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ASSESSING THE HAZARD CONTRIBUTES TO RECONSTRUCTION

Earthquakes Pose a Serious Hazard in Afghanistan

The nation of Afghanistan is located in a geologically active part of the world where the northward-moving Indian plate is colliding with southern part of the Eurasian plate at a rate of about 1.7 inches per year (43 mm/yr) (fig. 1). This collision has created the world's highest mountains and causes slips on major faults that generate large, often devastating earthquakes. An example is the magnitude 7.6 earthquake on October 8, 2005, in Kashmir, Pakistan, which caused more than 80,000 fatalities and left an estimated 4 million people homeless.

Each year Afghanistan is struck by moderate to strong earthquakes, and every few years, a powerful earthquake causes significant damage or fatalities. As Afghanistan rebuilds following decades of war and strife, new construction and development need to be designed to accommodate the hazards posed by strong earthquakes. To assist in reconstruction efforts, the U.S. Geological Survey (USGS) has developed a preliminary seismic-hazard map of Afghanistan. This preliminary assessment of Afghanistan's seismic hazard incorporates data from thousands of earthquakes (a subset is shown in figure 1) combined with data about historical accounts of earthquakes, information about active faults, and models of how earthquake energy travels through the Earth's crust in the region. The resulting map is the first detailed, systematic assessment of expected levels of ground shaking in Afghanistan that uses modern hazard-analysis methodologies.

Earthquakes in Afghanistan are most abundant in and near the northeastern part of the country where the effects of the plate collision between India and Asia are most pronounced. In this region, tectonic forces have created the mountains of the Hindu Kush and Pamirs along with frequent moderate to large earthquakes (see fig. 3). Historical accounts show that the damaging earthquakes have also occurred elsewhere, even in the

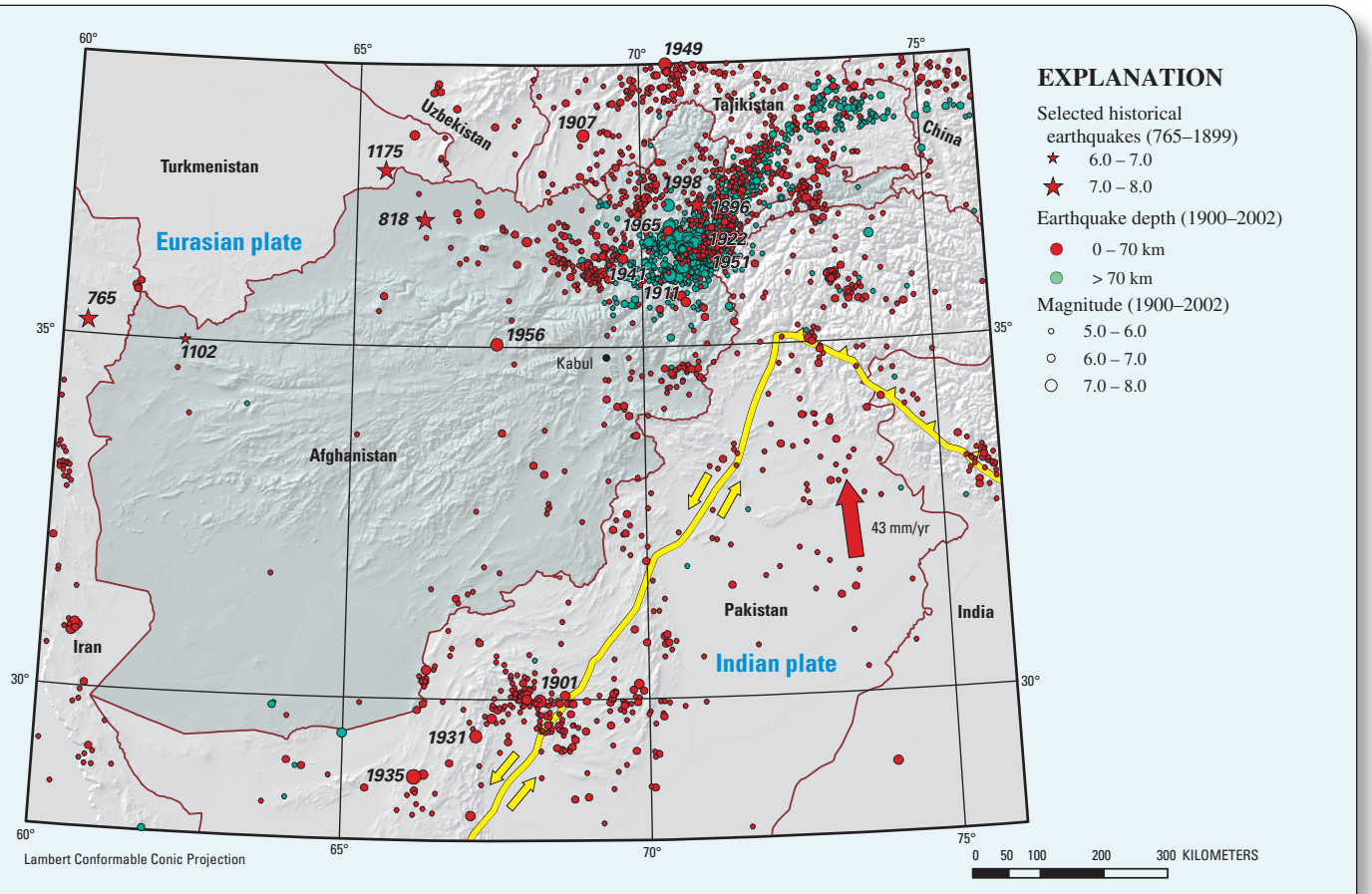

Figure 1. Map showing generalized boundary of the Indian and Eurasian tectonic plates in southern Asia (yellow line) and locations of historical earthquakes. Dates of selected significant earthquakes are shown in bold. Red arrow shows the general direction and rate of the Indian plate movement. Yellow arrows show left-lateral sense of motion on the western plate margin. The collision of the Indian and Eurasian plates is the driving force that causes most of the earthquakes in eastern Afghanistan.

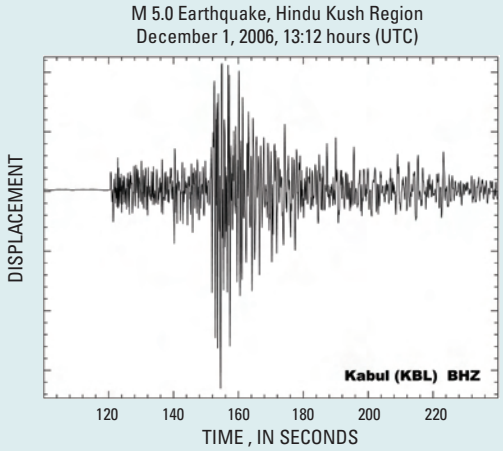

Figure 2. Seismogram of a magnitude 5.0 earthquake in the Hindu Kush region as recorded at the newly operating Kabul seismic station. The excellent quality of data from this station makes it a valuable source of information to accurately locate and characterize earthquakes throughout southern Asia.

seismically less active parts of the country; the map of earthquakes in Afghanistan (fig. 1) shows that the frequency and size of earthquakes varies across the country, and so does the hazard.

Past Earthquakes and Current Monitoring

Future earthquakes are most likely to occur in areas of numerous historical earthquakes; therefore, seismically active areas have comparatively high seismic hazards. As a first step in assessing Afghanistan's seismic hazards, the USGS compiled a comprehensive catalog that combines information from written accounts of historical earthquakes with data from instrumentally recorded earthquakes to determine the locations, sizes, frequencies, and depths of significant earthquakes (accessed April 9, 2007, at http://pubs.usgs.gov/of/2006/1185/). In this catalog, we evaluated data from more than 12,700 earthquakes, and summarized historical accounts of significant earthquakes in Afghanistan that occurred as long ago as A.D. 738.

Afghanistan and the surrounding region contain very few high-quality modern seismograph stations. As a result, it is difficult to detect and accurately locate earthquakes. To address this, the USGS, in cooperation with Kabul University, reestablished the Kabul seismic station (KBL) in 2006 after a 20-year hiatus. This station fills a critical gap in the global coverage of modern, high-sensitivity seismographs, and data from it are transmitted in real time to the USGS and its partners (fig. 2). Data from the station allow us to better determine the location, size, and depth of earthquakes throughout southern Asia and give us new insight into the characteristics and frequency of Afghanistan's earthquakes.

The Geologic and Tectonic Setting of Earthquakes

To fully understand the causes of the modern earthquake activity, we must evaluate it in the context of Afghanistan's geologic and tectonic setting. To provide this framework, the USGS has prepared a seismotectonic map that shows the country's major geologic regions and fault systems and how they might be related to earthquakes (accessed April 9, 2007 at http://pubs.usgs.gov/of/2005/1264/). Four distinct geologic domains are shown in figure 3; each has a different and complex geologic history. In these domains, there are hundreds of known faults, but none of the faults have been studied in sufficient detail to determine their current activity and how much they contribute to the seismic hazard.

Mapping Probable and Possible Quaternary Faults

If faults are active and have moved in recent geologic time, evidence of this movement is commonly visible on the land surface. Faults that have moved

Photo captions:

(Upper) Damaged structures along the trace of the reactivated fault scarp that ruptured during the October 8, 2005, earthquake. (Photo by Dr. Takashi Nakata, Hiroshima Institute of Technology, Japan.)

(Middle) Near-total destruction of homes on a terrace of the Kunhar River. (Photo from U.S. Department of Defense, provided by Lt. Col. Wiley Thompson; email: wiley-thompson@us.army.mil). Image accessed April 9, 2007, at *http://www.geo.oregonstate.edu/people/faculty/yeatsr_research.htm*

(Lower) Ground deformation caused by the thrust-fault scarp that formed during the earthquake. (Photo by Dr. Takashi Nakata, Hiroshima Institute of Technology, Japan.)

multiple times during the Quaternary Period (the last 1.6 million years) or those that have moved in the Holocene epoch (the last 10,000 years) pose the greatest seismic hazard. The published literature contains virtually no information on active faults in Afghanistan, so as a first step to recognize potentially active faults, we systematically examined satellite images of Afghanistan and created a map and database of probable and possible active faults (fig. 4) (accessed April 9, 2007 at http://pubs.usgs.gov/of/2007/1103). Our analysis of these images indicates that a number of Afghanistan's faults have surface features that are typical of active faults, but detailed field studies are now needed to confirm the activity and to accurately determine the slip rates of individual faults.

Seismic Hazard of Afghanistan

The long history of earthquakes throughout much of Afghanistan highlights the need to understand the level of hazard in various parts of the country. By combining our data on the locations, sizes, and frequencies of earthquakes with the locations and estimated activity rates of major faults, we can forecast the probable levels of future ground shaking. The likelihood of this shaking is represented on seismic-hazard maps; the maps show the probability of exceeding a certain strength of shaking in a 50-year time period. The hazard maps show that the likelihood of strong shaking in the next 50 years is highest in northeastern Afghanistan and along the corridor adjacent to the Chaman fault system (fig. 5).

The newly released seismic-hazard map of Afghanistan is a generalized map that is based on the limited, publicly available data. To further improve and upgrade this map, continued monitoring of earthquakes with modern seismic instruments is needed, and geologic studies are needed to accurately measure the rates of movement on major faults. With better information about earthquakes and active faults, we can refine estimates of the country's seismic hazard.

Even though the seismic-hazard map is generalized, it provides government officials, engineers, and private companies who are interested in participating in Afghanistan's growth with crucial information about the location and nature of seismic hazards. As demonstrated by the devastating Kashmir, Pakistan, earthquake in 2005, the social and economic impacts of a major earthquake are catastrophic and can last for years. These maps will allow officials to make informed decisions about the designs and locations of critical structures such as powerplants, dams, pipelines, and hospitals and will facilitate growth and development throughout Afghanistan by allowing facilities to be constructed that can better withstand strong earthquakes.

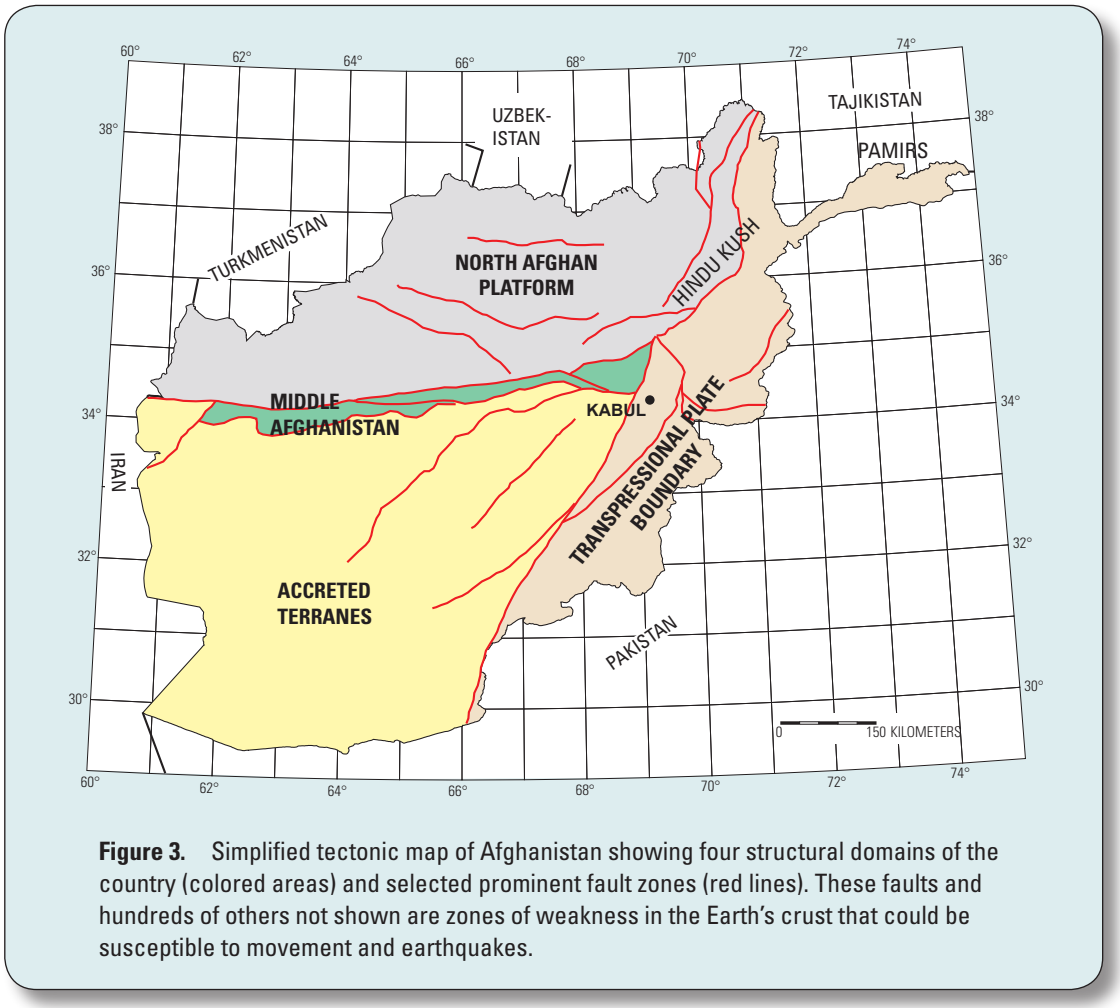

Figure 3. Simplified tectonic map of Afghanistan showing four structural domains of the country (colored areas) and selected prominent fault zones (red lines). These faults and hundreds of others not shown are zones of weakness in the Earth's crust that could be susceptible to movement and earthquakes.

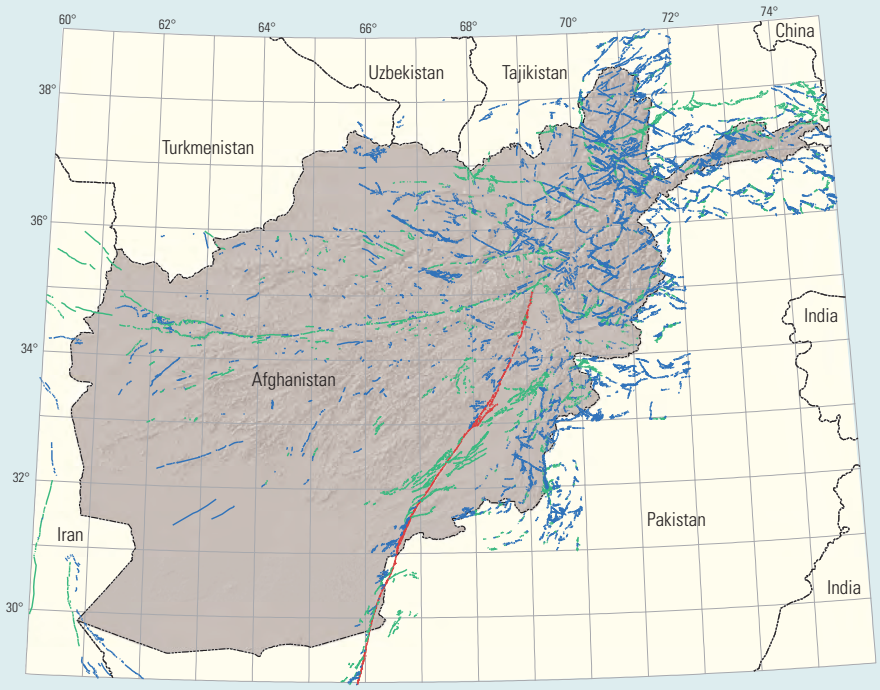

Figure 4. Shuttle-radar topographic map of Afghanistan showing the locations of features thought to be probable or possible young faults. The Chaman fault system (shown in red) and related faults, which extend from south-central Afghanistan to the northeastern corner, are the most active and hazardous faults. Faults shown in red are thought to have the highest slip rate and therefore are the most hazardous. Faults in green probably have lower slip rates and are likely to be less hazardous. Features in blue are considered to be even less active but may still pose a hazard.

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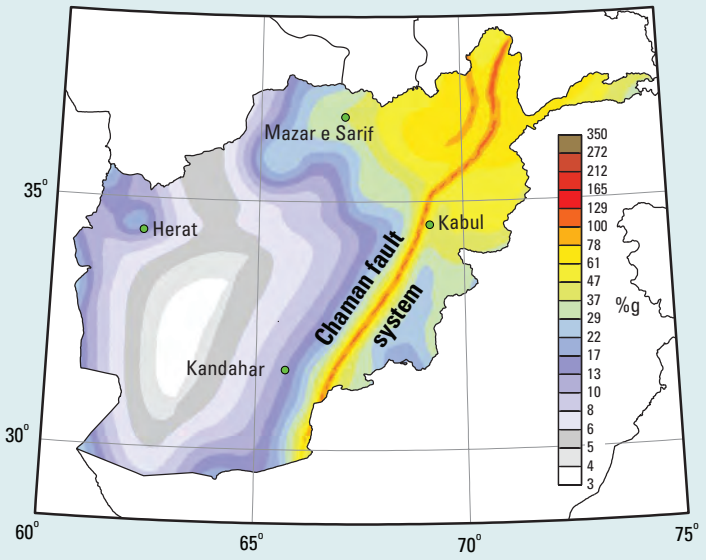

Figure 5. Generalized seismic-hazard map of Afghanistan showing the level of shaking (peak ground acceleration measured as a percentage of the force of gravity, (g) that is likely to occur with a 2–percent probability in the next 50 years. This probability is equivalent to saying that the strength of shake at a particular site will probably be exceeded every 2,500 years. Warm colors show higher hazard, and cool colors show lower hazard. The strongest expected shaking is concentrated on major active faults in eastern and northeastern Afghanistan.

The USGS Afghanistan Project

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