RECURRENCE INTERVALS OF SEVERAL 20TH-CENTURY EARTHQUAKES IN THE IRANIAN PLATEAU BASED ON ARCHAEOLOGICAL EVIDENCE

[1]BERBERIAN, M. and [2]YEATS, R.S. [1]Najarian Associates, Eatontown, NJ 07724-2255, USA; [2]Earth Consultants International, 1654 NW Crest Place, Corvallis, OR 97330

Introduction

We use the rich archaeological and historical record in Iran and Turkmenistan, locally more than 5000 years long, to determine earthquake recurrence intervals for faults and areas that have sustained damaging 20th-century earthquakes. Archaeological data include (1)evidence of collapse of structures, (2)sudden abandonment of a site, (3) sudden migrations of populations, (4) hiatus in record due to site abandonment, especially when older layer shows evidence of destruction, (5) contemporary accounts of earthquakes, and (4) proximity to seismogenic faults. Other origins of destruction, such as fire, conquest, or other natural disasters must also be considered.

Zagros Mountains

In the Dinevar-Nahavand region, the 1957 (M6.7) and 1958 Firuzabad (M6.6) earthquakes on the Zagros Main Recent strike-slip fault were preceded by an earthquake cluster in 1008 and 1107 AD and by archaeologically-documented earthquakes in the periods 224-459 AD and 1650-1600 BC, giving return times of 850-950, 500-800, and 1800-2100 years, respectively. The interval between the oldest shocks is twice as long as the more recent intervals, suggesting an unrecorded missing event. if so, the return time of earthquakes is 500-1000 years, consistent with the high displacement rates in the Zagros Mountains.

Ipak reverse fault, north-central Iran

The Ipak fault in the Iranian Plateau sustained 85 km surface rupture in the Bo'in Zahra earthquake of 1962 (M 7,2). Excavation in the Sagzabad mound shows skeletons beneath collapsed walls of a late 3rd millenium BC civilization. Abandonment of the nearby Qabrestan mound occurred at the same time. Distribution of intensities for the ancient and modern earthquakes is similar. The Ipak fault is the only candidate fault for the penultimate earthquake; this gives a recurrence interval of 4000 years on this fault.

Rudbar fault, western Alborz Mountains

The 1990 Rudbar-Tarom earthquake (M7.3) on a strike-slip fault was preceded by a large event near the beginning of the first millenium BC when the Marlik civilization abruptly declined, and excavation of the Royal Necropolis of Marlik revealed broken objects and broken and displaced stone slabs. The recurrence interval for earthquakes in this area is 3000 years, but this applies to the area, not to a specific fault because the active Manjil and Dailaman reverse faults in this area did not rupture in 1990.

Kopeh Dagh Range, Turkmenistan

The Kopeh Dagh (Kopet Dag) strike-slip fault ruptured in 1948 near Ashgabat M7.2). This area was struck by earthquakes previously near the beginning of the Christian era and around 2000 BC, a recurrence interval of 2000 years. The penultimate earthquake is based both on historical and archaeological data; the Parthian city of Nesa (Mithradatkert) together with other settlements east of Ashgabat (Ashkabad) were destroyed between the rule of the early Arshakid and later Arshakid dynasty around 10 A.D. This earthquake had a magnitude estimated as 7.1. The Parthian palace walls at Nesa are offset right-laterally about 30 cm on the Kopeh Dagh fault. The oldest earthquake, also estimated as Ms 7.1, is based on the destruction of Ak Tapeh, 18 km northeast of Ashgabat with evidence of collapsed buildings, a

skeleton of a man trapped in the building, and evidence of sudden abandonment. The presence of reverse faults and transverse right-lateral strike-slip faults in the Kopeh Dagh Range indicate that the 2000-year recurrence interval refers to an area source rather than the Kopeh Dagh right-lateral fault.

Southern Khorassan

This region was struck by a cluster of large earthquakes from 1936 to 1997, including the 1968 Dasht-e Bayaz (M7.4) and 1997 Zirkuh (M7.1) earthquakes, both of the latter with extensive surface rupture. A large Seljuk mosque at Qa'en was destroyed by an earthquake in 1066 AD with intensities at Qa'en larger than any experienced there in the 20th-century earthquakes, including an event close to Qa'en in 1976. The Timurid mosque at Qa'en was built in 1368, and it is still standing, despite damaging earthquakes in 1549, 1675, 1875, and the 1936-1997 cluster. Intensity distribution probably rules out the faults that ruptured in the largest 20th-century earthquakes, even though the slip rate and 1968 displacement on the Dasht-e Bayaz fault suggest a recurrence interval of 1000 years. Several active faults near Qa'en are candidate faults for the 1066 event; the Pavak-Boznabad right-lateral fault is long enough to produce an earthquake large enough to destroy the Seljuk mosque. One could apply a 900-year recurrence interval for an area source with the understanding that (1) the 1066 earthquake ruptured faults that did not rupture in the 20th century, and (2) the 1066 earthquake was a single event whereas the 20th-century earthquakes comprised a cluster.

Concluding remarks

The short archaeology-based recurrence interval in the Zagros Mountains relative to the Iranian Plateau is consistent with its being close to a plate boundary with a higher velocity field. The large number of archaeological sites and historical monuments close to active faults indicates that future studies relating archaeology to earthquakes are warranted, particularly near Tehran, where one-fifth of the population of Iran is at risk. The Cheshmeh 'Ali and Qaytariyeh mounds are near the North Ray-Eivanekay, South Ray, Kahrizak, North Tehran, and Mosha active faults. The Qeytariyeh, Darrus, Saltanatabad, Bustan-5, 'Abbasabad, and Galanduak archaeological sites near Tehran were actively occupied in the period 1200-1000 BC, then suddenly abandoned around 1000-900 BC. The reason for abandonment is unknown, but could be an earthquake. Archaeological evidence thus far is inconclusive in establishing recurrence intervals for individual faults or for the Tehran metropolitan area as a whole.

References.

Berberian, M., and Yeats, R.S., 1999, Patterns of historical earthquake rupture in the Iranian Plateau. Bull. Seismological Society of America, v. 89, p. 120-139.

Berberian, M., and Yeats, R.S., Recurrence intervals of several 20th-century earathquakes in the Iranian Plateau based on archaeological evidence. Submitted to Journal of Structural Geology.

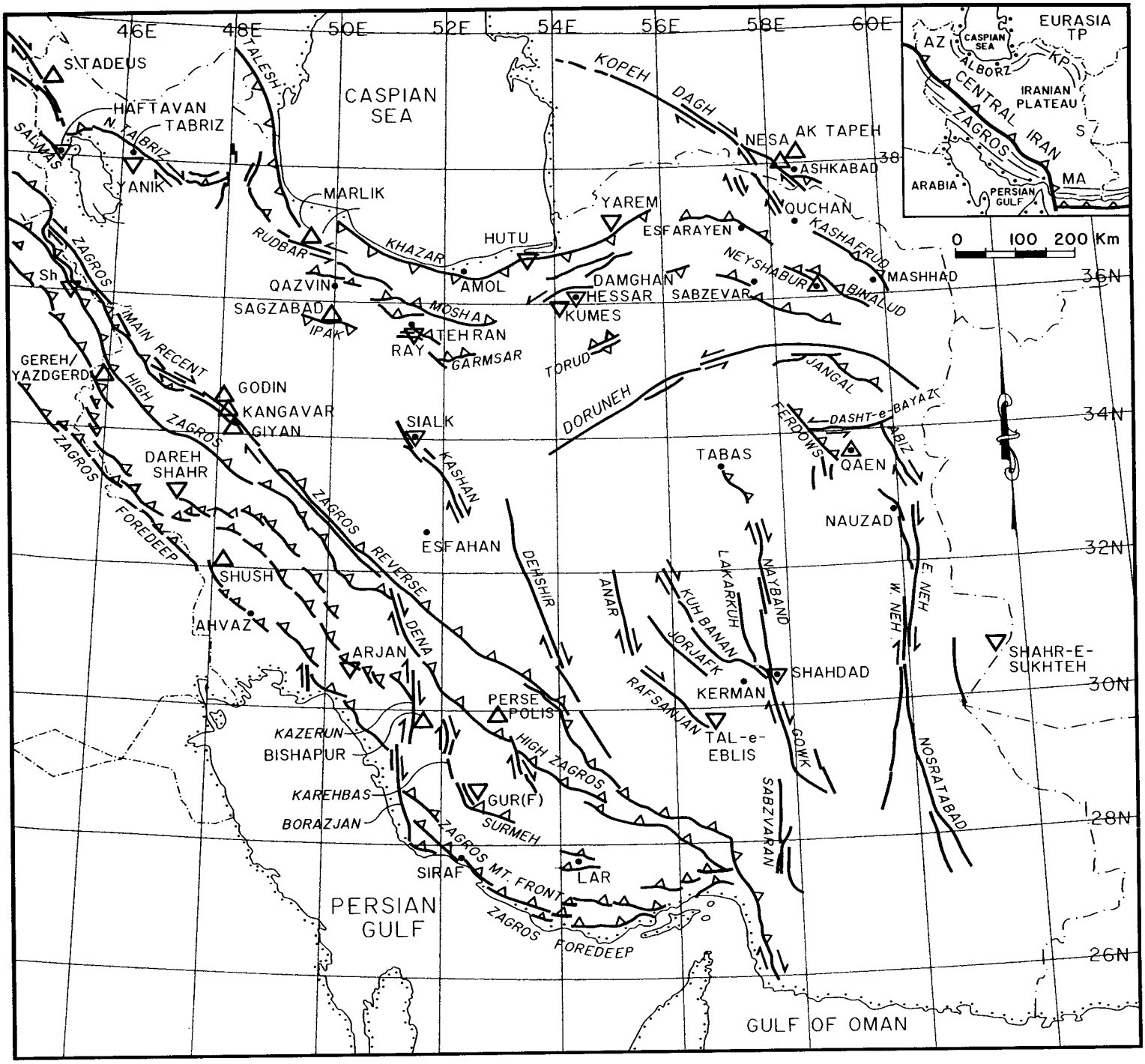

Figure 1. Principal active faults (names in italics) and active archaeological sites in Iran and adjacent regions. Reverse faults shown with teeth on hangingwall side. Strike-slip faults shown with arrows. Faults without teeth or arrows: sense of slip unknown. Inset (top right): Map of Iran showing boundary with Arabian plate (line with teeth). AZ, Azarbaijan; KP, Kopeh Dagh mountain belt; MA, Makran accretionary wedge; S, Sistan; TP, Turan platform. Archaeological sites that have provided earthquake information are shown by triangles. Those located near seismogenic faults or within the meizoseismal regions of large-magnitude earthquakes, but have not yet provided earthquake information in archaeological reports are shown by inverted triangles.