CAUCASUS SEISMIC INFORMATION NETWORK

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ABSTRACT

The geology and tectonics of the Caucasus region is highly variable. Generating a structural model and characterizing seismic-wave propagation and attenuation in the region requires data from local seismic networks. Such data were not available until recently due to the absence of dense seismic networks. However, in the last two years the Republic of Georgia, Armenia, and Azerbaijan have installed modern seismic networks with the assistance of the International Science and Technology Center (ISTC).

The Caucasus Seismic Information Network (CauSIN) project is developing a unified, coherent database of the geology and active tectonics of the Caucasus region, and the database includes historical data as well as data from the new networks. This database will be used to obtain a detailed crust/upper mantle structure in the Caucasus, eastern Turkey, and northwestern Iran. Current models have been obtained from long pathways and do not have adequate spatial resolution. Availability of data from more than two-dozen new seismic stations in the region, in conjunction with extensive geophysical data (e.g., surface-seismic reflection profiles, gravity maps, and geological maps) will improve the model resolution and correlation with tectonic units.

Progress to date of the CauSIN project includes the collection of geological, geophysical, and earthquake data that exist at national data centers of participating countries. At a meeting held in May 2004 in Strasbourg, France, participants from Armenia, Azerbaijan, and Georgia agreed on standardized formats for a unified database of the historical and current geological and seismic data. A June 2004 meeting in Vermont addressed issues such as improved seismic-event location, further standardization of formats and techniques, and improved cohesion of the unified database. Preliminary results of these efforts will be presented.

OBJECTIVE

The primary goal of this project is to develop a database of geology and active tectonics in the Caucasus region. Data will include the localized, shallow crustal structure obtained from geophysical surveys for oil exploration.

With this new database, we will be able to improve the identification of earthquake locations and identify potential "ground truth" (GT) events. The dense network, calibration events (mining and quarry blasts), improved models, and better location algorithms (including multiple-event grid search, and double difference) will improve the event locations. Scientists in collaborating countries are eager to assist with this task since improved locations will aid in the identification of active faults.

With the ground truth events serving as validation, we will obtain a detailed crust/upper mantle structure in the Caucasus, eastern Turkey, and northwestern Iran, using data from newly installed seismic stations as well as ground station networks (GSNs) and other stations operated as part of the national networks. The model will incorporate extensive geological and geophysical data (e.g., surface seismic-reflection profiles, and gravity maps) and seismic data.

RESEARCH ACCOMPLISHED

Thus far, our primary effort has been to improve communication between the research groups in the collaborating countries and to collect station and event-epicenter locations for the local networks in the Caucuses region. Figure 1 shows the locations of stations in the local network. The GSN stations are also shown, in blue.

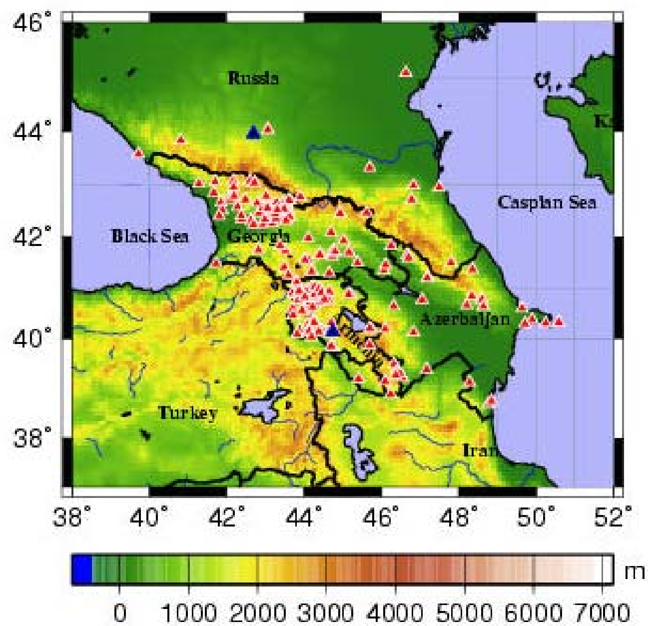

Figure 1. Stations in the local network, shown as red and white triangles. The two blue triangles are GSN stations.

An event database has been compiled at the Institute of Geophysics in Georgia from the event catalogues of Armenia, Azerbaijan, and Georgia. The database includes events dated as far back as 50 AD. A total of 300 events in the database are dated before 1900, which will be helpful in understanding the historical seismicity of the region and characterizing major faults. The database also includes over 25,000 events that occurred between 1900 and 1980. Many of these events have analogue recordings, which have been in storage for years, and some of them have been lost to water damage and fires. Scientists in Georgia have begun to convert these recordings to digital records before they are irretrievably lost.

Figure 2 shows the seismicity of the study area. This is a subset of the event catalogue and includes only events from 1980 to 1997. Many of these events are digitally recorded, and we have begun to add both strong motion and regional digital records to our database.

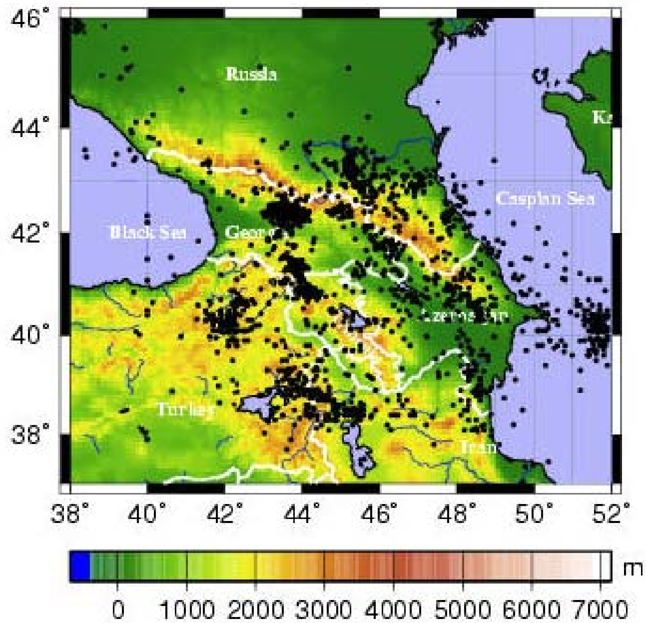

Figure 2. Earthquake epicenters from local stations for events of magnitude 3 or greater and for dates spanning 1980 to 1997.

Meetings held in Strasburg, France, in May 2004and Burlington, Vermont, in June 2004 have yielded agreement as to a common digital data file format, so that in the future data will be easily and quickly available to all collaborators. Figure 3 shows an example of such an opportunity. This record of the M_w = 5 Agri earthquake of July 1, 2004 in eastern Turkey was made at the MDTA station in the Georgian local network.

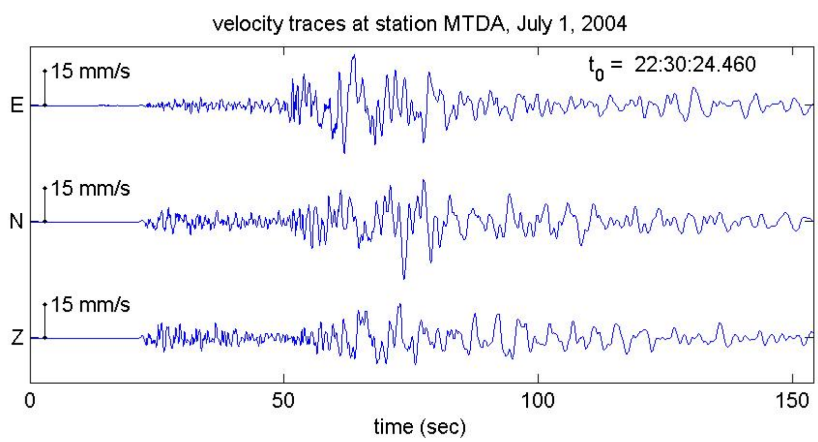

Figure 3. July 1 2004, Agri earthquake recorded at a station in the local network in Georgia.

HISTORICAL PERSPECTIVE

The following summary focuses on several tectonic features and problems of a complex major segment of the Alpine-Himalayan Belt, the segment that extends from the Caucasus and South Caspian Sea southward across the East Anatolian-Iranian Plateau, down into the collision zone with the Arabian plate.

This segment has become of prime political and scientific importance in recent years. Several of its principal features to be discussed are (1) the Bitlis-Zagros suture zone of continental-continental collision between the Arabian and Eurasian plates, (2) some basic problems and tectonics in the Zagros and Caucasus regions, (3) the question of whether subduction is being initiated beneath the South Caspian Basin, (4) some peculiar features of the seismically active Alborz and Talysh mountain belts that appear to wrap around the south and southwest border of the South Caspian Basin, and (5) tectonic implications of seismic-wave attenuation observed in the Turkish-Iranian Plateau.

Included in this summary are published results of our collaboration with Georgian colleagues at the Department of Geology and Paleontology, Tbilisi State University, and the Geological Institute of the Georgian Academy of Sciences.

Continental Collision, the Bitlis-Zagros Suture Zone, and the Zagros:

Figure 4 illustrates a schematic stage of continental collision between the Anatolian microplate and the Arabian and Eurasian plates. This continental collision usually is considered to be one of the youngest on Earth, initiated only 10–12 million years ago (e.g., Sandvol et al., 2003). However, Hempton (1985, 1987) has presented evidence that initial suturing began near the west end of the Bitlis suture (shown in Figure 4) around the mid-to-late Eocene (45–36 million years ago). It pre-dated the opening of the Red Sea and the development of the Dead Sea Transform Fault (DSF in Figure 4). Lateral closure apparently progressed gradually, completing the length of the Bitlis suture (shown in Figure 4) almost 5 million years ago.

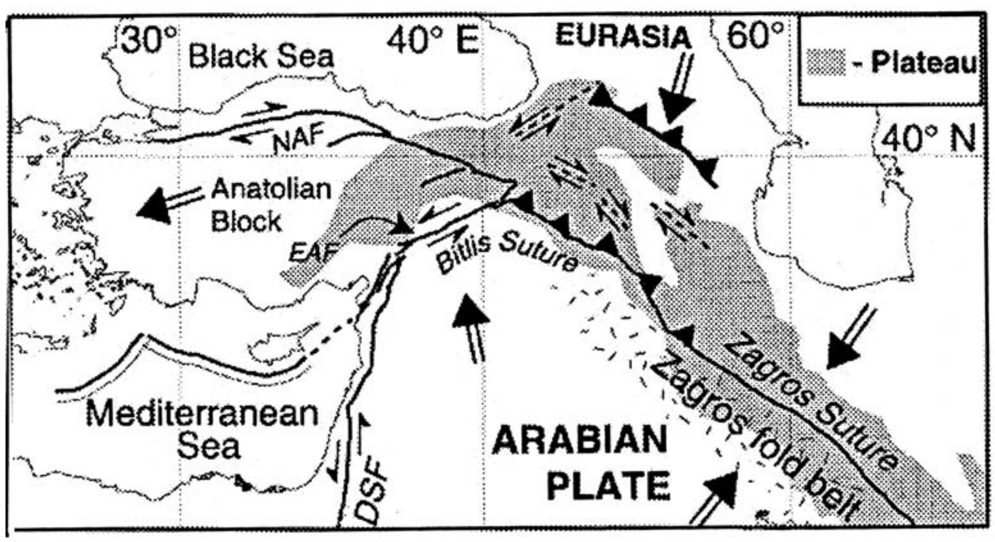

Figure 4. A schematic stage of continental collision between the Anatolian microplate and the Arabian and Eurasian plates.

Dewey et al. (1986) interpreted the East Anatolian plateau as undergoing a thickening to 52 km, which had begun in the Medial Miocene and transmits deformation to surrounding regions, such as the Lesser Caucasus. As will be seen, re-interpretation here is necessary. For example, the modern Caucasus extends east-southeast from the Black Sea to the Caspian Sea (Figure 4). A huge amount of stratigraphic data, mostly not published in the western literature, has been collected in the Caucasus over many years by our Georgian colleagues. These data contain the first stratigraphic evidence of a relatively late stage of Tethys subduction critical for the Caucasus' subsequent growth.

This stage began at the turn between the late Eocene and Oligocene, about 37–38 million years ago, when the single Ocean Tethys was transformed into the enclosed and semi-enclosed sea basins of Paratethys. Shallowing of these basins began gradually. Then, dramatically, a complete inversion of these basins, with the formation of the Greater and Lesser Caucasus, began in late Miocene time, 10–12 million years ago, with inversion proceeding at a higher rate (not less than 1.6 mm/yr average) during Pliocene-Quaternary times. The amount of vertical displacement of relevant key marker beds, measured with respect to their subsidence and uplift, is approximately 10 km (Adamia et al., 2002a, 2002b).

The front of the Zagros fold belt in Figure 4 extends over the Arabian platform. This belt also is considered to be young (Pliocene). Jackson and McKenzie (1984, 1988) and their colleagues (e.g., Berberian, 1995) interpret the Zagros to be an active basement-involved fold-and-thrust belt undergoing possibly 20 mm/yr northeast shortening, modified by local zones of strike-slip faulting, such as the Main Recent Fault located along the northwest portion of the Zagros suture (Figure 4). Many of their well-constrained focal mechanisms are interpreted to occur on reverse with thrust faults dipping 40°–50° NE within the continental basement at 8–12 km depth, and with no hypocenters detected deeper than 20 km. Deformation of the sedimentary cover, ranging in thickness from some 6 to 15 km, appears to be predominantly aseismic above the Lower Cambrian Hormuz salt horizon. Spectacular fold trains are presumably detached from the underlying Hormuz Salt and other salt horizons. Recent balanced cross sections across the Zagros, however, have been interpreted to indicate that the earthquakes described above might be originating in some of the sedimentary strata above the Hormuz (McQuarrie, 2004).

A major problem here is the rarity of exposed thrusts, deep wells, and published seismic sections across the Zagros fold belt. This makes structural and tectonic interpretation difficult (e.g., Blanc et al., 2003). As a result, the correlation of specific earthquakes with specific faults is questionable in most cases (Berberian, 1995). To partially circumvent these difficulties, Berberian has utilized a wealth of supplementary data for many years in his analyses of the Zagros. He and most students of the Zagros identify the Zagros suture in Figure 4 with a major regional fault, the Main Zagros Reverse Fault. If this is correct, it supports a Pliocene age for the Zagros. But a potentially critical factor in this case is whether a parallel, complexly deformed belt, the Sanandaj-Sirjan Belt, on the NE side of the designated suture in Figure 4, is an integral part of the Zagros, as maintained by Alavi (1994). If so, then the Zagros suture would lie further NE in Iran, possibly between the Sanandaj-Sirjan belt and the remnants of a parallel interpretive magmatic arc, the Urumiah-Dokhtar Arc, an Andean-type arc of possibly Upper Cretaceous age.

CONCLUSIONS AND RECOMMENDATIONS

Efforts at improving communication and increasing the availability of seismic data among the countries of the Caucuses have met with success. We have begun to build a database, which can be used toward the final goal of improving crustal models of the region.

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