Earthquakes in Afghanistan

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Seismological Research Letters in the press 2003.

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 $M \leq 7.7$, 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.

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.

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).

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.

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).

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 $\log M_0 = 15.94 + 1.5M_S$ 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 (1.6×10^{28} dyne cm) is roughly 50% higher in eastern Afghanistan than in western Afghanistan (1.1×10^{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 ($\approx 8 \times 10^{27}$ 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 $3x10^{11}$ 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

We thank James Jackson for discussions concerning the active tectonics of the region and for his critically reading of the manuscript, and Ruben Tatevosian and George Hallows for helping with the retrieval of information from the Russian and Pakistani press respectively.

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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

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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).

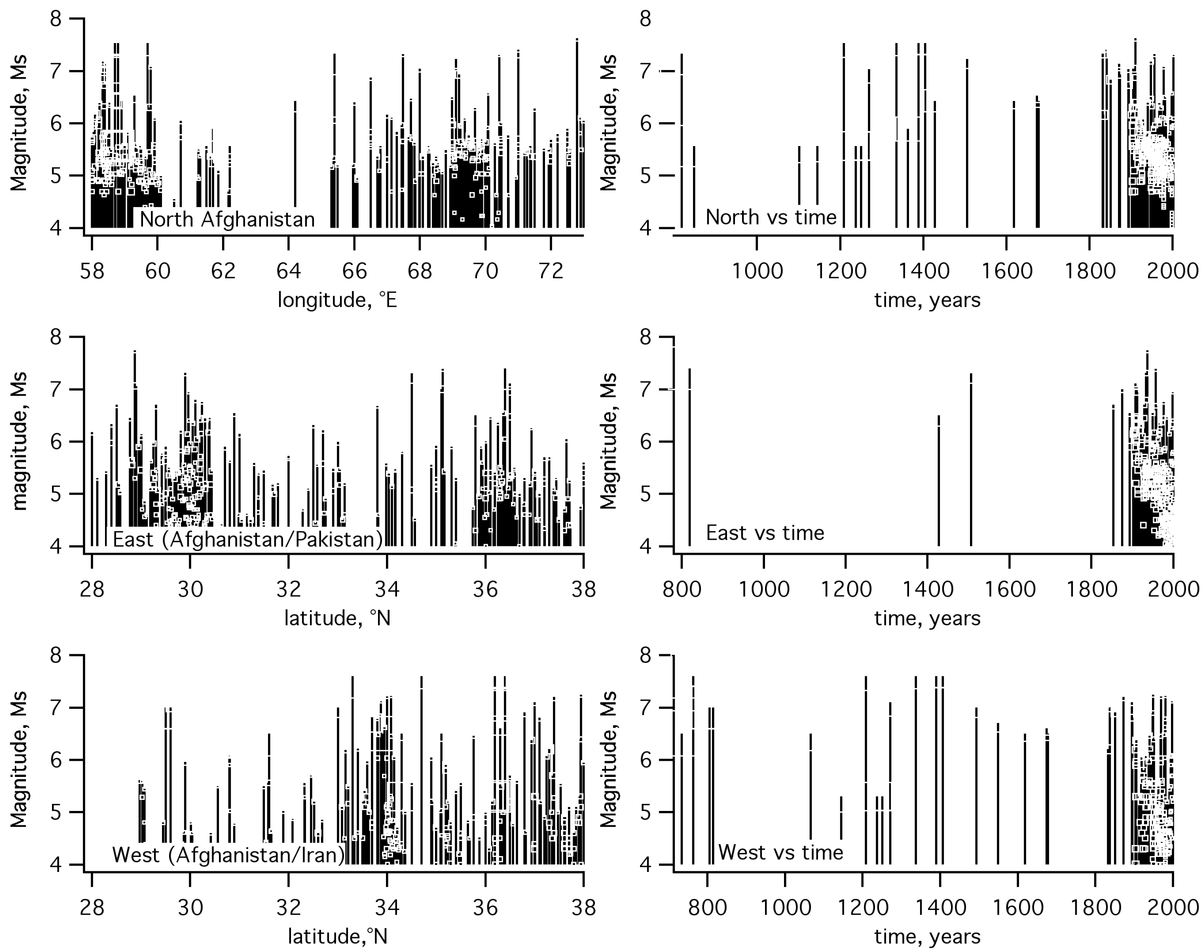


Fig.4 Seismicity of Afghanistan. **a**) Historical earthquakes 732-1890 from Figure 2 and Table 1, **b**) significant events since 1890 from Table 2. **c**) Historical and recent significant earthquakes from a. and b. **d)** shows the entire catalog (Tables 1 & 2 and electronic appendix Table 4).

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.

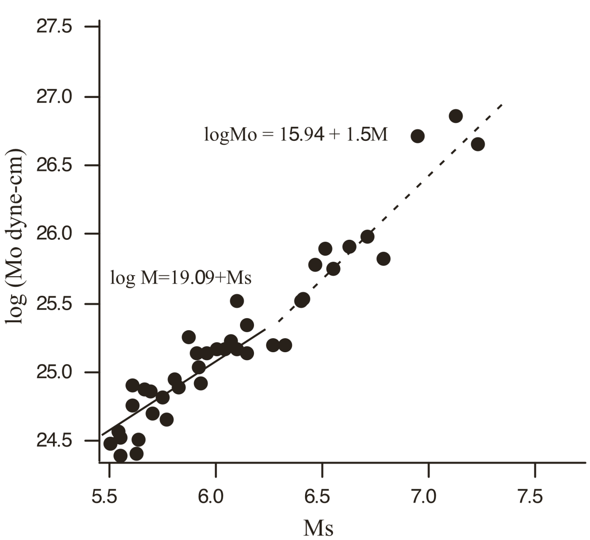


Fig.6 Moment release along Afghanistan's 900-km-long western border with Iran expressed as an equivalent slip rate assuming a seismogenic thickness of 20 km. Each bar corresponds to the mean slip rate from the indicated date to the present. Two thirds of the moment release occurs north of 34°N (Table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

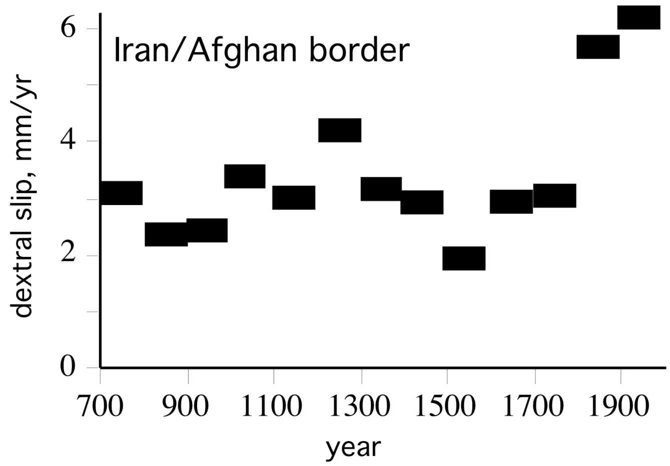
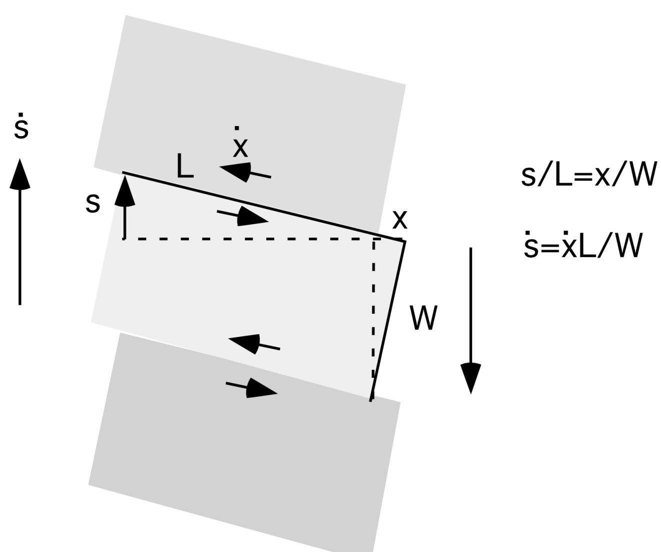


Fig.7. Schematic relation between slip rate and dextral shear for bookshelf faulting along Afghanistan's border with Iran north of 34°N. Dextral shear rates $\dot{s}$, exceed sinistral fault slip rates by a factor increased by the aspect ratio of fault length to block width (L/W), which is of the order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

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

ELECTRONIC APPENDIX

NARRATIVE DESCRIPTIONS OF EARTHQUAKES IN AFGHANISTAN 819-2000

819 Jun (7.4) The earliest earthquake in Afghanistan for which we have information occured in *Dhu'l-Hijja* 20 aH = June 819, in the region between modern Meymaneh, Andkhvoy and Mazar-i Sharif [Abu'l Fida:ii.26, Ibn al-Shihna:vii.59. Ibn al-Athir]. It affected a large area in which many houses were destroyed, with heavy casualties affecting severely other urban centers many tens of kilometres apart, including Faryab (36.42N, 64.91), Taliqan (35.78N, 64.16E) and others which are not named in the districts of Juzjan in the west, and Tukharistan in the east of these places. The shock destroyed a quarter of the city of Balkh (36.75N, 66.90E) and ruined the *masjid-i jami* there [Ibn al Jauzi quoted by al-Suyuti:24].

As a result of the earthquake the desert of Sidreh (36.75N, 66.22E) which lies between Shaburghan (36.67N, 65.74E) and Balkh, was flooded by an excessive rise of the water table, which in places turned the country into a fertile area. Some of this flooding seems to have been permanent resulting in creation of new oases [Qudama:210; al-Masudi: pp.43-45].

The shock was felt in Marv (37.56N, 63.32E) and probably also at Amul (39.11N, 63.57E) and Transoxania [Ibn al-Athir:vi.252]. Aftershocks lasted for a month or so. That this earthquake is mentioned by several sources suggests its importance, and from the radius of the felt area we assess a magnitude of Ms≈7.4.

Damage in both Transoxania and the towns of Faryab and Taliqan to the west, is considered unlikely, and it is possible that *Ma vara'al-nahr* (Transoxania) mentioned in some early sources should stand for *Marv al-Rud*, or Lesser Marv, i.e. Bala Murghab, which is confirmed by Qudama who says that the regions of Marv and Tukharistan were affected, and probably also Amol [Gorshkov1947]. An earthquake of this magnitude would certainly have been felt across the Oxus, but probably without damage.

849 A series of earthquakes was reported from Herat; information from other areas is lacking. The first damaging shock in Herat in 234 aH = 849 caused some houses to collapse. [Ibn al-Jauzi 38v; al Soyuti 26]. It is most likely the reference is to Herat in Afghanistan, but it should be borne in mind that there was also a town of this name in Fars, near Istakhr [Yaqut iv.959]

1102 Feb 28 This second Herat earthquake destroyed a number of houses and other buildings, including heavy damage to the *masjid-i jami*, with some casualties in the city. According to Isfizari:ii.55, on the night of Friday 8 Jumada I, 495, there was a calamity (*nazileh*) in Herat; the western side of the mosque and most of the northern and southern sides were destroyed. A rather different version specifies that a strong shock, with a north-south motion, caused the collapse of many buildings in Herat, the masjid-i jami suffering heavy damage. The closeness of *nazileh* to *zalzaleh* (earthquake), and the apparent support of this reading in a variant text, confirms that an earthquake was responsible for the damage [Fahmi in Barbier 1860].

1364 Feb 19 On 6 Jumada I, 765 = 19 February 1364 a third destructive earthquake occurred in Herat [Hafiz-i Abru:xxxvii; Hafiz-i Abru, Manjmu:48; Fasih:iii.96]. Most of the buildings in the city were ruined, particularly the tall structures. The shock caused the battlements to fall from the ramparts and several meters fell from the top of the *Falak al-Din* minaret. The *masjid-i jami* in the city was again damaged; the main arch collapsed although its two supporting pillars remained intact.

The information about this earthquake suggest that the shock originated some distance from Herat possibly in the Gulran district, with damage in Herat caused by long-period ground movements.

It is important to note, that in spite of the prominence on Herat during the middle ages, no information regarding serious damage has been found in the voluminous source material.

1410 Earthquakes were felt in Balkh (36.75N, 66.90E) and Bukhara (39.77N, 64.42E). Landslides in the mountains dammed streams to form a deep lake at a place which is not given [al-Umari: fol.153v]. It is not possible to assess the effects of the earthquake on the cities mentioned. Balkh and Bukhara were both brought under the authority of Shah Rukh this year, but there is no reference to the earthquake in any of the Persian and Timourid sources, so al-Umari's authority remains obscure. Damage to Balkh cannot have been serious or one would expect it to have been more widely described in historic materials.

The earthquake is comparable to the event of A.D. 819 in the extent of the area affected and the number of shocks experienced. The mention of mountains in this region suggest an epicentral region east of Bukhara [Melville 1978].

1428 All that is known about this event is that in the year 831 aH = 1428, there was an earthquake in Taliqan, with shocks lasting 10 days, in which many people were killed [al-Umari: fol.159v]. Even the location can be questioned, since Taliqan of Qazvin or Talikan of Merv may have been shaken, both areas being almost equally seismically active. Earthquakes in Merv are more likely to have been recorded than those further west at this period, and as al-Umari's source may have been the same as for the 1410 event, a tentative location of this event in northern Afghanistan may be preferred [Melville 1978].

1505 Jul 6 (7.3) For this earthquake (3rd Safar 911 aH, or 6 July 1505) we have an eyewitness account. In Kabul (34.53N, 69.13E) the shocks ruined the ramparts of the fort, even the walls of gardens. Paghman (34.58N, 68.95E) was particularly badly affected, all houses there being destroyed and 70 or *80 people were killed*, with numerous casualties in nearby towns and villages. Most of the houses in Tipa (Tibah, 34.68N, 69.01E)) were levelled with the ground.

Between Istarghach (Istarghij, 34.91N, 69.07E) and the plain (*maidan)* for about 6 or 8 farsakhs (31 to 42 km), in some places the ground rose as high as an elephant, in others, sank as deep. It is not clear from the text whether *maidan* here refers to the plain or to the town of *Maidan* (shahr) which is at the southern end of the Paghman range, west southwest of Kabul. Villages and groves slipped from their place and many rising grounds were levelled and dust rose from the tops of the mountains. Between Paghaman and Begtut, the valley just north of Paghaman, there was a landslide, where water springs emerged to the surface. Thirty three aftershocks are reported on the day of the earthquake with two or three a day, for the next month.

A greatly abbreviated notice of this earthquake in Kabul is given also by al-Asafi, who puts the event in 912 aH (1506) and says that destruction was general among citadels *(qal'at)* and houses in which many people perished al-Asafi (p.934).

At the time of the earthquake, Babur was outside Kabul, preparing for his campaign against Kandahar; it took him about a month of hard work to repair the fort (*Bala Hissar*) at Kabul (Babur: fols. 157r-158r, pp.247-8).We have no information of the effects of the earthquake from other places and is not known how far the shock was felt. Babur's memoirs do not mention any damage or repairs in other places through which he traveled during his campaign against Kandahar.

Baird-Smith (1843b) assumes that the effects of the shock extended hundreds of kilometres to Kandahar, Ghazni and Jalalabad for which we could find no evidence, while other modern writers confuse the word *qal'at* mentioned by al-Asafi with the town of Qalat north-east of Kandahar. The available information clearly suggests that the earthquake was associated with at least 40 km long surface rupture of the Paghman fault, 20 km north-west of Kabul, which strikes N20°E. Much of the destruction was reported from Istargij, Tibeh to Paghman, localities which lie along the fault. Vertical offset on the fault appears to have been approximately 3 m. An unknown amount of strike-slip faulting may also have occurred.

1519 Jan 3 There is little macroseismic information about this earthquake in north-east Afghanistan. It is mentioned in the sources that describe Babur's campains to Swat; they say that the earthquake occurred on Monday, 1st Muharram 925 (3 Jan. 1519) in the direction of the region adjoining Bajaur (c.34.9N, 71.4E), and that it lasted half an hour (sic); after the earthquake Babur conquered the citadel of Bajaur (Abu 'l-Fadl, al-Asafi, sub.ann.).

The region meant here should be along the middle course of the river Kunar, north-east of Jalalabad (34.43N, 70.45E) near Arandu (35.32-71.56). The survival of this notice in the sources suggests that the earthquake, which occurred in this sparsely populated and mountainous area, was a relatively large event.

Wilson (1930) commits a double error with this earthquake: he reads Bujnurd for Bajaur, places the event in Iran, and confuses this earthquake with that of Kabul in 1505. The quality of the data allows only an estimate of the general location of the event, which may have occurred on the Kunar fault, but it does not permit an accurate assessment of its presumably sizable magnitude.

1832 Jan 22 (7.4) This was a large earthquake with an apparent epicentral area in the district of Badakhshan in northeastern Afghanistan. It occurred at 11 pm local time on 22 January 1832, and together with its damaging aftershock of 21 February destroyed most of the villages in the district, allegedly killing thousands of people.

In Kalafgan (36.77-69.93) all forts and houses were destroyed and many lost their lives. In Jorm (36.84-70.7) 35 km east of Kalafgan, houses collapsed and 12 people out of 25 were killed. From a total population of 310 in three nearby villages 156 were killed. In the valley of Kowkcheh (36.60-70.85) the shock triggered numerous rockfalls and in the neighbouring valley of Varaduj (36.68-71.13) a fort and houses were destroyed, and a whole mountain-side fell into the valley damming the river for eight days before the dam was breached. In the Sargulam valley, 72 of a population of 155 perished.

The earthquake was felt strongly in Kabul (34.53-69.14), it caused some panic in Lahore (31.56-74.35) and it was reported from Srinagar (34.08N, 74.8E), Kokand (40.52-70.95) and Bukhara (39.78-64.43). (Burnes 1834 i.17,.ii.203; Masson 1844; Wood 1872; Journ. Asiat.Soc. Bengal, vol.1, p.34, 146, 1832; Trans. Geol. Soc. London, vol.3, p.492)

The earthquake was felt over an area of 450 km radius, an indication which, on the authority of Musketof and Orloff (1893.242), Kondorskaya and Shebalin (1977.202) is interpreted as a subcrustal event of focal depth of 180 km, consistent with depths of recent large events in the region. They assign to it an epicentral intensity of IX and a magnitude m_b of 7.4.

The earthquake was followed by a long series of aftershocks, one of which (21 Feb.) caused rockfalls that blocked valleys in Badakhshan, adding to the damage, a rather unusual characteristic of deep earthquakes.

1842 Feb 19 (7.5) This earthquake in north-east Afghanistan occurred during the second Afghan War on 19 February 1842. A famous account of the earthquake and its aftershocks are related by Lady Sale (**PLATE 1**) who was held hostage with her colleagues during the several months following the earthquake (Sale, 1843). On 5 January British forces had surrendered Kabul and began their retreat to Jalalabad, 120 km west of Kabul, still garrisoned by the British who had hastily restored its dilapidated defences damaged by the earthquake. Much of what has been written about this earthquake is based on contemporary accounts and press reports (Eyre 1843; Gleig 1846; Sale 1846, Englishman 1842) and on less useful, later works and earthquake catalogs (Stenz 1945).

The earthquake occurred at 11h 40m local time. At Jalalabad (34.43N, 70.45E) situated on the right bank of the Kabul river, ground movements were very strong; not a man could keep his legs; everyone was prostrated, and nausea affected all. The defences of Jalalabad itself, which had just been repaired, were seriously affected. A substantial length (2.4 km) of the newly built parapets were damaged without loss of life. Several breaches were made in the old adobe bastions and in the curtains in the Peshawar (east) face. The Kabul gate was reduced to a shapeless mass of ruins. However, in a matter of days the damage was repaired (Abbott 1879, IO 1843, Memoirs 1875).

Within the walls a third of the local houses were destroyed, the collapse of tall houses choked the streets leaving no room for escape. Some people were injured but few of the inhabitants were killed. In the British garrison only 4 men were killed, and many were injured, but none seriously. On the whole, loss of life was small, compared to the nature and extent of damage. A report written after the earthquake contains a complete set of sketches indicating the extent of damage to the walls of Jalalabad. (IO 1842; Heuckroth and Karim 1970). Outside of the walls, presumably along the river face, the ground opened in several places and water appeared on the surface. According to Baird-Smith (1842b), the waters of the Kabul river were twice thrown from their bed,
North of Jalalabad the shock caused considerable damage to settlements on a portion of the Suffid Kuh range of mountains (Baird-Smith 1842b). In the regions of Laghan and Kunar, villages were ruined killing dozens of children and women. The large settlements of Chaharbag and Tigri in the Alingar valley suffered severely, scarcely a house being left standing, and several hundreds of people were killed (Eyre 1843).

Further to the north, damage was considerable in the fort of Budeeabad where several English prisoners (including Eyre and Lady Sale) were confined. The motion of the ground was so severe that people could only with difficulty maintain their balance. Walls, gateways and corner towers, were all much shaken, or thrown down. Almost all the houses in the fort were damaged and a few collapsed, but all hostages entirely escaped injury. Eyewitness accounts indicated that the fort of Budeeabad had suffered less than the other 40 forts in the valley. In one fort a tower fell, killing five people, others had not a wall remaining (Sale, 1843).

Along the valley from Buddeabad to Tigri, none of the forts escaped damage, with few inhabitable, and mostly masses of ruins (Eyre, 1843). In the Kunar valley, where the shock triggered landslides and rockfalls from the hills, the forts of Shewa and Pashat were totally destroyed (IO 1842).

Outside this region, damage was far less severe but widespread. To the west, some parts of the fort of Tezeen is said to have been destroyed (Heuck & Karim 1970), while at Kabul the shock caused little more than general panic; the walls of the European ward, were badly shaken and came down a few days later (Baird-Smith 1842b). There is no evidence that Kabul and its fort needed any repairs after it was re-taken by the British forces on 15 Sep 1842 (IO 1842). Nor are there damage reports from Argandeh, Bala Maidan and Jalriz, west of Kabul, where the shock caused some concern, but details are lacking (Sale 1843).

It appears that the effects of the earthquake extended more to the east of the Laghan-Kunar region. At the camp of Kawulsur, 13 km from Peshawar, the shock was violent. Many of the camels that were carrying the baggage of the troops were thrown down, people were obliged to support themselves, and many suffered severe nausea (Delhi Gazette).

According to press reports from Peshawar, the largest urban center east of the apparent epicentral region, the shock lasted intermittently for almost two minutes and destroyed one tenth of its adobe houses killing 40 to 50 people (Delhi Gazette; Memoirs 1875). There is some evidence that some small damage extended to Kalabagh, particularly in the part of the town on the right bank of the Indus, but it is not certain whether this was due to the earthquake, to the great flood of the Indus in 1842, or to both (Binnie personal communication).

Interestingly several reports have survived for this earthquake recorded at remote distances from the epicenter, implying that the magnitude of the earthquake was considerable. At Shalkur, in Little Tibet near Skardu, at an epicentral distance of 410 km, the shock was strong enough to be mentioned in official dispatches (Baird-Smith 1842a). Although we have no information about damage between Kalabagh and Ferozopore, at Ferozopore (560 km) the shock was widely felt and it was rather strong (Baird-Smith 1842a). At Ludiana (650 km) it lasted more than 90 seconds.

Eastward along the Himalayan front it was felt at Lansdour and Dehra (Baird-Smith 1843). At Simla (720 km) the earthquake was barely perceptible; however, it disturbed the records in the magnetic observatory (Mallet 1853; Baird-Smith 1842b; Boileau 1845). Mussoorie (820 km) was the most easterly limit of the earthquake where the shock was perceptible (Baird-Smith 1842b).

In the plains fronting the Himalaya the shock was barely felt but at Poojna and along the Doab Canal at Kulsea (860 km). There, the water in the canal was unusually muddy and was disturbed by a high swell (Baird-Smith 1842a). The shock was felt at Saharanpur (860 km) but attracted no particular attention (Baird-Smith 1842a). In Delhi (910 km) the shock was generally felt (Baird-Smith 1842b). About 30 km south-west of Delhi, at Sonub (930 km), the shock was not felt but allegedly was responsible for a change in the flow rate of a hot spring (Baird-Smith 1842b)

To the south and southeast of the epicenter the shock was felt slightly at Quetta (650 km) and it was scarcely felt in the Sind (1100 km) .

Although it is not clear as to precisely where the epicentral area was located, from the evidence available some reasonable deductions can be made. We know that maximum damage occurred over a large area in the eastern Laghan and Kunar regions between Budeeabad, Jalalabad and Pashtat, which could have well extended toward the north-east into an area from where we have no information. It is unlikely that the epicentral area extended to the south-east along the supply route of the British forces, and most certainly it did not extend much to the west; significant damage apparently did not extend to Tezeen and beyond Kabul.

These observations and the fact that all known aftershocks were reported from the Jalalabad-Budeeabad region, very few from Peshawar to the eastward, and none to the westward (Baird-Smith 1842b) suggest that the location of the epicentral region must be sought in eastern Laghan in the Kunar district, possibly associated with oblique thrust faulting along the southern section of the Kunar fault system about 35.0N, 71.0E (Chmyriov et al. 1972).

Aftershocks continued to the beginning of the following year, most of them being strong to damaging chiefly in the region of Jalalabad (Baird-Smith, 1843). The large number of aftershocks and the prolonged duration of the aftershock sequence which extended for months, suggest a crustal event.

From the area within which the earthquake was felt we estimate the surface wave magnitude of this event to be $M_S \approx 7.5$.

1874 Oct 18 (7.0) Little is known about this earthquake which on 18 October 1874 caused serious damage in the region north of Kabul. According to local sources [Furon 1925a,b; Stenz 1945.3] it occurred on an afternoon during Ramadan about the middle of Sher Ali Khan's reign. This is consistent with the date of an earthquake in Kabul on 18 October 1874 reported in the press [The Times 1.12.1874 p.5]

The densely populated region of Kohestan (35.12N, 69.30E) and the nearby villages of Golbahar (35.14N, 69.30E) and Jabal Saraj (35.13N, 69.24E), 70 km north of Kabul, were almost totally destroyed with many casualties. The ground opened up, presumably due to liquefaction, in the vicinity of Jabal Saraj.

Press reports say that in Kabul (34.53N, 69.13E) more than 1000 houses were destroyed and many people were killed [Fuchs 1886.485). However no corroborating evidence has been found to support this, and this statement may refer to the losses sustained in the Kohestan.

Press reports add that the shock was felt at Sekunderabad (32.42N, 65.05E) [Times of India:7-11-76] and Kandahar (31.61N, 65.70E) [Ballore 1905.207] about 490 km south of Kohestan. However, it is not clear which of the many Sekunderabads in Afghanistan and India is meant here. The shock was perceptible 530 km north of Kohestan, in Samarqand (39.66N, 66.95E) at 13h 30m lasting for 1-2 min [Musketof and Orloff, 1893.460]. We can find no mention in consular despatches from Mashhad of an earthquake having been felt in the city [FO.Persia.60.361.1874]

The earthquake occurred near the north terminus of the Pagham fault, from where ground deformation was reported. Its magnitude may be assessed roughly from the area of perceptibility, which suggests $M_S \approx 7.0$.

1892 Dec 20 (6.5) This earthquake occurred in the Chaman area, about 90 km north-west of Quetta, near the Pakistan-Afghanistan border, where it caused spectacular deformation of the newly laid railroad that crossed the Chaman fault (Griesbach, 1893). Left-lateral offset of the Chaman fault occurred although the length of surface rupture is not precisely known. A surface wave magnitude of M_S 6.8, is consistent with the minimum known length of the rupture, the relatively small area over which the earthquake was felt, and early teleseismic instrumental data. A detailed discussion of this event can be found in Bilham and Ambraseys (2003).

1893 Feb 13 (5.9) This earthquake caused some concern at Chaman but no damage. In Quetta it was much stronger than the shock of 20 December 1892 which implies that this was not an aftershock but a separate event with an epicenter not far from the town. It may be the shock which is said to have caused damage at Pishin and Baghihindu sometime in early 1893 NT(47.470; 48.348-349).

The earthquake was recorded at Strasbourg (Rebeur-Paschwitz 1893, 1897) and if it be assumed that it occurred somewhere near Quetta, its magnitude should be about 5.9.

1899 Dec 31 An earthquake in Kabul on 31 December 1899 at about 10 pm, brought down many adobe houses and several people were killed. It was apparently preceded by foreshocks in October and November. (Martin 1907)

1906 Oct 24 (7.1) This was a large, globally-recorded earthquake with an epicenter somewhere on the border of Uzbekistan with Afghanistan. The shock was felt with low intensities within a radius of about 380 km: at Tsardzhui, Bukhara, Katta Kurgan, Samarkand, Tashkent, Khodzent (Leninabad 40.29N, 69.63E), Khorog, Kelif, Kerki, as far as Ufra (40.02N, 53.04E) but it was only at Aivadz (36.95°N-68.95°E) and Termez (37.22N, 67.27E) that the shock was strong enough to cause damage. We could find no macroseismic information from Afghanistan.

Macroseismic information is insufficient to define an epicentral area; instrumental data merely confirm a general location in the region north of Termez. (Seismische Monatsber. Physikal. Observ. Tiflis, 1906, p.9, Tbilisi); Gubin (1960), Levitski (1908); Mitskevich (1937); Spesivcheva (1933), Izvest. Post. Tsentr. Seism. Komis., vol.3, no2

1907 Oct 23 (6.1) Little is known about the effects of this earthquake in the region of Kerki in Turkmenistan, except that it caused some damage at Kizil Ayak on the Amu Darya. This event occurred on the time of an earthquake in Sicily and instrumental readings are confused. (Scheu & Lais, 1912) .

1908 Jul 26 (5.3) An earthquake in north-west Afghanistan caused damage to a few villages in the Injil area (34.6N 61.5E) north-east of Herat, but details are lacking. The shock was strong at Herat, at nearby Karizak and everywhere in the Herat valley, where it is said to have lasted for one minute. The shock was felt at Torbat-i Jam but there is no evidence that it was felt in Mashhad, 320 km north-west of Herat. [PRO.FO.Mashad 248/939(01.08, 15.08, 01.09.1908); Patterson (1908)].

1909 Jul 7 (≈7.5) This earthquake, probably consisting of two events, one shallow and the other deep, was widely recorded one minute apart by the global seismographic network of the time. The solution by Gutenberg gives a rough location (±3°) at 36.5°N, 70.5°E, which places a single event somewhere in Badakhshan in north-eastern Afghanistan, at a focal depth of 230±30 km, to which Gutenberg assigns M = 7.1(±0.5) and m_B = 7.6 (±0.4) (Gutenberg, 1947, a location and depth which were adopted by later authors who assign to the earthquake a larger magnitude of 8.0, presumably by adding to 7.1 a depth correction (Duda, 1965; Kondorskaya and Shebalin, 1997).

Until recently, published macroseismic information exclusively derived from Russian territory north of the Amu Darya river, favors an deep location, not only because of the large area over which the earthquake was felt, but also because, in spite of its large magnitude, the shock did not cause damage anywhere in the territory. Along the alluvial valley of the Amu Darya river a few local houses suffered minor damaged in Patta Kesran (37.1, 67.2), Aivadj (36.98, 68.03) and Sarai Kamar (near Kirovabad 37.24, 69.09) but not in near-by Termez (37.2, 67.3) where the shock was rather strong but caused no damage. To the north of these places the earthquake was felt chiefly in alluvial valleys (Khorog (37.49, 71.55), Samarkand (39.66, 66.95), Khodzent (40.29, 69.63), and Kokand (40.53, 70.93)), which at great epicentral distances tend to enhance ground motions in large earthquakes. It was perceptible at Kerki (37.83, 65.20), Katta Kurgan (39.90, 66.25), Chust (41.00, 71.23) Andijan (40.79, 72.34) and Murgab (38.17, 73.95).

This information has lead to a macroseismic location near the large urban settlement of Aivadj on the Amu Darya, after which the Russian catalog names the event and assigns to it a magnitude m_b of 7.7, and a radius of perceptibility of 700 km (Kondorskaya and Shebalin 1997). However, unpublished reports of the Political Agents in India, Iran and the Hindu Kush, as well as the Indian press show that damage was serious south of the Amu Darya in Badakhshan (37.6, 70.8), in Afghanistan and in the region of the North-west Frontier. Maximum effects were reported along the Kunar valley, from Asmar (35.03, 71.36), Aradu (35.32, 71.31), Drosh (35.55, 71.80) as far north as Chitral (36.02, 71.75), and from the levy posts between these places.

Unspecified damage, probably due to landslides and rockfalls, was also reported from Alpurai (34.90, 72.65), Karori (34.88, 72.76) and Besham (34.93, 72.87). The Lady Minto hospital in Swat (34.90, 72.49) was damaged and in villages between this place and Dir (35.20, 71.88) houses collapsed without fatalities.

In the Northwest Frontier Province rockfalls destroyed levy posts, disrupted telephone lines and blocked many passes into Badakhshan where summer camps were destroyed. We have no information from Jalalabad in Afghanistan, but in Kabul (34.53, 69.14), several houses collapsed and about 10 persons were killed, in addition to many cattle.

We have no details from Khost (33.3, 69.9) and Waziristan (32.9, 70.6) south of Jalalabad, except that the shock was felt in these regions. Because of hostilities access to these regions was restricted. Some houses were damaged in Kohat (33.60, 71.44) to the south, and in Gilgit to the NE (35.92, 74.29). To the west, in Lahore (31.56, 74.35) the shock was strong enough to awake people and cause some panic. The earthquake was felt strongly at Mussoorie (30.45, 78.08), it was reported from Srinagar (34.08, 74.81), and it was barely perceptible in Tashkent (41.31, 69.29).

The earthquake was followed by many aftershocks which were reported from the upper Kunar region, the largest of which on 7 September caused some additional damage in Swat.

We interpret this sequence to have been a double event consisting of a shallow earthquake that caused damage and aftershocks in the Kunar area, followed by a deep earthquake centered further west. Instrumental readings are too few and too inconsistent to attempt a revised instrumental location but the data suggest two consecutive shocks each of $M_S \approx 7.5$, separated by an interval of little more than one minute. The second event appears to have occurred west of the first and its focal depth may have been subcrustal. [IO.L.P/S.7.230.1102,1114,1146 (Swat) 08,10,15.07.1909; IO.L.P/S 7.230., 1114,1171 (Kabul) 17.07.1909; IO.L.P/S 7.230.1275 (Gilgit) 07.1909; IO.L.P/S 7.231.1341.1401 (Mashhad) 31.07.1909; IO.L.P/S 7.231.1466 (Dir) 15.09.1906; IO.L/P&S Turkestan no.1401, Gubin (1960.344); Paisa Akhbar.10-14.07.1909, Spesivcheva (1933), Kondorskaya and Shebalin (1997), Biullet. Postr. Tsentr. Seism. Komm. for 1909, BCIS Strasbourg Archives Files:1909.no.11.

1911 Jan 1 (7.1) This was a relatively large earthquake in northern Afghanistan, followed four hours later by an aftershock of M_s = 6.5. Macroseismic information is sparse, some of which is confused with the effects of the large (M_s = 8.3) Kebin earthquake two days later.

Maximum damage in the January 1st earthquake sequence occurred between Feyzabad (37.12N, 70.56E), Khnabad (36.68N, 69.11E) and Kalan (35.19N, 69.23E). In the region of Kalan 60 houses collapsed killing 240 people; in Khanabad 70 houses were destroyed and twi people were killed, while in the region of Feyzabad houses, the number of which is not given,were ruined with fatalities. Damage extended to the region of Kabul (34.53N, 69.13), where about 300 houses collapsed killing 460 people.

The shock was rather strong at Shuburghan (36.67N, 65.74E), Termez (37.22N, 67.28E) and Mazar-I Sharif (36.70N, 67.10), and less so at Kerki (37.82N, 65.20E) and Peshawar (34.01N, 71.54E). At Takhtebazar (35.96N, 62.91E) lamps were set swinging and plaster fell off ceilings. At nearby Kushka (35.31N, 62.41E) the earthquake was hardly felt but it was noticed because of the swinging of lamps. The shock was generally noticed in Bukhara (39.77N, 64.42E) and Kattakurgan (39.90N, 66.25E), but it was hardly perceptible in Tashkent (41.31N, 69.30) , Samarqand (39.66N, 66.96E) and Kushka. [Zakaspiskoe Obozrenie:21-23.12.10; Turkestanskie Vedomosti:21.12.10; Shpil'kov 1914; Gorshkov 1941]. The India Office consular correspondence gives no evidence the shock to have been felt at Herat (34.14N, 62.17E) or at Mashhad (36.16N, 59.51E). It is impotant to point out that far-field information comes chiefly from sites on alluvial basins that could have enhanced ground motions at large distances.

The epicentral area of the earthquake that can be assessed from macroseismic information, therefore, must be sought near 36.0N, 70.0E, but it is not clear whether it belongs to the first or to the second shock. The main shock and its largest aftershock were widely recorded instrumentally. An early crude instrumental location places the main shock in the Altai (43.4N, 74.0E) which is 880 km to the NE of the macroseismic epicenter [Nikiforov 1912], while later relocations bring it closer to the adopted epicenter, i.e. to 38.0N, 66.0E given by Gutenberg and Richter (1965), and 36.5N, 66.5E by Kondorskaya and Shebalin (1997).

Instrumental data are sufficient to allow calculation of the surface-wave magnitude of the main shock from 29 stations using the Prague formula, which gives M_s = 7.1(+-0.3), compared to m_B = 7.2 in Gutenberg and Richter. For the forshock at 14h 59m, from seven stations we find M_s = 6.5(+-0.2). In these calculations we have assumed normal depth.

Gutenberg and Richter estimate a depth of 50 km for the main shock and 20 km for the foreshock. The pattern of intensity distribution does suggest somewhat greater depth than normal for the main shock, but the small difference between body and surface magnitudes does not. We have no additional data that could help decide on the actual depth.

1913 Sep 9 (5.0) A strong earthquake at Ayvadz (36.98, 68.03) on 9 September 1913 cause the collapsed of adobe and the damage of stone masonry houses. The shock caused liquefaction of the ground in the Shaartuz area (37.27, 68.13) [Gorshkov 1941].

1918 Nov 29 (6.2) A violent earthquake took place in Afghanistan, between Kalat-i Ghilzai (32.11N, 66.90E) and Ghazni (33.56N, 68.42E) causing many deaths due to the collapse of houses. It is also said to have increased the flow of water in springs and qanats, and that even some dry qanats begun to yield water [IO L/P&S Balucistan/10/814]. The shock was strong at Jabal Saraj (35.13N, 69.24E) where some walls were thrown down [Heuckroth and Karim 1970].

1931 Sep 10 (5.0) In 1855 a group of nine 36-45 m high minarets existed in the complex of the *musalla* of Gauhar Shad in Herat (34.34, 62.19), two of which collapsed in the earthquake of 10 September 1931. The earthquake shock was felt at Murgab (37.49, 61.98) [Gorshkov 1941; Byron 1937:99; Blunt 1957).

1933 Oct 16 (5.6) A damaging earthquake on 16 October 1933 caused the collapse of three forts in the Oruzgan (32.93, 66.63) region. Slides and rockfalls were reported from this area and from Day Chupan (32.63, 66.77) where the shock caused great concern. [Heuckroth and Karim 1970]

1934 Mar 30 A damaging earthquake on 30 March 1934 in the hills south of Maimana (35.92, 64.78). The villages of Pashtunb Kote (35.90, 64.78), Bato (35.72, 64.80) and Purkhisht (35.72, 64.87) were totally destroyed, and people fled the region and took refuge in the hills. The shock triggered slides and caused cracks in the ground. There is no evidence that damage extended to Maimana. Aftershocks continued for 10 days. No teleseismic data have been found for this event [Furon (1951); Huckriede, (date); Kursten et al (1962); Stenz (1945)].

1935 May 30 (7.7) (Quetta) This entry on the largest earthquake near the SE border of Afghanistan is extracted from Ambraseys and Bilham (*Earthquakes in Northern Baluchistan*, Bull. Seism. Soc. Amer. in the press 2002). Although Baluchistan in 1935 had one of the lowest population densities on the subcontinent of India, it occurred where most of the population lived. For this reason, and despite the initiation of earthquake resistant design triggered by the nearby 1931 sequence, the 1935 Quetta earthquake resulted in the largest number of fatalities of any earthquake on the Indian plate or its boundaries in the past two centuries.

Quetta was ceded to the British in 1877. Before then Quetta was a station which controlled the trade route from India to Kandahar, as well as the Bolan Pass to the south, and the road to Kalat and to Persian Baluchistan. Although a sketch of the fort at this time looks quite imposing an 1839 report describes Quetta as "a most miserable mud town with a small castle on a mound having one small gun on a rickety carriage " (Spate, 1954). Photographs of the town just before, and after, the 1935 earthquake reveal a busy frontier town that was severely damaged by the event.

Detailed information survives for the Quetta earthquake, (Situation Reports 31.05-13.08.1935, Files no. 1 to 73 in the Archives of the Government of India Bureau in Simla), as well as from West (1936), Jackson (1960), Skrine (1936), and Piney (1938). Most of the damage to rural and urban houses, chiefly of mud brick construction, was enclosed within a narrow zone, with Baleli and Quetta in the north extending in a south-westerly direction into the Harboi Hills, about 160 km long and 25 km broad. A great deal of the land in the zone is unproductive, containing only a few large villages where water could be found in underground irrigation and water supply conduits (qariz, qanat). In addition to the towns of Quetta and Mastung at least 100 villages in Quetta subdivision and Kalat State were totally destroyed.

Starting from the north, Baleli was totally destroyed, 108 people were killed and 23 were injured. At Kuchlagh all houses were ruined and the railway depot collapsed with the loss of 8 lives and 9 injured. Further south, Sheik Manda was razed to the ground and in near-by Nauhissar 77 people were killed and 28 injured.

Quetta, a military garrison town, with a population of about 40,000 (summer population 65,000), is built on a slope crossed by two nullahs (watercourses). The Habib Nullah separated the Civil Lines and town from the cantonment, and the Durani Nullah, a kilometre further north, ran parallel to it for most of its length. Both nullahs were crossed by bridges at several points. The Civil Lines was the more densely populated part of the town. It occupied an area of about 4 square kilometres and it was located south of Habib Nullah, an area with a high water table in the spring. This low lying part of Quetta was utterly destroyed, and about 15,000 people lost their lives (Pinhey, 1938). The Police Lines, the Durbar Hall, the Civil and Mission Hospitals, and the Club were ruined and the Residency was damaged. The only buildings that survived the earthquake with minor damage were the few reinforced concrete structures and the new railway quarters, constructed since the 1931 earthquake using earthquake-resistant principles, and situated in the most damaged part of the Civil Station.

North of the Habib Nulla, on higher ground, the cantonment was much less affected and only a few houses collapsed. The Garrison church and the British and Indian Military hospitals were undamaged. The only serious damage done to the cantonments was a belt about 1 km wide immediately adjoining the Durani watercourse and the Civil Lines, damage decreasing rapidly towards the north-east. Here a good deal of damage was done to the Fort and some of its buildings collapsed.

The airfield, with its modern hangars and barrack blocks, stood to the north-west, apart from the city and cantonment. In the RAF lines the hangars were left standing but little else. Every aircraft was so damaged that it was unsafe to fly. The earthquake caused no serious damage to the piped water supply nor to the power stations which continued to work on restricted load.

South of Quetta, Kansi was totally destroyed; 1,010 people were killed and 370 were injured. Also Sariab was razed to the ground with the loss of 1,206 lives and 641 people injured. At Durani 101 people were killed and 114 were injured. At Spezand, Dingar and Mand-i Haji local houses were flattened but the railway station at Spezand was not destroyed. Tiri was utterly destroyed with the loss of 710 lives and 275 people injured. Mastung, 65 km south of Kuchlagh, was flattened by the shock together with the Khan's palace, killing altogether 1,736 people and injuring 716.

South-west of Mastung, small settlements in the Shirinab valley which extends from Kuhnak to Manguchar, along a distance of 90 km by road, were destroyed. This region was within the thinly populated tribal territory belonging to the Khan of Kalat, and damage details are lacking. Pringabad, the only large settlement in this region was destroyed; 369 people were killed and 234 were injured. Manguchar, 100 km south of Kuchlagh, was also destroyed; 185 people were killed and 185 were injured.

Destruction extended south into the State of Kalat, 155 km from Kuchlag. Kalat itself was ruined with 120 people killed and 50 injured. In Kalat State, out of a population of 10,000, 2,900 were killed and 5,000 injured. It was estimated that all villages between Quetta and Kalat were destroyed with 70% of population either dead or injured.

Outside the epicentral region damage was widespread to dilapidated rural houses, particularly in many places in the Indus valley and in the Spin Baldak (Qla-i Jadid) and the Kandahar regions of Afghanistan (Stenz, 1945).

Liquefaction of the ground and mud volcanoes were reported in the valley north-west of Quetta. Some 20 km south of Kalat on the main road to Surab, about 5 km east off the road near the village of Thok (28.333°N, 66.517°E), large quantities of liquid mud were observed coming out from the top of an old mud volcano at the time of the earthquake, the eruption lasting for nine hours. None of the local inhabitants could recall any similar event in the past. The new flows had spread out beyond the limits of the old occupying an area of radius 140m.

Official figures for the loss of life in the earthquake are no more than estimates (Pinhey, 1935). In Quetta about 26,000 people were killed, of which a few thousand bodies were left buried in the ruins of the town. Outside Quetta numbers are even more uncertain, particularly in the Kalat tribal area, and where more than the 8,410 deaths recorded. Altogether, the earthquake could have killed about 35,000 people, but reliable figures are lacking.

The telegraph lines from Kalat and Quetta to Chaman and Jacobabad were broken, but communication with the Government of India at Simla was established by radio. The railway and road communications, including the section through the Bolan Pass were not badly damaged. Several small road bridges suffered slumping of their abutments and five segments of the Quetta - Nushki rail track had to be replaced at its crossing with the zone of ground fissures (Thomson, 1936).

Administration became difficult owing to the fact that nearly all the subordinate civil officers and police had been killed. However, the fact that the troops escaped with few casualties allowed a quick rescue and evacuation of survivors, the disposing of thousands of dead by burial or by burning, sealing the town to prevent looting and the outbreak of epidemic disease, protecting and salvaging of property, and controlling the rehabilitation of the region. Two battalions of the 7th Gurka Rifles who were posted in Zhob and Chaman respectively at the time of the earthquake felt the earthquake and returned to find their regimental institute damaged beyond repair (Mackey, 1962).

Following the earthquake new laws were enacted for regulation of the distribution to relatives of property salvaged in the earthquake, for settlement of property claims and for the compulsory application of earthquake resistant design for all new public buildings and engineering structures, (Robertson 1948, and Khan 1956). Priority was given to the repair and reconstruction of destroyed qanats (underground irrigation channels) throughout the affected area to secure the next harvest.

Contrary to what has been said by a number of authors, that the shock was felt within a radius of only 280 km, Urdu and Hindi press reports confirm that the shock was felt over a large area, as far as Amritsar, Sultanpur and Simla to the east (1,000 km), to Jatti (610 km) on the mouth of the Indus to the south, Dera Ismail Khan (500 km) to the north, and Chagai (250 km) to the east, in the last two directions information is lacking beyond these points into Afghanistan..

The earthquake was followed by a long sequence of relatively small magnitude earthquakes, the largest of which in the south part of the epicentral area did not exceed a magnitude Ms 6.0. Shocks continued to be felt until the beginning of October. No shocks were reported before the earthquake, but a bright orange glow was seen over Quetta to the west, and further south, near Kalat, flashes of light were reported along the flanks of the mountains on both sides of the valley.

Following the earthquake a survey of the north-west dipping thrust faults south-west of Quetta, which runs for a few kilometres to the south-west along the northern flanks of Chiltan, showed no signs of any movement, although 20 cm of uplift was detected on bed-rock benchmarks near the Quetta brewery that lies 5 km west of the town on the hanging wall of the fault. Ground deformations which extended discontinuously for about 105 km were followed the south side of the Chiltan Range toward Kalat, striking N15E. Over the greater part of this distance they took the form of strands of open cracks, 2 to 20 cm wide, mostly in alluvium. About 8 km west of Mastung the ground of the west side of these cracks was downthrown on average by about 80 cm, though a little further south the sense of vertical movement was reversed. In some places, instead of a throw or open cracks, the ground had been heaved up, the uplifted portion being 30 cm or more high and several metres wide.

Where the locus of ground deformation crossed the railway that runs from Spezand to Nushki, about 3 km west of Mastung Road Station, the track had been uplifted and the rails buckled. Where bedrock intervened along these zones of fissures in alluvium, the cracks died out, with rockfalls and shattered rock taking the place of fissuring along the same line. This was well seen to the north-west of Mastung Road, on the southern flanks of the Chiltan Range. The zone of fissures extended further south, past Kalat. A few kilometres of SW of the village, ground cracks passed beneath an adobe house, displacing its walls but leaving them standing.

It appears, therefore, that the earthquake was associated with the zone of faults that lie along the east edge of the Chiltan range and that this zone extends to the south passing near the towns of Mastung and Kalat. Leveling data confirm abrupt uplift of the foot of the range but triangulation data that would reveal extent and sense of strike-slip motion have yet to be released. The first-order North Baluchistan Series of the Survey of India measured in 1909 (Burrard, 1911), passes southward through Quetta and along the Chiltan range. Remeasurements of some of these stations were in progress during the earthquake.

Our instrumental position, a relocation using p-waves from 231 stations and present ISC location procedures, is 160 km south of Quetta, about 40 km west of Kalat and close to the location computed by Engdahl et al. (1998) and Ramanathan & Mukherji (1938). The formal errors are about 15 km, but as most of the stations are grouped to the north-west. the true position could be further to the north-west. The surface wave magnitude calculated from 25 station magnitudes is 7.7, to which corresponds a seismic moment of 17.0×10^{27} dyne cm, estimated by Singh and Gupta (1980).

Lawrence et al. (1992) and Yeats et al (1997) associate these ruptures with the Ghazaband fault zone, one of a series of large north-south left-lateral strike-slip systems that accommodate plate boundary shear. A temporary seismic network operated in the region in 1978 suggests that microseismicity was at that time concentrated near the ends of the 1935 rupture (Armbruster et al., 1980). Fault plane solutions in the area confirm left-lateral faulting on this trend, and, in spite of the lack of reported observations of strike-slip offsets at the time, this is the most likely mechanism for the 1935 earthquake.

1935 June 02 M=6.0 (Quetta) This was the largest aftershock of the 1935 sequence which added to the damage at Kalat, Maguchar and Mastung but not in Quetta. Had it occurred by itself it would have been considered a severe earthquake, and had there been any houses in the lower part of Quetta left to damage, the shock would certainly have damaged them. The aftershock triggered more slides in the Shirinabad valley and rockfalls from the sides of the Chiltan Range, south-west of Quetta, the dust rising 500 m above the mountain. Some damage reported from Nushki could be due to this aftershock.

1935 Jul 5 This earthquake occurred on the borders of Afghanistan and Uzbekistan and affected the region on both sides of the Amu Darya river. Information is too poor to allow location of its epicentral region which must be sought between Baisun and Shirabad in Tadzhikistan where some damage was done to unnamed localities, and to the irrigation system of Talishkan and Tazhdiul

The shock was strongly felt to the south at Shibarghan in Afghanistan at Sari-i Pul, Aq Chah, Balkh (Wazirabad), Mazar-i Sharif and Tashkurgan, where it caused insignificant damage. The earthquake was reported from a large area disproportionate for its magnitude. For example it is alledged that it was perceptible at Srinagar, at an epicentral distance of more than 700 km. (India Weather Review for 1935, Simla); Gorshkov DATE, Spesivtsev et al. (1941); Heuckroth & Karim (1970).

1948 Jan 28 (6.5) A damaging earthquake occurred in the region of Balkh in northern Afghanistan, over a large area between Shah Anjir (36.34, 67.22) and Mazari Sharif (36.70, 67.11). Much damage occurred near the Dulan Pass, at Shah Injir, Yakatal and Quduk Mulla, where a number of people and domestic animals were killed. At Mazari Sharif (36.70, 67.11), 45 km from the pass, old houses and shops were destroyed and the dome and towers of the shrine building fell down. At Samangan, 90 km away, a few houses were ruined and the sugar storage building was destroyed. The shock was strong at Maimana (35.92, 64.76) but it did not cause significant damage. The earthquake was widely felt, as far as Kabul (34.53, 69.12), Dushanbe (38.57, 68.77) and Samarkand (370 km), but not at Herat (Ittilaat 13.11.1326); Heuckroth & Karim (1970).

1950 Sep 24 (5.6) An earthquake on 24 September 1950 with an instrumental location on the Iran-Afghanistan border, just south of Taiabad. There are no macroseismic data for this event except for the unconfirmed information that about this time a shock caused the collapse of a 16th century minaret in the Musalla of Gawrshad in Herat, 130 km away, already in ruins, leaving seven minarets leaning in different directions (Byron 1937:99; Dupree 1971; Blunt 1957).

1952 An earthquake at noon on a day at the end of autumn probably in 1952, occurred in the Schkurigal-Bashgal region, at Ozzuk (35.80, 71.27), Appsigh (35.80, 71.25), and the upper Bashgal basin and Deywanababa (35.90, 71.30), but not in Lulook (35.77, 71.22), where damage was caused by falling rocks. Cracks in the ground and in snowfields were reported from Deywanababa and Barge Matal (35.67, 71.33). In the Munjam valley (36.02, 70.76) the shock was strong but it did not destroy any houses, even though falling rocks were numerous [Danby et al. 1972].

1955 Aug 29 This was one of the many shocks that preceded and followed the August 29th event over a period of one month, ruining many houses at Gulran in north-west Afganistan. The shock was felt strongly 100 km away, across the border in Iran, at Torbat Sheykh Jam, where it caused no damage. No association of this event can be made with the shocks recorded by the Soviet and Indian networks during the period 28 to 30 August (Bozorgnian, 1962; Heuckroth & Karim, 1970).

1956 June 9 (7.4) A large magnitude earthquake occurred in the Bamian district, Afghanistan. Much of the destruction was in the valley between the Kahmard and the Saighan mountains, a sparsely populated region with no large villages, at an altitude over 3000 m. Little is known about damage to individual settlements, except that the few small mountain villages around Kahmard (35.33N, 67.50E) and Saighan (35.17N, 67.70E) were totally destroyed, and those in the district of Yakwalang (34.73N, 66.97E) were heavily damaged with loss of life. Contrary to information in the press the earthquake caused surprisingly little loss of life, fewer than 70 people.

The epicentral region may be defined roughly within an are about 120 km long and 40 km wide, running from Yakwalang in the south to Kahmard and Doab (35.55N, 67.81E) in the north-east. Within this zone the earthquake triggered rockfalls and landslides which were one of the causes of additional destruction. The largest slide occurred at Kami Kharqushaq (35.36N, 67.53E), about 15 km north-west of the village of Kahmard. An estimated 100,000 cubic metres of limestones and marls slid down damming the upper valley of the Kamar river, holding back eight million cubic metres of water for four days. The dam gave way on 14 June, and the flood swept away the settlements in the valley, drowning about 350 people, leaving behind a small lake that marks the site of the slide. Another large landslide at Darra-i Shikari (34.88N, 67.78E), about 25 km north-east of Bamian (34.82N, 67.53E), blocked roads and disrupted communications, killing a number of domestic animals. Also at Yakwalang, slides blocked roads and killed herds of animals.

Outside this region, around Pul-I Khuni (35.95N, 68.71E), Baghlan (36.14N, 68.70E), Kunduz (36.73N, 68.86E), Seh Kundi (33..35N, 68.40E) and Kabul (34.53N, 69.13E) the shock casued some damage, great panic, but no loss of life.

The earthquake was felt as far as Termez (37.22N, 67.27E), Motovabad (37.34N, 68.67E) and Chitral (36.02N, 71.75E) and it was perceptible at Stalinabad (38.57N, 68.78E) but not in Peshawar [Wesson (1972), Furrer (1956); Heuckroth & Karim (1970)]

1956 Sep 16 (6.7) A damaging earthquake occurred in the Lohgar district (33.98N, 68.99E) in north-east Afganistan, near the border with Pakistan. Little is known in detail about the damage in the epicentral area which includes the villages of Said Karani (33.68N, 69.37E), Laza and Jaji (33.78N, 69.67E) where a number of houses collapsed and a few people were killed. In the Hindu Kush the earthquake caused landslides and snow-avalanches depending on local conditions. Some villages suffered slight damage while others suffered none. Deywanababa (35.90N, 71.30E) was outstanding in being the scene of an avalanche that killed a few people. The shock triggered rockfalls from the Mangal mountain that killed a number of animals. Also in Nuristan, the shock caused snow-avalanches from area above the snow-line.

The earthquake was felt over in Afghanistan and Pakistan in an area disproportionately large for its magnitude. Felt reports are available from the districts of Hazarajat, Parwan (35.1N, 69.2E), Ghazni (33.63N, 68.95E), Kohat (33.59N, 71.44E), Parachinar (33.90N, 70.10E), Behsud (34.38N, 67.53E), Rawalpindi (33.69N, 73.04E) and Srinagar (34.08N, 74.81E), within a radius of over 300 km.

A large aftershock on 16 September was felt in the Lohgar district, in Kabul, in the region of Jalalabad and across the border at Parachinar.[Wesson (1972); Danby et al. (1972); Seism. Bull. Sep. 1956, p.5,10, Met. Dept. India, Delhi; Heuckroth & Karim (1970).

1962 Sep 12 (6.0) An earthquake in the Thakar province of north-east Afganistan. The available macroseismic information is insufficient to define an epicentral region. In Afganistan the shock was strong in the districts of Baghlan and Qatghan and it was felt up to 250 km away at Jalalabad, Kabul and Mazar-i Sherif. In the north, in Tadjikistan and Uzbekistan, the shock was equally strong at Karshi, Samarkand, Leninabad and Khorg. The shock was felt within a radius of 450 km. The large felt area and small magnitude suggests that this was a lower crust event (Zemletriasenia v SSSR v 1962, (1964) pp.70,82, Izd. Nauka, Moscow); Heuckroth & Karim (1970).

1968 Sep 3 (5.0) This relatively small earthquake has been relocated by Engdahl et al (1998) in northern Afghanistan between Nahrin and Khanabad, at a focal depth of 40 km. While we can find no macroseismic information from Afghanistan, the event was widely felt in the plains of Amu Darya and reported from 37 localities in Tajikistan, up to epicentral distances of 250 km. It was felt strongly at Dangana (37.60, 69.78), Dangara (38.09, 69.33), Iol (37.77, 70.18), Khorog (37.49, 71.54), Kulyab (37.91, 69.78), Moskovski (37.61, 69.70), Obi Garm (38.72, 69.70), Pyandzh (37.23, 69.09), and it was perceptible at Dushanbe (38.57, 68.78) and Regar (38.52, 68.18) (Zakharova et al., 1972).

1972 Jun 24 (6.4) A damaging earthquake in the district of Takhar in northern Afghanistan on 24 June 1972. The large villages of Khost Fering, Nahrin (36.07N, 69.13E), Ishkimish (36.38N, 69.32E) and smaller settlenets within a radius of about 25 km were ruined. A few hundred houses collapsed and about 20 people were killed. Damage to local houses was reported from Baghlan, Pul-i Khumri and Warsaj at epicentral distances of 60 km. The shock was felt at Kabul, in Peshawar and Rawalpindi in Pakistan, and as far as Kulyab (37.91, 69.78), Khorog (37.49N, 71.54), Obi Garm (38.72N, 69.70E), on the Nurek dam site (38.39N, 69.32E), and in Samarkland (39.66N, 66.95E) in Soviet Central Asia, that is, within a radius of 370 km. It was perceptible at Dushanbe (38.57, 68.78).[Seismological Bulletin for 1972, Seism. Center Kabul Univ., Kabul], Danby (1972) .

1975 Oct 3 (6.8) An earthquake on the Chaman fault zone, close to the borders with Afghanistan at Spin Tezha, followed 12 hours later by an aftershock of 6.5. Little is known about the effects of these events in the epicentral region, a sparsely inhabited area of the Afghan border, except that they caused some minor damage at Quetta. The shock was felt strongly at Quetta and in north-west Baluchistan.

The trace, probably of only a small segment, of a north-south trending discontinuous surface fault break was found in alluvium which could be followed for about 5 km south of Spin Tezha along the Chaman fault zone. It showed an average left-lateral displacement of about 4 cm, with minor dip-slip up to the west, consistent with the earthquake focal mechanism. Farah (1976); Lawrence& Yeats (1979).

1976 Mar 19 (5.5) A relatively small earthquake on 19 March 1976 caused considerable damage in Samangan province, killing about 50 people and ruining more than 1,000 local houses. Maximum damage was reported from the areas of Khulm (36.69, 67.69) and from the nearby Tashkurgan gorges. Rockfalls and slides in the eastern section of the Khulm Gorge buried several vehicles adding to the loss of life. The shock was strong at Kornilovka, and was felt at Termez, Denay, Khorog, Dushanbe, and Kulyab and it was perceptible at Samarkand (Zemltr.v CCP1976(280) p.160.

1981 Jun 13 (5.4) A damaging earthquake in northern Afghanistan. Little is known about its effects in the epicentral area which was somewhere between Samangan and Jozjan, where a number of people were killed. The shock was felt along the Amu Darya from Termez to Parkhar and further north in Uzbekistan at Kurgan Tyube and Dushanbe. It was perceptible at Samarkand at an epicentral distance of 390 km.

1982 Dec 16 (6.5) A destructive earthquake in north Afghanistan. Little is known about the effects of this event apart from the fact that it destroyed approximately 7,000 houses, killing 450 and injuring 3,000 people in the Baghlan district. The shock caused serious damage and loss of life in the coal mines in the district. The earthquake was felt as far as Tashkent, Murgab and Tarbela, over an area of a radius of 520 km.

1983 Dec 7 (4.6) A small earthquake in Afghanistan with an instrumental epicenter in the region of Takhar. The shock was felt at Kuliab and Khorog at an epicentral distance of about 200 km.

1984 Jul 3 (5.2) We have no macroseismic data from Afghanistan for this earthquake in the Takhar district. The shock was felt at Khorog, Kuliab, Nurek, Kabodien, and was perceptible at Dushambe, Samarkand and Tashkent. (Barinova et al.,1987; Kondorskaia et al.,1987)

1986 Jan 12 (5.5) An earthquake in north-east Afghanistan with an instrumental location near Kabul. No macroseismic information is available with the exception that the shock was felt strongly in the Kabul area and at Peshawar in Pakistan.

1998 Feb 4 (5.9) A destructive earthquake in the Rustaq area (37.12, 69.82) of north-east Afghanistan resulted in estimated losses of 2,300 people killed, 800 injured and 8,100 houses destroyed, the shock making 8,000 homeless. The earthquake triggered extensive landslides which added to the damage, killing nore than 6,000 livestock. The shock was felt at Dushanbe in Tadjikistan and was perceptible in Tashkent.

1998 May 30 (6.5) A destructive earthquake in north-east Afghanistan. The shock killed about 4,000 people, injuring many thousands in the districts of Badakhshan and Takhar.

The shock was strong at Mazar-i Sharif (36.70, 67.11). It was felt in Kabul (34.53, 69.13), and in northern Pakistan at Peshawar (34.00, 71.54), Rawalpindi and Islamabad (33.72, 73.06), as well as at at Dushanbe (38.57, 68.77) in Tajikistan, Andijan (40.79, 72.34) and it was perceptible at Samarkand (39.66, 66.95) and Tashkent (41.31, 69.30).

1999 Feb 11 (5.8) An earthquake in the Lowgar (Logar) and Vardak provinces of Afghanistan destroyed approximately 7,000 houses, killing 70, injuring about 500 people, and making at least 14,000 homeless. Damage extended to Kabul where several people were injured. The shock was felt in Pakistan at Peshawar and Islamabad.

2002 Jan 3 13:40 (6.3) The Takhar province of the Hindu Kush. No damage or casualties have been reported so far. Buildings shook in several major cities including Kabul, Islamabad, Delhi, Peshawar and Mazar-e-Sharif, in northern Afghanistan.

2002 March 3 (7.2) The epicenter of the earthquake was in the Hindu Kush region with a depth of 195 km. The earthquake was felt in Kabul, Jalalabad, Faizabad, Mazar-i-Sharif and Bamiyan. In Kabul, 32 houses were destroyed, 20 persons injured and 6 persons killed in the city. Except for cracked walls, there were no reports of destruction or injuries in rural areas adjacent to Kabul. A landslide 20 km south-east of Aybak, on the road to Ruy-e-Du Ab district in the Surkenda Valley created a transient lake. Damage was extensive in the villages of Souchi Bala Payan, Targane and Yawan and two other settlements. Although 340 houses were destroyed the absence of reports of significant injuries or deaths is perceived due to the fact that the earthquake took place during the day when most people were not at home. The reports from Baharak district, located east of Faizabad, indicate that a limited number of houses were destroyed in villages around the district capital and one death was registered in Malang Ab. In Jurm, there are reports of two houses destroyed in Dashteq, another eight in Abad, fifty in Souch and six in Zardeh. (UN Office for the Coordination of Humanitarian Affairs (OCHA) OCHA/GVA - 2002/0052 4 Mar 2002. Afghanistan- Earthquake OCHA Situation Report No. 1).

2002 March 25. (Ms=6.0, 5.1, 5.8) A series of shallow earthquakes hit the Nahrin district of Baghlan province in the evening of 25 March, the early morning 26 March and the afternoon of 27 March. The epicenter of the earthquakes was located southeast of Nahrin district in Baghlan province. The affected area included a radius of 12-15 km around Nahrin. Other affected areas include Burkha, Panshjiri, Lakankhel and Toli, In all 78 villages were affected by the earthquakes resulting in approximately 1200 deaths OCHA Situation Reports No. 1-7 Afghanistan – Earthquake. OCHA/GVA - 2002/0076, 30 March 2002.

Table 4 Earthquakes of all magnitudes (Electronic Supplement)

See html document appendix