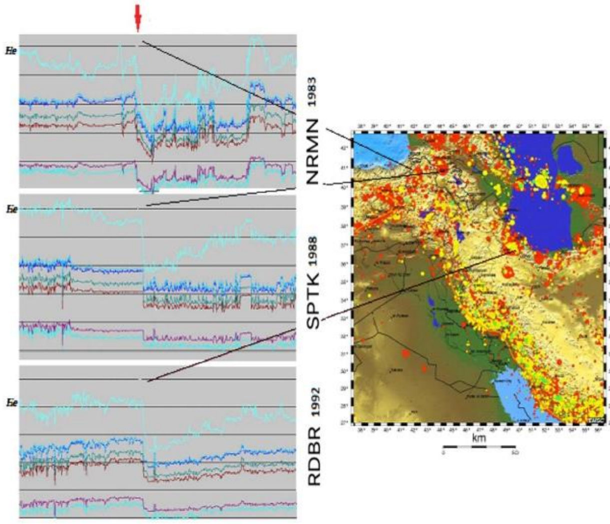

Fig. 2. Comparison of the cases Narman (NRMN), Spitak (SPTK) and Rudbar (RDBR). The time series shows the same pattern prior the strongest and closest to Kajaran observation point earthquakes. Collected data on Na , K, HCO3, SO4, F, Cl, Mn, pH, Eh

This observation allowed us to confirm the presence of stages in the earthquake preparation process with the same duration. It is quite unexpected that the time for precursor appearance does not depend on the magnitude of earthquakes. It also contradicts the Raid's proposed concept of the earthquake nature. Another interesting observation is the daily distribution of earthquakes, studied by histograms, showing its non-unilateral character.

The region of Italy and Greece is characterized by a one-time daily peak of activity at midnight. The region of the Armenian Highlands and Anatolia have two peaks of activity - at midday and midnight. Seismic data from the Aegean area show that strong earthquake distribution here is adjusted to summertime.[5] The focal mechanism for strong earthquakes is different as well.[6] In the Armenian highlands, it usually has a transformed character with dominantly horizontal movement, unlike in Greece and Italy, where it shows dominantly vertical movements (fig. 3).

It is interesting that the strongest earthquakes in the region occurred at the time of a new or full moon. This type of connection was noticed earlier by many scientists. However, most researchers believe that the moon plays the role of some kind of trigger for seismic events. Although the exact mechanism of that triggering is not known yet.

All the above mentioned leads to the conclusion that earthquake-generating forces have a strong connection to the planetary cycles. Some characteristics in general earthquake distribution allow us to assume that this connection may even be a dominant factor in determining the time of a strong earthquake, as well as and its focal mechanism.

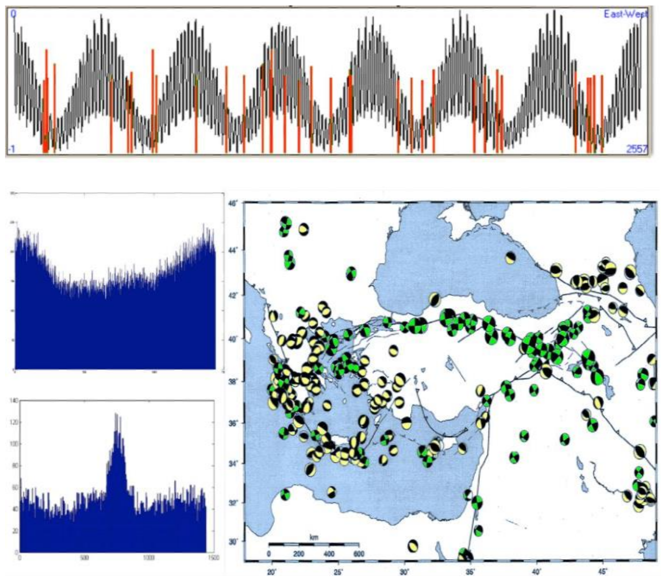

Fig. 3. The dominant focal mechanism for the territory of the Middle East and Greece. The black Curve represents the 1995-2001 tide [5]. Yellow beach balls represent dominantly vertical movements and green beach balls represent dominant transform faults [6]. The histograms represent the daily distribution of earthquakes regardless of magnitude for Greece (upper chart and Armenia (lower chart) regions, with midnight and midday maximums, accordingly.

An earthquake at the same location means the activation of the same tectonic fault, consequently, the earthquake generating force should repeat itself if not in magnitude, but in direction. The best test for this is the cases of repeating earthquakes in the same seismic heart at different times. Some of these earthquakes in the same location were repeated a year later, others happened at particular orientations of the Sun and Moon (fig. 4).

Further research shows that all strong earthquakes in the region occur with a special orientation of tectonic faults towards the position of the Sun and Moon. The best illustration for that is the Gaziantep double earthquake in Turkey on 06.02.2023 with M=7.4 and M=7.6. Not only did the main earthquake happen on a new moon, but the orientation of the general South-East Anatolian fault was directed to the position of the Sun, parallel to the surface of the Earth's ecliptic. The second earthquake hit 9 hours later, at the exact time when, due to the rotation of Earth, the corresponding tectonic fault also took a position parallel to the Earth's ecliptic. There are many cases where the orientation of an active tectonic fault is not arbitrary during the main shock.

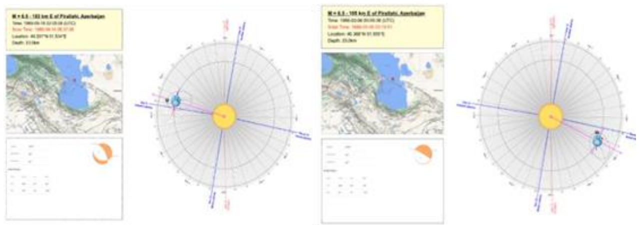

Fig. 4. The position of the Sun and Moon during an earthquake in the Caspian Sea with a difference of 3 years. M=6.5 1989, 1986.

However, current "positioning studies" are not that informative due to the lack of proper modeling tools. It is necessary to be able to orient the position of an active tectonic fault towards the planetary positions, to switch from a Heliocentric positioning system to a Geocentric one, with the ability to calculate the degree of inclination from solar ecliptic and the tilt of inclination, working in both 3d and polar coordinate system. GIS-based data can provide information about tectonic fault positions as well as coordinates and magnitude of earthquakes. However, information about the earthquake focal mechanism, as well as the planetary position in polar coordinates with regard to the coordinate of each earthquake epicenter, required a heavy visualization capacity.

The tectonic fault propagation azimuth constantly changes its direction towards the Sun and Moon position during the day. Its angle of inclination from the Earth's ecliptic depends on its location on the surface of the globe, daytime, and season time. Its latitude determined the range of changes in the angle between the surface of the ecliptic and the surface of the tectonic fault. The daytime, when these two surfaces will be subparallel, depends on the longitude of tectonic fault positioning on the globe and its inclination angle. This position is probably the most significant, because, being in this position, every point of the tectonic block at the time has the same acceleration towards the position of the Sun. The daytime when it's happening, because of the changing height of the sun above the horizon, most probably will also determine the direction of movement.

The earthquake's appearance dependency on the planetary position can be studied in more detail using different statistical analyses of seismic data and some precalculated positioning parameters.

However, these parameters should be generated by modeling software for past earthquakes.

The combination of these data with geochemical time series may lead to a more detailed study of the earthquake preparation process with the possibility to predict it with high accuracy.

The main challenge in software development is the different character of data involved in the calculation and visualization processes. On the one hand, this is the positioning of our planet towards the Sun and Moon, on the other hand, the position of the active tectonic fault towards both Earth and Moon ecliptics at the time of an earthquake. The visualization of mutual orientation is another challenge.

The constantly changing speed of linear movements of our planet with the combination of the earth daily rotation, as well as rotation around the common barycenter with the Moon, gives every object on the Earth's surface an acceleration. Tectonic blocks with different sizes will react differently depending on their geometry and total mass. The vector sum of these accelerations is also responsible for the tides, where we see only the vertical movement of the water. Earth crust tides are more complicated since they all have 4-dimensional (X, Y, Z, Time) components constantly changing direction and amplitude [2].

We assume that at the time of an earthquake, the generating force should be parallel to the surface of the fault. The calculation of these forces, if they have a planetary character will be a challenge without corresponding modeling tools. The quantity of seismic events to be calculated only in our region is enormous. If we consider earthquakes with relatively low magnitude in the calculation the amount of data will grow exponentially. However, increasing the range of earthquake magnitude involved in the positioning calculation process will allow the application of statistical approaches for research.

Part of the data for statistical approaches should be pre-generated by modeling tools. However, local catalogs often include data from mining explosions, and those should be eliminated. It can be done using daily histograms of seismic data and a map of local mining activity.

This report is a first attempt to present the possibility of rewards and the challenge scope for achieving the target. However, the importance of earthquake forecasting is hard to overestimate. The proper cooperation will greatly contribute to the challenge of solving the task.

Monitoring of the earthquake preparation process can be carried out using a combinational analysis of field-collected data on observation points and computational data from positioning system modeling. The usage of AI can possibly also contribute to the problem-solving process, however, the "data in" should be carefully prepared before the attempt.

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