Earthquakes in Afghanistan

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We summarize the written history of earthquakes in Afghanistan from 734 AD to the present in the form of a new catalog of more than 1300 earthquakes, and narrative accounts of damage sustained during 47 of the more significant events (see electronic supplement). Afghanistan is among those regions where written records of historical earthquakes are sparse, and where contemporary publications provide circumstantial, telegraphic and occasionally misleading information. Early annals of the region from travelers' accounts and the narratives of explorers contain macroseismic information that is often of more utility than is available in records from the last half-century. Even in the 19th and early 20th century, communications have remained poor due to the skeletal development of roads, phone lines and government infrastructures, resulting in few published notices about earthquake locations and damage. Newspapers were unavailable until the first quarter of the 20th century and contain news mostly from the Kabul area.

For earthquakes before 1900 we estimate a surface-wave magnitude based on felt area and perceived intensity of damage, and for recent earthquakes we establish a relation between surface wave magnitude and seismic moment. Using this relation we assign moment-magnitudes to earthquakes throughout the entire catalog, thereby permitting estimates of cumulative-moment released throughout the past 1200 years. The early catalog is incomplete particularly in the SE and SW margins of Afghanistan, yet in most regions it has value in forming a basis for evaluating seismic hazards in the region. We recognize regions that are currently seismically quiet but where earthquakes have occurred historically, and aseismic regions elsewhere where the historical record is probably complete, but where earthquakes may be anticipated from their tectonic setting. Afghanistan's boundaries with the Lut Block in the west, and with the Indian Plate in the east, are defined by earthquakes with magnitudes M≤7.7, and outline a promontory of the Eurasian plate driving towards the Arabian plate at 3-4 cm/yr. Central Afghanistan is largely aseismic and appears to move as part of the Eurasian Plate. Special difficulties arise in the historic record in distinguishing between shallow moderate earthquakes that occur within a few minutes to days of deep earthquakes beneath the Hindu Kush, and in southern Afghanistan.

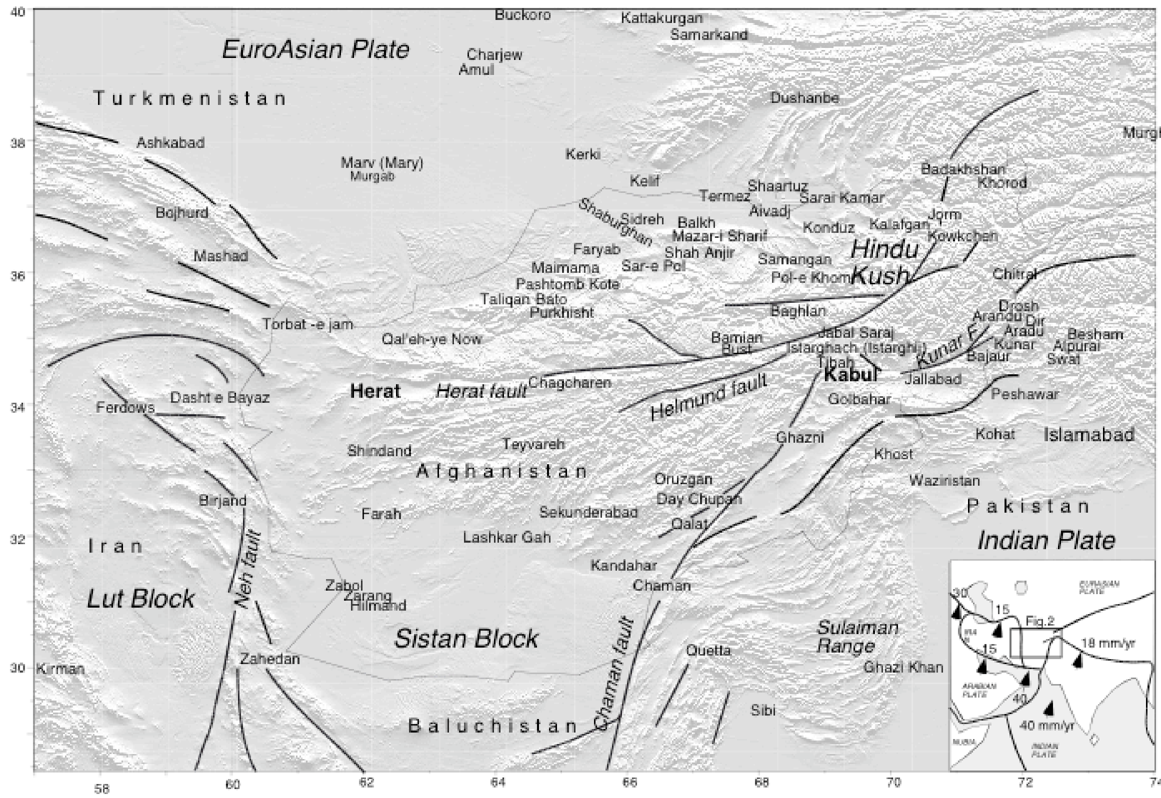


Figure 1

INTRODUCTION

Earthquakes in Afghanistan, particularly the earlier ones, have been assigned by different authors widely different locations, magnitudes and depths. The indiscriminate use of data from these works results in considerable differences in estimates of regional moment rates and location. Our intention in this article is to re-assess the historic seismic record from the time of the earliest known Afghan earthquakes in the 8th century, to the present time.

The study area is defined by the coordinates 29° to 38°N latitude and 58° to 73°E longitude (Figure1), and includes the whole of Afghanistan, the eastern part of Iran, southernmost Turkmenistan, Uzbekistan and Tajikistan, western Baluchistan and north-western Pakistan.

TECTONIC SETTING

Afghanistan lies on the southern fringe of the Eurasian plate, subject to collision with the Arabian Plate to the south and transpression with the Indian plate to the south-east at rates of approximately 30 mm/yr and 40 mm/yr respectively. These rates are based on plate velocities averaged for the past few million years (De Mets et al., 1990) unconstrained by local geodetic measurement. Revised estimates of the Arabia-Eurasia convergence rate based on recent GPS data suggests that the Arabia’s collision rate with Eurasia may have reduced to 22 mm/yr (Sella et al., 2002), with some fraction of this convergence rate being expressed on Afghanistan's western border with Iran in the form of dextral shear. Left lateral slip along India's border with Asia through Baluchistan and Afghanistan is approximately 29.5 mm/yr based on three GPS tracking sites in central and southern India (Sella et al., 2002). It is uncertain whether the Sistan Block of southern Afghanistan is mechanically part of the Eurasian plate because minor shortening may be occurring across the mountains of northern Afghanistan. A single GPS measurement on the eastern edge of the Sistan Block indicates that this shortening is small (D. Hatzfeld, personal communication, 2002). Finally, Stein et al, (2002) have suggested that part of Sind province may be moving southward towards the Indian plate at a few mm/yr as a result of stresses near the Makran Triple junction. This would have the effect of further reducing the sinestral slip rate in Baluchistan and SE Afghanistan.

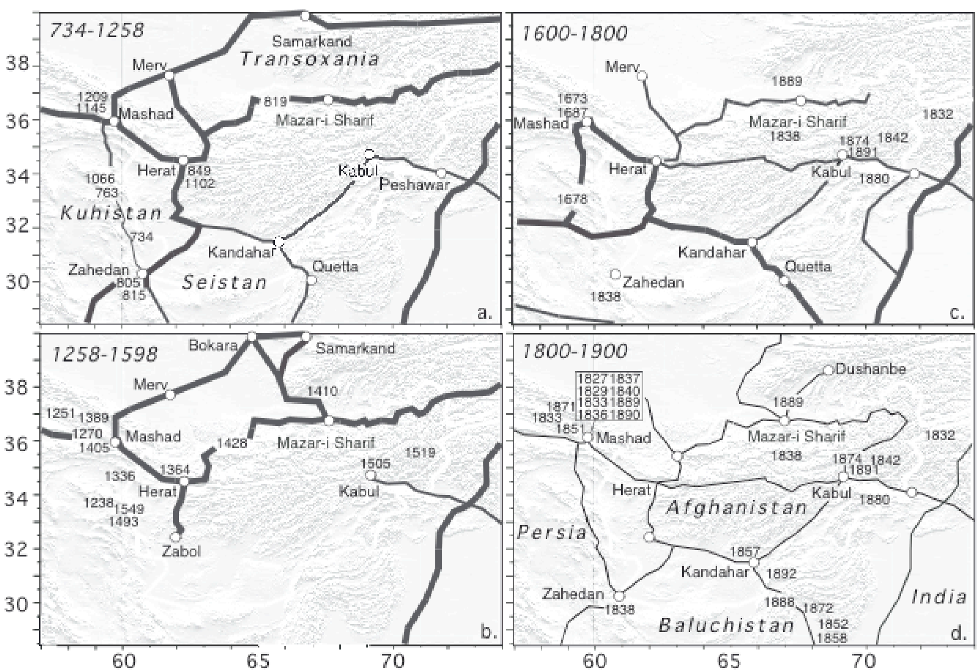


Figure 2 Evolution of Aghhan trade routes in the past 1300 years showing the dates of historic earthquakes discussed in the text. Pre-1800 major routes indicated by thick lines, minor routes by thin lines.

Earthquakes with sub-crustal focal depths (>100 km) are associated with subduction of oceanic crust occurring today in the Makran in the south, and with a descending slab beneath the Hindu Kush in the north (Pegler and Das, 1998). Elsewhere, seismicity is restricted to the upper 30 km of the continental crust and the lower crust is generally aseismic (Maggi et al 2000a,b).

Seismicity in the region is not distributed uniformly. Within the wide deforming belt are several large areas, such as western and central Afghanistan, that appear to have relatively little seismicity during the 20th century and to behave as effectively rigid blocks, Figure 4.

Eastern Iran is dominated by two belts of N-S right-lateral strike-slip faulting following the east (Sistan) and west (Nayband-Gowk) sides of the relatively aseismic Dasht-e-Lut block. Both belts contain long strike-slip faults but also exhibit components of shortening and reverse faulting. These belts accommodate N-S right-lateral shear and some shortening between central Iran and western Afghanistan.

The northern end of the eastern Sistan belt ends abruptly against a system of E-W left-lateral faults in Khorassan, which includes the Dasht-e-Bayaz fault system that ruptured in 1968 and 1979. and the Doruneh fault. These E-W faults contribute to the N-S shear by rotating clockwise as they move (Jackson et al.,1995). Farther north, the seismicity of eastern Iran merges with that of the Kopeh Dagh and eastern Alborz, both of which are dominated by thrust and reverse faults with some strike slip (Jackson et al., 2002).

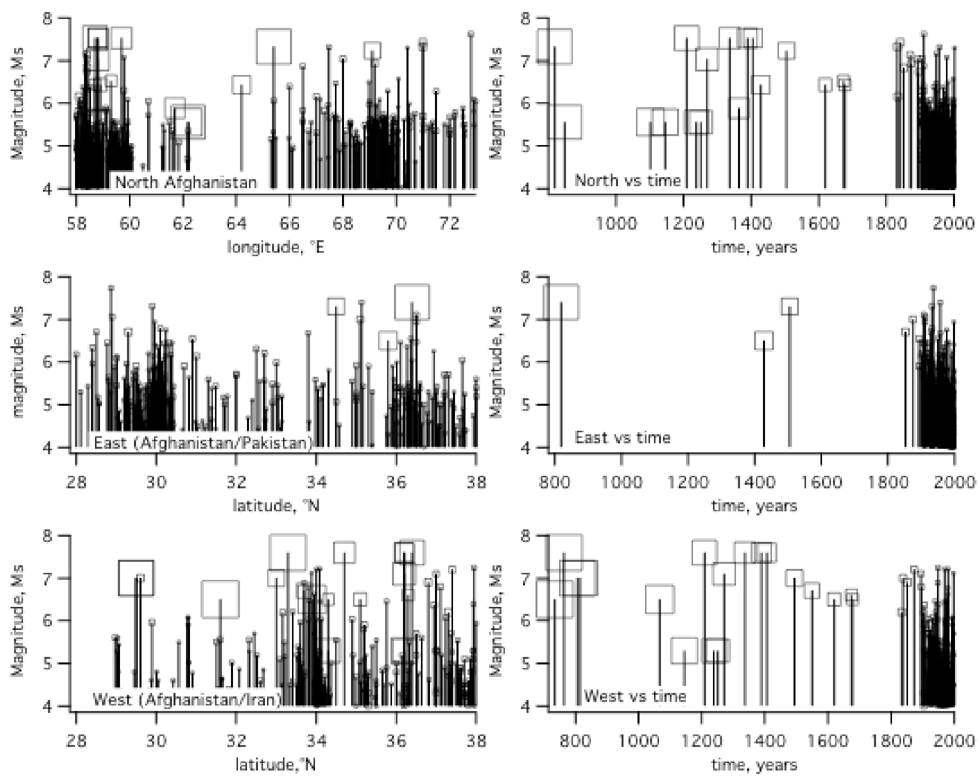


Figure 3 Distribution of earthquakes in time and space along Afghanistan's northern (34-38°N), eastern (58-61°E), and western (66-70°E) borders. Earthquakes with uncertain magnitude not shown. Squares are coded according to date (see panels right).

To the south of the region covered by this study, between 57° and 67° E, the Makran coast is a subduction zone, with the Arabian sea floor subducting at a shallow angle to the north. Unusual aspects of this subduction zone are the 300-km-wide accretion prism of sediments scraped off the Arabian sea floor to form the E-W ranges of the Makran and the near absence of bathymetric expression of a trench (White, 1982). The subduction results in a volcanic arc expressed as an ENE trending range in the southern Sistan Block, where several deep focus earthquakes have been recorded.

Near 60° E the N/S ranges of Sistan merge with the E/W ranges of the Makran, which for 500 km eastward are subject to the full convergence rate between the Arabian Plate and the Eurasian promontory of western Afghanistan. Offshore from this coastline the slow-spreading Murray Ridge marks the transition from the Arabian to the Indian plate (Minshull et al., 1992), and at 65° the seismicity again becomes intracontinental. For this reason the Makran coast at about 62°E has hitherto been regarded as an important transition in the Alpine-Himalayan belt (Molnar and Tapponnier 1975) separating the complexities of the Middle East from those of central Asia.

The region covered by this study includes the western edge of the India-Eurasia collision. From the Baluchistan coast at about 66°E the seismicity trends northward in a zone of predominantly left-lateral strike slip, with a component of convergence increasing northward (Bernard et al 2000). This zone includes the major Ornach-Nal, Ghazaband and Chaman strike-slip faults, which continue the left-lateral motion as far north as Kabul, where it joins the Herat Fault, and ultimately the Hindu Kush and Pamir Ranges. The Chaman fault itself may accommodate as much as 19-24 mm/yr of strike-slip motion (Lawrence et al 1992). At latitude 29°-30°N slip is partitioned into strike-slip and convergent components separated by approximately 100 km (Ambraseys and Bilham, 2003). East of Quetta a zone of E-W folds and thrusts in the Zhob and Loralai ranges form a bulge into the Indus plain, joining with the N-S Sulaiman ranges in the east along the Afghan-Pakistan border.

The northern part of the study region includes part of the compressional Tadjik basin, overridden by the Hindu Kush to the south and the Pamir to the north (Burtman and Molnar 1993), and touches on the western end of the Hindu Kush deep seismic zone. Many earthquakes in the depth range 70 to 300 km occur in this region, forming a contorted slab dipping steeply north in the Hindu Kush and steeply south in the Pamir (Pegler and Das 1998). This presumably represents a relict ocean basin consumed by subduction within the last 10-15 Ma.

HISTORIC MACROSEISMIC DATA

For the early period our main sources of macroseismic information are Persian documents, while for the later period, British and French consular reports are available that occasionally refer to earthquakes outside the Kabul region. Figure 3 and 4 illustrates the location of historic earthquakes in different regions of Afghanistan. Numerous shocks have been reported from the capital, Kabul, but although these events have caused general alarm they are typically associated with little damage [Furon 1925a]. A few documents written by European residents in the capital [Niedermayer 1936; Stenz 1945], and expedition reports [Danby et al., 1972] add minor additional data, and demonstrate the difficulty of retrieving reliable macroseismic information outside Kabul. An important source of data in the 20th century is the little-known work by Heuckroth and Karim (1970), who retrieved reports from the Kabul press for the period 1928 to

1969. Secondary publications and catalogs are available that contain no important new data, viz. Samizay (1998), NEIS Catalogue of Significant Earthquakes, and the U. S. National Earthquake Information Center's Earthquake Database. The GSHAP catalog, in particular, is uncritical and occasionally misleading (http://seismo.ethz.ch/GSHAP/index.html).

An annotated summary of case histories for shallow earthquakes in Afghanistan is listed in Appendix A, together with the more important sources from which these data have been derived. Notices of felt earthquakes at single locations, such as in Kabul, Herat and at a few other urban centers are numerous but as they add little information to the overall seismicity of the region they have been excluded.

It is clear from the limited number of events described in the appendix that the historic record for Afghanistan is far from complete. In contrast, macroseismic information for contiguous surrounding regions is more complete. Historic earthquakes in Pakistan, Tadjikistan, Uzbekistan, Turkmenistan are described in Kondorskaya and Shebalin (1997), earthquakes in eastern Iran are described in Ambraseys and Melville (1982) and Moinfar et al. (1994), and earthquakes in Baluchistan are described by Ambraseys and Bilham (2003). Data discussed in these sources are not repeated in the present article.

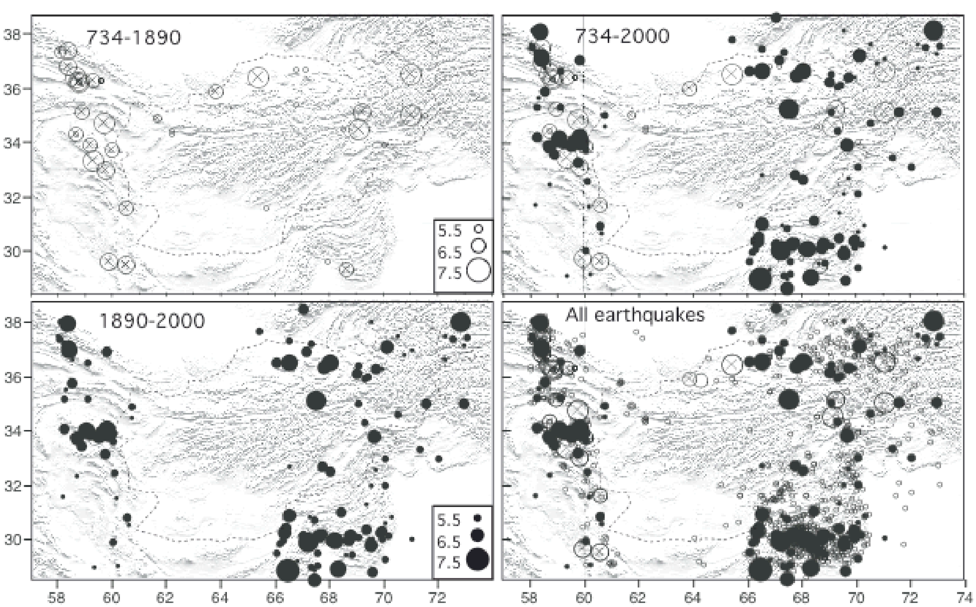


Figure 4 Historic and Instrumental earthquakes 734AD-2002

RECENT INSTRUMENTAL DATA

Instrumental data are available from station bulletins world-wide since the end of the 19th century, particularly from Russian and Indian stations, that are useful for the assessment of magnitude before the advent of the magnitude scale in the mid-1950s. Earthquake locations of diverse quality are given by various agencies and authors: BAAS, ISS, ISC, (See abbreviation list in References) by the Russian network and by Gutenberg and Richter (1965). Some events in the region have been relocated by Nowroozi (1971), Quittmeyer & Jacob (1979) and Engdahl et al (1998).

Figure 5

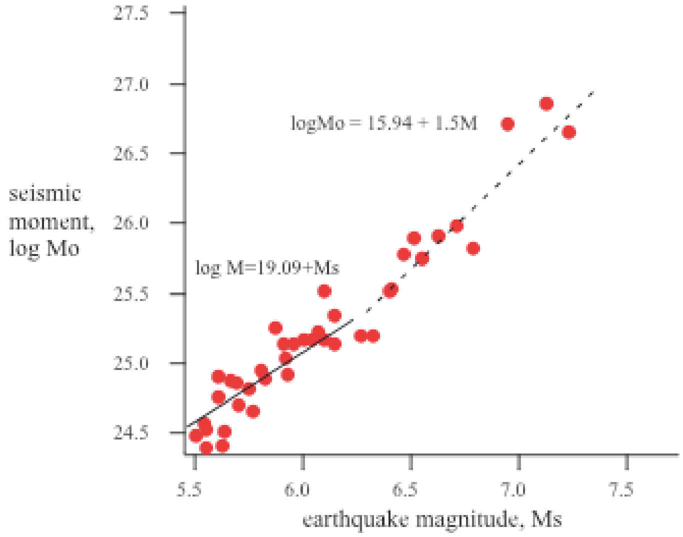


Figure 6

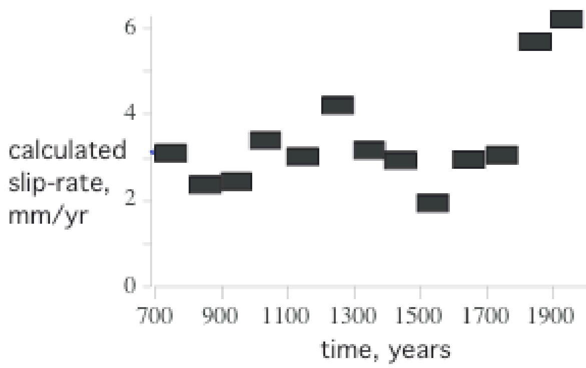
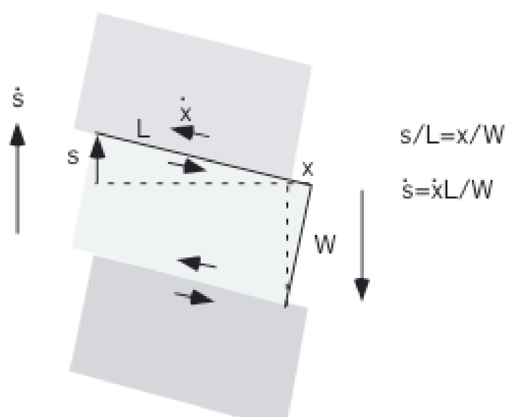


Figure 7



Epicentral location and Depth. Early instrumental epicenters in Afghanistan, like elsewhere, are unreliable and are frequently based on a poor distribution of global seismic stations. For this reason it is important to correlate early epicentral determinations with felt reports where these are available. A special difficulty attends this type of epicentral verification, especially in north-western Afghanistan where earthquakes occur in both the crust at shallow depths and at subcrustal depths (>70 km). Shallow earthquakes cause heavy local damage and loss of life, but if they occur in a remote part of the country they may fail to be reported. In contrast, large deep earthquakes that cause little or no damage are felt over a large area, and are therefore reported from multiple urban centers. This may have the effect of skewing the perceived location of instrumentally-determined earthquakes toward populated areas, and almost certainly will bias the historic record. Thus, deep events are unlikely to have escaped notice historically, but shallow earthquakes will be recorded only when they occurred near trade routes and literate population centers.

The case of the recent pair of earthquakes of 3 and 25 March 2002 in the Hindu Kush is illustrative of the problem. The first of these damaging events occurred at a depth of 250 km with a magnitude of 7.4, and the second occurred at a depth of less than 10 km with a magnitude of 6.1. The deeper and much larger event was felt over a large area, and caused widespread but relatively minor damage, including about 150 fatalities. In contrast the second, shallow shock, 120 km south-west of the first, caused great damage within a relatively small area, killing about 1200 people, but it was felt within a radius of only 200 km. If this pair of earthquakes had occurred in the pre-instrumental period it is very likely that their effects could have been conflated into a single event of large epicentral intensity and large radius of perceptibility, to which one could assign a shallow depth and a large magnitude.

Magnitude. Few earthquakes before the mid-1970s have hitherto been assigned a surface wave magnitude. Gutenberg and Richter (1965), Abe (1981), and Abe and Noguchi (1983a, b) have calculated Ms or m_b values for fewer than 8% of the 147 post-1892 instrumentally recorded events discussed in this article.

Our study commenced by reviewing each event in the parametric catalogs described above to remove double entries, obvious errors and spurious events. For 1410 remaining events we merged a large body of macroseismic information derived from diverse primary sources, both published and unpublished.

Early earthquakes are far less well located and it is often difficult to ascertain even their true epicentral area, although for most of them there is little ambiguity about their general location. While it is certain that many small to medium magnitude events are absent in the record, it can reasonably be assumed that those few for which damage details survive were important events.

Epicentral Locations. The final dataset consists of 1312 shallow earthquakes of all magnitudes, 98 fewer than in recent parametric catalogs. Discarded entries include spurious events, repeated entries, field explosions in Uzbekistan, and underground detonations in Turkmenistan in the 1960s and 1970s. Macroseismic epicentral locations before the 1970s, if well defined, were selected in preference to instrumental epicentral locations, and constitute 12% of the total number of entries. Otherwise instrumental locations and focal depths were adopted, in a descending order of preference, 9% from Engdahl et al (1998), for well determined earthquakes (DEQ); and 6% from Quittmeyer & Jacob (1979) after checking. Locations in northern Afghanistan reported by the Russian network (15%) and by ISC were also used (48%), while a number of events before 1966 of particular interest were relocated in this study using the ISC procedure (4%). Fewer than 4% of the entries in the dataset were adopted from Nowroozi (1971), BCIS and USGS.

Ms magnitude estimates. For all the earthquakes identified in the region after 1896 we examined station bulletins for associated surface-wave readings of amplitudes and periods, and for events where such data were found, surface wave magnitudes were calculated from the Prague formula (Willmore, 1979) without restricting its validity to the arbitrary chosen narrow period and distance range employed by NEIS and ISC.

The calculation of station magnitudes with station corrections required the compilation of a magnitude database that required extracting about 9,000 surface wave amplitude/period readings from station bulletins, which were then used to estimate M_S event values for 545 earthquakes.

Mw seismic-moment estimates. Having calculated M_S for the most important events of the last century we proceeded to assess semi-empirically their moment magnitude, M_W. Seismic moments Mo of earthquakes after 1977 were taken from the Harvard Moment Tensor Solution Catalog (CMT). To these we added a few seismic moments for post-1969 events that were calculated from special studies of body-wave modeling.

First we considered the global average log(Mo)-M_S relations of Ekström and Dziewonski (1988). However, as these authors point out, there is regional bias in Mo and such global relationships may be inappropriate for the estimation of tectonic motion in continental regions. We therefore calculated a regional M_S - log(Mo) relation which is based on the 94 M_S - log(Mo) pairs from crustal events (h<40km), binned into units of 0.2 in M_S and 0.2 in log Mo. We used a bilinear relation with slope 1.0 at M_S <6.2 and slope 1.5 at M_S >6.2, for which there is theoretical justification (Ambraseys and Douglas, 2000), and obtained

$\log M_0 = 19.09 + M_S$ for $M_S \leq 6.2$ ....(1.1)

and $\log M_0 = 15.94 + 1.5 M_S$ for $M_S > 6.2$ .... (1.2)

with Mo in dyne-cm. These relations fit the data well (Figure 5). In this figure the two small events (<4.5) that fall well above the fitted relation are probably subcrustal events whose M_S have not been corrected appropriately for depth. The data fit equally the relation obtained above if the regression coefficients are determined from individual, rather than binned, data points. These relations differ little from (1.1 & 1.2) and for a given M_S yield smaller Mo values than the global average relation of Ekström and Dziewonski (1988) by an average factor of 0.68 for $M_S \leq 6.2$, and by 0.62 for $M_S > 6.2$.

A similar overestimation of Mo from global relations was found from a much larger number of data for the Eastern Mediterranean region, which confirms that in these areas global Ms-Mo relations yield Mo values that are too high while regional relations yield values closer to those calculated directly (Ambraseys 2001). From the derived Ms to Mo relations (1.1 & 1.2) we estimated seismic moments for those events for which only Ms was previously available.

Parametric catalogs. Table 1 lists all 52 earthquakes before 1891 for which we could find information from contemporary sources. Table 2 presents a list of 148 shallow Ms ≥ 5.5 earthquakes from 1891 to 2002. Appendix 1 summarizes the macroseismic effects of the more important earthquakes in these tables. For shocks in surrounding countries this information is given in the publications quoted. Table 4 presents a list of 1313 earthquakes from earliest times to the present and is provided as an electronic supplement.

DISCUSSION

Most pre-19th century earthquakes were reported along trade routes (Figure 2) that have remained unchanged since pre-Hellenistic times, governed as they are by the physiography of Afghanistan and the availability of fresh water. This, and the propensity for established and persistent settlements to develop along and at the confluence of trade routes, brings with it the danger that the surviving historic record provides a somewhat biased geographic view of Afghanistan seismicity. Yet the absence of recent earthquakes in the large desert depressions of Afghanistan suggests that these regions are empty of both roads and earthquakes. The one exception to this observation is the cluster of the deep subduction earthquakes beneath the sparsely populated Chagai Mountains along the southern border of Afghanistan with Baluchistan (see front cover).

Deformation along the eastern and western margins of Afghanistan is highlighted by seismicity throughout historic and recent time (Figures 3-4). Afghanistan appears to be a promontory of the Eurasian plate penetrating southward between Iran and India, with relatively minor seismic evidence for significant convergence in the northern Afghan mountains, as suggested by recent GPS data from SW of Farah. The total cumulative seismic moment release in the entire catalog ($1.6\text{x}10^{28}$ dyne cm) is roughly 50% higher in eastern Afghanistan than in western Afghanistan ($1.1\text{x}10^{28}$ dyne cm). If the Hindu Kush and Kopeh Dag regions north of 35 °N are ignored (thereby removing the contribution from thrust and deep earthquakes from the summation), the rates are comparable ($\approx 8\text{x}10^{27}$ dyne cm). Despite this similarity, the seismic record is considered too incomplete to estimate a meaningful slip rate on Afghanistan's eastern and western borders.

Table 3 Estimated fault slip rates in E Iran/W.Afghanistan calculated from cumulative scalar seismic moment for historic and recent intervals of time. Recent rates are typically double historic rates suggesting probable incompleteness in the seismic record.

Latitude range	epoch	historical rate	1800-2000 rate
29-38°N	800-2000	3.7 mm/yr	6.0 mm/yr
29-36°N	800-2000	2.9 mm/yr	4.6 mm/yr
29-34°N	800-2000	1.6 mm/yr	3.2 mm/yr
30-34°N	800-2000	1.7 mm/yr	3.4 mm/yr
34-36°N	1200-2000	5 mm/yr	6.9 mm/yr

Notwithstanding these difficulties we provide slip-rate estimates for the Afghan/Iran boundary for which we have a 1200 year history of events. We sum the cumulative seismic moment release for this 900-km-long western boundary, increasing it by 25% to account for the contribution from earthquakes less than Ms=5.5 (Ambraseys & Sarma, 1999), and assuming a seismogenic thickness of 20 km and a rigidity modulus of $3\text{x}10^{11}$ dyne-cm^2. Slip rates from the earliest times to 1700 show a surprisingly uniform slip rate of approximately 3 mm/year, with rates in the past two centuries doubling to approximately 6 mm/yr (Figure 6). In Table 3 we show the different rates associated with different latitudinal segments of the plate boundary.

The dextral shear rate between Arabia and Asia near the eastern Afghan border is estimated to be 38 mm/yr from the NUVEL-1A plate motion model (DeMets et al, 1990), but 22 mm/yr from the more recent REVEL GPS-based plate motion model (Sella et al., 2002). The inferred 22 mm/yr rate is reduced by ≈10mm/yr convergence across the Zagros mountains (Tatar et al., 2002), and the remainder is partitioned between faults east and west of the Lut block. With at least 2 mm/yr to the west of the Lut Block (Jackson et al., 1998; Berberian et al, 1999) the inferred dextral shear rate between Afghanistan and Iran reduces to ≈10 mm/yr.

Our cumulative-moment release estimates (3-6 mm/yr) for slip velocity are thus smaller than estimated plate-closure vector rates. One reason for this is that our scalar summation fails to account for the contribution to dextral slip from block rotation within the boundary between Afghanistan and Iran. North of 34°N the western edge of Afghanistan changes in character, from a series of dextral strike slip faults approximately parallel to the slip vector, to a sequence of roughly east-west sinistral faults separating blocks whose rotation contributes to dextral slip. The shear displacement accommodated by block rotation is proportional to the aspect ratio of the blocks (Figure 7). Assuming fault lengths of ≈100 km (the approximate width of the zone of faulting in Figure 2) and an uniform north-south separation of these faults 30-50 km, the plate boundary slip rate accommodated by block rotation would be 2-3 times higher than the slip rate on the block bounding faults. The spacing of E/W faults north of 34°N does not resemble the simple view depicted in Figure 6, and fault lengths and spacing can be chosen to give arbitrarily small or large aspect ratios (e.g. 2-4). Summations of moment release south and north of 34°N reveals mean slip rates (1200 year average) of 1.6 mm/yr and 7 mm/yr respectively. Hence the northern part of the zone could have accommodated up to 7-21 mm/yr in the past 800 years, consistent with REVEL inferred velocities.

In contrast, our estimate of slip rate south of 34°N is considerably lower than inferred rates, suggesting that the historical record is incomplete in this geographical region, a conclusion reached also by Walker and Jackson (2001). The moment deficit corresponds to several M>7 earthquakes.

The historic record in eastern Afghanistan within the Chaman fault system on Afghanistan's eastern boundary with the Indian plate is much sparser than in western Afghanistan with merely three events in the period 800-1800 (Figure 3). Moreover, different plate boundary processes prevail. An example of strain partitioning occurred in the 1930's (Ambraseys and Bilham, 2003). The Mach 1931 (Ms=7.3) earthquake absorbed approximately 1 m of east-west convergence, followed in 1935 by the Quetta (Ms=7.7) earthquake with more than 3 m of inferred sinistral slip. Distributed seismicity in the 400-km-wide Sulaiman lobe of western Pakistan represents significant shallow thrusting in this region, that also does not contribute directly to plate boundary slip. A scalar summation of moment release along this eastern boundary thus results in a misleading estimate of plate boundary slip rates along Afghanistan's eastern boundary.

Silent both in the historic record and in the record of recent seismicity is a 300-400 km segment of the Chaman fault system on the Afghan/Baluchistan border between 31° and 33.5°N. The absence of historic earthquakes here, with the exception of the 1892 M=6.8 Chaman earthquake at the southern end of this segment, may represent a gap in the historic record, but it is unlikely that events since 1890 are missing. The locations of the 1857 Kandahar, and the 1505 and 1891 Kabul earthquakes appear to be too far from the plate boundary to represent activity on the Chaman fault. The plate boundary velocity at this location is estimated to be 2-4 cm/yr suggesting that M>7 events could occur at <200 year intervals.

The historical record reveals damaging events along the northern mountains fronting the Turam depression and in Turkmenistan. This suggests that some convergence is occurring between Asia and the Sistan block. The absence of recent earthquakes in the western half of this region and their occurrence intermittently in the past 1200 years suggests that future earthquakes may not be unexpected in this region (Figures 3 & 4). Recent earthquakes along this zone have occurred with decreasing frequency and magnitude towards the west suggesting that convergence between the Sistan block and Asia may result in minor counter-clockwise rotation of the Sistan block relative to Asia. This would have the effect of reducing both the left-lateral slip rate and the convergence rate on the Chaman transform fault system.

Slip on the Herat fault would have little effect in absorbing north-south convergence, perhaps explaining why it appears largely aseismic both historically and during the instrumental period. Earthquakes in the historical record near Herat and Kabul could indicate that the fault is intermittently active, but these earthquakes could also have occurred on nearby faults.

CONCLUSIONS

The historical record in Afghanistan over the past 1200 years delineates a tectonic view of the country ploughing southward into the Arabian and Indian plates as a promontory of the Eurasian plate. Both its western margin with Iran, and its eastern boundary with Baluchistan, have a long history of damaging earthquakes, with the exception a ≈300 km segment of the Chaman fault system. This segment represents a real seismic gap in left-lateral seismic moment release in the past century, and a possible gap in historical knowledge in earlier centuries, since no evidence for creep on the faults in the region between 31°N and 33°N has been reported. We note that a large earthquake on the northern Chaman fault would result in significant damage in the Kabul region.

Deep earthquakes are associated with subduction of the Arabian plate beneath the Makran coast along its southern border, and a descending slab beneath NE Afghanistan. Because of incomplete spatial reporting, these deep earthquakes are difficult to distinguish in the historical record from shallow earthquakes that occur at similar times. This may have the effect of biasing upward the estimated magnitude of an earthquake sequence if unwittingly assessed as a single event. A pair of earthquakes in March 2002 provide a recent example of such a sequence – the 4 March M=7.2 earthquake at >150 km depth causing widespread low intensity damage, followed on 25-27 March by a sequence of shallow Ms≤6 earthquakes with severe surface intensities.

The greater part of the interior of Afghanistan is seismically inactive, but the more heavily populated north and east experience significant seismicity. In particular, north-eastern Afghanistan, near and north of the capital, Kabul, has a long history of damaging deep and shallow earthquakes. Historic earthquakes along the north-facing frontal ranges in western Afghanistan have no recent instrumental counterparts suggesting that infrequent future damaging earthquakes will recur in this region.

We apply a regional bi-linear relation between Ms and Mw derived from recent earthquakes to the entire catalog of earthquakes for which we have obtained estimates of surface wave magnitude, and sum scalar moment release throughout the past 1200 years. Only for western Afghanistan is the catalog sufficiently complete to form general conclusions about the relative regional velocities implied by seismic activity. The inferred dextral slip rate of Afghanistan with Iran (3-6 mm/yr) is consistent with the dextral shear inferred indirectly from GPS measurements (≈10 mm/yr) when the contribution from block rotation north of 34° is taken into account. South of 34°N, and for much of Afghanistan's boundary with Pakistan and Baluchistan, the cumulative seismic moment is significantly less than that inferred from plate motions.

ACKNOWLEDGMENTS

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REFERENCES

Newspapers With very few exceptions, references to press reports are omitted.

ZAK Zakaspiskoe Obozrenie:21-23.12.10, Ashkhabad

TUR Turkestanskie Vedomosti:21.12.10, Tashkent

Abbreviations

BAAS British Association for the Advancement of Science; Seismological Committee Reports, 1890-1917

BCIS Bureau Central de l'Association International de Sismologie, Catalogues & Reports, Strasbourg, 1902-1914

BPTS Biullet. Postr. Tsentr. Seism. Komm. 1905-1911

DLG *Delhi Gazette*, 19-20.02.1842

ENG *Englishman* (Calcutta) 16.05.1842 et seq.

FO Public Records Office, Foreign Office, London

GSH Global Seismic Hazard Assessment Program (GSHAP see *Annali di Geofisica* 1999)

JASB J. Asiat.Soc. Bengal, vol.1, p.34, 146, 1832; ii 439 & 564; xii.1049.

IO India Office, Political Proceedings of the Government of India, P/S various London

ISC International Seismological Centre, Regional Catalogue of Earthquakes 1964-2000

ISS International Seismological Summary, 1918-1963

ITT *Ittilaat* (Tehran)

NAT Nature (London)

PAI *Paisa* (Lahore)

SMT Seism. Monatschr. Tiflis Seism. Observatory

SZ Sredneaziatskaya Zhizn 1906:222,262

TGS Trans. Geol. Soc. London, vol.3, p.492

TIM *The Times* (London)

TIN *The Times of India* (Delhi)

TV *Turkestanskie Vedomosti* (Tashkent) 1906.161, 1910.282, 286

USG U.S. Geological Survey Earthquake Data Base, National Earthquake Information Center, (Updated 2001)

ZEM Zemletriasenia v CCCP, Institut Fiziki Zemli, Izd. Nauka, Moscow, 1960-1989

Z0 *Zakaspiyskoe Obozrenie* (Ashkhabad) 1910.280-281

Historical Sources

Abu 'l-Fadl 'Allami, *Akbar-namah*, i.236, Bibl. Ind. 1881, [1569]

Abu 'l-Fida Ismail b. Ali, *Al-mukhtasir fi akhbar al-bashar,* vol.2, p.26, Istanbul, 1869

al-Asafi, Ulughkhani (d.1605) *Zafar al-walih bi-muzaffar wa alih*, ed. E. Ross, London 1928

Babur, Zahir al-Din, (d.1530) *Vaqi'at-i Baburi,* fasc. A.Beveridge, Gibb Memorial Ser. 1905, trans. Beveridge, The memoirs of Babur, London 1921

Barbier de Meynard, C. (1860) Extraits de la chronique persane de Herat, *J. Asiat.* vol.16.461

Fasih Khwafi, *Mujmil-i Fasihi*, ed. M. Farrukh, 3 vols, Mashhad, 1340/1961

Hafiz-i Abru, Nur al-Din, *Majmu' al tawarikh*, in F. Tauer, *Cinq opuscules de Hafiz-i Abru concernant l'histoire de l'Iran au temps du Tamerlan*, Prague 1959

Hafiz-i Abru, Nur al-Din, *Jughrafiya: qismat-i rub'-i Khurasan: Herat,* ed. M. Naravi, Tehran 1349/1970

Ibn al-Athir, 'Izzal-Din, *al-Kamil fi 'l-tarikh,* (13th c.) ed. C.J. Tornberg, Leiden 1851-76

Ibn al-Jauzi, 'Abd al-Rahman, *Kitab al-muntazam fi tarikh al-muluk wa 'l-uman,* ed. Hyderabad, 1938-41 [1181]

Ibn al-shihna, Muhammad, *Raudat al munazir fi akhbar al-awa'il wa'l-awakhir*, Marginal work in vols 7-9 of Ibn al-Athir (vol.7, p.59)

Isfizari, Mu'in al-Din, *Raudat al jannat fi ausaf madinat Hara*t, ed. M. Kazim Imam, 2 vols, Tehran 1338/1959

Qudama b. Jafar, *Kitab al kharaj,* excerpts ed. J.M. de Goeje, Bibliotheca Geograph. Arab., vol.4, pp.210-11

al-Suyuti, Jelal al-Din, *kashf al-salsala 'an wasf al-zalzala,* ed. A.L.Sa'dani, Fez. 1971

al-Umari, Yasin al-Khatib, *Al-athar al-jaliya fi 'l-hawadith al-ardiya,*

Yaqut, Abdallah, *Mu'jam al-buldan*, ed. Wüstenfeld, Leipzig, 1866-73

Journal Articles

Abbott, A. (1879) *The Afghan War, 1838-1842, a journal and correspondence of the late Major-General Agustus Abbott*, ed. C.R. Low, Bentley, London

Abe K. (1981) Magnitudes of large shallow earthquakes from 1904 to 1980, *Phys. Earth & Plan. Inter.*, vol.27, pp.72-93

Abe K. (1994) Instrumental magnitudes of historical earthquakes, 1892 to 1898, *Bull. Seism. Soc. Am.*, vol.84, pp.415-425

Abe K., Noguchi N. (1983a) Determination of magnitude for large shallow earthquakes 1898 to 1917, *Phys. Earth & Plan. Inter.*, vol.32, pp.45-59

Abe K., Noguchi S. (1983b) Revision of magnitudes of large shallow earthquakes 1897-1912, *Phys. Earth & Plan. Inter.*, vol.33, pp.1-11

Ambraseys N., Melville C. (1982) *A history of Persian earthquakes*, Cambridge Univ. Press

Ambraseys N. (2001) Reassessment of earthquakes, 1900-1999, in the Eastern Mediterranean and the Middle East, *Geophys.J.Int.,* vol.145, pp.471-485

Ambraseys N., Douglas J. (2000) Reappraisal of surface-wave magnitudes in the eastern Mediterranean and Middle East, *Geophys. J. Intern.*, vol.141, pp.357-373

Ambraseys N. and R. Bilham (2003) Earthquakes and associated deformation in northern Baluchistan 1892-2001, *Bull. Seism. Soc. Am.*(in press)

Ambraseys N., and D. Jackson (2002) Early earthquakes in northern India and Tibet, *Current Science* (submitted for pub.)

Ambraseys N., and Jackson J. (1998) Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region, *Geophys. J. Int.*, vol.133, pp.390-406

Baird-Smith R. (1842a) Notes on the recent earthquakes on the North-West Frontier, *J. Asiat. Soc. Bengal,* vol.11, pp.242-75

Baird-Smith R. (1842b) Memoir on Indian earthquakes, *J. Asiat. Soc. Bengal*, vol.12, n.136, pp.258-75, no.144, pp.1042-44

Baird-Smith R. (1843) Memoir on Indian earthquakes, J. Asiat. Soc., vol.12, pp.1046-1054, Calcutta

Ballore, Montessus de (1905) *La géographie séismologigue*, A. Colin, Paris

Ballore, Montessus de (1924) *La géologie séismologigue* , A. Colin, Paris

Barinova A., Shakirzhadova G. et al. (1987) Zemletriasenia Srednei Azii i Kazakhstan, *Zemletrisenia v CCCP v 1987 g*, pp.46-59, Moscow

Bellew H. W. (1862) *A political mission to Afghanistan in 1857,* London.

Berberian, M., J. A. Jackson, M. Qorashi, M. M. Khatib, K. Priestley, M. Talebian and M. Ghafuri-Ashtiani, 1999,The 1997 May 10 Zirkuh (Qa'enat) earthquake (MW 7.2): faulting along the Sistan suture zone of eastern Iran, Geophys. J. Int., 136 (3), 671-694

Bernard M., Shen-Tu B., Holt W.E., Davis D.M. (2000) Kinematics of active deformation in the Sulaiman Lobe and Range, Pakistan, *J. Geophys. Res.,* vol.105, pp.13253-13253

Blunt W. (1957) *A Persian spring,* Barrie, London

Bolt B. (1960) The revision of earthquake epicenters, focal depths and origin-times using a high-speed computer, *Geophys. J.,* vol.3. pp.433-440

Bozorgnia M. (1962) *Newspaper earthquake reports in Iran for the period 1944 to 1962,* Report Natl. Iranian Oil Co., Tehran

Burnes A. (1835) Travels into Bokhara, vol.2, p.15., J. Murrey, London

Burnes A. (1842) *Cabool; personal narrative of a journey to, and residence in that city*, J. Murray, London

Burtman V.S. and Molnar P. (1993) Geological and geophysical evidence for deep subduction of continental crust beneath the Pamir, *Geol. Soc. Amer. Special Paper* 281

Byron R. (1937) *The road to Oxiana*, Black, London

Chmyriov V.M., Mirzad S.H. (1972) *Tectonic map of Afghanistan,* Ministry Mines & Industr., Kabul

Danby C.J., Hore M., MacDermott K., Pelly R.C., Taylor G.C., Wesson P.S. (1972) *Report of the Canbridge Hindu Kush expedition,* pp.66-83, St.John's College, Cambridge

De Mets C., R.G. Gordon, D.F. Argus, S. Stein (1990): Current plate motions. *Geophys. J. Int.* (101) 425-478

Dupree N.H. (1971) *A historical guide to Afghanistan*, Afghan Air Authority, Kabul

Duda, S. (1965) Secular seismic energy release in the circum-Pacific belt, *Tectonophysics.* vol.2. pp.409-452

Ekström G., Dziewonski (1988) Evidence of bias in estimation of earthquake size, *Nature*, vol.332, pp.319-323

Engdahl E.R., Van der Hildt, R.D., Buland. R.P. (1998) Global teleseismic earthquake relocation with improved travel times and procedures for depth determination, *Bull. Seism. Soc. Am.*, vol. 88, pp.722-743

Eyre V. (1843) *The military operations at Cabul*, J. Murray, London

Farah A. (1976) A study of recent seismotectonics in Pakistan presented at the CENTO Working Group on Recent Tectonics, Instanbul (manuscript)

Fuchs C.W. (1886) Statistik der Erdbebe von 1865-1885, *Sitzungsb. k. Akad. Wissen. Math.-Natur. Cl.*, vol. 92, no.3. pp.215-625., Vienna

Furrer K. H.(1956) Annual Geological Report UNESCO Mission to Kabul, (dated Geol.Service Kabul 28.08.1956) Dept. Earth Sci., UNESCO, Paris.

Furon R. (1925a) Les séismes de la region de Caboul, *Compt. Rend. Acad. Sci.*, Paris

Furon R. (1925b) *L'Afghanistan*, Paris

Gleig N.A. (1846) *Sale's brigade in Afghanistan*, J. Murray, London

Gubin I.E (1960) *Zakonomernosti seismicheskih proiavlenii na territorii Tadzhikistana*, Izd. Akad. Nauk, Moscow

Gorshkov G.P. (1941) *Katalog zemletriasenii na territorii CCCP,* Trudi Seismolog. Inst., no.95. p.28, Moscow

Gorshkov G.P. (1947) *Zemletriasenii Turkmenii,* Trudi Seism., no.122, Akad. Nauk, Moscow

Gutenberg B., Richter C. (1945/65) *Seismicity of the earth and associated phenomena,* Hafner, N.Y.

Gutenberg B. *Unpublished worksheerts,* Millikan Memorial Library, Cal. Inst. Tech.
Hall, L.A. (1979) Archival resources for Afghan history in Afghanistan and Pakistan, *Afghan Studies,* vol.2, pp.75-77, London
Heuckroth L.E., Karim R.A. (1970) *Earthquake history, seismicity and tectonics of the regions of Afghanistan*, Publ. Seism. Center, Kabul Uiversity, Kabul
Jackson, D. (2002) The great western-Himalayan earthquake of 1505: a rupture of the central Himalayan gap? *Tibetan Studies I*, pp.147-159, Brill's Tibetan Studies Library, Leiden
Jackson J., Haines A.J., Holt W.E. (1995) Accomodation of Arabia-Eurasia plate convergence in Iran, *J. Geophys. Res.*. **100**, 15,205-15,219.
Jackson, J., K. Priestley, M. Allen, and M. Berberian (2002). Active texctonics of the South Caspian Sea, Geophys. J. Int., 148, 214-245.
Kondorskaya N., Shebalin N. (1997) *Nov'i katalog sil'nih zemletriasenii na territorii SSSR*, Izd. Nauka, Moscow
Levitski G. (1908) *Biulletin postoiannoi tsentralnoi seismicheskoi komissii 1902-1907,* Imperat. Akad. Nauk, vols 1-3, St. Petersbourg (continued to 1912 by P. Nikiforov)
Lawrence R, Yeats R (1979) Geological reconnaissance of the Chaman fault in Pakistan, *Geodynamic of Pakistan,* ed. A.Farah and K.A DeJong, pp.351357, Quetta
Lawrence R.D, Khan S.H, Nakata T. (1992) Chaman Fault, Pakistan-Afghanistan. In Major active faults of the world. Results of IGCP Project 206, Eds. Buckham RC. and Hancock, *Annales Tectonicae*, Special Issue suppl. vol.6, pp.196-223
Maggi A., Jackson J., McKenzie D., Pristley K. (2000a) Earthquake focal depths, effective elastic thickness and the strength of the continental lithosphere, *Geology*, vol.28, pp.495-498
Maggi A., Jackson J., Priestley K., Baker C. (2000b), A re-assessment of focal depth distribution in soutern Iran, the Tien Shan and northern India: do earthquakes really occur in the continental mantle?, *Geophys. J. Int.*, vol.142, pp.629-661
Martin F.A. (1907) *Under the absolute amir*, Harper, pp.255-258, London
Masson C. (1844) *Narrative of various journeys in Baluchistan, Afghanistan, the Punjab and Kalat*, R. Bentley, vol.2, London
Melville, C. (1978) *Arabic and Persian source material on the historical seismicity of Iran,* PhD Thesis, Univ. Cambridge.
Minshull T.A., White R.S., Barton P.J., Collier J.S. (1992) Deformation at plate boundaries around the Gulf of Oman, *Marine Geology,* vol.104, pp.265-277
Mitshkevich A. (1937) Epitsentralnaia zona zemletriasenii Samarkandskogo raiona, *Trudi* no.2, Samark. Seism. Stan., Tashkent
Moinfar A., Mahdavian A., Maleki E. (1994) *Historical and instrumental earthquake data collection of Iran*, pp.446, Publ. Iranian Cultur. Affairs Inst., Tehran
Molnar P.and Tapponnier P. (1975) Cenozoic tectonics of Asia: effects of a continental collision, *Science*, vol.189, pp.419-426
Musketof N., Orloff A. (1893) Katalog zemletriasenii Possiskoi imperii, *Zapis. Imper. Puss. Geograf. Ob.*, vol.26, p.242, Sanktpeterbug
Niedermayer R. (1936) *Der Wüstenzug der deutschen Expedition nach Persien und Afganistan*, p.108, Hamburg
Nikiforov P.M. (1912) *Byullet. Postoiannoi Tsentral. Seism. Comm.*, 1911, p.3, St. Petersbourg
Nowroozi A. (1971) Seismotectonics of the Persian plateau, Eastern Turkey, Caucasus and Hindu Kush regions, Bull. Seism. Soc. Am., vol.61, pp.317-342.

Patterson J. (1908) Seismic diturbances; Simla Observatory, Monthly Weather Review, July issue, p.71, Calcutta

Pegler G. and Das S. (1998) An enhanced image of the Pamir-Hindu Kush seismic zone form relocated earhquake hypocenters, *Geophys. J. Int.*, vol.134, pp.573-595

Quittmeyer R., Jacob K. (1979) Historical and modern seismicity of Pakistan, Afghanistan, northwest India and southeastern Iran, *Bull. Seism. Soc. Am.*, vol.69, pp.777

Rebeur-Paschwitz E. von (1893) Ueber die Aufzeichnung der Fernewirkungen von Erdbeben, *Petermann Mitteil*. vol.9, pp.201-212

Rebeur-Paschwitz E. von (1895) Horizontalpendel-Beobachtungen auf der Kaiserlichen Univesitäts Sternwaarte zu Strassburg 1892-1894, *Beiträge z. Geoph.,* vol.2, pp.211-534, Leipzig

Sale F. (1843) *A journal of the disasters in Afghanistan 1841 - 1842,* vol.2, Galognani, Paris

Sale, R. (1846) *The defense of Jalalabad,* Hogarth, London

Samizay, M. (1998) Earthquake history and hazard zones in Afghanistan, *Afghan Mosaic Magazine*, July issue

Scheu E., Lais R. (1912) *Catalogue régional des tremblements de terre 1907*, Publ. Bureau Centr. Assoc. Intern. Seism., Strasbourg

Sella, G., F.;T. H. Dixon, and A. Mao, (2002). REVEL: A model for recent plate velocities from space geodesy, *J. Geophys. Res.,* 107(4), 10.1029.

Spesivtseva V.P. (1933) Istoriko-statsticheskie materiali po seismichnosti Sredi Azii, *Trudi Seismol. Instit.*, Material. po Seismotekt. Akad. Nauk, no.34, Leningrad

Spil'kov, G.A. (1914) Zemletriasenie 1911 g. Pamirah i ego posledstviya, Izvest. Imper. Russ. Geograf. Ob-va, vol. 50, pp.69-97, Petrograd.

Stein, S., G. Sella, and E. Okal, The January 26, 2001 Bhuj earthquake and the diffuse western boundary of the Indian plate, in *Plate Boundary Zones*, American Geophysical Union Geodynamics Series 30, 243-254, edited by S. Stein and J. Freymueller, Washington, D. C., 2002.

Stenz E. (1945) Strong earthquakes in Afghanistan*, Quart. Bull. Polish Inst. Arts & Sci*., Jan. & Dec1945

Sykes L.R., and Landisman M. (1964) The seismicity of east Africa and Gulf of Aden and the Arabian Seas, *Bull. Seism. Soc. Am.*, vol.54, pp.1927-1940.

Tatar, M, D. Hatzfeld, J. Martinod, A. Walpersdorf, M. Ghafori-Ashtiany, J. Chéry. The present-day deformation of the central Zagros from GPS measurements, 10.1029/2002GL015427, 10 October 2002

Willmore P.L. (1979) *Manual of seismological observatory practice*, World Data Center A for Solid Earth Geophysics, Rep. SE-20, Natl. Oceanic and Atmosph. Admin., Denver.

Wesson P.S.,1972; The 1972 Cambridge Hindu Kush expedition, pp.66-82, St. John's Coll., Cambridge

Wilson A.T. (1930) Earthquakes in Persia, *Bull. School Orient. Afric. Studies*, vol.6, p.103

Wood J. (1872) *A journey to the sources of the river Oxus*, J. Murrey, London

Yates R., Sieh K., Allen C. (1997) *The geology of earthquakes*, Oxford Univ. Press, p.483

Yule H. (1858) *A narrative of the mission sent by the Govt.-General of India to the court of Ava in 1855, with notices of the country,* London

Zakharova A., Ibragimov R., Iodko V. et al (1972) Zemletriasenia Sredni Azii, *Zemletriasenia v CCCP v 1968 godu*, Izd. Nauka, pp.65-72, Moscow

FIGURE CAPTIONS

Fig. 1. Tectonic setting of Afghanistan showing principle faults and locations discussed in the text. The inset shows relative velocities at plate boundaries from REVEL (Sella et al., 2002) and Tatar et al., 2002. The motion of India relative to Eurasia along Afgahnistans eastern boundary with Pakistan is inferred from Nuvel 1A (DeMets et al, 1990).

Fig. 2 Evolution of Aghhan trade routes in the past 1300 years showing the dates of historic earthquakes discussed in the text. Pre-1800 major routes indicated by thick lines, minor routes by thin lines.

Fig. 3 Distribution of earthquakes in time and space along Afghanistan's northern (34-38°N), eastern (58-61°E), and western (66-70°E) borders. Earthquakes with uncertain magnitude not shown. Squares are coded according to date (see panels right).

Fig.4 Seismicity of Afghanistan. **a**) Historical earthquakes 732-1890 from Figure 2 and Table 1, **b**) significant events since 1890 from Table 2. **c**) Historical and recent significant earthquakes from a. and b. **d)** shows the entire catalog (Tables 1 & 2 and electronic appendix Table 4).

Fig.5 A plot of Ms vs log(Mo) for recent well-located events reveals a change in scaling at approximately Ms=6.2. We use these relations to derive the moment magnitudes for other earthquakes in the catalog for which we have obtained surface-wave magnitudes.

Fig.6 Moment release along Afghanistan's 900-km-long western border with Iran expressed as an equivalent slip rate assuming a seismogenic thickness of 20 km. Each bar corresponds to the mean slip rate from the indicated date to the present. Two thirds of the moment release occurs north of 34°N (Table 3) where block rotation facilitates dextral shear between Iran and Afghanistan.

Fig.7. Schematic relation between slip rate and dextral shear for bookshelf faulting along Afghanistan's border with Iran north of 34°N. Dextral shear rates $\dot{S}$, exceed sinistral fault slip rates by a factor increased by the aspect ratio of fault length to block width (L/W), which is of the order of 2-3 in eastern Iran.

Index to Tables 1-3

Y, M, D, OT correspond to year, month, day and origin time in hours and minutes.
E and **N** corresponds to longitude and latitude in degrees respectively.
R Epicentral locations were adopted from the following sources

1- Epicenters computed by BAAS/ISS/ISC
2- Rough macroseismic locations or epicenters adopted by BAAS/ISS with no calculation. Calculated from the Prague formula with station corrections
3- Macroseismic epicenters from well defined macroseismic observation
4- Relocated positions using ISC procedures
5- For early earthquakes, locations calculated by Ambraseys and Melville for western Afghanistan
6- Quittmeyer and Jacob relocated events in the time period 1914 through 1965, using a computer program similar to the one described by Bolt (1960) (Quittmeyer and Jacob 1979)
7- From Engdahl et al. 1998. We adopted only recomputed locations that have a well determined depth (DEQ in their columns 2-4).
8- Few locations were taken from BCIS for the period 1953 through 1965 during which ISS did not report small events.
9- In the absence of other locations we accepted some data marked LEQ and FEQ from Engdahl et al. (1998).
10- Nowroozi recalculated epicentral locations of earthquakes in the region between 1950 and 1965, using the program by Sykes and Landisman (1964) Nowroozi (1971). N
11- PDE locations
0- Locations in northern Afghanistan taken fron reports of the Soviet network.

n number of seismographic stations used by ISS/ISC to calculate epicentral position
p actual number of stations greater than that given by ISS/ISC
M_s Surface wave magnitude
r 1: calculated from the Prague formula with station corrections
2: calculated from the Prague formula from few stations with station corrections
3: ISC
4: Moscow
5: calculated from macroseismic data

h focal depth from sources in R
log(M_o) dyne.cm
q 0: Mo not available
1: CMT Harvard
2: converted from M_S from equations described in text
3: from other sources: (Bernard et al., 2000)

M_o moment magnitude
m_b (or m_B) body wave magnitude from ISC
M surface wave magnitude from ISC

TABLE 1 Significant historic Afghanistan Earthquakes 734-1891. Fifty one earthquakes are listed of which 11 are described in the electronic appendix).

Y	M	D	OT	N	E	R	M_s	r	logMo	q	M_w	location
734	0	0	0	31.6	60.5	3	6.5	5	25.7	2	6.4	Sistan-I
763	0	0	0	33.3	59.3	3	7.6	5	27.3	2	7.5	Qayin-I
805	12	2	0	29.5	60.5	3	7	5	26.4	2	6.9	Sistan-I
815	0	0	0	29.5	60.5	3	7	5	26.4	2	6.9	Sistan-I
819	6	0	0	36.4	65.4	3	7.4	5	27	2	7.3	Balkh
849	0	0	0	34.3	62.2	3	5.3	5	24.4	2	5.6	Herat
1066	5	0	0	33.9	59.2	3	6.5	5	25.7	2	6.4	Kuhistan-I
1102	2	28	1800	34.4	62.2	3	5.3	5	24.4	2	5.6	Herat
1145	0	0	0	36.2	58.8	3	5.3	5	24.4	2	5.6	Nishapur-I
1209	0	0	1200	36.4	58.7	3	7.6	5	27.3	2	7.5	Nishapur-I
1238	0	0	0	34.3	58.7	3	5.3	5	24.4	2	5.6	Gonabad-I
1251	0	0	0	36.2	58.8	3	5.3	5	24.4	2	5.6	Nishapur-I
1270	10	7	1200	36.2	58.8	3	7.1	5	26.6	2	7	Nishapur-I
1336	10	21	600	34.7	59.7	3	7.6	5	27.3	2	7.5	Kwaf-I
1364	2	10	0	34.9	61.7	3	5.8	5	24.9	2	5.9	Herat
1389	2	0	0	36.2	58.8	3	7.6	5	27.3	2	7.5	Niishapur-I
1405	11	23	0	36.2	58.8	3	7.6	5	27.3	2	7.5	Nishapur-I
1410	0	0	0	36.7	66.8	3	0	0	0	0	0	Balkh
1428	0	0	0	35.9	63.8	3	6.5	5	25.7	2	6.4	Taliqan
1493	1	10	600	33	59.8	3	7	5	26.4	2	6.9	Muminabad-I
1505	7	6	0	34.5	69.1	3	7.3	5	26.9	2	7.2	Kabul
1519	1	3	0	35	71.5	3	0	5	0	0	0	Bajaur
1549	2	15	2400	33.7	60	3	6.7	5	26	2	6.6	EQayin-I
1619	5	0	0	35.1	58.9	3	6.5	5	25.7	2	6.4	Dughabad-I
1673	7	30	0	36.3	59.3	3	6.6	5	25.8	2	6.5	Mashhad-I
1678	0	0	2400	34.3	58.7	3	6.5	5	25.7	2	6.4	Gonabad-I
1687	4	0	0	36.3	59.6	3	0	0	0	0	0	Mashhad-I
1827	3	17	0	36.3	59.6	0	0	0	0	0	0	Kabul
1829	0	0	0	36.3	59.6	0	0	0	0	0	0	Kabul
1832	1	22	0	36.5	71	3	7.4	5	27	2	7.3	Badakhshan
1833	0	0	0	37.3	58.1	3	6.2	0	25.3	2	6.2	Shirvan-I
1833	4	19	0	36.3	59.6	0	0	0	0	0	0	Kabul
1836	0	0	0	36.3	59.6	0	0	0	0	0	0	Kabul
1837	12	14	0	36.3	59.6	0	0	0	0	0	0	Kabul
1838	0	0	0	29.6	59.9	3	7	0	26.4	2	6.9	Nasratabad-I
1838	1	7	0	35.4	66.8	3	0	0	0	0	0	Jurm
1840	1	26	0	36.3	59.6	0	0	0	0	0	0	Kabul
1842	2	19	1140	35	71	3	7.5	5	27.2	2	7.4	Kunar
1851	6	0	0	36.8	58.4	3	6.9	5	26.3	2	6.8	Quchan-I
1852	1	24	345	29.3	68.6	3	6.7	5	26	2	6.6	Kahun
1857	6	0	1230	31.6	65.7	3	0	0	0	0	0	Kandahar
1858	8	25	0	28.3	68.4	3	0	0	0	0	0	Jacobabad-P

1871	12	23	1800	37.4	58.4	3	7.2	0	26.7	2	7.1	Quchan-I
1872	12	15	0	29.6	67.9	0	0	0	0	0	0	Sibi-P
1874	10	18	0	35.1	69.2	3	7	5	26.4	2	6.9	Kohistan
1880	2	8	0	33.9	70	3	0	0	0	0	0	Khurum
1888	12	28	0	0	0	0	0	0	0	0	0	Quetta-P
1889	4	0	0	36.3	59.6	0	0	0	0	0	0	Kabul
1889	10	0	0	36.7	67.1	3	0	0	0	0	0	Mazar
1890	9	0	2100	36.3	59.6	0	0	0	0	0	0	Kabul
1891	6	0	0	34.5	68.5	3	0	0	0	0	0	Paghman

TABLE 2 Significant Afghanistan Earthquakes 1892-2002. One hundred and forty-seven are listed and 36 are described in the electronic appendix.

Y	M	D	OT	N	E	RR	n	M_s	R	h<40	$\log M_o$	bq	M_w	m_B	M_b	location
1892	12	20	20	30.9	66.5	3	3	6.5	1	0	25.8	2	6.5	0	0	Chaman-P
1893	2	13	400	30.7	67.4	3	3	5.9	2	0	25	2	6	0	0	Chaman-P
1893	11	17	1500	37	58.4	3	3	7.1	0	0	26.6	2	7	0	0	Quchan-I
1895	1	17	1100	37.1	58.4	3	0	6.8	0	0	26.1	2	6.7	0	0	Quchan-I
1901	10	17	557	31	68.4	3	0	6.1	1	0	25.2	2	6.1	0	0	Loralai-P
1902	9	20	632	38.5	67	0	0	6.2	4	40	25.3	2	6.2	0	0	
1903	1	20	824	37	71	0	0	5.5	4	0	24.6	2	5.7	0	0	
1903	3	22	1435	33.2	59.7	3	0	6.2	1	0	25.3	2	6.2	0	0	Durukhsh
1903	9	25	120	35.2	58.2	3	0	5.9	2	0	25	2	6	0	5.3	I
1903	12	23	300	29.5	67.5	3	0	5.9	2	0	25	2	6	0	0	Bolan
1904	7	27	520	33	72	1	0	5.7	1	0	24.8	2	5.9	0	0	
1904	11	9	328	36.9	59.8	3	0	6.4	1	0	25.5	2	6.3	0	0	Tedzhen-Tu
1905	6	19	127	29.9	60	3	0	6	1	0	25.1	2	6	0	6.8	Nasradabad
1905	9	26	128	30.3	69.9	3	0	6.4	1	0	25.6	2	6.4	0	0	Sulaiman
1906	10	4	652	37.2	67.3	0	0	5.7	4	20	24.8	2	5.8	0	0	
1906	10	24	1539	36.5	68	0	0	7.1	1	32	26.6	2	7	0	6.8	Ayvadzh
1907	10	23	2025	37.7	65.4	3	0	6.1	1	0	25.1	2	6.1	0	6.1	Kersk
1908	1	12	1019	30.2	67.7	3	0	5.6	2	0	24.7	2	5.8	0	0	
1908	3	5	220	30.2	67.7	3	0	6.4	1	0	25.6	2	6.4	0	0	Harnai-P
1908	6	3	1556	28	67	1	0	6.2	1	0	25.3	2	6.2	0	0	Quetta-P
1909	9	7	1528	33	70	1	0	6	1	0	25.1	2	6	0	0	
1909	10	20	2341	28.9	68.3	3	0	7.1	1	0	26.5	2	7	0	0	Kachhi-P
1910	8	17	1158	28.4	67	4	0	6.3	1	0	25.4	2	6.3	0	0	Sind-P
1911	1	1	1018	36.5	66.5	0	0	6.9	1	40	26.4	2	6.9	0	6.6	Mazar-i
1911	1	1	1459	36.5	66	3	0	6.5	1	20	25.7	2	6.4	0	6.3	Shuburghan
1911	2	18	1841	38	72.8	0	0	7.7	1	26	27.5	2	7.6	0	7.4	Serez
1912	8	23	1402	35	71.5	3	0	6.4	1	0	25.5	2	6.3	0	0	Kunar
1913	3	27	913	29.5	67.5	3	16	5.6	1	0	24.7	2	5.8	0	0	Dhadar-P
1914	5	21	826	32	69.5	1	33	5.7	1	0	24.8	2	5.8	0	0	

1914	11	4	1106	32	70	3	22	5.7	1	0	24.8	2	5.8	0	0	
1917	8	29	1300	37.4	58.1	3	0	5.7	2	0	24.8	2	5.8	0	0	
1917	11	28	1442	36.5	59.1	0	0	5.7	4	0	24.8	2	5.8	0	0	
1917	12	1	947	30	71	1	13	5.6	1	0	24.6	2	5.7	0	0	
1918	3	24	2314	34.9	60.7	3	23	6	1	0	25.1	2	6.1	6.3	0	Torbat-I
1918	11	29	1041	32.7	67.7	3	24	6.2	1	0	25.3	2	6.2	0	0	Ghazni
1919	5	23	610	32.5	68	3	35	6.3	1	0	25.4	2	6.2	0	6.48	Zarghun
1919	6	1	1246	30	71	2	8	5.5	1	0	24.6	2	5.7	0	5.81	
1919	6	15	1849	30	71	2	15	5.5	1	0	24.6	2	5.7	0	0	
1920	2	27	351	35	69	1	25	5.9	1	0	25	2	6	0	0	
1923	5	25	2221	35.2	59.1	3	39	5.8	2	0	24.9	2	5.9	0	0	I
1923	7	16	1323	37.5	70.5	1	14	5.5	2	15	24.6	2	5.7	0	5.6	
1923	9	14	810	29	59.3	4	14	5.6	2	0	24.7	2	5.8	0	0	
1923	10	1	816	29	67.5	4	41	6.1	1	0	25.2	2	6.1	0	0	Kachhi-P
1928	3	8	1814	31.5	60.1	3	26	5.5	1	0	24.6	2	5.7	0	0	I
1928	8	21	1902	32.3	58.7	3	25	5.6	1	0	24.6	2	5.7	0	5.3	
1928	9	1	609	28.8	69.6	6	88	6.5	1	33	25.6	2	6.4	0	0	?
1928	10	15	1419	28.5	67.4	4	106	6.7	1	33	26	2	6.6	0	0	Katra-P
1928	12	14	28	28.8	68.1	1	35	5.6	1	33	24.7	2	5.8	0	0	
1929	6	4	704	37.3	66.5	0	33	5.7	2	14	24.8	2	5.8	0	5.7	
1929	7	13	736	37.2	58.2	3	64	6.1	1	0	25.2	2	6.1	0	0	Quchan
1931	8	24	2135	30.1	67.6	3	136	6.8	1	40	26.1	2	6.7	0	0	Sharigh-P
1931	8	27	1527	29.9	67.2	4	155	7.3	1	33	26.9	2	7.2	0	0	Mach-P
1931	8	28	1940	28.8	67.4	6	22	5.6	1	33	24.6	2	5.7	0	0	
1932	9	8	725	31.6	58.2	3	45	5.6	1	0	24.7	2	5.7	0	0	I
1933	10	16	435	32.7	66.5	3	45	5.6	1	0	24.7	2	5.7	0	0	Uruzgan
1935	5	15	201	28.4	67.5	3	68	6	1	33	25.1	2	6	0	0	Kotra-P
1935	5	30	2133	28.9	66.4	6	231	7.7	1	33	27.6	2	7.7	0	0	Quetta-P
1935	6	2	916	30.1	66.9	6	104	6	1	13	25.1	2	6.1	0	6	Quetta-P
1935	10	28	1205	31.3	69.3	0	52	5.6	1	33	24.7	2	5.8	0	0	
1936	6	30	1926	33.6	60	3	78	6	1	0	25.1	2	6	6.2	0	Bamrud
1937	11	11	1711	37.5	72.2	0	-1	5.5	4	0	24.6	2	5.7	0	0	
1937	11	13	1150	38	69.5	0	31	5.6	4	10	24.7	2	5.8	0	5.6	
1938	12	19	1856	36.6	58.5	3	0	5.6	2	0	24.7	2	5.8	0	0	Khorasan
1940	5	4	2101	35.8	58.5	3	106	6.5	1	0	25.6	2	6.4	6.2	0	Khorasan
1940	7	17	636	36.7	72.2	6	35	5.6	2	33	24.7	2	5.8	0	5.7	
1940	7	17	1144	36.8	70.7	0	43	5.6	4	15	24.7	2	5.8	0	5.6	
1940	8	1	1945	38	72.5	0	28	5.5	4	20	24.6	2	5.7	0	0	
1941	2	16	1639	33.4	58.9	3	74	6.2	1	0	25.3	2	6.2	6.4	0	Muhammadabad
1945	10	1	516	29	67.3	6	49	5.9	1	33	25	2	6	0	0	Nagau
1946	6	20	37	29.5	66	1	31	5.8	1	0	24.9	2	5.9	0	0	
1947	9	23	1228	33.7	58.7	3	126	6.9	1	0	26.3	2	6.8	6.4	0	Dustabad
1947	9	26	304	33.8	58.6	3	57	6	1	0	25.1	2	6.1	0	0	Ferdows
1948	1	28	1551	36.4	67.7	6	80	6.5	1	33	25.8	2	6.5	6.3	6.9	Samangan
1948	6	18	1844	37.5	58	3	54	5.5	1	0	24.6	2	5.7	0	0	
1948	10	5	2012	38	58.3	0	175	7.2	1	0	26.8	2	7.2	0	7.3	Ashkhabad

1949	2	24	2302	30.1	69	6	55	5.9	1	33	24.9	2	5.9	0	0	
1950	5	9	1116	37.9	58.4	3	120	6.4	1	0	25.5	2	6.3	6.1	0	I
1950	9	24	2256	34.5	60.7	3	91	5.6	1	0	24.6	2	5.7	5.6	0	Herat
1951	5	14	407	30.2	70.1	6	76	5.7	2	33	24.8	2	5.8	0	0	
1952	9	15	1128	30.6	70	6	50	5.5	1	33	24.6	2	5.7	5.8	0	
1952	10	10	1847	30.4	69.3	3	147	6.2	1	2	25.3	2	6.1	0	0	Sulaiman-P
1952	12	25	2222	29.3	70	4	124	6	1	33	25.1	2	6	0	6	Sulaiman-P
1954	1	23	1606	37.4	72.5	0	67	5.8	4	9	24.9	2	5.9	0	5.8	
1955	2	18	2248	30.2	67	3	85	5.7	1	33	24.8	2	5.8	0	0	Chaman-P
1956	1	11	2216	30	69.6	6	-1	5.5	4	24	24.6	2	5.7	0	0	
1956	5	13	750	30	69.9	3	90	5.9	1	33	25	2	6	0	0	Sulaiman-P
1956	6	9	2313	35.1	67.5	6	334	7.4	1	33	27	2	7.3	0	7.2	Bamyan
1956	6	10	101	34.9	67.7	6	-1	5.6	1	20	24.6	2	5.7	0	5.5	
1956	9	16	837	33.8	69.6	3	250	6.7	1	11	26	2	6.6	0	0	Jaji
1956	9	24	1020	34	69.6	6	114	5.6	1	1	24.7	2	5.8	0	0	Kabul
1958	3	22	1107	35.3	67.4	6	120	5.9	1	20	25	2	6	0	5.9	
1960	8	14	2237	36.3	69.9	0	90	5.5	4	15	24.6	2	5.7	0	5	
1962	9	12	2057	36.4	69	4	147	6	1	35	25.1	2	6.1	0	6.3	
1965	2	2	1556	37.4	73	1	152	6	1	15	25.1	2	6.1	5.3	6	
1966	2	7	426	29.8	69.5	3	245	6.7	1	17	26	2	6.6	5.8	0	Sulaiman-P
1966	2	7	2306	30.2	69.8	7	230	6.5	1	17	25.6	2	6.4	5.6	0	Loralai-P
1966	8	1	1909	29.9	68.7	3	229	6.1	1	19	25.4	1	6.2	5.5	6	Duki-P
1966	8	1	2030	29.9	68.6	7	179	5.8	4	10	24.9	2	5.9	5.4	0	
1966	8	1	2102	30.2	68.8	3	286	6.9	1	9	26.3	2	6.8	5.7	5.7	Duki-P
1966	10	25	1007	29.9	68.8	7	122	5.8	2	19	24.9	2	5.9	5.2	0	
1968	8	31	1047	34	59	3	301	7.2	1	33	26.8	2	7.1	6	0	Dasht
1968	9	1	727	34.1	58.2	1	262	6.5	1	14	25.6	2	6.4	5.9	6.5	Ferdows
1968	9	11	1917	34	59.5	3	162	6	1	33	25.1	2	6.1	5.7	0	Gonabad
1968	11	15	625	38	58.1	3	127	5.9	1	18	25	2	6	5.1	5.6	
1971	5	26	241	35.5	58.3	3	185	5.6	1	25	24.6	2	5.7	5.4	5.6	
1971	9	8	1253	29	60.2	3	151	5.6	4	34	24.7	2	5.8	5.3	0	
1972	6	24	1529	36.3	69.7	7	336	6.4	1	28	25.5	2	6.3	5.9	0	Takhar
1973	1	20	1246	29.4	68.6	7	98	5.6	4	17	24.7	2	5.8	5	0	
1974	12	28	1211	35	72.9	7	358	6.3	1	14	25.2	1	6.1	5.9	0	
1975	10	3	514	30.2	66.3	7	281	6.8	1	1	26.1	2	6.7	5.4	0	Spin-Tezha-P
1975	10	3	1731	30.4	66.4	7	293	6.5	1	2	25.6	2	6.4	5.5	0	Spin-Tezha-P
1976	3	19	1303	36.6	67.8	7	266	5.5	4	5	24.6	2	5.7	5.9	5.7	Khulm
1976	11	7	400	33.8	59.2	3	321	6.5	1	0	25.7	2	6.4	5.8	6.5	Vandik
1977	7	13	809	29.9	67.3	7	196	5.6	1	10	24.4	1	5.6	5.1	0	
1978	3	16	159	29.9	66.2	7	239	5.9	1	12	25.3	1	6.1	5.3	5.8	Nushki-P
1978	5	6	1116	29.8	66.1	7	291	5.8	1	17	24.9	1	5.9	5.4	5.8	
1979	1	16	950	33.8	59.5	3	384	6.8	1	11	25.8	1	6.5	5.9	6.7	
1979	11	14	221	34	59.8	4	399	6.6	1	10	25.9	1	6.6	6	6.6	Khwaf
1979	11	27	1710	34.1	59.8	1	411	7.2	1	8	26.7	1	7.1	6.2	7.3	Buniabad
1979	12	7	923	34.1	59.9	1	319	6	1	10	25.2	1	6.1	5.9	6.1	
1982	12	16	40	36.1	69	7	530	6.5	1	36	25.8	1	6.5	6.1	6.7	

1984	2	1	1422	34.6	70.5	7	485	5.9	3	9	25	1	6	5.9	5.9	
1985	5	6	304	30.9	70.3	7	436	5.7	1	17	24.9	1	5.9	5.6	5.6	
1990	3	4	1946	29	66.4	4	515	6.1	1	20	25.2	1	6.1	5.8	6.1	Kalat-P
1992	5	10	404	37.2	72.9	7	508	5.6	3	38	24.8	1	5.8	5.5	5.8	
1992	5	20	1220	33.3	71.3	7	607	6	1	20	25.2	1	6.1	5.9	6	Kohat
1992	8	28	50	29.2	66.8	7	436	5.6	1	5	24.4	1	5.6	5.6	5.6	
1993	11	16	1552	30.8	67.2	7	379	5.6	1	29	24.5	1	5.6	5.4	5.6	Pishin
1994	2	23	802	30.8	60.5	7	650	6.1	1	12	25.2	1	6.1	6	6.1	Sistan
1994	2	24	11	30.8	60.5	7	640	6.1	1	10	25.5	1	6.3	6	6	Sistan
1994	2	26	231	30.8	60.5	7	541	5.9	3	7	25.2	1	6.1	5.7	5.9	
1994	2	28	1135	30.6	60.6	5	400	5.5	3	30	24.5	1	5.6	5.5	5.5	
1994	5	1	1200	36.9	67.1	7	630	6.3	1	23	25.2	1	6.1	5.9	6.3	
1995	6	11	2155	32.6	69.7	7	353	5.6	1	27	24.5	1	5.7	5.1	5.5	
1997	2	27	2108	30	68.2	7	678	6.9	1	21	26.7	1	7.1	6.1	6.9	Sibi-P
1997	2	27	2130	30	68	7	498	6.4	3	25	25.5	2	6.3	5.8	6.4	
1997	3	4	1303	29.4	68.8	7	476	5.8	1	24	24.7	1	5.7	5.3	5.8	
1997	3	20	850	30.1	68	7	441	5.6	3	27	24.9	1	5.9	5.4	5.6	
1997	5	10	757	33.9	59.8	1	725	7.1	1	7	26.9	1	7.2	6.2	7	Zirkuh
1997	6	25	1938	33.9	59.5	1	541	5.7	1	11	24.9	1	5.9	5.4	5.8	
1998	2	4	1433	37.1	70.1	7	552	5.9	1	29	24.9	1	5.9	5.5	6	
1998	4	10	1500	32.5	60.1	1	458	5.7	3	26	24.7	1	5.8	5.2	5.7	Birjand
1998	5	30	622	37.1	70.1	7	760	6.5	1	29	25.9	1	6.6	5.7	6.7	
1999	2	11	1409	34.3	69.2	1	432	5.8	3	32	25	1	5.9	5.3	5.8	
1999	7	12	342	30	69.5	1	565	5.5	1	20	24.6	1	5.7	5.5	5.6	
2002	3	25	1456	36	69.4	P	0	6	0	8	25.2	1	6.1	6	6.1	
2002	4	12	400	35.9	69.2	P	0	5.9	P	10	25	2	6	0	5.9	

Table 4 Earthquakes of all magnitudes (Electronic Supplement)
See html document.

APPENDIX NARRATIVE DESCRIPTIONS OF EARTHQUAKES IN AFGHANISTAN 819-2000 See html document.