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# Study of the Seismic Heterogeneity in the Gerede Segment of the North Anatolian Fault, Turkey

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トルコ北アナトリア断層ゲレデセグメントにおける地震学的不均質構造の研究

International Collaborative Research (Project No.: 2020W-02)

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The main purpose of this project was to conduct a high density observation of earthquakes along the Gerede Segment of the North Anatolian Fault in Turkey. Because of the health situation due to the Corona virus, we were unable to carry out the field study. The planned seismicity observations are important for combining the earthquake information with a resistivity survey along this segment of the fault, which is scheduled for August to September 2022. This report contains information about the planned seismic observations, so that this investigation can be carried out in the future.

Weekly to monthly conference calls were held between Japan and Turkey researchers during 2021 and 2022.

**Objectives**

The Bolu-Gerede segment of the North Anatollian fault in western Turkey is anticipated to have a large (M7.2 ~ 7.5) damaging earthquake in the near future, 29% (Poisson) and 48% (time dependent) in 30 years. This probability is higher than any onshore fault in Japan. To understand the fault structure and provide hazard information for the expected large earthquake, we propose to operate a temporary dense seismic network. Data from the seismic observations will enable us to evaluate the current earthquake activity, clarify the fault structure and identify likely locations of asperities (local areas of large slip during a large earthquake that produce the most severe shaking).

**Significance**
1. There is surprisingly very little information about the current earthquake activity of this region because of the sparse National Turkey Network and there has never been a temporary deployment of dense seismic stations. Greatly needed baseline data about the rates of seismicity, b-values, precise locations, focal mechanisms and earthquake stress drops will be obtained.
2. The Bolu-Gerede segment has an active creeping section of about 4~6 mm/year. Such fault creep is relatively rare around the world and understanding the seismicity and fault movement during the period leading up to a major earthquake, is a fundamental seismological research

topic.

3. This project is part of a Japan-Turkey effort to study the Bolu-Gerede segment. A funded 3-D resistivity survey is scheduled for August to September 2022. Combining the obtained fault structure from this survey with the active earthquake locations from our dense seismic will provide unique data for understanding the details of the fault structure.

4. The Bolu-Gerede segment runs directly through the city of Gerede and the last major event (M7.2) in 1944 killed over 3900 people and destroyed more than 20,000 buildings. Identifying the exact location and geometry of the fault from microearthquake locations and identifying possible asperities for the expected major earthquake from b-values and stress drops, is important for hazard mitigation. This information can be used to anticipate areas of the strongest shaking during the expected earthquake, and will be shared with local government officials and the director of the Disaster and Emergency Management Authority of the Ministry of Interior of Turkey.

**Seismic array**

The planned seismic array covers an area of about 120 x 30 km$^2$ around the Bolu-Gerede fault segment. The planned instrumentation consists of 8 broadband seismometers and 30 short-period seismometers. The short-period instruments are mainly to record arrival times and first motions of the small earthquakes. These data are used earthquake locations, focal mechanisms, and earthquake tomography to determine the 3-D velocity structure. The waveforms recorded on the broadband instruments are used to determine moment tensors, attenuation results and source studies of the larger earthquakes. Station locations and logistics were prepared by Baris, Mori, Oshiman during a reconnaissance trip in September 2019 (Fig. 1).
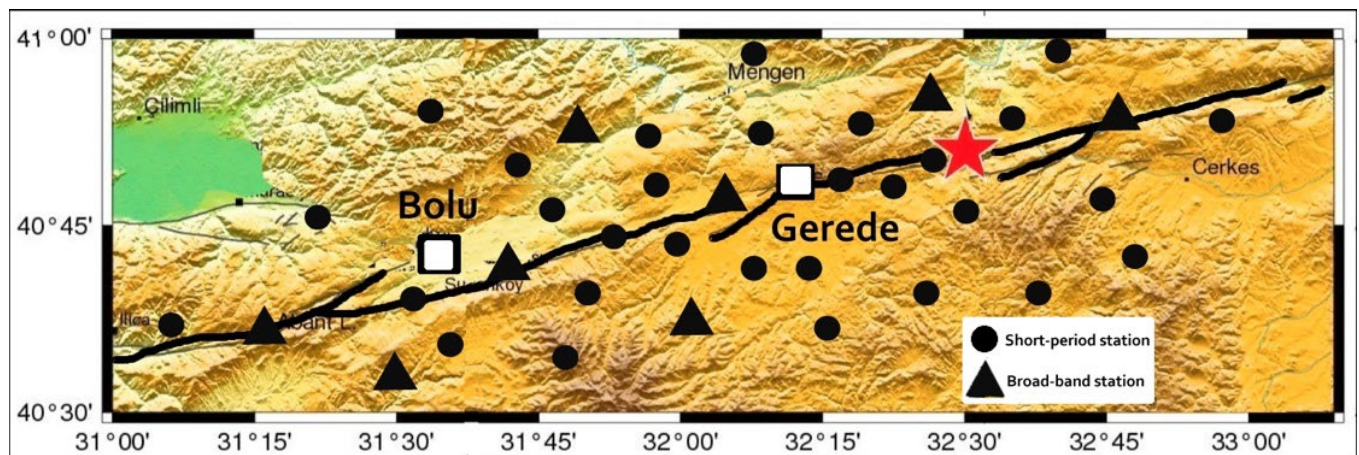


Fig. 1. Map of Bolu Gerede segment of North Anatolian fault (black lines) and planned seismic array. White squares are cities. Red star is epicenter of M7.2 1944 event.

**Instrumentation**

Originally, the short-period seismometers were to be provided by DPRI and the broadband seismometers by the Turkish universities. However, since travel funds were not used from the

DPRI budget, funds were used to purchase a broadband seismometer and recording system that is currently being installed in Bolu city close to the Bolu-Gerede segment. There are negotiations with the city provide support for maintenance of the instrument.

**TUBITAK Project**

We also submitted a proposal to the TUBITAK (Turkish government funding) for construction and maintenance of the seismic network in the Bolu-Gerede Region. This project was funded in 2021. However, because of economic factors, such as the decreasing value of the Turkish currency, the received funding was not sufficient to carry out the proposed work. Because the stated work could not be completed with the allocated budget, the funding for this project was declined.

**1944 Gerede Earthquake (Ms7.2)**

We collected old seismograms for the devasting 1944 Gerede earthquake. We are in the process of analyzing these historical seismograms (Fig. 2). From the body wave and surface wave analyses, we hope to confirm the focal mechanism, depth and extent of faulting for the earthquake.
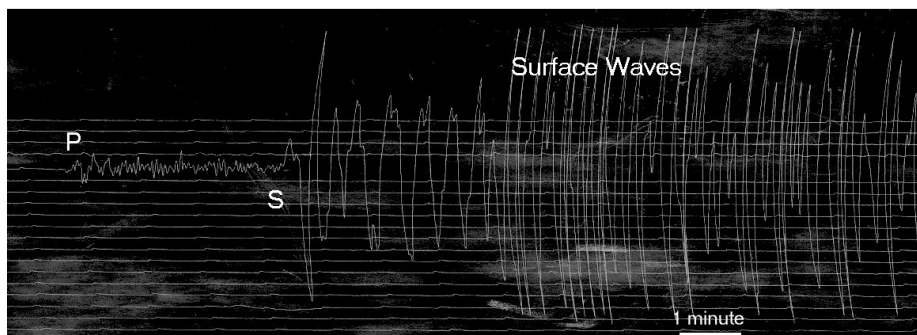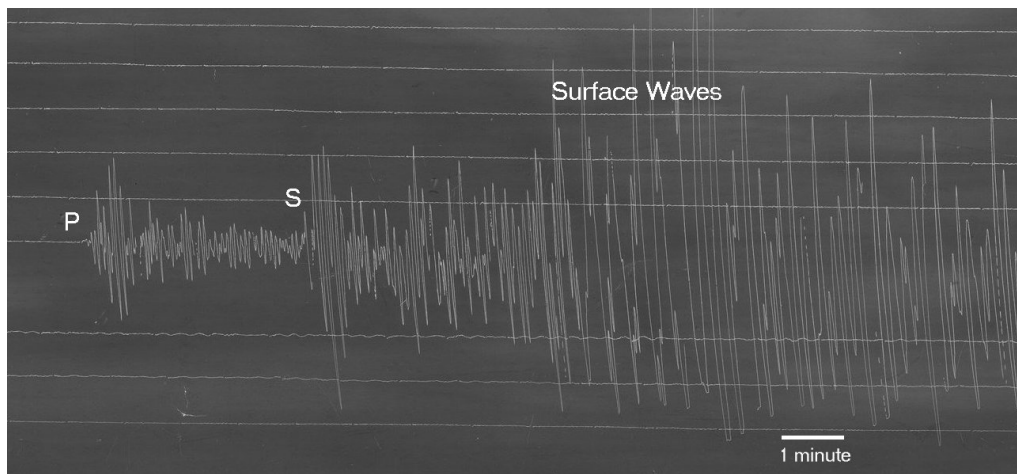
Fig. 2. Seismograms of the 1944 Gerede earthquake recorded at Copenhagen, Denmark (top) and Debilt, Netherlands (bottom). The P, S and surface waves can be clearly seen.

## Future Anticipated Results

Some of the project funds that were designated for travel, were used to purchase computers at Kocaeli and Istanbul Universities. These computers are being used for analyses of current seismic data from a limited number of permanent seismic stations in the region. The analyses include locating earthquakes and studies of regional velocity structures.

In this project, the primary objective is to investigate the fault structure and seismological heterogeneity in the area of the 1944 Bolu-Gerede earthquake. For this purpose, the seismic data from such a network should produce the spatial distribution of earthquakes on and near the segment, spatial changes of b-values, three-dimensional velocity structure, focal mechanism solutions and stress tensor inversion of small earthquakes. These seismological results combined with the fault structure to be obtained from the 2022 resistivity survey, may be used to identify the asperities on the fault zone. Installing a dense seismic network is also a first step in establishing comprehensive seismic observations covering the whole North Anatolian Fault Zone.

## Project Members

Serif BARIS, Kocaeli University, Project leader

Professor, Bogaziçi University, Conduct moment tensor inversion and data process

Cengiz Celik, Bogaziçi University, Collect, store and playback MT data

Ali PINAR, Professor, Bogaziçi University, Conduct moment tensor inversion and data process

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Deniz CAKA, Res. Assoc., Kocaeli University, Data Analysis of earthquakes

Kudret TEKIN, Seismologist, Disaster and Emergency Management Authority(AFAD), Station Maintenance and Data Collection

Hakan Asaf ALÇIK, Bogaziçi University, Conduct focal mechanism solutions

Mustafa Kemal TUNCER, Istanbul University, MT observations in Turkey

Ryokei YOSHIMURA, Professor, DPRI Kyoto University, Process MT data and PI of MT project

James J. MORI, Professor, DPRI, Kyoto University, co-PI, Data Analysis