Multi-Disciplinary Earthquake Researches in Turkey :

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Abstract

Following the devastating Mw 7.4 İzmit earthquake on 17 August 1999, major state-of-the-art earthquake studies were conducted in the Marmara region, specifically in the Marmara Sea. However, continuous geochemical, geophysical and geodetical monitoring of pre-earthquake period was needed for earthquake forecast and hazard estimation. Multi-disciplinary monitoring was hoped to bring about detection of reliable signals (anomalies in the measured parameters) in the earthquake preparation period. In 2001, with the financial support of the Istanbul Metropolitan Municipality, TUBITAK MRC EMSI established a geochemical monitoring network composed of soil radon and spring water monitoring stations in the land area of the Marmara Region. This geochemical network was run successfully until 2005 contemporaneously with pre-existing continuous seismological and geodetical networks and quite valuable and encouraging data were collected during this period (İnan et al., 2008). The multi-disciplinary earthquake researches in the Marmara Region were intensified in 2005 when TÜBİTAK granted a US $ 12 million project to a consortium for a multidisciplinary earthquake research project (İnan et al., 2007). The TUBITAK MRC EMSI has since been leading and coordinating this multi-disciplinary and multi-lateral project; namely, "Multi-Disciplinary Earthquake Researches in High Risk Regions of Turkey Representing Different Tectonic Regimes - TÜRDEP". Other consortium members are the Ministry of Construction and Settlement's General Directorate of Disaster Affairs (GDDA) and 14 Universities*.

Multidisciplinary approaches employed under the scope of TURDEP Project in three earthquake-prone regions (the Marmara Region, the Aegean Extensional Province and Eastern Mediterranean – East Anatolian Province containing the East Anatolian Fault System) include micro-seismology, geochemistry of soil radon and water emanating from major fault/fracture

zones , borehole tilt measurements, GPS and microgravity -aided crustal deformation measurements. At present, More than 220 monitoring stations of various kinds are at present operated online, collected data are transferred on real/near-real time and data evaluation is performed on a daily basis.

In the Marmara region, multi-disciplinary earthquake research effort is based on continuous data collected and evaluated from 32 micro-seismology stations, 20 soil radon monitoring stations, 10 spring water monitoring stations, 21 GPS stations and three borehole tilt measuring stations. All the data transferred online and data evaluation is being performed on a daily basis.

Continuous geochemical monitoring in the Marmara Region have been conducted in the Marmara Region (land area) since 2001; with increasing number of monitoring stations each year. Seismicity in the region has been monitored by dense micro-seismology network to aid the evaluation and interpretation of geochemical data. Both cold and hot springs emanating from fractures and fault zones have been sampled on daily basis and variations in hardness, as well as major anions/cations have been monitored. The variations in temperature and electrical conductivity have been continuously monitored on hourly basis. Soil radon gas activity has also been monitored at 15 min interval. The data from all online stations are transferred to the center on daily basis, evaluated and interpreted in the light of seismic activity. So far, no reliable anomaly has been detected in spring waters that may be utilized as earthquake precursor; probably major crustal deformations has not occurred because the largest earthquake in the region has not exceeded M 5.0 since comprehensive and systematic observations started in 2001. However, reliable soil radon time series suggest quite good relation between soil radon gas anomaly and seismic activity in the Marmara Region (İnan, 2008). From these ongoing studies, preliminary assessment of the success of geochemical monitoring suggest that site selection for continuous radon gas monitoring is very important, and when appropriately determined, results in successful observations. Pre-earthquake soil radon anomalies systematically verified the closest relation (positive correlation) between radon gas anomaly and earthquake activity (magnitude between 4.0 and 5.3) for epicentral distance of up to 150 km according to strain radius approach (Dobrovolsky et al. 1979; Montgomery and Manga, 2003). However, in case of crustal anisotropy, pre-earthquakes anomalies could not be observed in soil radon at stations located within the strain radii of some earthquakes. Thus, dense network with as many stations as possible to be deployed on

all known active fault segments in a region would be a beneficial strategy for detecting short-term pre-earthquake signals.

These multi-disciplinary monitoring need to be conducted continuously and for several years and even for several decades until sufficient data are acquired to obtain scientifically reliable and accurate explanations for the earthquake phenomena. In the case of the Marmara region, one of the disadvantages of the land area monitoring is that the Main Marmara Fault is known to cross the Marmara Sea and that sea bottom monitoring, which is hoped to be realized in the future, will fill the gap in these integrated and multi-disciplinary researches.

The Turkish Scientific and Technological Research Council (TÜBİTAK) has recently granted 12 million USD for a multi-disciplinary and multi-lateral earthquake research project (TÜRDEP) that will continue for four years. The project started in November 2005 and will be completed by November 2009. The Earth and Marine Sciences Institute of the Marmara Research Center (MRC) of TÜBİTAK is leading and coordinating the multi-lateral project involving the Ministry of Construction and Settlement's General Directorate of Disaster Affairs and 14 Universities* (Figure 1).

Geochemical monitoring (e.g., Physical properties and the chemical composition of warm and hot spring waters as well as soil radon concentrations) have been realized continuously since early 2007 in different tectonic regimes in Turkey, alongside micro-seismological observations, providing a multi-disciplinary approach. Marmara region as well as Aegean Extensional Province are seismically very active and more than 20 moderate earthquakes with Richter Magnitude (ML) $\geq$ 4.0 (between 4.0 and 5.0) have occurred in these regions During the monitoring period. Micro-seismological monitoring showed no foreshock activity prior to these earthquakes yet it provided good control for continuous geochemical monitoring. By contrast, hydro-geochemical have been recorded in the electrical conductivity and ion concentrations of some spring waters, each lasting for weeks. Precursory anomalies in soil radon have been recorded before earthquakes associated strike-slip faults. On the other hand, some spring waters as well as soil radon stations located within the deformation zones of impending earthquakes did also not show anomalies. The reason for this miscorrelation is interpreted to be due to discontinuities between the focal zones and the monitoring sites leading to stress/strain anisotropies.

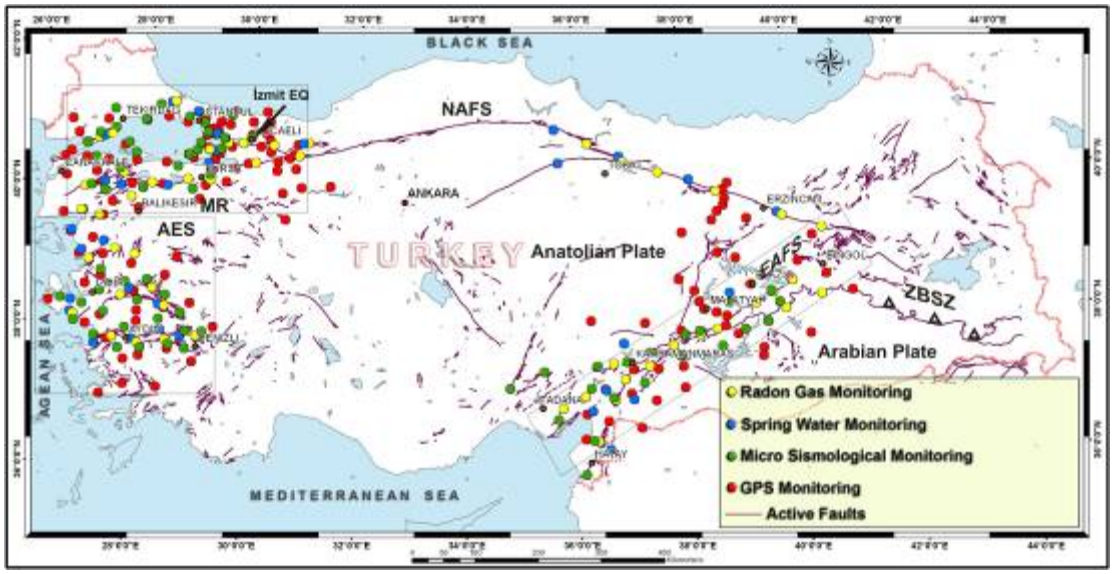

Figure 1. Locations of the established and continuously-run monitoring stations under the scope of the project. MR=Marmara Region, AES=Aegean Extensional System, ZBSZ=Zagros Bitlis Suture Zone, NAFS=North Anatolian Fault System, EAFS= East Anatolian Fault System. Arrow head points to the epicenter of the Izmit earthquake of 17 August 1999 (Mw=7.4).

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Participating Universities in the TÜRDEP Project are (in alphabetical order) Boğaziçi University, Cumhuriyet University, Çukurova University, Dicle University, Dokuz Eylül University, Ege University, Eskişehir Osmangazi University, Fırat University, Hacettepe University, İnönü University, Istanbul Technical University, Süleyman Demirel University, Kahramanmaraş Sütçü İmam University, and Yıldız Technical University.