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ABSTRACTS

CHALLENGES AND APPROACHES FOR SEISMIC SOURCE CHARACTERIZATION OF CRUSTAL FAULTS IN DATA-POOR REGIONS

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Seismic source characterizations of crustal faults for probabilistic seismic hazard analyses (PSHAs) conducted in regions with limited data often face considerable challenges that can have large impacts on the hazard results. Seismic source characterizations include parameters such as fault geometry, style of faulting, segmentation, magnitude, and recurrence. Despite significant advancements during the last two decades in the ability to recognize and characterize Quaternary faults (e.g., lidar, satellite imagery, geophysics, photogrammetry, geochronology techniques), data limitations remain common and largely stem from issues related to accessibility, environment/geomorphic preservation of prehistorical earthquakes, lack of study, and ultimately funding limitations. In such cases, seismic source characterization efforts are often overly reliant on the historical record and regionally or globally compiled active fault datasets. These datasets possess varying levels of completeness, detail, and vetting that may lead to inaccuracy and hence, imprecise estimates of probabilistic hazard. Based on experience reviewing and developing crustal fault source models for critical infrastructure in data-poor regions throughout the world, we identify common challenges, recurrent pitfalls, and potential undesired consequences of data-limited seismic source models in regions with poorly characterized faults. Additionally, we outline a repeatable and adaptable approach to crustal fault

source characterization in data-poor regions that (1) addresses primary challenges, (2) maximizes publicly available data, and (3) establishes a baseline framework for defining seismic source parameterization. Key to this approach is exhaustive literature review in all languages, interaction and discussion with local experts to understand published/unpublished data and level of study, critical review of geologic and geomorphic data, clear and explicit identification of primary uncertainties, and the use of logic trees to capture the appropriate epistemic uncertainty in developing the seismic source parameters.

OVERVIEW OF THE SEISMIC STRUCTURE IN THE CAUCASUS

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The Greater Caucasus is segment of the Alpine-Himalayan mountain belt, that has undergone rapid uplift in the past 5 million years. Being one of the youngest mountain systems of the earth, it can be considered as the unique place to understand early stage of mountain formation. Recent studies showed, that region has lack of instrumentally obtained observation data and requires improving and extending geophysical monitoring systems to understand its complex structure. Relatively lower resolution seismic velocity models of this region show contradictory lateral variability. Furthermore, recent waveform modeling and relocation of old earthquake dataset has clearly demonstrated the presence of deep earthquakes (with a maximum hypocentral depth of 175 km) below the Greater Caucasus. The region has been largely unexplored in terms of the detailed uppermost mantle and crustal seismic structure. Seismic network resolution in the Caucasus countries has been improved during past several years. National networks deployed new seismic stations and established good collaboration in exchanging online waveform data. Recently Seismic Network of the region improved tremendously in the framework of the joint regional project "The Uplift and Seismic Structure of the Greater Caucasus" , supported by USA Department of Energy, IRIS Passcal and Science and Technology Center in Ukraine (STCU). Project has started since April 2017. Scientific teams from Armenia, Azerbaijan, Georgia and USA (Michigan State University, Oregon State University, Missouri State University) jointly deployed 53 seismic stations in the region. Our seismic array has two components: (1) a grid of stations spanning the entire Caucasus and (2) two seismic transects consisting of stations spaced at distances of less than 10 km, that cross the Greater Caucasus. Our study address fundamental questions about the nature of continental deformation in this poorly understood region. Using data from over 106 new seismic stations in Azerbaijan, Armenia, Russia, and Georgia, we hope to gain a better understanding of the structure of the Greater Caucasus and the nature of seismogenic deformation in the region

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EARTHQUAKE LOCATION IMPROVEMENT IN THE CAUCASUS USING CNET DATA

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The Greater Caucasus is a segment of the Alpine-Himalayan mountain belt that has undergone rapid uplift in the past 5 million years. The Caucasus is a unique place to understand the early stages of mountain building. Until recently, this region has had a lack of reliable digital data that has required extending existing geophysical monitoring systems. Relatively low-resolution seismic velocity models of this region show different lateral variability. The area has been largely unexplored regarding the detailed uppermost mantle and crustal seismic structure. Seismic network resolution in the Caucasus countries has improved during the past several years. National networks deployed new seismic stations and established collaboration in exchanging online waveform data. Recently, the seismic networks in the region improved tremendously in the framework of the joint regional project "The Uplift and Seismic Structure of the Greater Caucasus," supported by the USA Department of Energy, IRIS PASSCAL and Science and Technology Center in Ukraine (STCU). Scientific teams from Armenia, Azerbaijan, Georgia, and the USA (Michigan State University, Oregon State University, and the University of Missouri) jointly deployed 53 seismic stations. Our seismic array has two components: (1) a grid of stations spanning the entire Caucasus and (2) two seismic transects consisting of stations spaced at distances of less than 10 km that cross the Greater Caucasus. Our study addresses fundamental questions about the nature of continental deformation in this poorly understood region. Using data from new seismic stations in Georgia, we used this new data to study seismicity and the complex seismic structure of the area. We present earthquake locations recoded over 6 years of seismic deployment of the area

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ATTENUATION STRUCTURE OF THE CAUCASUS

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The Caucasus represents a tectonically complex and seismically active segment of the Alpine-Himalayan continental-continental collision zone. Observations from historical and instrumental periods indicate high seismic activity in the Caucasus. The study of the properties and characteristics of seismic wave attenuation is a significant component in constructing models of ground motion induced by earthquakes, which are later used to solve engineering problems such as seismic hazard assessment. The seismic wave attenuation model is one of the most important components for modeling the seismic source, particularly for solving source inversion problems. In our study of frequency-dependent Pg and Sg attenuation models in Georgia, we considered frequencies from 1 Hz to 4.5 Hz to analyze the behavior of both Sg and Pg waves. To perform attenuation calculations, we used the Reverse Two-Station Method (RTM) and the Two-Station Method (TSM). Our research included approximately 400 seismic events from Georgia and its surrounding borders

that meet specific criteria: magnitudes above 3.0Ml, depths less than 35 km, and epicentral distances within 150 km from monitoring stations. The data was obtained from the Earth Science and National Seismic Monitoring Center of Georgia (GNSM), which integrates the region's modern seismic network, including 14 new posthole broadband stations funded under the SNECCA project and approximately 40 stations under the TRANSEC project (2017-2021). Our observations indicate high attenuation in the Greater Caucasus, consistent with a hot crust underlying the mountain belt. We also identified isolated pockets of highly attenuating crust in the Javakheti region, potentially linked to volcanism in the area. Additionally, we observed significant differences between the RTM and TSM Q models in the Rioni basin, suggesting a notable site amplification effect on the TSM results. We plan to quantify this effect in future research.

SEISMIC HAZARD AND RISK

Tuna Onur[1]

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Earthquakes impact people through damage to manmade structures. Therefore it is important to understand how buildings and infrastructure in a community will respond to earthquakes. In order to estimate how much earthquake risk communities are exposed to, the following are needed: 1) probabilistic seismic hazard assessments, which quantify earthquake occurrence and how much the ground shakes at a reference site given the size, location and other characteristics of earthquakes that can happen in a region, 2) microzonation studies, which quantify the effects of local site conditions and near-surface geology on the ground shaking and other effects such as liquefaction and earthquake triggered landslides, 3) development of an exposure database that shows what kind of structures are in a community and where they are located, as well as vulnerability and fragility functions that describe the probability of being various damage states given a certain level of earthquake shaking. Once estimates of direct damage to structures are made, downstream impacts can be calculated, such as human impacts (casualties, injuries, post-earthquake shelter needs, etc.), response and recovery related impacts (volume of debris that needs to be cleared up, interruption of lifelines including transportation, power, communications, etc.), and economic impacts (dollar losses, business interruption, etc.). Seismological analyses and research are a key component of understanding seismic hazard. Robust estimates of earthquake locations and magnitudes are important for the quality of hazard assessments. Locally recorded strong ground motion data is critical in understanding local seismic wave propagation at damaging levels of ground shaking. Probabilistic seismic hazard assessments also underpin the seismic loads for which new buildings are designed in modern building codes. Probabilistic seismic hazard assessments have various outputs that are used in building codes such as hazard maps, uniform hazard spectra, and hazard deaggregation plots. Building codes and the underlying seismic hazard assessments need to be updated regularly as more earth science and research become available. An up to date building code serves as an effective risk reduction tool (as long as code compliance is ensured) by avoiding creation of new risk to communities as well as by being used as guidance for seismic retrofits of existing building stock.

REGIONAL SEISMIC HAZARD MODELS AND OVERVIEW

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Recent seismic hazard assessments efforts in the Caucasus and Central Asia supported by the Seismic Cooperation Program of the Lawrence Livermore National Laboratory in California, US, have included a series of activities to significantly improve the quality of these assessments. These improvements started with the digitization of invaluable data that were sitting in the paper-based archives of the participating countries: Georgia, Armenia, Azerbaijan, Tajikistan, Kyrgyzstan and Kazakhstan. Then, using Coda Calibration Technique, reliable moment magnitudes were directly computed down to magnitudes of about 2.5, which also allowed development of better regional magnitude conversion relations for older events. Local institutions were trained to be able to make use of this new technique and to continue to utilize it for routine magnitude calculations. In parallel, earthquake relocations were performed with a series of quality checks to make sure both the locations and depths of earthquakes are calculated with better reliability and resolution. In addition, all the available analogue and digital strong motion data were compiled, analogue data digitized, and a strong motion database was created to use for validation of the ground motion models used in the seismic hazard assessments. Georgia was the first country to complete a seismic hazard assessment (in 2019) using these new data and methods. Next (in 2024) the three participant countries from Central Asia: Kazakhstan, Kyrgyzstan and Tajikistan finished their seismic hazard assessments in coordination with each other. Azerbaijan seismic hazard assessment is also in its last stages and is expected to be released soon. It is important to note that there are numerous new initiatives in the region for seismic and strong motion data collection and active fault studies. Therefore, these assessments need to be updated regularly. The Georgian team is already starting to work on an update of the 2019 study with new data.

REGIONAL PSHA RESULTS FOR THE CAUCASUS AND CENTRAL ASIA

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This presentation provides the results from recent probabilistic seismic hazard assessments (PSHA) efforts in the Caucasus and Central Asia under the Seismic Cooperation Program of the Lawrence Livermore National Laboratory in California, US. The activities of this program led to a significant improvement in the quality of these assessments and the regional training provided under this program improved the local capacities to conduct such analyses. For a selected ground shaking level, PSHA provides the probability of exceeding that level of shaking. Alternatively, PSHA can provide the ground shaking levels at various locations, for a selected probability of exceedance. The latter is the manner in which building codes use PSHA for determination of earthquake loads that engineers use to design buildings. PSHA highlights areas where earthquakes are more likely, but a large earthquake can happen even in low hazard regions, because a typical PSHA is not time-dependent and has no predictive power. In other words, high seismic hazard areas identified in a PSHA does NOT mean that the next big earthquake will happen in these regions, or if a damaging earthquake happens in an area identified as low hazard in a PSHA, that does NOT invalidate the hazard assessment. In each PSHA, multiple source models were generated and multiple ground motion models were used in a logic-tree fashion. The national models in the Central Asia PSHA were harmonized across country borders. Ground motion models were validated using as many strong motion records as possible, but the lack of strong motion data in the region made this task challenging. A new Seismic Cooperation Program initiative saw the installation of many strong motion instruments in the region, which will improve the understanding of strong motion attenuation in the region. The full reports with PSHA outputs (hazard maps, uniform hazard spectra, hazard curves, and hazard deaggregations) for different probability levels and various ground motion parameters can be found at the following links. Georgia: https://www.osti.gov/biblio/1511856 and Central Asia: https://www.osti.gov/biblio/2318777

SEISMIC COOPERATION IN THE CAUCASUS AND CENTRAL ASIA

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With support from the U.S. Department of Energy, Lawrence Livermore National Laboratory and the Incorporated Research Institutions for Seismology are collaborating with seismic monitoring centers in the Caucasus and Central Asia to expand national seismic networks through the installation of permanent broadband seismic stations. The main goal of the project is to improve regional network coverage by making high quality data from new stations openly available to the global scientific community. The multi-year project involves deployment of more than fifty posthole broad-band sensors across six participating countries: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, and Tajikistan. Additionally semi broad-band stations will be deployed for local monitoring of volcano and mud-volcano sites in Armenia and Azerbaijan; and standalone urban type strong motion sensors will be deployed in large cities. To facilitate data exchange and incorporate diverse sources of real-time data into national monitoring solutions, the project also supports the installation of high-capacity servers for participating monitoring centers. Station deployments began in the summer of 2021 and are planned to be completed in 2023. The project is implemented through the Seismic Targeted Initiative of the International Science and Technology Center in Kazakhstan and the Science and Technology Center in Ukraine.

CODA-ENVELOPE BASED MOMENT MAGNITUDES

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Reliable estimates of moment magnitude and source mechanism for seismic event are essential parts of understanding a seismic region and for probabilistic seismic hazard analysis (PSHA). Although waveform modeling-based methods (e.g. moment tensor inversion) is routinely used for moderate-sized and larger earthquakes (M>4 for regional catalogs), these inversions require good azimuthal distribution of stations and very good knowledge of the Earth’s structure in the region, which makes waveform modeling difficult to perform on smaller earthquakes. Robust regional-specific seismic event characterization requires well-calibrated regional seismic stations to produce reliable and stable estimates of earthquake source parameters which can be derived using the coda wave calibration method. The Coda Calibration Tool (CCT) is an application designed for calibrating 1D shear wave coda measurement models to observed data using a small set of reference moment magnitudes calculated from other methods, such as moment tensor inversion. These calibrated measurement models can then be used to generate coda moment magnitude MW using source spectra for seismic events in the calibrated region. In this presentation we describe the methodology of using the CCT for calibrating a region's seismic stations. CCT enables robust and rapid processing of local and regional coda envelopes to estimate stable source spectra, moment magnitude, and apparent stress. We present two calibrations for the Caucasus and Central Asia regions and examine their performance on 4 recent earthquakes with magnitudes Mw 3.86, 3.88, 4.38, and 5.25 that occurred in the surrounding regions. The results exemplify the stability of the calibrations that we hope to be used to facilitate reliable estimates of moment magnitude and source mechanism for seismic events at local and regional distances in the Caucasus and surrounding regions in the future. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

APPLICATION OF GEOLOGICAL, VOLCANOLOGICAL AND SEISMIC DATA FOR GEOTHERMAL ENERGY EXPLORATION:THE CASE FOR ARMENIA

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Armenia is a landlocked country in the South Caucasus, bordered by Iran, Georgia, Azerbaijan, and Turkey, with a population of about 3 million. As part of the Anatolian-Armenian-Iranian orogenic plateau, Armenia has been subject to continental collision between the Arabian and Eurasian plates from the Neogene to Quaternary periods, resulting in extensive and long-lasting volcanic activity. Studies by Sugden et al. (2021) show Armenia has one of the densest clusters of Quaternary monogenetic volcanoes on Earth, with 516 volcanoes in an area of ~30,000 km². These volcano clusters are mostly oriented NW to SE, perpendicular to the main stress direction caused by NE movement of the Arabian plate. Armenia also has several active faults, which have caused many strong historical earthquakes. While these geological features pose serious hazards, they also hold significant potential for geothermal energy. Geothermal energy presents a local and sustainable source of energy, especially critical in Armenia, which currently relies heavily on imported fossil and nuclear fuels. Notably, dozens of thermal mineral water sources, often located near volcanic systems and active faults, are known within Armenia. The presence of numerous thermal mineral springs, especially near volcanic and fault systems, further suggests geothermal potential. Our preliminary geochemical studies, done using geochemical thermometers, have identified several geothermal anomalies. Within the framework of our study for geothermal potential assessment, funded by the USAID PEER Program and US NAS, we have developed a unified geological, geophysical, volcanological, and geochemical database, highlighting promising geothermal sites. Initial results from ambient noise seismic tomography (ANST), using data from Armenian seismic networks, offer further insights into subsurface structures favorable for geothermal energy. This comprehensive approach provides a foundation for Armenia to diversify its energy resources by advancing sustainable geothermal power.

PYSOLATE: A PYTHON-BASED THRESHOLDING TOOL TO DE-NOISE OR DE-SIGNAL SEISMIC WAVEFORMS BASED ON THE CONTINUOUS WAVELET TRANSFORM

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Removing noise from seismic data to increase signal-to-noise ratios is one of the most important problems in seismology. An abundance of preprocessing methods have been applied to extract signals out of noisy data as increased noise in the microseismic band is a challenge to lowering regional monitoring thresholds. Improved accuracy of shorter period (<20 second) waveform simulations is only useful if clear short period signals can be extracted from noisy waveform records. The application of a filtering method that removes microseismic noise, thus isolating the seismic signal, will be key to better utilization of improved short-period waveform simulations. To this effort, following the Langston et al. (2019) CWT application we developed a Python based toolset that implements the CWT-based non-linear thresholding operations to de-noise or de-signal seismic data. We test this application using the 2020 Mw 6.5 Monte Cristo Range earthquake sequence to assess automation and portability into a processing scheme. We find that the denoiser performance varies with event size and distance from the station. As expected, smaller events are best observed on the closer stations after denoising, and larger events can be denoised on stations further from the event. Preliminary results show that denoising many events using a single noise model will be helpful in aftershock sequences, where signals arrive in rapid succession and no clear noise window can be identified. Further analysis will help us understand how far stations can be for this process to produce useful signals. This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. LLNL-ABS-843563.

PETROGENESIS, MANTLE SOURCE CHARACTERISTICS AND TEMPORAL/SPATIAL EVOLUTION OF THE COLLISION RELATED LATE

MIOCENE TO RECENT VOLCANISM ACROSS ANATOLIA AND LESSER CAUCASUS

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The Eastern Caucasus Mountains in Georgia include products from extensive Miocene volcanic activity that are being unraveled by geological mapping supported by geochronology and geochemistry. This article presents new zircon U–Pb geochronology and whole rock geochemistry of the volcanic ash layers of the intermountain Neogene basin of the Eastern Caucasus. Our investigation in the region demonstrates that these ash layers, whose eruption center(s) have not been identified yet, has age and geochemical characteristics of the Mtkvari (Kura) ignimbrite of the Samtskhe-Javakheti volcanic highland. This study shows that zircons from both formations crystallized at the same time ~ 7.50 Ma ago and have geochemical and morphological similarity. Taken together with the geography of the region (200–300 km from the volcanic source to the sedimentary basins), it is likely that the source of the ash layers was the Upper Miocene volcanic eruptions on the Samtskhe-Javakheti volcanic highlands. Based on the distribution, thickness, and age of the volcanic ash layers and the analysis of the structure and scale of the Mtkvari ignimbrite, the widely distributed ash likely resulted from a Plinian-type eruption in the Samtskhe-Javakheti volcanic highland. These eruptions led to the formation of the large-scale caldera structure (Niala caldera) and the Mtkvari ignimbrite. The inferred caldera extends to the northeastern territory of Türkiye (Turkey), i.e., NE of the Kars Plateau. Ideally, this western portion of the caldera and volcanic highlands can be characterized in the future, and a unified structure model of this volcanic center can be established.

DETERMINATION OF LOCAL SITE EFFECTS IN ANTAKYA BASIN WITH DATA OBTAINED FROM MICROTREMOR MEASUREMENTS AND EARTHQUAKE RECORDS

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On 06.02.2023, at 04:17 and 13:24 Turkey time, two earthquakes with magnitudes of Mw 7.7 and Mw 7.6 occurred, respectively, with the epicenters in Pazarcık (Kahramanmaraş) and Elbistan (Kahramanmaraş). Following the earthquake, a post-earthquake aftershock study was initiated jointly with Japanese researchers within the framework of the cooperation of "Japan Science and Technology (JST)" from Japan and TUBITAK institution from Turkey. For this purpose, in the first phase of the study, three or four accelerometers, totally 21 accelerometers, were located in Antakya, Iskenderun, Adıyaman and Kahraman Maraş, which were heavily damaged areas. In the next phase, which started in September 2023, all accelerometers except four were moved into and around the Antakya basin. During this period, an earthquake with a magnitude of Mw = 5.3 was recorded approximately 300 km away from the Antakya basin. In this study, these earthquake data recorded with 16 accelerometers were analyzed. As a result of the analysis, it was determined that the accelerometers placed inside the basin had amplfications of up to 10 times compared to the accelerometers outside the basin. Although it was 300 km away, it was understood that one of the important reasons for the great damage caused by the Kahramanmaraş earthquake in Antakya was due to basin effects.

SHEAR WAVE SPLITTING AND UPPER MANTLE ANISOTROPY IN THE CAUCASUS

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The Lesser and Greater Caucasus are a broad zone of diffuse deformation resulting from the convergence of the Arabian with Eurasian plates and is one of the best places on earth to study early stages of continental collision. In order to investigate upper mantle deformational fabrics in this region, we have determined shear wave splitting parameters using the Caucasus Seismic Network (CNET). CNET is a network of approximately 150 broadband seismic stations deployed as linear transects and 2-D arrays through the countries of Georgia, Armenia, Azerbaijan, and Russia. Our results show fast polarization directions are generally northeast-southwest throughout the Lesser Caucasus, with average lag-times of 0.8 s. We observe fast polarization directions rotate and become parallel to the strike of the Greater Caucasus orogenic belt. For stations along the eastern Greater Caucasus and within the Kura basin, the fast directions generally have a northwest-southeast trend with an average lag-time of 1.2 s. These results agree with prior studies conducted in the East Anatolian Plateau and Kura Basin. The azimuthal variation in these preliminary results is uncertain, as the lag times from events coming from similar azimuths vary more than expected. We are working to expand these initial results using data from local networks to increase the resolution of anisotropy in the region. These new results give us further insight into upper mantle strain fabrics and anisotropy of the region and can help us understand the uplift mechanisms for the Greater and Lesser Caucasus.

NETWORK MAINTENANCE INFORMATION STRATEGIES FOR THE SNECCA PROJECT

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The Seismic Network Expansion in the Caucasus and Central Asia (SNECCA) project is a multi-year effort initiated in September 2018 and running through 2024 to expand national seismic monitoring networks in Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, and Tajikistan. Planned deployments under this project were impacted significantly by COVID-related travel restrictions, however operators have now completed construction and installation of the seismic and strong motion stations following best practices. Real-time archiving for these stations has been established at the EarthScope Data Management Center for publicly accessible data. As all participating SNECCA countries transition from construction to regular network operations, we look to continue supporting technical interchange across borders on network servicing and maintenance strategies, developing data products, and information management. This extended initiative proposal includes all participating countries as well as EarthScope (formerly IRIS), Lawrence Livermore National Laboratory (LLNL), and other collaborators. Flexibility will be incorporated to address differing needs, and also support additional countries such as Ukraine through a similar process.

LARGE EARTHQUAKE ON JANUARY 22, 2024, WITH MW=7.0 ON THE BORDER OF KYRGYZSTAN AND CHINA

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The large Uqturpan earthquake of January 22, 2024, with Mw=7.0 occurred in the Southern Tien Shan (STSh) region, in the Gissar-Kokshaal fault zone, which detaches the STSh from the Tarim Basin. The STSh fold-and-thrust belt is one of the largest collisional orogens in Eurasia. The paper presents the results of the analysis of instrumental data and strong motion records for the main shock. The Uqturpan earthquake was felt in the territory of Kyrgyzstan, Kazakhstan, Tajikistan, Uzbekistan, Turkmenistan, Azerbaijan, Russia, India. The intensity at the epicenter of the main shock reached 8-9 points according to the MSK-64 scale in the Xinjiang Province (China), on the southern coast of Issyk-Kul Lake (Kyrgyzstan) it was 5-6 points, in Almaty (Kazakhstan) and its suburbs - 5 points, Bishkek (Kyrgyzstan) - 4.5 points. Data on the intensity for populated areas of Central Asia were collected, and the dependence of the intensity in points on the distance for this earthquake was received. The earthquake was accompanied with numerous aftershocks. It was found that the orientation of the aftershock cloud, recorded during the first ten days after the main shock, coincides with the orientation of active faults and the strike of the NP1 nodal planes of the main shock focal mechanism. The features of the aftershock process over a 5-months period are analyzed in accordance with the Omori and Båth laws. It is shown that Båth's law on the relationship between the magnitudes of the main shock and the strongest aftershock is worked. The action of the Omori law, which shows the rate of decrease in the number of aftershocks in the regular stage of the aftershock process

implementation, is verified. Two stages can be distinguished according to the time course: 1–19-day period, consistent with the Omori law, the tilt angle was -1.2; in the period from the 20th day until the end of the considered sample, random fluctuations in aftershock activity are observed. Besides, 60 accelerograms of strong motions were processed according to the data of Central Asian stations in the range of hypocentral distances from 88 to 2225 km, using the SeismoSignal software. The largest amplitudes of PGA accelerations equal to 30–43 cm/s2 correspond to an intensity of 6 points and were recorded from 88 to 182 km from the epicenter. The dependence of the maximum amplitudes of strong PGA (Peak ground acceleration) motions on the distance was created and breakup on intensity areas in accordance with the correlation relations between the parameters of ground motions and macroseismic descriptions of effects at the locations of seismic stations was done. The obtained fault plane solutions of the main shock and the strongest aftershocks showed the predominance of reverse-thrust type of focal mechanisms. The extension of nodal planes along the fault, which is consistent with the north-eastern orientation of the aftershock cloud and, in general, with the geodynamic conditions of the Tien Shan and the Tarim Basin junction zone, was established.

INTEGRATING DISCIPLINES FOR SLOPE STABILITY: GEOLOGY, REMOTE SENSING AND MODELING

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Slope stability is a critical aspect in the prevention of landslides and erosion, vital to safeguarding infrastructure and communities. This poster delves into the interdisciplinary approach of integrating geology, remote sensing, and modeling to analyze, predict, and mitigate slope failure. By combining geological insights with advanced remote sensing technologies and predictive modeling, we aim to provide a comprehensive understanding of slope

dynamics, offering more accurate risk assessments and sustainable solutions. Explore how the fusion of these disciplines leads to innovative strategies for managing slope stability challenges.

FAR-FIELD DEFORMATIONS OF THE 2023 KAHRAMANMARAŞ EARTHQUAKES REVEALED BY SPACE GEODESY

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The slip patterns during and after large earthquakes provide reliable validation of earthquake fault mechanics and active tectonics. The 6.2.2023, Kahramanmaraş earthquake sequence (Mw7.8, 7.6) provides a new opportunity to understand the character of the left-lateral East Anatolian Fault Zone which forms a part of the plate boundary between the Arabian and Anatolian plates. The availability of long-term, continuous GNSS observations constrains slip models in the near-field while revealing far-field deformations over Anatolia that are well outside the rupture zone (>700 km) and not predicted by elastic models. The detection of these far-field motions has significant implications for long-distance earthquake interactions and for estimating earthquake hazard potential. Furthermore, the earthquake

sequence provides new constraints on the geodynamics of E Mediterranean plate interactions.

MODELING GNSS VELOCITIES TO CONSTRAIN ACTIVE TECTONICS AND FAULT SLIP RATES IN THE CAUCASUS REGION

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Most earthquakes are a consequence of active tectonics, driven ultimately by plate tectonics. The Caucasus are part of a broad system of tectonic convergence that stretches from the Alps in the west to the Himalaya and southeast Asia in the east, where the African, Arabian and Indian plates all move northward relative to the Eurasian plate. In and around the Caucasus, the pattern of active tectonics is primarily driven by the convergence between the Arabian and Eurasian plates. Tectonic motions can be measured by high precision GNSS surveying, where the motions of continuous GNSS stations or survey benchmarks are tracked on a daily basis. GNSS networks in the region are operated by a variety of agencies, often in combination with regional seismic networks. This study incorporates velocities computed from as much publicly available GNSS data as possible, along with additional data from networks in Georgia and Armenia. In addition, we incorporate published site velocities from previous studies. The general pattern of velocities shows northward to north-northeastward motion relative to the Eurasian plate. The rate of convergence across the Caucasus as a whole increases from west to east, with sites in SW Georgia moving ~5 mm/yr relative to the Eurasian plate, increasing to >10 mm/yr in eastern Armenia and Azerbaijan. The orientations of site velocities show systematic variations, which result from a combination of the rotation of crustal/lithospheric blocks and from the elastic deformation

caused by faults that are locked by friction at shallow depth. The GNSS velocities contain information about both long-term fault slip rates and the extent of potentially seismogenic regions on faults, although these effects must be separated through modeling. We present a preliminary block model to explain the observed motions. A block model is like a plate tectonic model in miniature, with motions of sites described as a superposition of tectonic block motion (rotation about a geocentric axis) and the elastic deformation that results from slip deficit on faults. We start from the models presented in earlier studies, which had much fewer, and lower precision, data available. We assess how well existing models can predict the newly available data, and make prelimnary estimates of fault slip rates.

DEFORMATION FIELD OF THE MAIN CAUCASUS FAULT IN THE EASTERN PART OF GEORGIA USING GNSS

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The central part of the Alpine-Himalayan mountain system, the Caucasus, is a seismically active region. As a result, the structures within it experience constant deformation, manifested through ruptures and frequent seismicity. Active seismicity refers to the frequent occurrence of earthquakes over time and space. The entire structure of the Main Caucasus Thrust Fault (MCTF), including its eastern segment, is characterized by continental convergence, which plays a crucial role in the orogenesis, formation, and development of the Main Caucasus Range. Currently, two distinct convergent movements are observed between the Indian-Eurasian and Arabian-Eurasian plates. The Caucasus region lies within the Arabian-Eurasian continental collision zone and is divided into two sections, the Greater and Lesser Caucasus, separated by an intermountain depression. Due to its tectonic and structural complexity, determining the deformation of the crust in this collision area is vital for advancing current knowledge, studying crustal deformation, and assessing seismic hazards.

ENHANCING THE SEISMIC DATABASE OF THE CAUCASUS THROUGH THE DIGITIZATION OF LEGACY BULLETIN DATA FOR HAZARD ASSESSMENT

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Compiling a uniform earthquake catalog by magnitude class is crucial for reliable seismic hazard assessment. Instrumental monitoring of seismic activity in the Caucasus has been ongoing for 125 years. The archives of the seismic monitoring center preserve unique data that depict regional seismic activity and provide critical earthquake information, which are essential components for seismic studies.Instrumental seismology in Georgia can be divided into two phases: the analog period and the digital period. Earthquake magnitudes in the analog era were calculated using a different magnitude class than in the digital era. In 2015–2018, data with magnitudes of K > 9 were entered into the database of the Earth Sciences and National Seismic Monitoring Center, and seismic hazard maps were created as part of this effort (Onur 2019, Godoladze 2024). From 2022 onwards, updates for the low-K Class magnitude have continued as part of the second phase of seismic hazard assessment project at the institute. Specifically, the web- database created in 2015 is used to digitize earthquakes recorded with analog instruments for K < 9. After digitizing the first arrival data, the hypocenters are recalculated/relocated. Updated earthquake data is important for refining the correlation between different earthquake magnitude classes. The K Class was the most widely used magnitude class during the analog era. Therefore, improving the correlations between modern and analog magnitudes will extend the earthquake catalog in terms of both time and area, as well as earthquake occurrence rates. This, in turn, will enhance the accuracy of seismic hazard assessment maps.

IMPLEMENTING NEW CORRELATIONS BETWEEN SEISMIC INTENSITY, STRUCTURAL DAMAGE, AND MICROTREMOR OBSERVATIONS TO CONSTRUCT A NEW APPROACH ON INTENSITY FORMULA IN SOUTHEASTERN TURKEY

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This research performed on the Kahramanmaraş earthquake of February 6, 2023, targeted to understand the distribution of seismic intensity in the affected areas and present a formula for calculating intensity specific to Eastern-Southeastern Turkey. This earthquake, the most devastating in Turkey's recent history, originated from the Narlı splay fault and spread bilaterally along the East Anatolian Fault (EAF), covering a significant seismic gap of the EAF and the Amanos Fault. It affected 11 provinces in Turkey's Southeast region and neighboring areas of Syria, resulting in a rupture length exceeding 300 km and causing over 50,000 fatalities.

The research analyzed seismic intensity across seven cities: Adıyaman, Gaziantep, Hatay, Kahramanmaraş, Malatya, Osmaniye, and Şanlıurfa. The project was preceded by a field damage survey, microtremor measurements and a questionnaire seismic intensity interview survey around AFAD seismograph sites.

The microtremor study was implemented in March, April, August and November using KINKEI, GEODAS-12-24ch, GEODAS-15-12ch and ATOM sensors from Japan for measurements. The Questionnaire intensity survey has been conducted to schools near AFAD seismic stations and structural damage area (DCA) microtremor measurement sites. Under favor of the National Education Bureaus in each target cities, we could proceed the online survey as a priority. However, with the exception of Hatay and Kahramanmaraş Provinces, respondents were geographically scattered and responses from the vicinity of AFAD seismic stations and damage concentration areas surveyed for damage were limited. In the future, examination of the correlation between the official damage data and the questionnaire intensity with a reference to the instrumental Modified Mercalli (MMI) in the other five prefectures is planned. The field damage survey evaluated the MM intensity based on the degree of structural damage (DMM intensity) around 31 AFAD seismographs and 25 damage concentration areas as per EMS98. DMM intensity varies from VII to XII. Instrumental MMI formulae were studied. It is found that SO2008 formula has a good match with damage-based MMI and introduction of modified JMA intensity (GM2024) to SO2008 formula slightly improved the range from X to XII. These two are new MMI formulae.
Microtremor measurements revealed a good match with AFAD Vs30 at the 10 seismograph sites, and predominant frequencies of HVSR there varies from 1.7 to 21 Hz. In general, the amplitude of HVSR 1.0 to 10, so the amplification factor based on Vs30 and predominant frequency can be used. Outcome of the analysis of single station microtremor measurements, Vs30s were found to be quite low in almost the entire region, but on the contrary, the results of the array analysis are different. Online questionnaire survey obtained 12,798 valid responses from seven provinces. Questionnaire MM (QMM) intensity ranging from VIII to X correlates well with AFAD strong motion parameters in Hatay province. Mahalle (neighborhood) level QMM intensity map in Hatay was developed exhibiting lower intensities at onshore areas. Such maps in other six provinces are under preparation. Interview survey conducted to the department of education of four most affected provinces found that "seismic intensity" has not been taught and learned in school education. Disaster education programs using seismic intensity brochure developed within the project were provided in four schools. Discussions among the members on the definition of seismic intensity generated a synergistic effect to understand the

bilateral and global utilization of seismic intensity to consider the utilization for earthquake disaster risk reduction in Türkiye.

GEOMORPHOLOGY OF A MEANDERING BEDROCK RIVER SYSTEM IN AN ACTIVE TECTONIC ZONE.

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The River Vere is 45 km long bedrock river with a drainage area of 194 km^2 and it intersects the Mtkvari River within the Georgian capital city of Tbilisi. The largely forested, suburban watershed typically is steeper than 40°, with a veneer of colluvium and moderately developed soils that overlay largely fractured and steeply dipping marine strata. A review of recent images shows the formation of active cutoff loops; hence, the bedrock river system is actively meandering. In this study we measured valley-channel cross sections, channel sinuosity, channel slope, meander wavelength, and total- and along channel-watershed area and compared these values to published and computed discharge. Results show that the modern River Vere is entrenched in a V-shaped valley, approximately 25 m below a narrow (<1 km) relic floodplain, within the larger river valley. Stream power calculations and breaks in relations of watershed area and discharge with meander wavelength, entrenchment ratio, sinuosity and channel dimensions indicate that the river system a product of geologically recent stream piracy.

NEOTECTONICS OF THE ANATOLIAN SCHOLLE: AN IDEAL EXAMPLE TO INHOMOGENEOUS CONTINENTAL DEFORMATION

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The Anatolian *Scholle* (and its surroundings) represents one of the best places on earth for the study the inhomogeneous style of continental deformation due to its unique location within the Alpide Plate Boundary Zone. The westerly escape of this continental block commenced as a consequence of the boundary forces generated by the collision in the east, which were subsequently reinforced by the slab pull of the retreating Hellenic Trench and/or the gravitational potential energy of the rising topography in the east and stretching in the west as extra forces. The aforementioned driving forces have resulted in the formation of four distinct neotectonic provinces within and around the Anatolian *Scholle*. These are: (a) the East Anatolian Province of Shortening (EAPS), (b) the Central Anatolia "Ova" Province (CAOP), (c) the North Turkish Province (NTP) and (d) the West Anatolian Province Extensional Province (WAEP). The strong correlation between the spatial distribution of discrete structures of these provinces and the Tethyside accretionary complexes demonstrates the impact of low-strength mechanical profile of the fine-grained sediments that host the deformation products of the neotectonic forces.

UNDERSTANDING THE SIGNIFICANCE OF ACTIVE TECTONICS IN THE LAKE SEVAN BASIN, ARMENIA

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The Lake Sevan Basin (the biggest fresh water reservoir in the area) is characterized by a range of geological hazards, including earthquakes, surface ruptures, volcanic eruptions, and landslides, all of which are influenced by active faults. These faults exhibit diverse kinematic behaviors, varying activity levels, and differing potentials for generating strong earthquakes. They surround the lake from the northeast and southwest, extending into the lakebed itself. To fully understand the active geological processes in this region, a multidisciplinary scientific approach is essential. Key areas of investigation include the structural dynamics of the basin, the relationship between volcanism and active faults over both spatial and temporal scales, the behavior of deep slopes under dynamic conditions, and the impacts of underwater ruptures and mass movements on lake water volume. Additionally, the spatial distribution, chemical composition, and origins of underwater gas emissions are critical factors for comprehending the basin's geological history and its contemporary dynamics. Given the high population density in the Sevan Basin—approximately 300,000 residents across 92 communities—and extensive land use, understanding these geological hazards is crucial.
The presence of multiple hazards within a confined area also offers a unique opportunity to develop knowledge and methodologies for studying their interactions. In summary, the interaction of tectonics, volcanism, landslides, and the potential for lake tsunamis in the Lake Sevan Basin necessitates a comprehensive cumulative hazard assessment for accurate risk estimation.

RELOCATION OF THE SEISMICITY IN THE CAUCASUS AND CENTRAL ASIA

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The Lawrence Livermore National Laboratory and the Institute of Earth Sciences (IES) at Ilia State University generated a new, comprehensive seismic catalog for the Caucasus region by combining data in the IES bulletin with bulletins of the Republic Seismic Survey Center of Azerbaijan, monitoring centers in Turkey and Armenia, and the ISC covering the period 1951 to 2019. We present the bulletin that contains some 20,000 relocated events. We first relocated each event using the single-event location algorithm iLoc and RSTT predictions and identified GT events. Then we relocated the entire seismicity of the Caucasus region with the multiple-event location algorithm Bayesloc, using the iLoc results as initial locations and the GT events as constraints. The improved view of the seismicity reveals a narrow band of crustal events along the southern flank of the Greater Caucasus and confirms both a region of deep seismicity beneath the northeastern Caucasus and the Caspian Sea.

The Lawrence Livermore National Laboratory, Michigan State University, and national networks in Central Asia (Kazakhstan, Kyrgyzstan and Tajikistan) compiled a comprehensive seismic bulletin for Central Asia between 1951 and 2017 that consists of some 400,000 events. Our objective was to to provide the most accurate catalog for a probabilistic seismic hazard analysis of the Central Asia region. We relocated some 235,000 events with iLoc, a state-of-the-art single-event location algorithm, using RSTT, a three-dimensional upper mantle velocity model. We present the relocation procedures and the final, quality controlled catalog of 147,429 events, including 256 new ground truth events in the region. The results show significant improvements in the view of seismicity, provide reliable input for the PSHA and allow for accurate delineation of active seismic zone boundaries.

SEISMIC MONITORING IN AZERBAIJAN

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Being part of the Alpine-Himalayan fold belt, the territory of Azerbaijan is characterized by high seismic activity. Annually, more than 5,000 earthquakes are recorded in the country, with 70-80 having a magnitude greater than 3. Over the past 15 years, more than 50 earthquakes with a magnitude greater than 5.0 have occurred in the republic. Between 2003 and 2024, seismic activity was uneven both in terms of the seismic energy released and the number of earthquakes recorded. From the earthquake epicenter map, it can be observed that the highest concentration of epicenters occurs in the Zagatala, Oghuz, Shamakhi-Ismayilli, Hajigabul, Saatli seismic zones, as well as in Talysh and the northwestern part of Iran adjacent to the Nakhchivan Autonomous Republic. In the Caspian Sea, epicenter clustering is noted in the northern Azerbaijani sector, around the Absheron Peninsula, and in the central part of the Caspian Sea.

The seismic moment tensor for strong earthquakes in Azerbaijan from 2003 to 2022 was calculated using broadband (BH) recordings from modern digital stations, employing the Time-Domain Moment Tensor inversion method. This approach allows the determination of the full seismic moment tensor, refining the depth of the earthquake and calculating the moment magnitude (Mw). A new module developed by Prof. John Nabelek has been applied since 2023.

Based on data from Azerbaijan's telemetric network, a database of earthquake focal mechanisms with magnitudes ≥3.0 was created. These studies revealed distinctive features of seismotectonic deformation in various seismogenic zones of the republic, which helped identify the main types of fault movements within the South-Eastern Caucasus.

Applying a comprehensive method of local seismic tomography using double-difference techniques and body-wave inversion, registered by the digital equipment of the Republican Seismological Service Center (RSSC), detailed velocity models were constructed, revealing crustal heterogeneities in individual focal zones.

SEISMICITY OF AZERBAIJAN

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In 2003, a digital seismic station network was established at the Republican Seismological Service Center (RSSC), consisting of 14 modern seismic monitoring systems by the company "Kinemetrics" (USA) with telemetric satellite communication channels. To enhance the level of comprehensive seismological and geophysical research, the number of digital seismic stations increased to 35 between 2008 and 2013, with four of them located in the Nakhchivan Autonomous Republic. Additionally, a network of ten stationary "Kinemetrics Basalt" stations on the Absheron Peninsula. In 2017, as part of the international project "Caucasus Transect," implemented by RSSC in cooperation with the University of Missouri (USA) and the Ukrainian Scientific and Technical Center, 17 new digital seismic stations were installed to study the velocity heterogeneities of the Earth's crust in the transition zone between the Kura Basin and the Greater Caucasus using seismic tomography.
In 2021, within the framework of the international project "Expansion of the Seismic Network in the Caucasus and Central Asia," implemented by RSSC with the support of the Ukrainian Scientific and Technical Center, the installation of 22 new "Nanometrics" (Canada) seismic stations began in Azerbaijan. For the first time in the world, 12 of these stations will be installed around the Lokbatan and Otman-Bozdag mud volcanoes to study their dynamics. Three borehole seismometers, Trillium 120. To date, 84 digital seismic stations are operating across Azerbaijan under RSSC. Magnetometric studies are conducted using modern proton magnetometers G-856 (USA) with "Maqus" software. Gravimetric studies include the investigation of non-tidal variations in gravity and the identification of seismic anomalies in the gravitational field. For these purposes, S-20 variometers and the latest CG-5 gravimeter are used.
In 2012, RSSC established a network of 24 stationary GPS stations across Azerbaijan. These stations form a geodetic network equipped with Choke Ring antennas, Zephyr Geodetic2, and TrimbleNetR9 receivers.

RECENT DEVELOPMENTS OF THE SEISMIC NETWORK OF GEORGIA

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The seismic networks in the region have improved significantly through joint regional projects, including "The Uplift and Seismic Structure of the Greater Caucasus" and "Seismic Network Expansion in the Caucasus and Central Asia," supported by the U.S. Department of Energy (DOE), Lawrence Livermore National Laboratory (LLNL), IRIS, IRIS PASSCAL, and STCU. Within the framework of the SNECCA ("Seismic Network Expansion in Caucasus and Central Asia") project, nearly 50 posthole broadband seismic sensors in collocation with strong-motion sensors have been deployed across six participating countries: Georgia, Azerbaijan, Armenia, Kazakhstan, Kyrgyzstan, and Tajikistan.

SEISMIC MONITORING IN GEORGIA

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Instrumental seismic monitoring started in the Caucasus in 1899 when the first seismograph was installed in Tbilisi. The seismic network in the Caucasus improved significantly during Soviet times. The data from this time was analog. Much of it is preserved in Tbilisi archives. In the 1990s, due to the collapse of the Soviet Union the analog networks deteriorated. In Georgia, for the next 13 years, the seismic network coverage was poor. The first permanent digital seismic station in Georgia opened in Tbilisi in 2003. Recently, the seismic networks in the region improved tremendously in the framework of the joint regional projects." The Uplift and Seismic Structure of the Greater Caucasus," and "Seismic Network expansion in the Caucasus and Central Asia" supported by the USA DOE, LLNL; IRIS; IRIS PASSCAL and STCU. Scientific team from Armenia, Azerbaijan, Georgia, and the USA jointly deployed over 70 temporal seismic stations. In the Framework of SNECCA project in Georgia, in the past 2 years 10 posthole and 4 surface broadband stations have opened. With support of Georgian Government Tbilisi Geophysical observation Tunnel fully has been reconstructed. The Georgian National Seismic Center is willing to contribute to IMS, providing a steady flow of real-time seismic data.

VS30-BASED SEISMIC ZONING OF THE BAKU URBAN AREA

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The objective of the study: zoning of the territory of the city of Baku by soil categories, Vs30 parameter and by reinforcement (based on engineering and seismic exploration studies). The equipment and software packages used in the study: 1. 24-channel seismic station - GEODE (USA, Geometrics); 2. Software packages - Seismodule Controller, ReMiVspect 4.0 and ReMiDisper 4.0 The effects of strong earthquakes show that soil conditions play a significant role in ensuring the seismic resistance of buildings and structures. This is because strong motion parameters such as amplitude, frequency and duration are highly dependent on-site conditions. Site conditions are divided into different categories in earthquake engineering regulations. The site classification system is based on the definitions of site classes in terms of the average shear wave velocity up to 30 m (Vs30) and the number of SPT-Standard Penetration Test blows. Recently, the idea of using the values of the prevailing periods to compile seismic microzoning maps, classify soils according to seismic properties, and also, to select the most favorable construction site depending on the dynamic characteristics of the soils in order to avoid resonance phenomena during earthquakes have been developed.

GEOPHYSICAL SURVEY IN CIVIL ENGINEERING

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Geophysical surveys have become an indispensable tool in modern civil engineering, offering non-invasive and cost-effective methods for investigating subsurface conditions. These studies utilize techniques such as seismic surveys and electrical resistivity tomography to determine groundwater levels and geotechnical properties to assess ground stability. Their integration into civil engineering projects enhances the accuracy of site assessments, optimizes design processes, and mitigates risks associated with construction. At the Institute of Earth Sciences and National Seismic Monitoring Centre, we focus on advancing geophysical methods to improve civil engineering projects' safety, efficiency, and sustainability. Geophysical surveys play a crucial role in infrastructure development, providing engineers with essential data for informed decision-making and project success.

SEISMIC MONITORING IN ARMENIA

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The Republic of Armenia and the neighboring areas are located in the central part of the Arabia-Eurasia collision zone, which is characterized by active seismicity.Over the past decade, the Institute of Geological Sciences (IGS) of NAS RA has developed an advanced and dense seismic network.To develop the local seismic network, the Institute of Geological Sciences in collaboration with the National Taiwan University and Institute of Earth Sciences, Academia Sinica (Taiwan) established 11 seismic stations with broadband seismometers and 6 cGPS (continuous) stations. Data from the existing seismic stations were collected, archived and treated, and main earthquake parameters were determined; the conducted works included catalogue maintenance, recalculation of the main earthquake data, calculation of seismic tomography with the input of recalculated and updated data, and adjustment of the three-dimensional (3D) velocity model for the area of the RA. Starting from 2017, the Institute of Geological Sciences has participated in two partner ISTC projects: A-2334 Project (Transect) “The Uplift and Seismic Structure of the Greater Caucasus” and KR- 2452 Project (SNECCA) “Seismic Network Expansion in the Caucasus and Central Asia” with support from the U.S. Department of Energy. In the framework of the indicated projects, 32 seismic stations with broadband seismometers were established along with 8 seismic borehole stations with fully broadband seismometers (Real Time) and 8 strong motion sensors. These two projects are implemented through the Seismic Targeted Initiative of the International Science and Technology Center and the Science and Technology Center in Ukraine.The records collected from the eight (8) already operational permanent seismic stations of the indicated network are in real-time mode sent to the International Seismology Center of the IRIS (Incorporated Research Institutions for Seismology). To download and archive the database of seismic stations, a new computer server was acquired under the project, and all required configurations were made to provide for its uninterrupted operation. Seiscomp software set is applied to produce automatic solutions for earthquakes recorded within the region. Adjustments and recalculations of the automatic earthquake solutions are implemented to produce the resulting main earthquake parameters with uncertainties reduced to the rate as low as possible. The collected data from all existing stations are widely used to determine and to re-estimate the main parameters of earthquake occurring in Armenia and in surrounding territories. These data are included in local bulletins and catalogues.For strong motions, the on-going research includes processing of design accelerograms, preparation and analysis of hazard response spectra (RS), selection of the actually recorded (real) acceleration time-history, and spectral matching of the time-history to the hazard response spectrum with application of Seismosoft (Earthquake Engineering Software Solutions, SeismoMatch, SeismoSignal, SeismoSelect, SeismoSpec) software set.All the results obtained from the data seismic stations mentioned above are used for the purposes of scientific research and are summarized in articles.

IMPLEMENTATION OF EUROCODE 8 IN GEORGIA

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This abstract examines the adaptation and implementation of Eurocodes, particularly Eurocode 8 (EN 1998) seismic standards, in Georgia. It highlights the translation, modification, and development of Nationally Determined Parameters (NDPs) specific to Georgian seismic conditions. Eurocode 8, part of the European structural design code suite, provides guidelines for designing

resilient concrete, steel, composite, masonry, and timber structures, along with geotechnical considerations for seismic resilience.

The adaptation process includes translating and adjusting terminology, formulating Georgian National Annexes, and conducting expert reviews to ensure alignment with local construction practices and regulatory frameworks. Procedural and technical steps for creating Georgian-specific guidelines are discussed, along with progress on the translation and implementation of Eurocodes 0, 4, 5, and 7, including their national annexes.

Further, strategies for training engineers, architects, and technical supervisors are outlined to support the widespread adoption and application of Eurocode standards in local projects. The transition from prior codes to Eurocode 8 is explored, focusing on both the challenges and successes in the integration process. Findings emphasize the importance of international standards in enhancing local infrastructure resilience and provide insights into the regulatory and educational efforts critical to a smooth transition to European standards in a region with considerable seismic vulnerability.

SAFETY EVALUATION OF BUILDINGS DESIGNED ACCORDING TO SEISMIC CODE OF GEORGIA

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In the paper the Georgian Seismic Code PN 01.01-09 requirements are reviewed concerning structural calculations of high rise buildings and their safety evaluation. The additional code requirements to design of high rise buildings including the following items: -Construction of response spectra for the construction site considering parameters of near and far located seismic sources. -Adjustment of the response spectra, based on the identification of building site soils, by their seismic properties (site specific response spectrum). -Composition of the set of accelerograms (at list 7), considering

the established engineering-geological and seismological parameters. -Structural calculations using 3D model, the multi-modal spectral method and the direct nonlinear dynamic (time history) analyses. A case study of seismic calculations of a multystorey reinforced concrete building is presented uncluding site specific seismic response numerical time history analyses based on the local geological conditions considering the soil nonlinearity. The conclusions based on the practical application of seismic Code are the following: -According to Georgian Seismic Code PN 01.01-09, high-rise and responsible buildings require geophysical studies using the new seismic hazard maps, the consideration of geology of construction site, time history and modal analyses. Their design meets modern requirements and the new geophysical data, and thus their reliability is ensured. -At the same time, conventional buildings are designed based on spectral theory using old (but officially valid) seismic hazard maps. As a result, their safety is significantly underestimated considering the new hazard data. -It's necessary to upgrade significantly the existing seismic code - but more convenient to use Eurocode with adjusted requirements regarding the site dynamic response. -It is recommended to implement the time history analyses for conventional buildings as well.

THE NEED FOR GEOLOGICAL STUDIES IN ASSESSING EARTHQUAKE HAZARDS IN CENTRAL ASIA AND IN THE SOUTH CAUCASUS

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Dept of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3AN, UK Throughout the South Caucasus and central Asia regions there is urgent need for the development of active fault maps, estimation of long-term averaged fault slip-rates, and development of detailed earthquake histories on dangerous active faults through paleoseismic techniques. All of these data types are essential inputs in earthquake hazard assessment, both regional 'probabalistic' approaches, and focussed 'deterministic / scenario' approaches that are required for analysis of hazard/risk/risk reduction to discrete

infrastructure projects and urban centres. Geological earthquake and active fault data are therefore of critical importance, in ensuring the resilience of existing and of proposed urban growth and major infrastructure projects. But the data are uneven, in need of updating, or not present across many regions. The need for improved geological information on active faulting recognises that large earthquakes are rare in any one region, such that an holistic view of hazard requires the integration of modern seismological and geodetic monitoring with insights from historical and prehistorical periods. In this presentation we highlight recent studies that bring together field-based, remote-sensing, and seismological insights to build improved characterisation of active faults. In ongoing work in Azerbaijan we identify major active faults within the Kura Basin crossing the major trans-national pipelines, and in proximity to the Caspian gas terminals. In Uzbekistan, we uncover sources of earthquake hazard near the UNESCO world heritage centre of Samarkand. We are undertaking forensic investigation of the major historical earthquakes, many of whose sources are unknown, to build a better understanding of vulnerability in cities including Asgabat (Turkmenistan), Tashkent (Uzbekistan), Almaty (Kazakhstan), Bishkek (Kyrgyzstan) and Dushanbe (Tajikistan). All of these studies are undertaken as part of long-running collaborations between the Active Fault and Earthquake Research group in Oxford, and with a network of partners across the regions.

MOMENT TENSOR SOLUTION FOR RECENT EARTHQUAKES OF GEORGIA

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This study presents the development of a web-based system for calculating earthquake moment tensor solutions in the Caucasus region, created at the "Institute of Earth Sciences and National Seismic Monitoring Centre." The system provides a user-friendly interface, enabling researchers to select seismic stations from an interactive map and define essential parameters required for moment tensor computations. This web application simplifies and accelerates the process of analyzing earthquake mechanisms, making it easier for researchers to access and work with seismic data in the region. The web-based system utilizes the AUTO-TDMT program, which was developed by Professor Douglas Dreger. This program employs a full waveform inversion approach, using broadband data from digital seismic stations, to obtain accurate moment tensor solutions.

Moment tensor solutions are crucial for understanding earthquake mechanisms and characterizing seismic sources. The ability to accurately determine the moment tensor parameters, such as fault orientation, slip, and seismic moment, offers valuable insights into the tectonics of the Caucasus region. Understanding the underlying faulting processes is vital for assessing earthquake hazards, seismic risk, and ground shaking potential in the region. Moreover, the web-based system enables researchers to calculate the Mw magnitude of earthquakes, providing a quantitative measure of earthquake size and energy release. Additionally, the system allows for the redefinition of earthquake depths, improving the accuracy of seismic source characterization. As a result, the obtained moment tensor solutions will improve our understanding of seismic activity in the Caucasus region, leading to more accurate seismic hazard assessments and better strategies for mitigating earthquake risks.

As a result, the obtained moment tensor solutions will improve our understanding of seismic activity in the Caucasus region, leading to more accurate seismic hazard assessments and better strategies for mitigating earthquake risks.

MODELING AND HAZARD ASSESSMENT OF THE 2014 MAY 17 DEBRIS FLOWS EVENT OF THE DEVDORAKI GORGE IN THE CENTRAL GREATER CAUCASUS, USING RAPID MASS MOVEMENT SIMULATION (RAMMS)

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Debris flows are a dominant geomorphic process in the Central Caucasus, are strongly correlated with heavy and prolonged rainstorms, often in association with intense glacier retreats or snowmelt. These events pose significant risks, causing loss of life, property damage, and disruptions to infrastructure, such as roads, communication lines, and pipelines. The northwestern slope of Mount Kazbegi, characterized by steep morphology and a significant elevation difference between the retreating Devdoraki Glacier tongue (the main source of occurring debris flows) and Terek river gorge (accumulation area) is a critical zone for debris flow generation. This study aims to simulate the debris flow event of May 17, 2014, which occurred in the Devdoraki Gorge on the northwestern slope of Mount Kazbegi, using RAMMS (Rapid Mass Movement Simulation) software. Through 2D and 3D visualization, it will be possible to analyze the physical characteristics and runout distance of the flow. Additionally, the research will assess the elements at risk (hazard, exposure, vulnerability) in the area based on the simulation results, providing key insights for future risk management and mitigation strategies.

DETERMINATION OF VOLCANIC ASH LAYERS SOURCE OF EASTER CAUCASUS NEOGENE BASIN: EVIDENCE FROM ZIRCON U-PB GEOCHRONOLOGY AND GEOCHEMISTRY

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The Eastern Caucasus Mountains in Georgia include products from extensive Miocene volcanic activity that are being unraveled through geological mapping supported by geochronology and geochemistry. This poster presents new zircon U-Pb geochronology and geochemistry of the volcanic ash layers in the intermountain Neogene basin of the Eastern Caucasus. The ash layers are distributed unevenly over a distance of about 200-300 km, with varying thicknesses. Despite the apparent scale of the eruptions, the eruptive center(s) was not identified. U-Pb geochronology and geochemistry of detrital zircons can provide valuable constraints on geological processes and source areas. Zircon isotopic dating, and whole rock geochemistry together, offer reliable arguments for correlating eruptive centers with deposition areas of the ash and flows.

GEOLOGY DATA INTO SEISMIC HAZARD: CURRENT AND FUTURE CHALLENGES

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Geological data plays a crucial role in Probabilistic Seismic Hazard Assessment,

helping us understand and mitigate the impacts of earthquakes on human settlements and infrastructure. This data provides essential insights into the Earth's structure, composition, and processes. This study presents a tectonic data set for the Probabilistic Seismic Hazard Assessment in Georgia, conducted in 2018. The data encompasses the processing and analysis of tectonic information from the region, which led to the creation of a map indicating seismically active tectonic faults. In addition, the study includes paleoseismic data collected throughout Georgia. A key focus of this data is the research conducted near the village of Okami, located within the contact zone of the Caucasus fold-thrust belt and the Kura basin. The findings indicate that there have been three strong earthquakes in the region over the past 49000 years, with magnitudes ranging from 6.2 to 7.5. While optimal data was utilized for the 2018 Probabilistic Seismic Hazard Assessment, we believe it is essential to expand the database in the future.

VS30 DATABASES FOR BASED SEISMIC ZONATION OF GEORGIA

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The Institute of Earth Sciences in Tbilisi, Georgia, specializes in geophysical survey methods to support civil engineering projects and seismic station site characterization. Using various geophysical survey methods such as seismic refraction and MASW (multichannel analysis of surface waves) we conduct Vs30 surveys, a critical parameter for evaluating site response and seismic risk.

To classify ground category, we use a 24-channel digital seismograph with 10 Hz geophones with vertical and horizontal components, and then analyze obtained data with relevant software packages. Our work spans urban areas such as Tbilisi, Batumi, etc. Where detailed subsurface velocity profiling supports construction planning and hazard mitigation.

Additionally, Vs30 measurements at seismic stations across Georgia provide essential data to enhance the national seismic monitoring network. To improve data management and accessibility, we are developing an online

geophysical survey database. This initiative aims to streamline the availability of geophysical data for both ongoing research and practical applications in infrastructure development and seismic resilience planning throughout the region. It also helps in creating a detailed seismic microzonation map.

TECTONIC OVERVIEW OF CENTRAL ASIA

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The report is devoted to the study of active tectonics of the Tien Shan and Dzungaria - the area of interaction of the two largest lithospheric plates: the Indo-Australian and Eurasian. Interest in this area is due to the fact, that its study can provide materials for answering some questions of the modern theory of tectonics of lithospheric plates, among which the problem of intra-continental mountain building. Indeed, the newest orogeny of these major structures develops at a distance of more than 2000 km from the direct interaction of these plates, which began about 55 million years ago. This distinguishes it from the situation that exists in the subduction zones and the situation in typical conflict zones, where one continent sinks under the other along the main thrust, as happened in the Alps or the Himalayas. Despite the detailed study of the Tien Shan and Dzungaria, many questions of its modern geodynamics remain unlighted or poorly illuminated. Among them: what is the distribution of current stresses within the orogenic belt? Are the main stresses within the marginal parts of the orogenus concentrated or evenlydistributed within the belt? What is the slip rate of Late Quaternary tectonic displacements in the zones of active faults?

SEISMIC MONITORING OF THE TERRITORY OF KAZAKHSTAN

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Seismic observations in Kazakhstan and their analysis are carried out by two seismological organizations: the National Center for Seismological Observations and Research of the Ministry of Emergency Situations of the Republic of Kazakhstan (NCSRO MES RK), former Seismological Experimental Methodical Expedition the Ministry of Emergency Situations of the Republic of Kazakhstan (SEME MES RK), and the Institute of Geophysical Research of the

National Nuclear Center of the Republic of Kazakhstan (IGR NNC RK) with their networks of stations and data processing centers in Almaty. Currently, the network of NCSRO MES RK includes 38 three-component seismic stations. Within the framework of the SNECCA project, new stations were installed, and several existing ones were modernized. The network of IGR NNC RK includes five seismic arrays (Akbulak, Borovoe, Karatau, Kurchatov-Krest, Makanchi) and eight three-component stations (Aktyubinsk, Borovoe, Kurchatov, Podgornaye, KNDC). The results of seismic observations are seismic event bulletins, a catalogue of earthquakes (natural and man-made), as well as a catalogue of numerous quarry explosions at mineral deposits.

SEISMIC MONITORING ON THE TERRITORY OF TAJIKISTAN

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Tajikistan is one of the most seismically active regions of Central Asia. Every 5-10 years, and sometimes more often, one or two strong seismic events occur on its territory, which to a greater or lesser extent cause damage to the national economy and population of the republic [1]. Seismic safety of buildings and structures, as well as the operation of existing, under construction and projected large hydraulic structures in conditions of complex relief and geological-tectonic structure of the region, which are constantly exposed to seismic impacts, requires continuous seismic monitoring. Currently, two seismological networks are conducting continuous seismological observations to record earthquakes in Tajikistan. The seismological network of modern digital stations of the Geophysical Service of the National Academy of Sciences of Tajikistan conducts seismic monitoring of Tajikistan at the regional level. This network annually registers from 3500 to 7500 seismic events with K R =5-15. In addition, there is a local network of digital seismic stations of Rogun HPP JSC, the main task of which is to provide seismic monitoring of the Rogun HPP construction area and its reservoir. Data from the international network of seismic stations are also used in determining the geolocation, perceptible and strong earth tremors. Due to the difference of programs and hodographs, the parameters (mainly epicenter coordinates and focal depth) of these seismic events determined by different seismological agencies do not always coincide. This is observed when comparing parameters of 7 point earthquakes, which occurred in Tajikabad region on 10.07.2021 and Mastchin region on 22.03.2023. Epicenter coordinates are determined quite close to each other, and the value of focal depth is different (from 10 to 33 km). The seismic monitoring system should provide detailed seismological and geophysical data [2]. It should register earthquakes with $M \geq 0.2$ with sufficiently high accuracy of coordinates and focal depth, which is necessary mainly to evaluate the seismic regime of areas of construction and operation of large structures, including hydraulic structures located in complex geotectonic zones. It is difficult to achieve this goal without using local hodographs. In our opinion, first of all, a unified program (for example, “SeisComp”) should be used to determine the parameters of seismic events in seismic monitoring systems.

USING PSHA RESULTS IN SEISMIC CODES IN CENTRAL ASIA

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The analysis of the catastrophic consequences of Turkey, February 2023 major earthquakes showed that one of the reasons of that was the absence of necessary response of authorities to new seismic hazard map, presented in Turkish seismic codes, 2018 and, evidently the misunderstanding of new map data using in design practice by constructors. Particularly, according to some scientific sources, published in 2020, the requirements of the 2018 Turkey seismic codes, including the application of a new seismic hazard map, entailed to a significant increasing for design seismic loads. I.e. scientists have given advance warning of increased seismic risk in the territory of Turkey due to the adoption of a new seismic hazard map The consequences of Turkey, 2023 earthquakes have triggered in Tajikistan the researches in the direction of new approach using in design practice the probabilistic seismic hazard assessment results presented in the form of correlated with each other PGA, response spectra and synthesized accelerograms has been developed by IGEES NAST in 2016-2020 for different return periods and different types of soils. At the same time the investigation of ensuring by the acting in Tajikistan seismic codes the specified level of earthquake resistance of buildings and structures has been conducted. During conducting this investigation, the following main approaches have been adopted: - the statement of some regulatory documents, declaring that in the case of earthquake's level corresponding to return period of 475 years the appearance of negligible damages in bearing elements of structure is allowable, i.e. structure "is working close to elastic range". Directly damages of the 3-rd grade, allowed by the codes, can be appeared in case of an earthquake with a return period of 2475 years level. - taking into account that one of the final results of PSHA is the set of 3-component synthesized accelerograms in load combination the earthquake acceleration is affected in all directions 100%, i.e. E=Ex+Ey+Ez. Determination the seismic loads in accordance with Tajikistan seismic codes is conducting using the following formulas: $S_{ik} = K_1 K_2 K_3 S_{0ik}$, $S_{oik} = Q_k A_i K_{\psi} \eta_{ik}$, Load combination in accordance with acting in Tajikistan codes, according to which mutual exclusion by direction is accepted COMBO=1.1*DW+1.1*DL+1.2*LL+1.2*LS+Ex (or Ey, or Ez) Determination the seismic loads has been accepted in current investigation $S_{ik} = Q_k R_s (T_i) \eta_{ik}$ Load combination, accepted in current investigation COMBO=1.1*DW+1.1*DL+1.2*LL+1.2*LS +Ex+Ey+Ez Based on said approach the investigation calculations for more than 30 high-rise monolithic reinforced concrete buildings of Dushanbe city have been conducted using LIRA SAPR software. According to the results of investigations, the design values of reinforcement of load- bearing reinforced concrete structures, which is an integral indicator of stress-strain state of structures, using the PSHA data are up to 1.5-3 times lower in comparison with values using the acting seismic codes. In turn, this indicates on the sufficient conservativeness of the current seismic codes of Tajikistan in terms of ensuring seismic stability of buildings and structures being constructed in country, and shows on perspectives for the possible optimization the current seismic codes of Tajikistan. The experience gained in Tajikistan in using the results of probabilistic seismic hazard assessment in real designing can be applied in the development of interstate seismic codes, entrusted to the CIS basic organization for earthquake-resistant construction – KazNIISA (Almaty, Kazakhstan), and in other countries, including China.

SIN-POSTCOLLISIONAL GEODYNAMICS, TECTONICS AND SEISMICITY OF GEORGIA

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Georgia, the westernmost part of the southern Caucasus, located at the junction of the European (mediterranean) and Aasiatic branches of the orogenic belt represents an area where the Tethys ocean was completely closed in the late Cenozoic as a result of prolonged convergence between the Eurasian and African-Arabian plates. The lithosphere of Georgia and adjacent areas represents a collage of Tethyan, Eurasian, and Gondwanan terranes. During the late Proterozoic–early Cenozoic, within the convergence area, existed system of island arcs and back-arc basins characterized the precollisional evolution of the region. The deep crustal structure of the region includes areas of two-layered ("granitic" and "basaltic") as well as three layered (sedimentary, "granitic" and "basaltic") continental crust. Suboceanic crust within the Black and Caspian Seas contains areas devoid of granitic layers. The Oligocene is considered to represent the onset of the syncollisional stage in the tectonic development of the Georgia and the Caucasus. The collision caused inversion of the topography and two fold-and-thrust belts of the Great and Lesser Caucasus, with an intermontane depression in between, were formed where intra-arc and back-arc basins had been. **Tectonic zoning**. Geological and paleogeographical data supported by paleomagnetic studies indicate the existence of several tectonic units in the Caucasus and adjoining regions that have distinctive geological histories. These are the Scythian platform, Great Caucasus, the Transcaucasus and the Lesser Caucasus **Seismic tomography models**. Several seismic tomography studies were performed in the region based on travel times of the P- and S-waves from local earthquakes. The velocity anomalies displayed in the tomographic model as high-velocity bodies down to about 200–250 km depth. Post-collisional sub-horizontal shortening of the Caucasus is estimated at about hundreds km. Such a considerable shortening of the earth's crust has been realized in the region through: (1) crustal deformation with wide development of compressional structures – folds, thrusts; (2) warping and displacement of crustal blocks with their uplifting, subsidence, underthrusting and (3) lateral escaping As a result of the continuing northward push of the Africa-Arabian plate in post-oligocene times, the Caucasus region has become an intracontinental mountain belt, with active structures and topography. The northward indentation of the Arabian block into the relatively mobile Caucasian–Middle Asia region guides the geometry of tectonic deformation, the seismicity and stress regime in the black sea-Caspian sea area (Ismail-Zade et al., 2020) The key structural characteristics of the Cavcasioni (Main range and Southern slope zones) is imbricates structure. The Paleozoic Basement rocks and sedimentary cover characterized by complete, intensive, linear, often isoclinal folding with mainly south-vergent imbricated thrusting. Basement rocks and sedimentary cover together underwent tectonic deformations (a thick-skinned). The Achara–Trialeti tectonic unit, extending from the black sea coast towards Tbilisi, are deformed into long linear moderately compressed folds. The system of the northern frontal faults overlaps the northerly lying stable rigid tectonic unit - the Georgian block. The marine basins of the Tethys in Late Cenozoic were replaced by Transcaucasian basins of euxinic type (Paratethys) and, later, by continental basins with subaerial condition of sedimentation. The Dzirula high subdivides the Transcaucasian intermontane depression into two foreland basins: the Rioni (Black Sea) in western Georgia and Kura (Caspian Sea) in Eastern Georgia. The Rioni and Kura foreland thin-skinned belt located between the Cavcasioni and Miner Cavcasioni is an example of continental mountain building during the Late Cenozoic. Compressional deformation of the forelands started in the Middle Miocene and reached its maximum in the Late Miocene-Pliocene. The building of the structures of the central and northern part of the western Kura foreland basin was formed by

Great Caucasus basement wedge(s) propagation along detachment horizons within the cover-generating thin-skinned structures represented by Neogene-Quaternary shallow marine and thick continental sediments. Structural cross-sections reveal the presence of south-vergent fault-related folds and duplex. Specific deformed shapes are developed in Pliocene (Akchagilian) sediments of the Didi Shiraki syncline. They form single sequences disposed with unconformity on the backlimbs of the Mirzaani (to the South) and Zemo Kedi (to the North) anticlines. There are numerous data, including large-scale geological mapping that indicates that the molasse of the Kartli basin are characterized by nappe structure. Georgia is an earthquake-prone region where devastating earthquakes have repeatedly caused significant loss of lives and damage to infrastructure and buildings. The large seismic event was the Mw 6.9 Racha earthquake on 29 April 1991. Its epicenter was located in the Southern Slope zone of the Great Caucasus. This earthquake, the strongest ever recorded in Georgia, took about 100 human lives and caused great destruction within densely populated areas As a result of a special survey, it was determined that the Borjomi-Kazbegi fault, a left-lateral fault with a 90-kilometer amplitude, does not exist in nature (CauSIN, 2007). Instead of the "Borjomi-Kazbeg fault" or E. Milanovsky’s „Tskhinvali-Kazbegi fault“, Moscow colleagues propose the existence of a giant, 800 km long transverse so cold Agrakhan-Tbilisi-Levant (Koronovski &Domina, 2007) In the Caspian region of Russia, no such structure exists (Kopp, 1997, 2007). Nothing similar is observed in Georgia either. All available geological data for the region indicates that nothing has been displaced by this "fault." There is no such structure in Armenia.