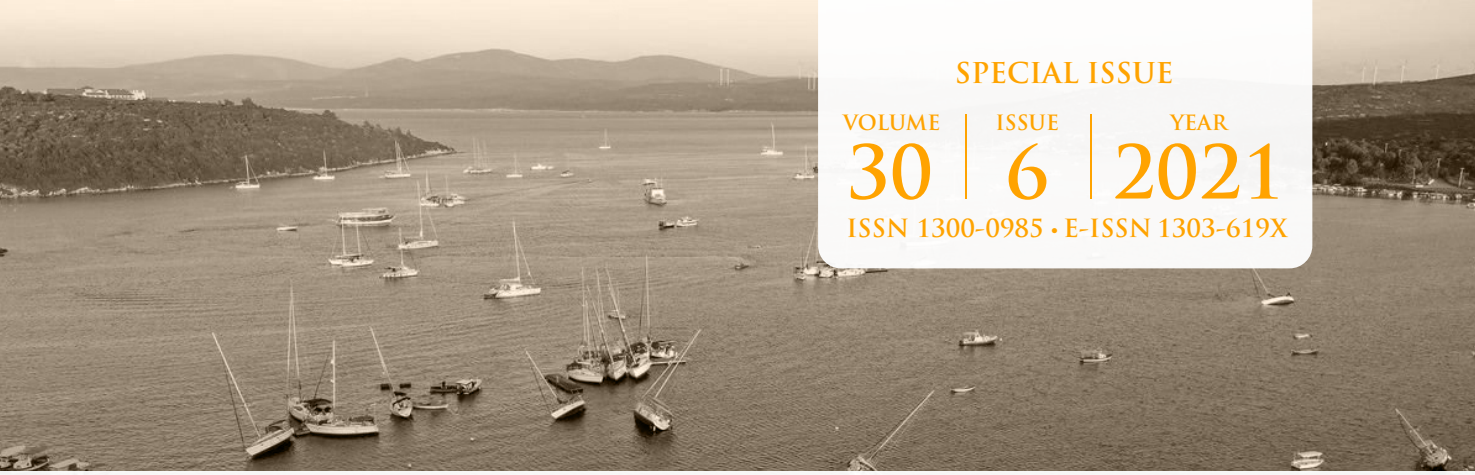

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SI:
Active Tectonics and Seismicity of the Aegean Region with special emphasis on the Samos Earthquake struck on 30 October 2020

NASA / JPL-Caltech / ARIA Product
Contains modified Copernicus Sentinel data (2020)
Earthquake Epicenter: USGS, Basemap: Google, Landsat, Copernicus

Guest Editors
Spyros PAVLIDES
Riccardo CAPUTO
Hasan SÖZBİLİR

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SCOPE OF JOURNAL

- The Turkish Journal of Earth Sciences is published electronically 6 times a year by the Scientific and Technological Research Council of Turkey (TÜBİTAK).
- It is an international English-language journal for the publication of significant original recent research in a wide spectrum of topics in the earth sciences, such as geology, structural geology, tectonics, sedimentology, geochemistry, geochronology, palaeontology, igneous and metamorphic petrology, mineralogy, biostratigraphy, geophysics, geomorphology, palaeoecology and oceanography, and mineral-deposits.
- The journal publishes the highest quality papers and comprehensive review papers on hot topics of current interest, with high quality illustrations.
- Submitted papers should have regional implications and attract international interest as the journal aims to provide a medium for interdisciplinary papers that would be of interest to many different specialists.
- Specialized papers can be submitted if they illustrate significant progress in that specific area of the earth sciences. In addition to original and review articles, we are also interested in publishing discussions of papers that have already appeared in recent issues of the journal.
- The journal also publishes thematic sets of papers on topical aspects of geology or special issues of selected papers from conferences.
- Short articles (6 printed pages maximum) for rapid publication reporting a significant advance in the earth sciences with regional impact are welcome. Contribution is open to researchers of all nationalities.

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Preface

Earthquake research as a research area covers the entire process covering the stages of prior to (pre-seismic), during (co-seismic), and after the earthquake (post-seismic) and requires the contribution of more than one research area in a multi-disciplinary approach. The strategic approach that is implemented by the Scientific and Technological Research Council of Turkey (TÜBİTAK) prioritizes the realization of the approach of co-creating and succeeding together across researchers. This approach that gained special importance during the pandemic is diffused in every means possible in our ecosystem and especially in the field of earthquake research.

An important source of resilience against earthquakes includes the production of scientific data based on the earthquake-oriented earth sciences research field, a collaborative approach focused on common goals, and the power to evaluate scientific data together. The earthquake of 6.9 magnitude that occurred in Kuşadası Bay near Samos Island is among the few major earthquakes that have occurred in this geography in the last century. Its impact has unfortunately caused loss of lives and damages in the city of İzmir, in residential areas connected to İzmir and Aydın, and in different residential areas including Samos Island. There is a time value of seismic data and it is critical to start on-site investigations of surface deformations that occur immediately. Time and continuity are crucial in field studies to obtain precious data for determining fault line characteristics that cause earthquakes as well as thousands of aftershocks in the face of continuing fault movements.

During the 30 October 2020 earthquake, TÜBİTAK supported researchers in undertaking field research onsite with their teams within 24 hours. During my visit to the researchers in the field, various examinations conducted on the active fault line were witnessed. This was followed by a special call of TÜBİTAK to bring researchers in this research area together with a multi-disciplinary approach. In the grant program of TÜBİTAK 1001, the special call included various basic and applied research topics in the field of earthquake research. A total of 80 research project proposals with a success rate of 33% was supported on earth science research, comprehensive scenario, foresight and modelling studies, digital technologies for earthquake engineering, robotic systems in search and rescue operations, use of innovative construction and advanced material technologies, engineering solutions for architectural designs, and socio-economic and social effects of earthquakes.

As an innovation, incentive points were given to research projects that documented coordination between multiple projects as a pilot implementation starting from the research area of earthquake studies. This incentive encouraged projects that interactively brought together multiple project proposals joined with a common roadmap. Through roadmaps, 18 coordinated projects are contributing to common goals, including human resource and infrastructure sharing. By creating coordinated projects in the earthquake research ecosystem, we have ensured the establishment of a platform structure extending from basic sciences to emerging technologies.

Moreover, with the coordination of the Ministry of Interior Disaster and Emergency Management Presidency, Turkish Naval Forces Office of Navigation, Hydrography and Oceanography and the TÜBİTAK Marmara Research Centre, the importance of collecting earthquake-oriented data not only on the land side, but also on the sea side was realized with a new collaborative national research expedition. The first phase of the Kuşadası Bay Expedition was carried out on May 28, 2021, with a platform approach to carry forward high resolution sea-based profiling studies beyond the existing bathymetry data. This project brought together scientists from different universities on the national research ship, the TÜBİTAK MARMARA Research Ship. The platform approach of this national research expedition that brought together 40 researchers for 2 years to work together for a common purpose is another important achievement for the earthquake-oriented earth science research ecosystem.

The International Active Tectonics and Seismicity Workshop ASASE2021 was organized in the field of earthquake research. In this jointly organized workshop, more than 100 scientists shared the results of active tectonic and seismicity studies in the Aegean Region by focusing on the 30 October 2020 Earthquake, the hypocentre of which was in the Aegean Sea, representing 35 different scientific studies. In the session that was dedicated to the Kuşadası Bay-Samos Island earthquake, observations were shared among countries, which stands out as an important step for cooperation in the Samos Fault line. The special session involved presentations contributed by researchers from Turkey and Greece on observations regarding the area where the earthquake occurred, including macro-seismic and geotechnical observations, irregularities observed in groundwater and geothermal resources, sea level changes, satellite-based rapid damage assessment studies and the data on earthquake-resistant building studies. The 11 scientific manuscripts that are included in this special issue of the *Turkish Journal of Earth Sciences* (Turkish J Earth Sci) define an important contribution to this research field and international collaboration.

Science based collaboration through co-creation holds important promise for earthquake research so that it can become a culture of working together. Scientific knowledge is more valuable when shared and new possibilities open with the focus of making an impact with the approach of working together. While underlining the possibilities that can be achieved with the approach of co-creation and succeeding together in the field of earthquake research, I would like to thank all scientists who contributed to scientific collaboration and the production of this special issue in Turkish J Earth Sci. I wish researchers success in their impact-oriented research in earthquake studies.

Hasan Mandal
The President of the Scientific and Technological Research Council of Turkey (TÜBİTAK)

Preface

In 2020, the Elazığ earthquake, on the 24th of January, followed by the Kuşadası Gulf-Samos earthquake, on the 30th of October, caused a great loss of life and property. After these earthquakes took place in different geological environments of the Anatolian geography, it has once again been revealed how crucial multidisciplinary earthquake researches are for our country, where a large part of it is at earthquake hazard. The multidisciplinary researches have started to increase recently, especially after the İzmit earthquake occurred on the 17th of August, 1999. In this respect, the special call for earthquake research announced by TÜBİTAK in 2021 within the scope of '1001-Scientific and Technological Research Projects' attracted great attention; as a result, around 70 projects were deemed worthy of support. We believe that the results of the aforementioned research projects are going to take the earthquake studies in our country to another level in near future. In this regard, the Turkish Journal of Earth Sciences organized an international webinar on the active tectonics and seismicity of the Aegean Sea after the Kuşadası Bay-Samos Earthquake occurred on the 30th of October, 2020.

Besides the countries neighboring the Aegean Sea, a total of 30 invited speakers from different countries attended the workshop, and many people joined the workshop. As the only journal in our country that is indexed by SCI in the field of earth sciences, the Turkish Journal of Earth Sciences aimed to publish special issues on different aspects of earth sciences as well as on earthquakes. In addition to other papers presented at the workshop, a total of 11 articles on the active tectonics and seismicity of the broader Aegean Sea and Western Anatolia were published in this special issue. Special thanks to the President of TÜBİTAK, Prof. Dr. Hasan Mandal for providing invaluable support in the organization of the workshop and the preparation of the special issue, to ULAKBİM Director Mehmet Mirat Satoğlu, Dr. Cihan Aksop, journal administrator Seval Özgül, to all the employees for providing technical support and to Dokuz Eylül University, Sivas Cumhuriyet University, and the Disaster and Emergency Management Presidency (AFAD) for their institutional support.

We are pleased to publish this special issue on the first anniversary of the earthquake. On this occasion, I would like to express my gratitude to Prof. Dr. Spyros Pavlides (University of Thessaloniki, Greece), Prof. Dr. Riccardo Caputo (University of Ferrara, Italy), and Prof. Dr. Hasan Sözbilir (Dokuz Eylül University, Turkey) for serving as guest editors and evaluating the articles meticulously and also to all authors who contributed to this issue by their valuable pieces of works.

Sincerely,

Orhan Tatar
Editor-in-Chief

Active Tectonics and Seismicity of the Aegean Region with special emphasis on the Samos Earthquake struck on 30 October 2020

Guest Editors: Spyros PAVLIDES, Riccardo CAPUTO, and Hasan SÖZBİLİR

Preface

The earthquake of Mw 6.9 magnitude that occurred on the 30th of October, 2020 in Kuşadası Bay on a fault along the northern coast of Samos Island is among the few major earthquakes that have affected this sector of the Aegean Region during the last century. Unfortunately, it has caused great loss of lives and damages in residential areas of the Samos Island and as far as in the city of İzmir. On the other hand, many devastating earthquakes were recorded in both countries facing the Aegean Sea, causing loss of life and property in instrumental and historical periods. This is well documented by a huge literature with countless papers based on specific and regional studies carried out on several seismogenic sources and associated earthquakes occurring in the broader Aegean Region between the Hellenic Arc and the North Anatolian Fault. From a geological and geodynamic point of view, this area represents a unique natural laboratory for investigating seismotectonics, making it of global scientific interest due to its intense seismic activity.

Considering the international interest risen by the damages both in İzmir on the Turkish side and on the Samos Island on the Greek side, a Workshop on "Active Tectonics and Seismicity of the Aegean Region with special emphasis on the October 30, 2020 Samos Earthquake (ASASE2021)" was organized online on May 20–21, 2021 under the leadership of TÜBİTAK and with the contributions of Dokuz Eylül University, Sivas Cumhuriyet University, the Aristotle University of Thessaloniki, and the University of Ferrara. The aim was to share and discuss the information that was already available at that time from numerous researchers but also to inform the public. Indeed, the most important action we, as earth scientists, could put forward against earthquakes is the production of scientific data, based on a collaborative approach and common goals. Although focusing on the effects of the Samos earthquake observed within the broader Aegean Region, the workshop represented an important occasion to discuss earthquake phenomena in general and to shed light on the active tectonics and seismicity of the area. A total of thirty oral and five poster presentations were presented by scientists from Turkey, Greece, Italy, Germany, Japan, Canada, and the United States of America during the two-day workshop. In these presentations, the latest scientific studies on earthquake geology and the seismicity of the Aegean Region, earthquake hazard sources, and tsunami hazards were presented and discussed among all scientists participating at the workshop. Updated data obtained on both the land side and the sea by the scientists were presented under a wide range of topics, investigation tools, and methodological approaches, such as active tectonics, geodynamics, seismic, tsunami, Global Positioning System (GPS), and Interferometric Synthetic Aperture Radar (InSAR) applications. The aforementioned issues reveal the importance of multidisciplinary and international research for better understanding and modeling active tectonics and Seismic Hazard Assessment based on the high-resolution data obtained by field studies, as well as by theoretical approaches.

We would like to emphasize that every new scientific knowledge becomes more valuable when shared, and new opportunities are obtained to create an impact within a collaborative approach in the field of earthquake research. This workshop also created a scientific bridge between scientists for dealing with natural disasters and especially the seismic activities that affect a wide region of the Eastern Mediterranean. This bridge that we have built must be strengthened with future collaborations.

In this Special Issue of the Turkish Journal of Earth Sciences, the following contributions have been selected from the workshop presentations after peer-review process (see Figure).

Source modelling and stress transfer scenarios of the October 30, 2020 Samos earthquake and its seismotectonic implications studied by **Sboras et.al. (2021)** by using seismological and geodetic data (GPS measurements and originally processed GNSS records), as well as their field observations on Samos Island few days after the mainshock. The integration of this information leads to a N-dipping normal fault (Kaystrios fault) that controls the central-northern coast of Samos Island. They modelled the seismic source and calculated the theoretical dislocation (using the Okada formulae) on the surrounding GPS/GNSS stations, comparing it with the measured values. They also studied the spatiotemporal evolution of the aftershock sequence by exploiting published seismological data (focal mechanisms and two seismic catalogues, one of which with relocated hypocentres) and calculated Coulomb static stress changes caused by the mainshock. This comparison suggests that more faults than the Kaystrios fault were involved in the aftershock sequence and that the Coulomb stress changes indicated various results according to each receiver fault. In the study by **Aktuğ et al. (2021)**, the finite source mechanism of the Samos earthquake was investigated using geodetic methods and the coseismic behavior of the earthquake was modeled. To determine the coseismic displacements, GNSS measurements were carried out at 62 sites. The maximum coseismic displacement was calculated -372 mm and 65.3 mm for the N and E component, respectively. The displacements at 62 sites were inverted for the fault geometry and the slips. The uniform slip modeling shows a finite source 43.1 km long and 16 km wide rupture, with 1.42 m of dip-slip kinematics along a north dipping normal fault extending from the Aegean Sea floor to a depth down to ~13 km. The **Stiros (2021)** contribution is an effort to explain macroseismic

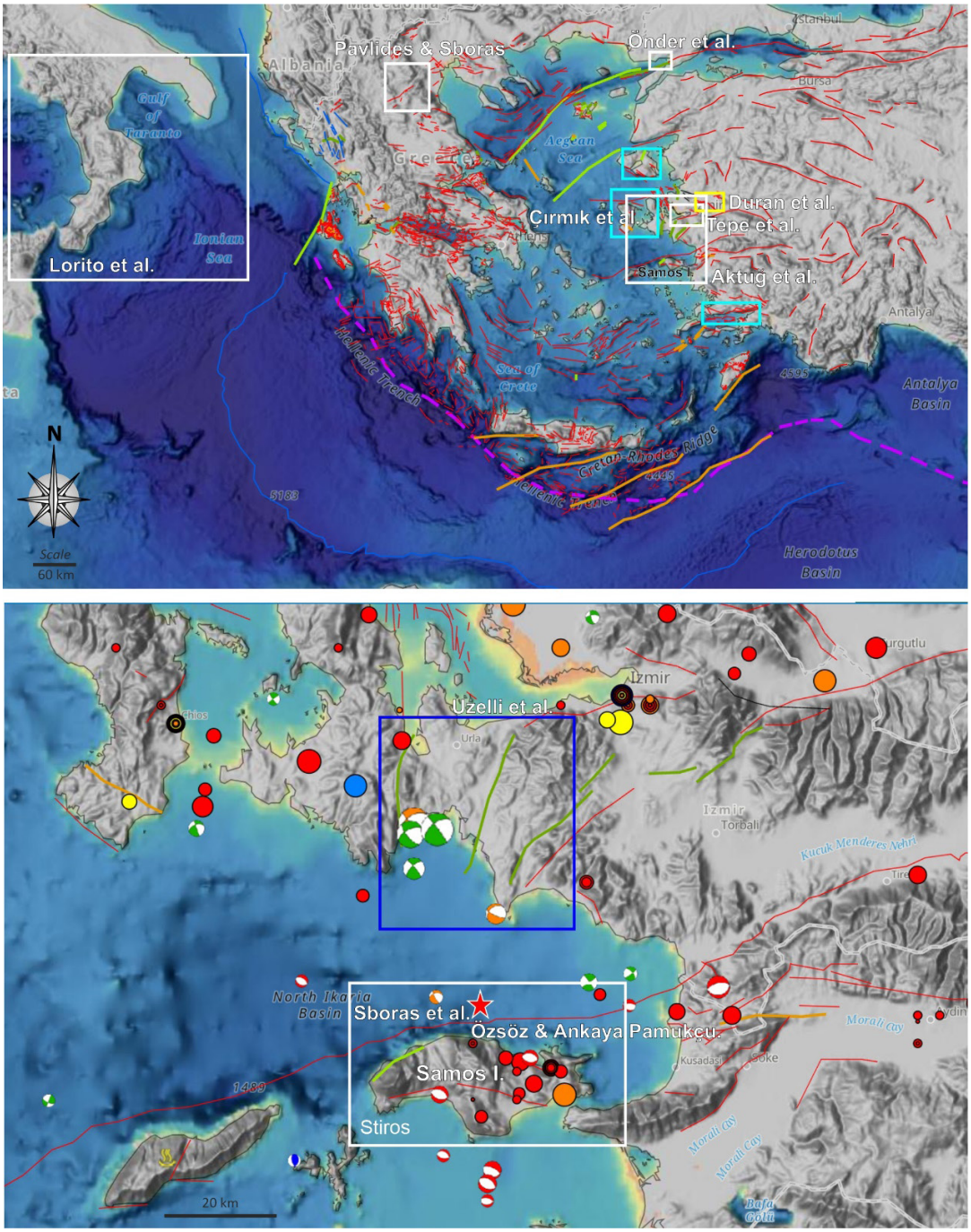

Figure. Seismotectonic map of the West Anatolia and the broader Aegean Region. The areas described in this special issue are also indicated in boxes. Base maps are from the Greek and Turkish Seismotectonic Database.

results and to join with seismic accelerations (strong motion), a serious and difficult subject. The author addresses it and by studying overturned ancient columns on Samos Island estimates a minimum ground acceleration, as well as some likely spectral frequencies concluding that though earthquakes similar to the 2020 Samos event are not uncommon, modelling of ancient earthquakes based on very limited historical information needs to be revisited. As such work is in principle useful particularly after the destructive Samos-Izmir earthquake of 30 October 2020. Detection and interpretation of precursory magnetic signals preceding rhe October 30, 2020 Samos event was studied by **Özsöz and Ankaya Pamukçu (2021).** They analysed swarm satellite magnetic data for 153 days before and 46 days after the earthquake. Pre-event and post-event anomaly search is constrained within the Dobrovolsky's Circular Area. They made 5 steps for processing satellite magnetic data to interpret the earthquake preparation phase. In the first step, they converted geographical coordinates into geomagnetic latitude and longitude. Secondly, intensity of the external magnetic field was evaluated by magnetic indices. Thirdly, preearthquake and postearthquake magnetic anomaly was constrained through magnetic indices and Dobrovolsky's Circular Area. The fourth step was the filtering short-wavelength magnetic anomalies using

first time derivative and trend removal (detrend), while during the last step anomalous residual magnetic variations of the satellite tracks were classified through RMS analysis. The cumulative number of anomalous points (y-axis) is plotted versus the date (x-axis). R2 values denote the degree of linear distribution of the anomalous tracks. For X, Y, Z, and F components of the magnetic field, R2 is computed as 0.90 0.87, 0.85, and 0.97, respectively. According to the authors, Y component of the magnetic field provided the best results in terms of interpretation. Regarding the results of the Y component, linear distribution and deviation from this distribution are fairly distinguishable. Water resources were monitored by **Uzelli et al. (2021)** in the areas of Bayraklı, Gülbahçe, and Seferihisar before the October 30, 2020 Samos earthquake. Especially, the water level rise steps observed in ten shallow wells in Bayraklı Plain are due to the compaction of the units during the earthquake. It is a significant finding that the instantaneous changes in the temperature, electrical conductivity, and groundwater level in the observation wells were determined at the time of and before the earthquake. In addition to causing sudden changes in groundwater levels, observations show that the seismic activity can keep water levels under control for a certain period. As in groundwater, the Samos earthquake also showed its effect on nearby fault zones. Faults in the Seferihisar and Gülbahçe geothermal fields were affected by the Samos earthquake, and formation new geothermal springs, gas leakage and liquefaction events were detected in these areas. Also, temperature and flow rate increases, especially in geothermal waters after the Samos earthquake, are quite remarkable. As a result, the formation of new geothermal springs on known fault segments (Gülbahçe-İçmeler and Tuzla Faults) and groundwater level changes in Bayraklı Plain are situations that should be carefully monitored in the long term.

The **Tepe et al. (2021)** paper is a remarkable attempt to further compile an updated historical earthquake catalog for the Izmir area using more than 20 earthquake catalogs, many of which have never been used in previous studies. Furthermore, they correlation historical earthquakes with seismic sources have the potential to produce destructive earthquakes. As such, it is in principle useful particularly after the destructive Samos event of 30 October 2020. **Duran et.al. (2021)** studied the palaeoseismic history of the Manisa fault zone (MFZ), which constitutes the western section of the Gediz Graben. According to the results obtained from the trenches, they detected six surface rupturing earthquakes since late Pleistocene-Holocene, which have occurred at 30.6 ± 8.8 ka (E1), 15.0 ± 5.0 ka (E2), 6.6 ± 1.3 ka (E3), 2.9 ± 1.3 ka (E4), 0.8 ± 0.4 ka (E5), and 0.1 ± 0.1 ka (E6) and can be correlated with 17 AD, 926 AD, and 1962 AD. The proposed interevent time, the estimation of the recurrence interval for the MFZ, varied between 0.95 ka and 3.8 ka for the Holocene, and the elapsed time since the most recent surface ruptured earthquake on the MFZ is 159 years. **Pamukçu et al. (2021)** provide detailed data on the seismic a and b-values within the first 24 hours and 14 days after the mainshock of Chios Island-Gokova Bay (Mw= 6.6), Lesvos Island-Karaburun (Izmir) (Mw=6.2) and Samos Island-Aegean Sea (Mw=6.9) earthquakes. The a and b values were found as 4.13 and 0.59 for the Samos Island-Aegean Sea earthquake, 4.20 and 0.81 for the Lesvos Island-Karaburun (Izmir) earthquake, 4.66 and 0.84 for the Chios Island-Gokova Bay earthquake aftershocks in 24 hours. The a-value and b values were calculated as 4.88 and 0.74 for the Samos Island-Aegean Sea, 4.77 and 0.87 for the Lesvos Island-Karaburun (Izmir) earthquake, 4.96 and 0.87 for the Chios Island-Gokova Bay earthquake and its aftershocks in 14 days. They found that there is a crustal problem at the lower crust of Samos Island and its surroundings, also the lower crusts of the regions including Lesvos and Chios Islands are stronger than the regions including Samos Island.

Recent earthquake activity in March 2021 in northern Thessaly is the subject of **Pavlides and Sboras (2021)** presentation. In this short opinion study, the authors aim to present new and old problems related to active faults as seismic sources, after the last March 3 and 4, 2021, (Mw = 6.3 and Mw = 6.0, respectively) earthquakes in Northern Thessaly, Greece. They suggest two new seismogenic sources responsible for the two strongest geological events of the 2021 earthquake succession, which differ from the previously known active faults indicating the role of inherited Alpine structures that seem more important today than in the past. Fault-controlled gas escapes in the shelf sediments of the Saros Gulf, NE Aegean Sea is described by **Önder et al. (2021).** They performed high-resolution seismic profiles along the submarine Ganos Fault, in the Saros Gulf and use the obtained results to better constrain the main fault segments affecting the area providing important information on this seismogenic structure. The survey also allowed to identify features on the seabed associated with the expulsion of hydrocarbon gases and fluids. According to the authors, understanding these interactions may provide valuable contributions to hydrocarbon explorations and early-warning strategies against earthquake risk.

Lorito et al. (2021) give an overview regarding tsunami hazard, warning, and risk reduction in Italy and the Mediterranean Sea. They describe the status quo of the tsunami hazard management by CAT-INGV and the other national agencies involved. The topics dealt with range from operational, organizational, and legal aspects of the earthquake and tsunami monitoring, to local hazard assessment, planning, awareness-raising and preparation, within an end-to-end excursus. They also describe the gaps and issues that need to be taken into account, as well as plans and strategies to tackle them.

We are most grateful to the reviwers Filippos Vallianatos, Ethem Görgün, Serkan Öztürk, Salah Moutafa, Alexandros Chatzipetros, Nevzat Özgür, Konstantinos Voudouris, George F. Karakaisis, Gerassimos Papadopoulos, Mosbeh R. Kaloop, Hediye Erdoğan, Betül Atalay, Gabriele Tarabusi, Paris Xypolias, Derman Dondurur, Eric Chaumillon, Marco Bonini, Georgios Deligiannakis, Şebnem Önder, Selim Özalp, Ömer Feyzi Gürer, Marinos Charalampakis, Jörn Lauterjung for their constructive criticism and suggestions, which undoubtedly improved the quality of the papers published in this special issue.

Thanks are also due to Prof. Dr. Orhan Tatar, the Editor-in-Chief of the Turkish Journal of Earth Sciences, for his constant support and encouragement during the preparation of this issue.