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Summary: In 1819 a rare mid-plate $M=7.7$ earthquake occurred between Bombay and Karachi. (Many texts list it as $M=8$). The mechanism of the earthquake has hitherto not been studied because it predates seismometers by 8 decades, and occurred prior to the establishment of widespread geodesy in India. An 1844 canal survey and 1826 eyewitness accounts are used to piece together a vertical deformation field, that is subsequently used to interpret subsurface slip. The fault apparently slipped by more than 11 m in a reverse sense dipping to the north, creating a fault scarp, still visible in satellite imagery.

Body of article: pages 1-21 describes historical data and their analysis

Appendix: pages 22-32 includes government accounts and news items

Slip parameters for the Rann of Kachchh, India, 16 June 1819 earthquake, quantified from contemporary accounts.

Abstract The 16 June 1819 Rann of Kachchh earthquake was felt throughout much of India. Although significant vertical movements of the ground caused flooding of regions near sea level, damming of a tributary of the Indus river, widespread liquefaction, and a local tsunami, the geometry of the fault plane has hitherto remained obscure. Dislocation models based on deformation data gathered 7 and 25 years after the earthquake suggest that a near-surface reverse fault, slipped locally more than 11 m, and that rupture extended at least 80 km along strike. Estimates of maximum uplift and depression during the earthquake yield similar, but not identical, solutions to those based solely on a levelling profile across the zone of uplift, known as the Allah Bund. The inferred $50\text{-}70^\circ$ N-dipping fault plane beneath the Allah Bund is unfavourably steep for reverse faulting, and its down-dip width (6-10 km) is short for slip exceeding 10 m. Some forms of listric fault geometry are also consistent with the observed surface deformation fields, with increased fault width (15-25 km) and similar coseismic slip. A geometric moment magnitude of $M=7.7\pm 0.2$ is obtained from the inferred slip parameters, assuming uniform along-strike slip, consistent with a magnitude estimated empirically from the intensity distribution. While a recurrence of the Kachchh earthquake is unlikely soon because of low inferred contractional strain rates in the region, the westward continuation of the Kachchh rift zone could host future ruptures contiguous with the 1819 event, with important consequences for the city of Karachi.

Introduction

The Rann of Kachchh (historically referred to as the Ran, Raun, or Runn of Cuch, Cutch, Kach or Kutch) is an arid region of western India devoid of vegetation that lies close to sea level. Rann derives from the Persian word Eriyan meaning “waste”. In the dry season the lowest part of the Rann is covered with a hard crust of evaporites, but during a vigorous monsoon the region is flooded to shallow depth and impassable on foot. The low hills of Kachchh separate the Rann of Kachchh from the Gulf of Kachchh to the south, and because of the Rann's low elevation above sea level, in some maps Kachchh is depicted as an island. The Rann is underlain by rift-like features, which have been mapped offshore beneath the continental shelf with a general east-west trend (Biswas, 1989). The collision of India with Asia has initiated a compressional stress regime in a northwesterly direction, very different from that at the time of rifting, and the reactivation of these normal faults in a reverse sense is both anticipated (Khattari, 1992) and demonstrated (Chung; 1993; Chung and Gao, 1995).

Several authors speculate on substantial shifts in the coastline of NW India since the visit of Alexander the Great (c.f. Burnes, 1835; Haig, 1894). In Medieval times the Rann is

believed to have been connected to the Arabian Sea to a sufficient depth to permit marine access by large boats. The stranded remains of these boats are reported to have been excavated from time to time and used as firewood by local villagers (Grindlay, 1808, cited by Burnes, 1834). On the basis of the burial rate of near-surface horizons the sedimentation rate for the past 9000 years is estimated as 2 mm/year by Gupta (1975).

Uplift in the 1819 event created an 80-km-long natural dam (the Allah Bund or Dam of God) across the Kori (Korree) branch of the Indus river (known as the Puran, Pharran, or Pooraun), which in 1826 was breached by a flood. The investigation of the 1826 flood resulted in surveys in 1827 and 1828 (Burnes, 1833; 1834) who estimated a 25 km width to the Allah Bund 7 years after the event. Lyell (1853) discusses the deformation in the earthquake including new materials elicited from Burnes and from the notebooks of early travelers. Suess (1904) and Wynne (1872) examine the evidence for uplift, but for want of unequivocal numerical data describing the deformation of 1819 conclude that it is unlikely to have occurred, a sentiment repeated as recently as 1976 (Glennie and Evans, 1976). Although Baker (1846) measured a profile of the uplifted Bund using survey instruments, his data were omitted from his 1846 publication and were not generally known until re-discovered and printed by Oldham (1898).

In 1926 Oldham collated and evaluated the available data, providing for the first time isoseismal maps and estimates of epicentral uplift and subsidence. Oldham (1926) opens his account with a review of extant documents including a discussion of the provenance of Burnes' several publications. He shows the earliest of these may have been a quarto, lithographed edition, but was apparently unaware of the handwritten account from which subsequent accounts may have been printed, which Burnes presented to the Geological Society of London on 18 Dec 1833 with the preamble "The following pages contain a memoir which has been already lithographed in another shape, but which has been since recast to enable the author to state the facts as they occurred & afterwards draw his conclusions, instead of mixing both together." The map that accompanied this was that prepared by W. Ballantine in 1831 entitled "A Sketch of the Runn and Countries adjacent to illustrate a Memoir on its formation, and the alterations of the Eastern Branch of the Indus by Lieut Burnes Ass. Q. M^r. Genl. "

The deformation data are used in the following article to provide constraints on the mechanism, magnitude and location of the 1819 earthquake. The credibility of the interpretation depends largely on the accuracy of the data, and it has been found necessary to examine some of the original sources cited by Wynne (1872) and by Oldham (1926). The article first examines the characteristics of the Earth's surface near the epicentre and concludes that the surface was essentially featureless and that no former fault scarp was present. The reliability of the coseismic deformation data are next evaluated, and possible perturbation by post seismic effects and subsequent earthquakes in the period 1844-6. The numerical data are interpreted with the assumption that they were generated by a single event with northerly, or northwesterly, directed slip, with confidence intervals estimated from the original observations.

The surface of the Rann of Kachchh before the earthquake of 1819.

In 1808 Captain R. M. Grindlay travelled through the Rann of Kachchh and provided qualitative information concerning the pre-seismic topography of the northern Rann of Kachchh. His path took him through Kori Creek to join the Puran River, which he identified as the easternmost distributary of the Indus, known northward as the East Nara River. In 1808 marine navigation in boats with moderate clearance was possible as far north as the Lallan Puttun dam, the first of several artificial dams encountered across the Puran river starting 24 km north of Sindri. A salt water anchorage existed south of this dam (bund), north of which fresh water was impounded for irrigation.

"We passed Sindri, and observed several inferior branches leading through the Rann, among which we saw a few **straggl**ing men and women. About 20 miles beyond Sindri we

reached Aly Bunder at night and came to anchor close to the mound that contains the fresh water” (journal of R. M. Grindlay cited by Burnes, 1835).

No significant fault scarp or highland existed between Sindri and the next fort northward, prior to the earthquakes. Had there been, they would have been selected to site dwellings or defensive positions above the monsoon flood levels. In 1808 according to Grindlay (Burnes, 1833) the surface of the Rann consisted of shrubs and bushes near the edge of the Rann that extended as far north as Allybunder, 32 km north of the Allah Bund. In a posthumous article MacMurdo (1839) states that “The Talpooras however erected two dams called the Morabund, which elevating the level draws the water into the Khattee and eastern districts, and another at Alibunder, with the same view. The waters do not know their way to the sea, which meeting no opposition is driven up to the dam of Alibunder. The mouths are gradually filling up with sand in the absence of the freshes that prevent its accumulation.” (Fresh = flood)

16 June 1819 earthquake

At approximately 7 p.m., on 16 June 1819, Fort Sindri and masonry buildings in villages within a radius of 80 km were destroyed by a violent earthquake. A tsunami from the Arabian Sea surged across the Rann and sand vents in the region were active to a height of 2-3 m for three days, venting water and gas (Bombay Public Consultations, 1819; MacMurdo, 1823). Reliable eyewitness reports near the epicentre are available only from Bhooj and Anjar from where the British resident (Captain James MacMurdo) and an army officer (Lt. Colonel Colin Milnes) sent daily dispatches to the Government at Bombay. MacMurdo lists 1543 people killed in the event, mostly in Anjar and Bhooj where 1547 houses were completely destroyed and many more damaged. MacMurdo remarks that “had the accident occurred in the night time, perhaps one third of the population of the province would have been buried in the ruins of their dwelling-houses”. He observes that damage to masonry structures was minor where these were constructed on rock, but catastrophic where constructed on soils. MacMurdo’s meticulous records probably underestimate the total number of fatalities because they fail to record damage in the northern Rann of Kachchh and southern Sind Province, which regions appear to have been close to the epicentre.

The fort at Anjar was destroyed, and a similar fate befell the fort at Sindri in the Rann of Kachchh. Sketches of Sindri fort before and after the earthquake collected by Lyell (1853) are reproduced in Johnson and Kanter (1992), and a view of the decaying ruins in 1869 is reproduced in Wynne (1872). According to testimony elicited by Burnes (1833, 1835) a tsunami flooded the Rann of Kachchh within minutes of the earthquake and survivors were forced to climb to the top of the ruin where they were rescued the following morning by boat. Ballantyne writing from Jooria on the northern shore of Kachchh on June 17 relates (MacMurdo, 1823) that “the whole town is a complete ruin” and on June 18th describes ground fissures symptomatic of catastrophic-lateral-spreading; “on examining the different rents, we found them to be of various extent from an inch to a foot in breadth; the depth however, being considerable, being 10, 15 and 20 feet. In some places a gravely soil had been thrown out; in others a wet black earth.” Although the tsunami and subsequent sand venting caused transient flooding of the Rann, and numerous rivers were temporarily active in Kachchh, two permanent changes occurred in the Fort Sindri region: the foundations of the fort and the surrounding Rann for a radius of many km subsided by more than 1 m, and a region 7 km north of the fort, including the bed of the river Puran was elevated by 3-6 m, preventing navigation northward into Sind province for several years. This natural dam became known as the Allah Bund. The details of the uplift and subsidence near Sindri are discussed in following sections.

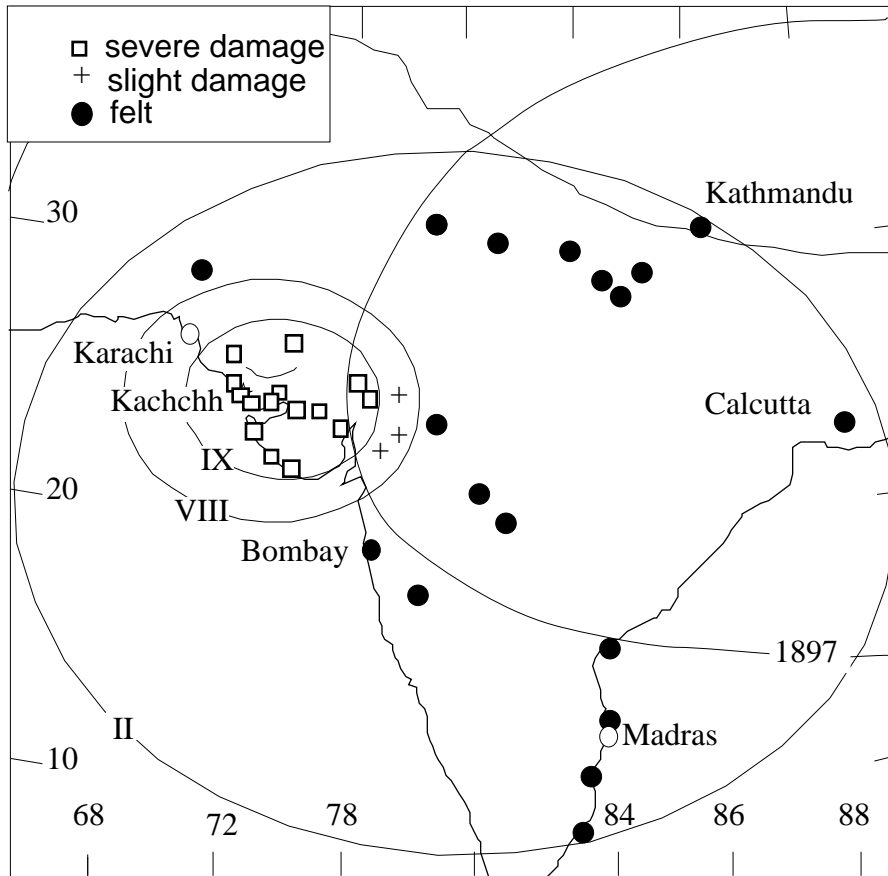


Figure 1 Rann of Kachchh earthquake 1819. Felt locations from Oldham (1926), 1897 isoseismal from Oldham (1899).

Large public buildings were partly damaged 140 km to the east in Ahmedabad and Surat but damage to residential structures was insufficient to warrant claims for damage to the government (Bombay Public Consultations, 1819). At Ahmedabad a 15th century Mosque, famous for its shaking minarets (artificial simulation of resonance in one caused sympathetic resonance of the other) was severely damaged, and its minarets destroyed. Arguing that they were merely ornamental, the government declined to rebuild the minarets. The earthquake was scarcely felt in Bombay, but reports were obtained of perceived motion at Kathmandu, Calcutta, the Baluchistan Hills and from Pondicherry south of Madras (Oldham, 1926), a felt radius of 1600 km. Based on the felt area later compilations have assigned a magnitude of 8.3 to the event (c.f. Dunbar et al, 1997), however, many of the intensity reports are from secondary sources. Aftershocks occurred with decreasing frequency in the next several months. MacMurdo (1823) reports 2-3 events/day in June, one per day until August, one every three days in September, six in October and 3 in November.

Earthquakes 1845-6

Damaging earthquakes in 1844, 1845 and 1846 are inferred from reports listed by Wynne (1872) but the information contained therein is sparse. Their closeness in time and the scant information available on damage led Oldham to suppose that the June 1845 event described in Nelson (1845) corresponds to the true date of the 1844 earthquake described by LeGrand Jacob (1860), who incorrectly ascribes Jeth Sumvut 1901 to 1844. Hindu Jeth Sumvut is June 1845. This interpretation is presumably correct in that a June 1844 event was not reported by Baker (1846) who was in the region from May to October 1844. But

some aspects of Nelson's 1845 letter are enigmatic. The identity of the author and the date of the letter to Nelson are neither recorded in the publication, nor in the archives of the Geological Society of London for 15 Dec. 1845, when it was entered into the minutes:

"One of Capt. McMurdo's guides was travelling on foot to him from Bhooj. The day he reached Lakhpat there were shocks of an earthquake, which shook down part of the walls of the fort, and some lives were lost. At the same time as the shock the sea rolled up the Koree (the eastern) mouth of the Indus, overflowing the country as far westward as the Goongra river (a distance of 20 English miles), northward as far as a little north of Veyre (40 miles from the mouth of the Koree), and eastward to the Sindree lake. The guide was detained six days (from June 19th to 25th), during which time sixty-six shocks were counted. He then got across to Kotree, of which only a few small buildings on a bit of rising ground remain. Most of the habitants throughout the district must have been swept away, the best houses in Sind being built of sun-dried bricks, and whole villages consisting only of huts made of a few crooked poles and reed huts. The guide travelled 20 miles through water on a camel, the water up to the beast's body. Of Lak nothing was above water but a Fakeer's pole (the flagstaff always erected by the tomb of some holy man); and of Veyre and other villages only the remains of a few houses were to be seen.

There are said to be generally two earthquakes every year at Lakhpat. The Sindree Lake of late years became a salt marsh". (letter to Nelson, 1846)

Were it not for mention of Sindri Lake and the guide's route from Bhooj westward to Kotri via Lakhpat, the letter could be describing the 1819 event. Had this been written in 1819 the McMurdo referred to in the letter would have been MacMurdo, the British Resident, who was visiting Anjar on the night of the earthquake, and whose name was spelled in both ways in contemporary accounts. LeGrand Jacob (1860) describes Lakhpat in Nov. 1851 as an abandoned city of 20 inhabitants (he saw 12 only), "the greater part of the houses deserted and many fallen down". However, despite vivid memories of the earthquake of 1819, 35 years prior to his visit, the inhabitants do not ascribe the ruins of Lakhpat in 1951 to Nelson's alleged 1845 tsunami and earthquake, 6 years prior to his visit. Moreover, damage to the fort was not evident in 1851.

"The ramparts of the town completely encircling it, are lofty, nearly three miles round, with a parapet of about seven feet, banquette about six; numerous bastions, some boasting a cannon, all loop-holed for musketry and in good order". Although Kotri in 1851 was a single "upper roomed cottage" 6 miles north of Lakhpat approached by a circuitous 15 mile passage by camel "owing to mud", consistent with the description of access to Kotri in Nelson's letter, this description also fits Lakhpat soon after the earthquake of 1819 (Burnes, 1833).

In contrast, Carless (1838) describes the Lakhpat garrison as a thriving community in 1837, suggesting that damage to the fort in the 1840's did indeed occur: "the walls are defended by numerous bastions, with guns mounted on them of all sorts and sizes. Most of them are so old as to be entirely useless" "It is now garrisoned by 50 Arabs and 150 Native soldiers, and contains a population of about 5000 persons, composed principally of merchants and Hindus, who have fled the tyranny of the Amirs"

Of relevance to the current study is that LeGrand Jacob (1860) describes apparent uplift of the Allah Bund of 2-3 m in 1819 and widening of the Bund to 7.5 km in 1844, with 1 m of additional uplift at Sunda, a navigational point on the river 5 km south of Sindri: "Spent all the afternoon with my tent filled by the best informed men in town and port, assembled for me by the karbharee before alluded to, as having been with Burnes in Sind etc, an intelligent man, himself giving information, and helping to get it from me from others. One of the Rao's garrison in Sindree at the time of its destruction in A.D. 1819 was also present. The following is an abstract of the notes made after much examination and cross examination.

The earthquake of Sumvut 1875 (AD 1819) that submerged Sindree, elevated the bed of the river to the height of 2 or 3 yards for the distance of 2 to 3 kos (5-7.5 miles) commencing about 2 kos above Sindree: the spot is called Ullah Bund (God's

embankment), but the monsoon has worn a water-way through it in an irregular narrow channel; the material being of clay, sand and gravel, this would soon be deepened and widened by any flow of water; the earth was also raised at a place called Sunda. The usual tide only reaches this Sunda, the spring tide now goes over it by a cubit, the earthquake of 1819 raised the ground as to leave the tide there waist high, but in Sumvut 1901 (AD 1844)* a series of shocks occurred, that raised the earth still more, so as to leave a cubit (foot and a half) as the greatest depth of water ever found there: these shocks also extended the breadth of the Allah Bund to the extent of 3 kos: before they occurred the usual tide went over the Sunda by about half a foot, but now not at all. At spring tides, however, a boat drawing a cubit of water can with some labour be taken over the Sunda.

Pursuing the upward course of the river it is thus described:- After passing the Sunda, a pool (Chuch) is reached called Muthar, where the water is waist deep at all times; this is half a kos long; then comes the Ibrahim Shah Peer flag-station, where there is nine feet or more, which continues past Sindri until the Ullah Bund is reached; through this Bund, as before explained, an irregular narrow channel continues the stream during the monsoon: at other seasons water terminates at the Ullah Bund so there is only the dry bed of the old river until we reach the “chuch” called the Bundrejo Duryao, some three kos higher up, where the water is waist high and salt; it lasts for 4 kos, and is terminated by the Suyundwalla Bund above described.

The earthquakes of 1844* here referred to I do not remember ever reading or hearing of, yet they are shown to have effected an important change in the earth’s surface: the shocks are said to have lasted during a whole month (All Jeth Sumvut 1901), and were so threatening that whilst they lasted the inhabitants feared to sleep in their houses”

* the Hindu lunar calendar Jeth Sumvut 1901 is actually June 1845. (c.f. Byramjen 1845)

Oldham considers the changes in elevation described in LeGrand Jacob’s account to be “very improbable” based on the observed elevation of the foundations at Sindri Fort in later years. Also, in view of omission of mention of an earthquake from Baker’s account, it is fairly certain that no second event occurred that may have distorted the deformation field recorded by him and modeled below, so that these later, somewhat uncertain events, are ignored.

Other events in the region

The survival of the evidently precariously stable minarets at Ahmedabad for the 400 years preceding the 1819 event indicates that this was the largest earthquake to have occurred in the region in this time interval. Thus, an earthquake in May 1668 which caused 30,000 houses to sink into the ground in the Indus Delta, and another of unknown severity near Surat in 1684 (Oldham, 1883), were evidently too weak to cause the Ahmedabad minarets to collapse. Anjar, 60 km SE of the Allah Bund, was close to the epicentre of a M=6.1 earthquake in 1956 in which 109 people were killed (Chung and Gao, 1995).

Deformation in the 1819 event

Two permanent changes occurred to the Rann of Kachchh in 1819: a basin was created with a total surface area of more than 1000 km² (Lake Sindri), and just to its north a region of the Rann was uplifted with a steep scarp facing to the south (the Allah Bund). Permanent changes occurred elsewhere but these are poorly documented.

Although Burnes (1833) evidently did not travel as far as the first of the artificial dams north of the Allah Bund, and did not undertake any precise measurements of the profile of the Allah Bund, he offers two consecutive glimpses of the channel cut by the Puran after the flood of 1826. On his first visit (28 March 1827) he was unable to define a precise northern limit to the Bund

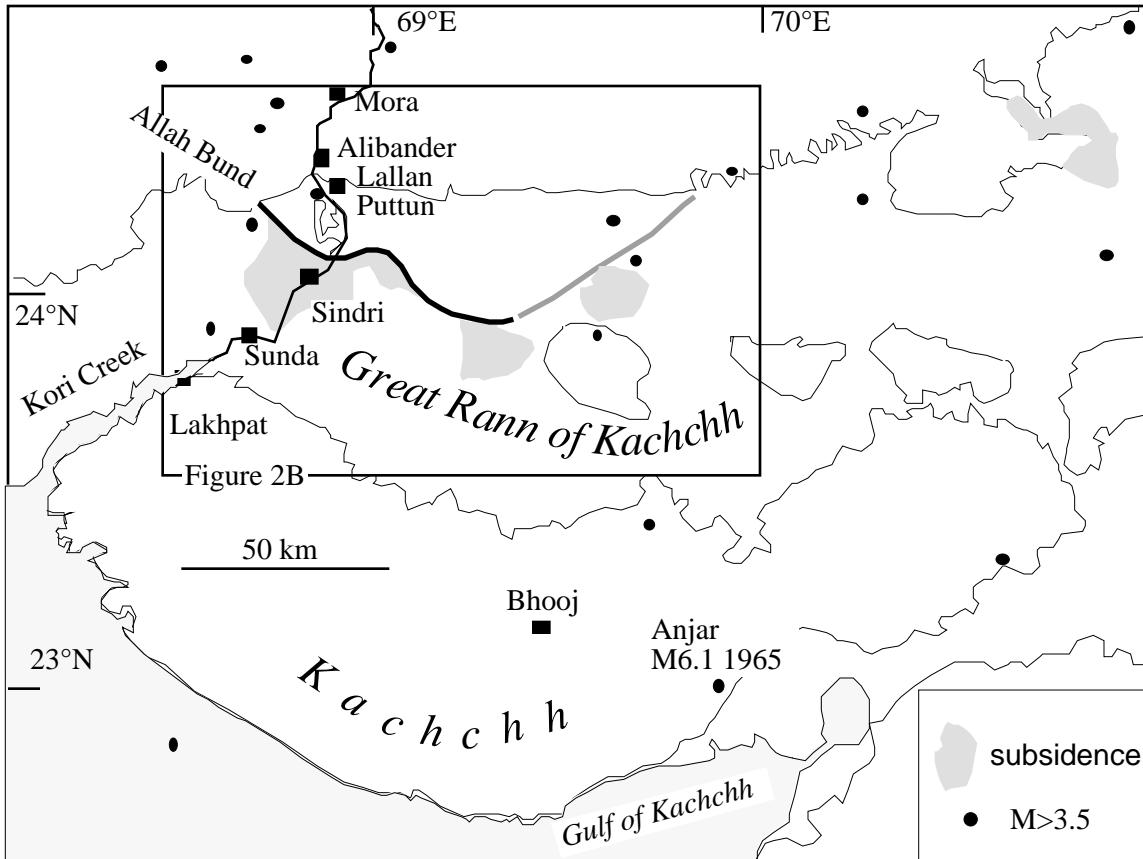


Fig. 2A The 1819 Kachchh earthquake dammed the Puran River north of a zone of uplift termed the Allah Bund, and submerged the region to its south surrounding the fort at Sindri. On the basis of morphological changes recorded by Survey of India maps Oldham (1926) suggests that faulting may have extended a further 100 km to the east (dashed). Earthquakes epicentres 1941-96 $3.5 < M < 5$ from PDE

“for it extends very far inland, perhaps 16 miles and by gradually sloping to the north, unites with the land, which renders it impossible to define its breadth with correctness”.... “the present channel through the Allah Bund, which is only one hundred and twenty feet wide, though from fifteen to eighteen feet deep....”.

His sketch map of the Bund reproduced in Oldham (1926) shows a 20 km long Bund with an acute angle just east of the Puran River (Figure 2B). When he revisits this on 9 August 1828, he increases his estimate of the length of the Bund, but offers no details of its precise, along-strike shape. His accompanying map shows the extended Bund in a very vague way (Figure 2B). He remarks of the channel in 1828:

“The channel through the Allahbund I found to be wider, with more of the west side washed away, and changed from a sloping declivity, to a perpendicular bank like the eastern shore. I sailed two miles up the river or channel which the flood of 1826 cut through the Allah Bund, and found the water gradually to decrease from two and a half fathoms to as many feet, which I was informed was its depth as high up as Chatitar above the Allibund, and about 20 miles distant.”

“The banks of the channel which it cut through are of clay, and as they are perpendicular, and the river comes directly from the north, without any windings, I can compare it to nothing so correctly as a canal, nor does its breadth, when a little way up, destroy the resemblance, being only sixty six feet. The natural bund, so called, is certainly the most singular effect of the earthquake of 1819. To the eye it does not appear more

elevated in one place than another, and being covered with a saline soil, has the appearance of the Runn on all parts”.

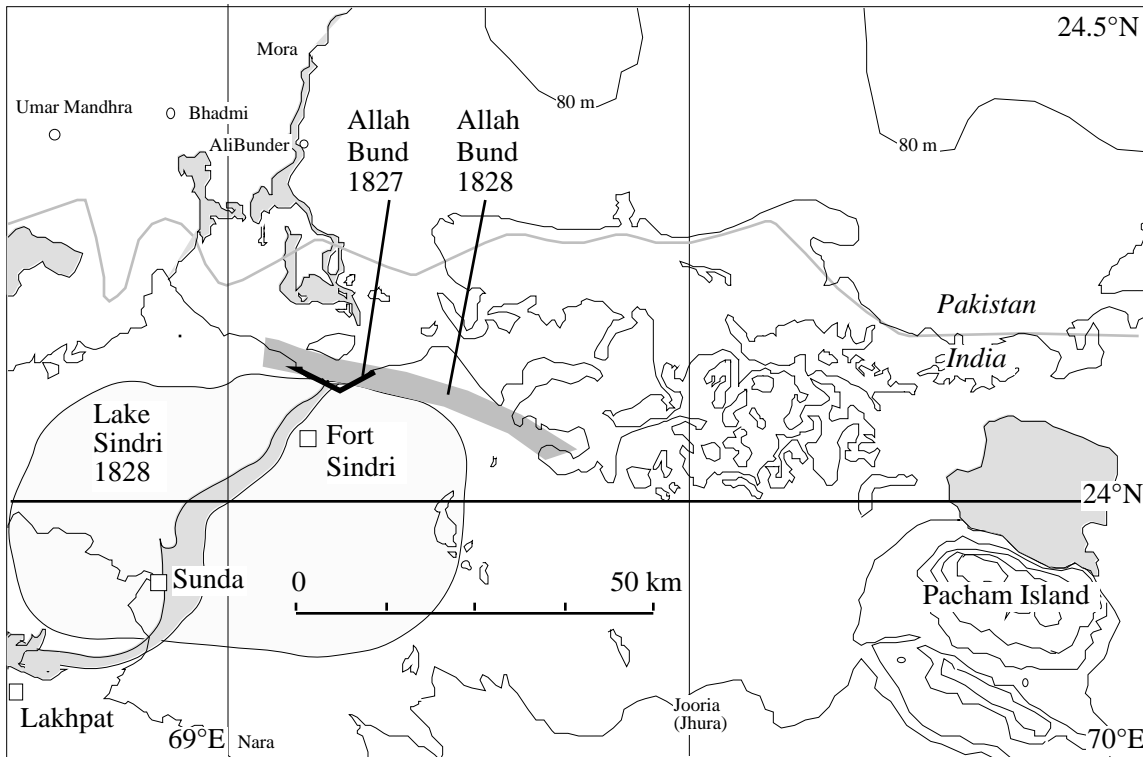


Fig. 2B Topography 1991 (TPC H-8D 1:500:000 Pilotage Chart) showing the location and original area of Lake Sindri, and Burnes' two sketches of the location of the Allah Bund. The 1827 sketch is reproduced by (Oldham, 1926) and the 1831 map is in Burnes (1833).

In 1844 a survey of Sind irrigation by an engineer (Baker, 1846) yielded a 61-km-long profile along the bed and bank of the Puran and tributaries north of the Allah Bund. Baker describes the surface soil of the Allah Bund as “light and crumbling, and strongly impregnated with salt; at the depth of one and a quarter to two feet it has more consistency, and is mixed with shells such as are now found abundantly on the shores of the lake” Baker did not extend his measurements south to Sindri.

Baker’s detailed levelling survey and map were accidentally omitted from his 1846 publication, and (despite an indication by the editor to the contrary) from subsequent volumes of the Bombay Geographical Society, and it was not until 1889 that the map of Baker’s survey was discovered and published in India (Oldham, 1889). Curiously, in his geological map of Kachchh, Wynne (1872) attributes features north of the Allah Bund to Baker’s map which must have been available to him in some form, but his monograph was written apparently unaware of the levelling profile, since he casts doubt on the authenticity of reported uplift. The section through the Bund is reproduced in Figure 3 from the Mora Bund to Lake Sindri, projected in this figure as a function of north-south distance. From his figure it is clear that the Lallan Puttun dam separated fresh water from sea water before the 1819 event.

Maps in the 100 years following the earthquake show the area of Lake Sindri to have shrunk. In recent topographic sheets (TPC H-8D 1:500:000 Pilotage Chart, Edition 4, 1991) the salt flats of Lake Sindri are indistinguishable from the adjoining Rann, and although the Puran is not shown, a small ponded salt flat is apparent north of the Bund (Figure 2 B). It was still a basin in 1874 when a recurrence of the 1826 Indus flood occurred. Wynne (1872) found the fort to be a ruin surrounded by dry land, yet Major

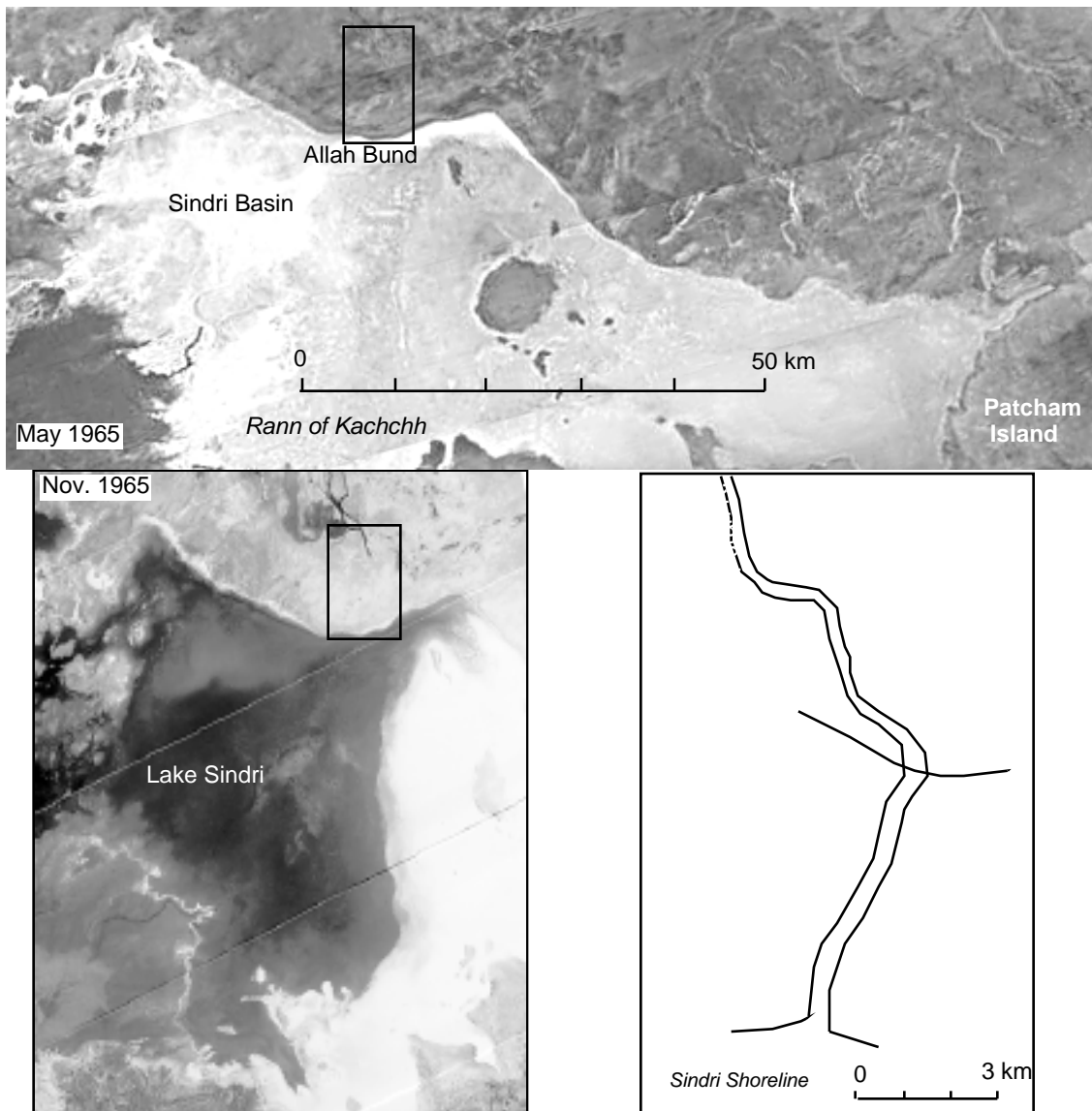


Fig. 2C Top and Left: Satellite Views of the Rann of Kachchh in dry and wet seasons (1965 de-classified Corona satellite images). The form of Lake Sindri in November approximates that mapped by Burnes. Right: Baker's 1844 sketch of the Puran River and Allah Bund superimposed on May 1965 image (inset area) reveals that his map of the course of the river north of the Bund was faithful to 100 m. The Allah Bund shows as a 90-km-long, double arc facing the salt wastes of the Rann. Ancient drainages are present on its surface, and an anastomosing delta has formed north of the Bund mapped by Burnes. In places Lake Sindri has eroded the southern 1-km-edge of the Bund presumably removing part of its 1819 crest. Lake Sindri beach berms are clearly expressed in the images.

Smith (Royal Engineers) is quoted by Col. Barton in 1877 (Bombay Gazetteer, 1880) as reporting in January 1875 "the channel at the Allah Bund was 70-80 feet across, the speed 2.5 feet to 4.5 feet per second", and Lake Sindri appeared as "a stretch of clear blue water broken only by the ruined tower of Sindri fort."

Burnes' 1827 map (reproduced in Oldham, 1926) shows the Allah Bund as two acute segments, but in his hand-written memoir (Burnes, 1833) presented to the Geological Survey of London 15 Dec 1833, his printed map (inscribed, Ballantine 1831) shows it as a linear 50 km zone striking N50W, and states it to be perhaps 80 km long (Figure 2B). Oldham (1926, p.99) in his summary map interprets the Allah Bund as a sigmoidal zone

(Figure 2A) guided by topographic changes evident in the Survey of India maps issued in 1880, and speculates also from topographic evidence, that a fault strand striking N40E, extends perhaps 150 km to the east (Figure 2A). No field observations of surface faults that cut recent sediments are reported anywhere in the region, although many of the structural features in the Kachchh region conform to surface morphology reminiscent of "Jura topography" (Wynne, 1872) suggesting recent tectonic compression.

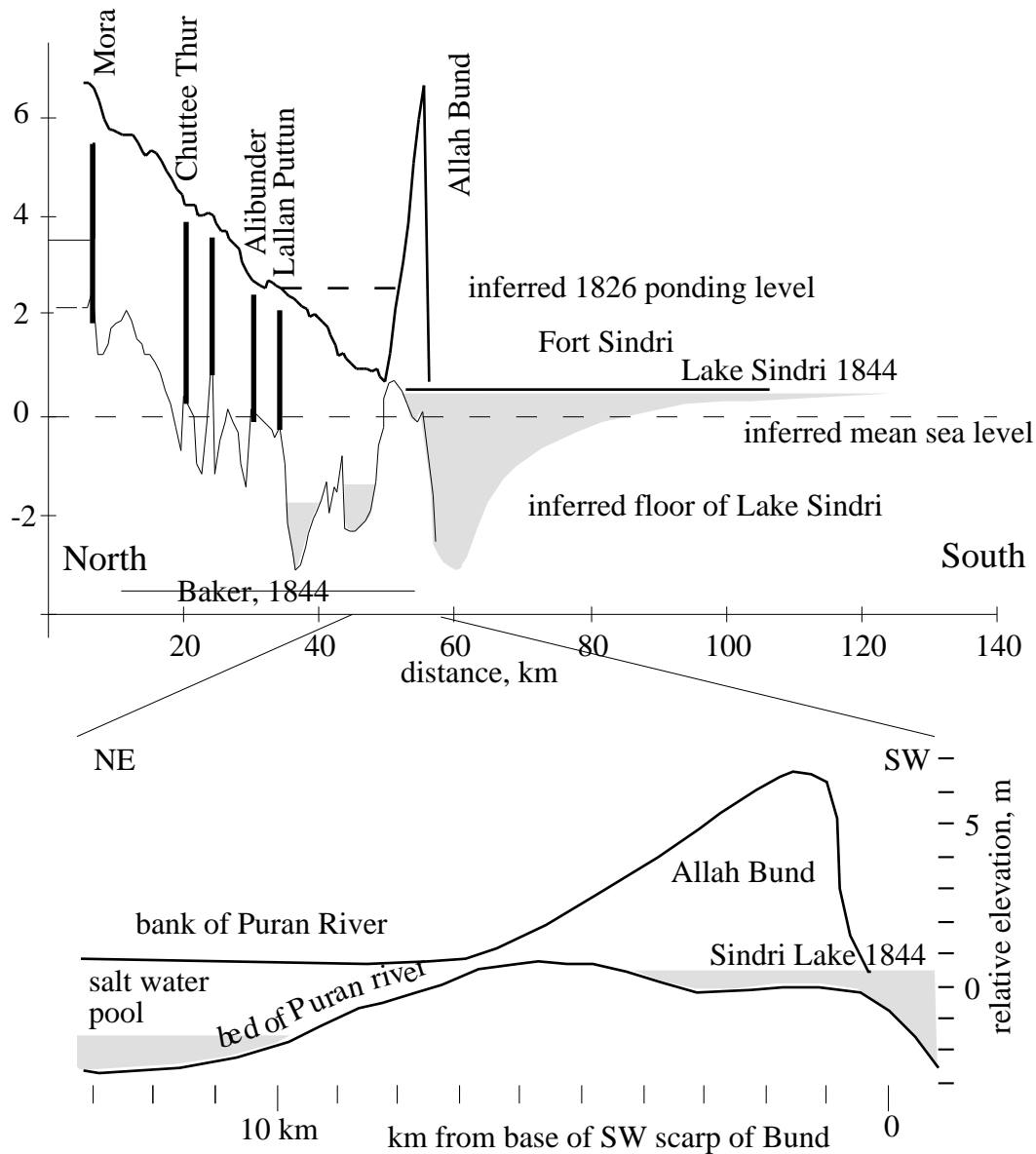


Figure 3 Baker's 1844 profile of bank and bed levels projected on a north-south section, and close up view section through the Allah Bund. Artificial dams are shown as vertical lines. Sea level is inferred from Grindlay's 1808 observation, that the Lallan Puttun dam separated sea-level navigation from fresh-water portage. Sindri lake level approximates high tide level. The 1826 flood would have ponded only to the level indicated if the raised bed of the Puran continued 4 m below bank level through the Allah Bund.

Oldham (1926) summarizes Baker and Burnes' accounts as follows. The peak elevation of the Bund was 6.2 m with a 600 m wide scarp dipping at 0.65° to the south and 0.052° to the north. Estimates of the width of the northern scarp vary from 3-12 km (Baker) to 24 km (Burnes). Subsidence south of the scarp attained depths of 3.5 m (although where Baker measured this depth is unclear), and extended with diminishing amplitude to 24 km south of the scarp. Ft. Sindri is estimated to have subsided at least 1 m, probably 1.6m, and possibly >3.3 m.

One of the uncertainties in these estimates concerns the undeformed surface level of the Bund prior to the earthquake, because it is to this level that estimates of coseismic deformation must be referred. As discussed above, there is little doubt that the observed surface morphology was formed entirely by coseismic deformation associated with the 1819 sequence of earthquakes.

Oldham (1926. p.23) argues that if the observations are referred to a datum just north of the Allah Bund taken from Baker's map, absolute uplift may have been 1 m less, and absolute subsidence 1 m more, than the maximum values estimated from local datums, e.g. the bed of the Puran or the level of Lake Sindri respectively. This however, does not take into account the pre-earthquake, seaward gradient of the land surface. The smooth surface of the bank of the Puran, mapped in Baker's profile, provides a surface whose extrapolation permits the absolute amplitude of uplift beneath the Allah Bund to be estimated. Baker's measurement datum was the level of water dammed behind the Mora Bund, but no precise estimate of sea level elevation is provided. The absolute level of Baker's datum above sea level can be estimated to approximately ± 0.3 m because it was possible to navigate to the base of the Lallan Puttun Dam prior to the earthquake, and because the level of Lake Sindri was replenished by high tides after the earthquake. With this assumption, two approximations to the pre-seismic land surface beneath the Allah Bund are possible: in one, a smooth curve is fit to the bank of the Puran between 17 km and 50 km north of the Allah Bund and extrapolated beneath the Bund, and in the other the curve is, in addition, constrained to fit to lowest estimated sea level at a distance of 50 km south of the Bund (Figure 4). Using the first approximation the peak elevation approximately 1 km north of the Bund increases from 6.2 m to 6.6 m, and using the second it reduces to 6.1 m. The goodness of the fit to Baker's river bank data is superior (see residuals in Figure 4) if the sea level constraint is ignored, and because it is by no means certain that the bank surface should asymptotically approach sea-level, the higher estimate is thus considered more reliable. Data used in subsequent models are summarized in Table 1.

The recorded region of maximum subsidence occurs along the Puran river and the Sindri region along a well-travelled trade route. Numerical data for the Allah Bund is obtained only where navigation was impeded and where a clear uplift profile was visibly manifest after the 1826 flood. Few roads exist to the east and yet fewer roads to the west that might have been explored after the event, and our knowledge of deformation is biased by this historical circumstance. Neither Baker nor Burnes travelled the length of the Bund to establish its lateral extent. In 1827 Burnes estimates its width as ± 16 miles (50 km), but in 1828 revises it on the basis of traveler's accounts of newly-necessary, circuitous routes around Lake Sindri, to 18 miles west to Ghari, and 24 miles east to Pacham Island (80 km). Baker indicates its length would be too difficult to survey because of the absence of drinking water. The Survey of India maps later in the century were used by Oldham to confirm that the Bund was at least 80 km long, and that morphological features suggest faulting for more than 150 km.

The southerly facing scarp width is likely to have been underestimated in 1826, since part of it was submerged, and in 1844, because it may then have been covered partly by sediments. Thus the south facing scarp could have been greater than the 600 m width estimated by Burnes, but because it determines only the closest approach of the subsurface fault to the surface, and has minor influence on deep slip parameters, its true width is of little consequence in the following analysis. The southern extent of subsidence is perhaps the

most clearly defined because this formed a fresh water lake that eventually became saline and finally dried up. Unfortunately, because a deep channel existed through the lake, some of the depths in subsequent descriptions relate the channel depth and lake depth in ways that do not permit true bathymetry to be evaluated precisely. When Burnes visited this after the 1926 flood the main river channel was fresh, as was the surrounding water in Lake Sindri. In following years the Rann shallowed, and although much of this may have been due to sedimentation, it is possible that postseismic deformation occurred (Oldham, 1926). In 1827 the width of the channel though the Bund was 40 m wide but by 1828 the flow had ceased and the waters of the Rann were saline. Deformation tapers to low values near the northern and southern limits of rupture, but no deformation is apparent >24 km from the Allah Bund (Table 1).

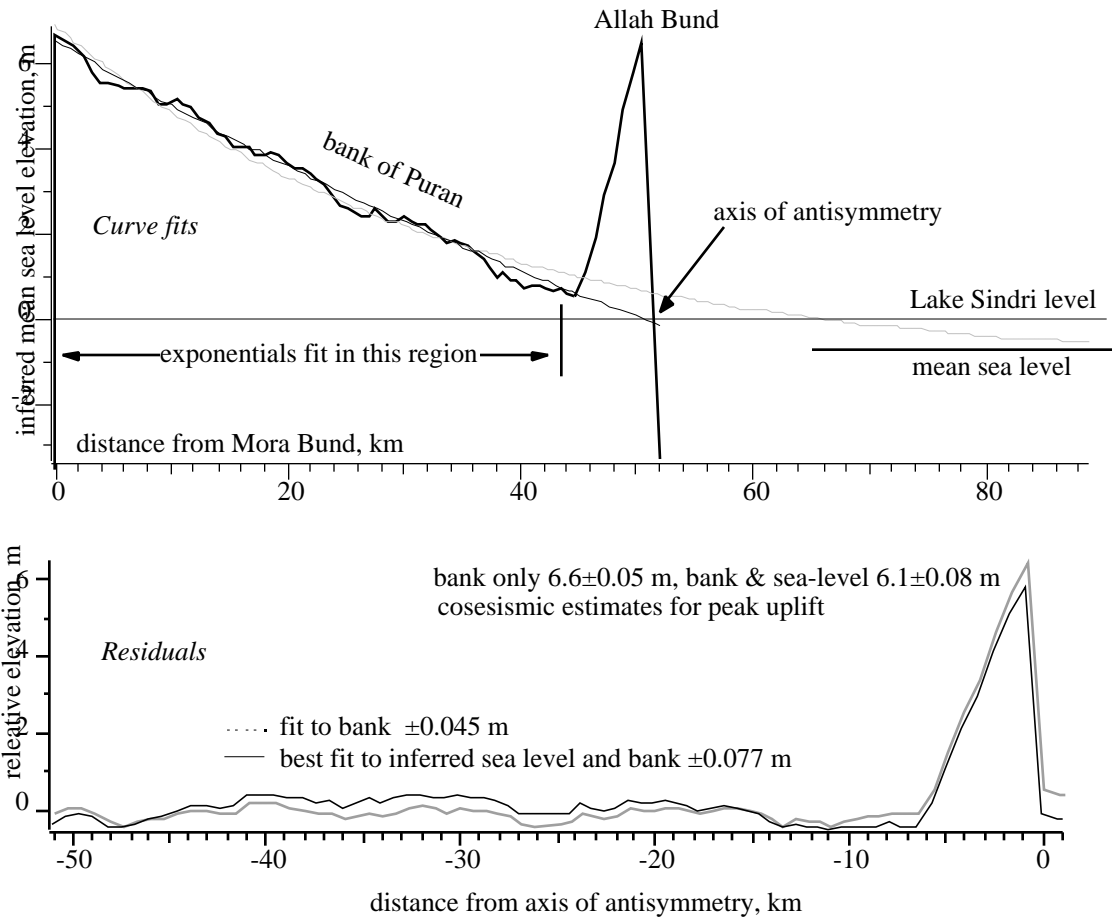


Fig. 4 Baker's 1844 profile, projected on a north-south line, with exponential approximations to the slope for the river bank (above). Lower panel shows residual elevations after subtracting inferred river profile from the observed data (below). A better fit to Baker's river-bank data is obtained if assumptions concerning morphologic relations to inferred sea level are ignored.

Slip on the fault is modeled as uniform slip in an elastic half-space using the formulation of Okada (1984). The procedure adopted to compare the surface deformation arising from one or more subsurface dislocations with the observed surface deformation, and to reject those whose theoretical geometries do not result in satisfactory agreement. By assuming two dimensional uniform slip in a northerly direction, for example, five unknowns remain to be determined - fault dip, slip, latitude, and the depth to the top and bottom of the

rupture. In practice, the latitude and depth of the rupture are determined to first order by the width and location of the section through the Allah Bund. That is, the approximate antisymmetry of the vertical deformation field requires an almost vertical fault whose surface extension must cut the Earth's surface at the southernmost expression of the Allah Bund. The half-width of the southward slope of the Allah Bund is approximately equal to the depth to the upper surface of the dislocation. In addition, simple numerical tests (Figure 5) show that a ratio of uplift to subsidence of 6: 3.3 requires the dip on the causal rupture to be to the north at 65° - 70° , requiring reverse slip on the fault.

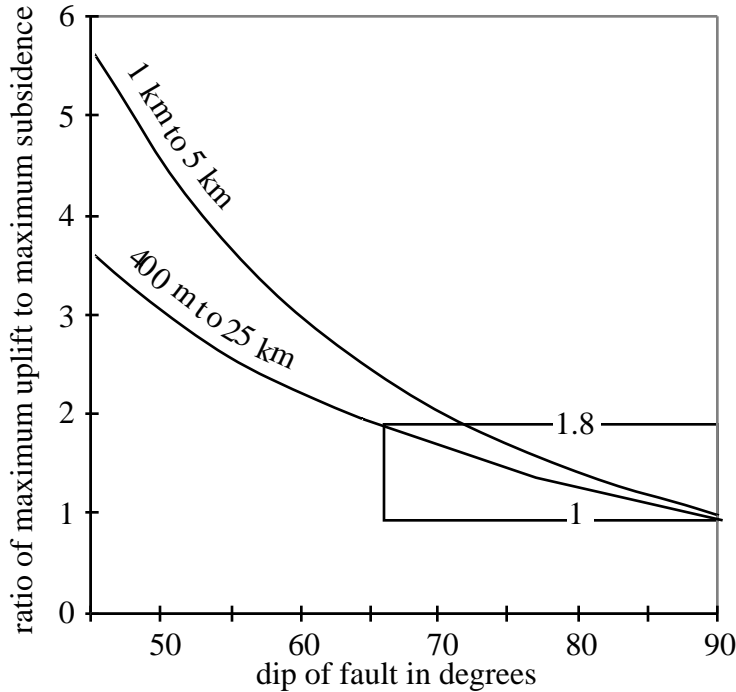


Fig. 5. The ratio of maximum uplift to maximum subsidence determines the dip of the fault in an elastic half space. A 1.8 ratio of uplift to subsidence favors a dip close to 70° largely independent of down-dip parameters (top and bottom of down-dip width indicated for two diverse solutions).

Planar dislocations constrained by maximum and minimum vertical deformation

In principle, having assumed the location and depth of the dislocation by inspection, only three observations are required to constrain the dip, slip and down-dip-width of the Kachchh rupture. Five data are available in Table 1, in addition to the continuous but incomplete spatial coverage from Baker's leveling data. Forward models were developed to estimate the sensitivity of the interpretation to each of the available data. The first suite of models (Figure 6) emulate the subsidence at Sindri (± 0.3 m), maximum uplift north of the rupture (± 0.3 m), maximum subsidence south of the rupture (± 0.3 m), and far-field constraints of uplift and subsidence less than 20 ± 10 cm at distances ± 24 km from the Bund. These models ignore the location of maximum uplift and subsidence, and instead use only their amplitudes as constraints. Least squares misfits between observations and model results for a range of possible slips and down-dip depths are estimated and contoured in terms of 1-3 sigma confidence intervals in Figure 6. Assuming the values listed in Table 1, the model misfits in Figure 6 are consistently lower for down-dip widths of less than 10 km than for larger fault widths. Acceptable combinations of dip and coseismic slip for a down-dip width of 10 km are 11.5 ± 1 m, and $68^{\circ} \pm 7^{\circ}$ respectively (1 sigma, Figure 7A).

Planar dislocations constrained by the Allah Bund profile

In models illustrated in Figures 6 and 7, Baker's profile has not been used to constrain the 1819 rupture parameters. Baker's map view of the Bund (reproduced from a tracing of the original by Oldham(1898)) shows the section (lower expanded view in Figure 3) to have been taken at N30E approximately normal to the strike of the Bund. Although Baker's numerical data are presumably more precise than the estimates for subsidence and uplift listed in Table 1, the profile has some puzzling characteristics. The transition between the

almost linear northern slope and the undeformed surface of the desert (6 km from the southern edge of the Allah Bund) is too abrupt to be caused by elastic deformation. If the shallowing of the bed of the Puran is used to estimate the northern limit of deformation, the width of the uplifted Allah Bund might be estimated to extend perhaps 4 km further north. Baker suggests that the channel may have filled by bank collapse at the mouth of the incised cut through the Bund but not to the north. A possible reason for the abrupt transition between the Bund, and the apparently undisturbed Rann north of the Bund, may be due to erosion of the bank caused by drainage of the impounded waters in 1926. A further problem with the data concerns the surprisingly linear northerly dip to the deformation field, again atypical of elastic deformation.

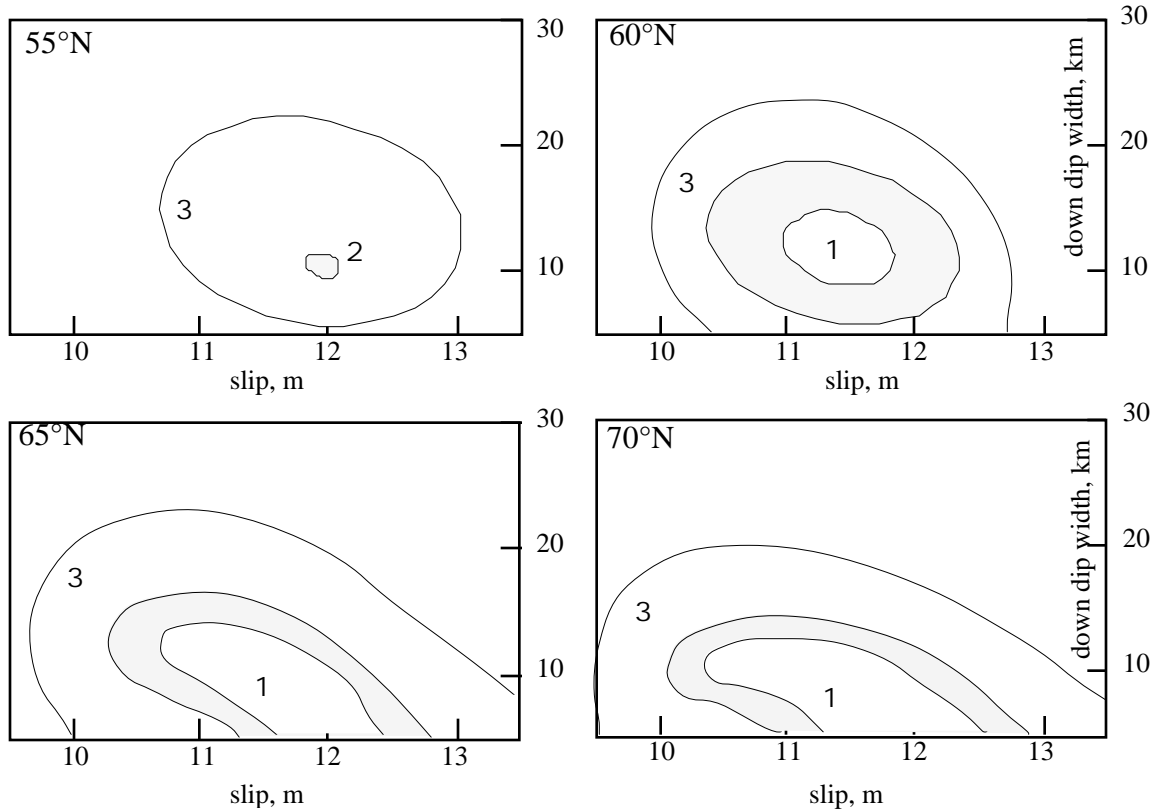


Fig.6 Misfit contours for solutions for slip and down-dip-width for four alternative northerly dips to the inferred rupture zone using constraints listed in Table 1. A down-dip width of 10 km is favored by the data, with a dip of at least 60°N

Notwithstanding these perceived problems with the levelling data, slip parameters were estimated from Baker's sectional profile of the Allah Bund by comparing the slope at 0.5 km intervals, with the theoretical slope estimated from a dislocation model. An observational uncertainty of 0.2 m per 0.5 km was assigned to these slope data, limited mainly by digitizing errors from Oldham (1898). Appropriate models require a down-dip width of 5 ± 1 km, dipping at $50 \pm 5^\circ$ with 12 ± 1 m of slip (Figure 7B). The shallower dips for the Bund-profile result from the model's attempt to fit the steep northerly slope, in addition to the subsidence evident between 6 and 8 km north of the southern edge of the Bund (Figure 4). A suite of models in which data were examined only from the southern 5.5 km of the uplifted Bund favored similar slip parameters. The models favored by the Bund data evidently prefer shallower down-dip widths than the maximum-minimum deformation field used in Figures 6 and 7A, and are inconsistent with the reported subsidence in Lake Sindri.

Subsidence at Ft. Sindri is required to be less than 1m, and maximum subsidence is preferred to be less than 2.2 m, values lower than those listed in Table 1.

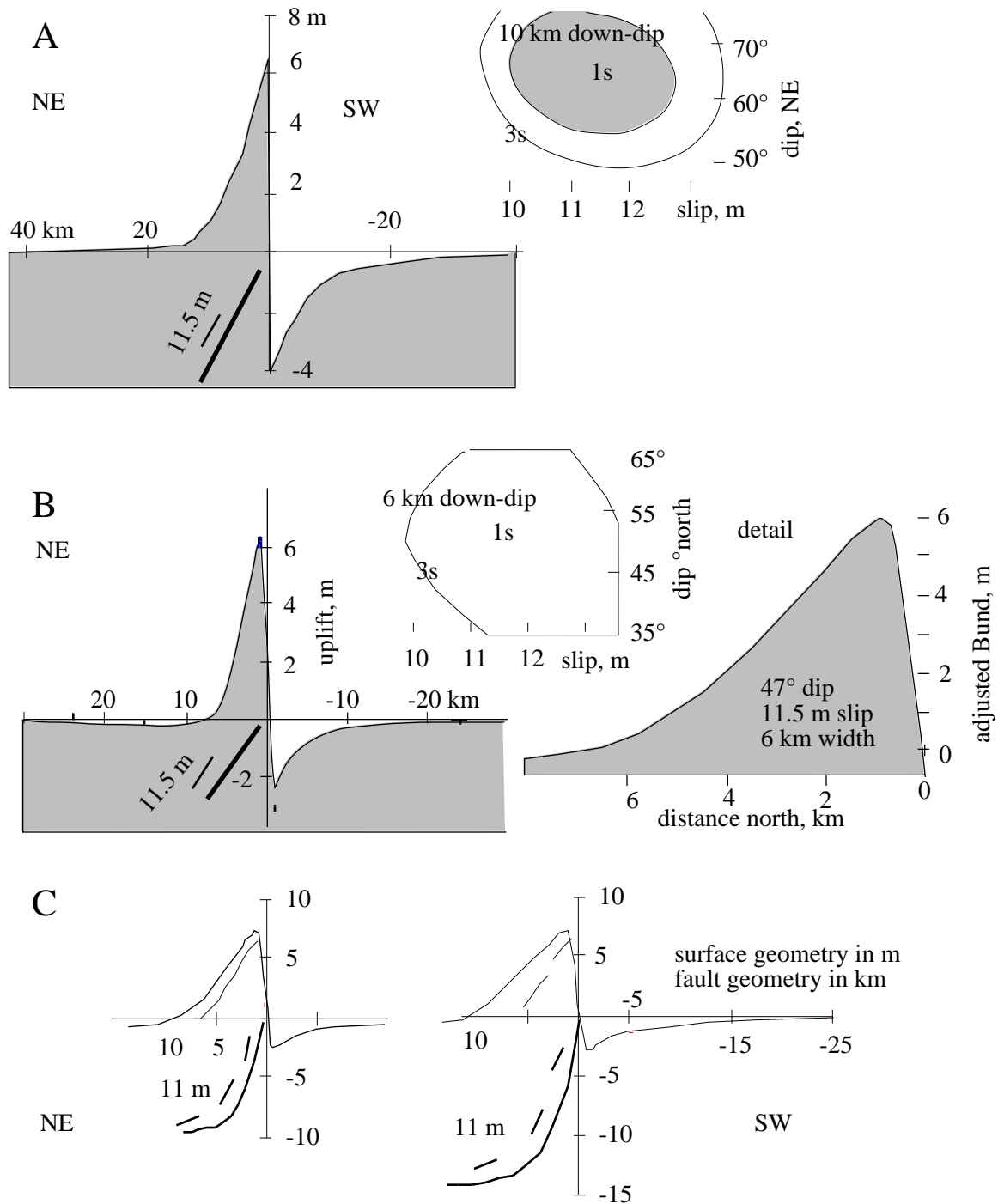


Figure 7. Contours showing a range of slip and dip solutions that fit point data from Table 1 assuming a 10 km deep dipping planar dislocation (Fig. 7A). Best fitting solution shown left. Figure 7 B shows best fitting solutions for a 5 km wide planar dislocation using only Baker's leveling profile (enlarged right) as a constraint. Figure 7C shows surface deformation arising from listric faulting. Listric faulting results in similar subsidence, much increased down-dip fault-width, but broader uplift than that associated with planar faults.

Listric fault models

The above models use planar dislocations with uniform slip. More realistic slip distributions and more complex geometries can also be proposed that also fit the data, but their exploration would be conjectural in the absence of additional constraints. Because >10 m of slip is large for a fault with <10 km down-dip width, a search for faults with longer down-dip width, but similar surface deformation is of utility. A class of listric faults was examined with a 2-D subsurface geometry of the form, $d=a+be^{-cx}$ where d is depth and x is distance from the southern edge of the Bund, and a , b and c are constants chosen to best fit the observed surface deformation field. In the examples shown the listric rupture surface was approximated by 10 short planar fault segments. These subsurface faults have steep near-surface dip and shallow dip at depth. Two geometries of several that approximate the data (but which predict a broader Bund profile) are shown in Figure 7C. The total down-dip length to the faults increases by a factor of 2-3 in these models to 15-23 km. A detailed examination of listric fault models was considered unwarranted in the absence of constraints from horizontal deformation.

Table 1 Deformation estimates for north-south section through the Allah Bund. Distances are measured relative to the inferred deformation-null separating uplift from subsidence. Uncertainties indicated as model input are used to estimate confidence levels of solutions.

parameter	maximum	minimum	model input
northerly extent of uplift <0.1 m	+ 24km	+6 km	6±1 km
maximum uplift	+6.6 m	+6.1 m	6.3±0.3 m
location of maximum uplift	+1 km	+0.6 km	1±0.2 km
antisymmetry null	0	0	-
location of maximum subsidence	-1 km	-200 m	-
maximum subsidence	-4.5 m	-2.5 m	-3.5±.3 m
subsidence at Sindri	-3.5 m	-1.5 m	-1.5±.3 m
location of Sindri	-6 km	-5 km	-6±1 km
southerly extent of subsidence >-0.1m	-40 km	-24 km	-24±2 km

Location and Magnitude of the 1819 Earthquake

No accurate estimates for the epicenter for the 1819 earthquake have hitherto been proposed although Chung and Gao (1995) attribute inappropriate locations south of the Allah Bund to Quittmeyer and Jacob (1979) and Chandra (1977), based on these authors' approximated coordinates. The above analytical solutions suggest that the 1819 rupture occurred 5-15 km north or northeast of the Allah Bund. The longitude is not determined by the available data to better than 1 degree.

The along-strike length of the Allah Bund is estimated by Oldham (1926) as 80-150 km, from which a geometric seismic moment can be estimated for the rupture. Because the eastward extension of the fault and its sense of slip is unconstrained by the historical record, it is ignored in the following estimates for magnitude. Using the relation $M_o = \mu * \text{slip} * L * W$ where $M_w = 2/3(\log M_o) + 10.6$ the range of parameters determined above correspond to a local magnitude of $M_L = 7.7 \pm 0.2$ using typical values for the rigidity modulus μ , and a range of down dip widths of 10-20 km.

An alternative method to estimate the magnitude is to use the intensity data reported for the event. An empirical relation between intensity and area of shaking constrained by 6 Indian events including the Anjar (1956) event is discussed by Johnson (1996) who offers a magnitude of $M = 7.5-8$ for the 1819 event (7.8 in Johnston and Kanter, 1990). A slightly lower intensity magnitude can be estimated from the data of Figure 1 where significant attenuation of intensity northward is evident, causing the isoseismals to be non-circular, especially for lower intensities. Moment magnitude, M_o , of an earthquake in the F94 model

is related to the area, S , enclosed within a specified isoseismal intensity contour, by an expression of the form

$$\log M_0 = a + b \log S + c S \quad (1)$$

where the constants a , b and c are determined empirically for each isoseismal area. Intensity magnitudes are shown in Table 2, although the intensity data from which they are derived are sparse and of uncertain quality. A mean magnitude estimated from the intensity data is $M=7.5\pm 0.2$ in reasonable agreement with the deformation data. Combining the intensity and deformation data, a preferred magnitude of $M=7.7\pm 0.2$ is assumed for the 1819 event. A more careful evaluation of authentic felt reports is needed to improve significantly on the mapped isoseismal estimation of magnitude.

Table 2 Isoseismal Areas and estimated Moment Magnitudes for the 1819 earthquake. Constants a , b , and c are preferred values from Johnson (1996).

Intensity	felt	VIII	
a	17.3	24.1	
b	0.959	0.44	
c	0.00126	0.00586	
radius	1600 km	140 km	
M_0 F94C	27.23	27.66	$\log_{10}(\text{dyne cm})$.
M	7.4	7.7	

Discussion

Although several forms of subsurface slip geometry are admitted by the data, they share several common features. Maximum and minimum vertical deformation values estimated six years after the earthquake yield preferred solutions for a $67\pm 5^\circ$ dipping fault, with a down-dip width of 6-10 km, and the short profile across the Bund measured 25 years after the earthquake, favours a dislocation with $50\pm 5^\circ$ northerly dip, 12 ± 1 m of slip and a down-dip width of 5-6 km. Listric faulting with dip shallowing to the NE is an alternative subsurface geometry that requires approximately 11 m of slip on a steeply NE dipping near-surface fault.

As noted above, it is assumed that slip vector was at N30E, normal to the Bund, and consistent with both the NE directed Indo-Asian plate convergence vector (Paul et al., 1994) and the p -axes of regional earthquakes (Chung, 1993; Chung and Gao, 1995). A N45E slip vector would require steeper dips, and shorter down-dip widths. Hence, the estimated dips are lower bounds, and a steep fault plane is a necessary, common feature of any interpretation of the data near the Allah Bund. At dips of 50° - 59° "Byerlee" friction causes a fault to "lock" in response to horizontal compression, unless significant fluid overpressuring is available to reduce friction on the fault (Sibson and Xie, 1998). The geometry of the Kachchh rupture is thus severely misoriented for reverse slip, and would have required fluid overpressuring to promote rupture. Fluid overpressuring is believed to be widespread in the lower crust (Sibson, 1992). Reservoir-induced seismicity throughout India suggests that fluid pressures play an important role in triggering shallow seismicity, and it is possible that this may be a common slip mechanism for the Indian subcontinent. The thick sediments in the Indus fan and the Rann of Kachchh, moreover, have favorable conditions for overpressuring. A consequence of probable north-easterly directed slip is that Oldham's inferred fault east of the Allah Bund, if it indeed exists, could absorb a large left-lateral strike-slip component with insignificant convergence, and thus minor vertical deformation (Figure 8).

Oldham (1926) suggests that postseismic surface changes occurred in the Sindri region that were not entirely the result of silting or precipitation of evaporites. The various sketches of Fort Sindri show it to have been initially surrounded by water close to the high-

tide or monsoon-surge level, and a few decades later to have been surrounded by dry land. Oldham suggests that this change was caused by a relaxation of coseismic subsidence. The wavelength of the vertical changes are considered too short to result from visco-elastic adjustment of the elastic crust. However, Brune (personal communication 1997) has demonstrated in computer simulations and foam rubber models, that dynamic effects associated with propagating wrinkles along the fault plane (Brune et al 1993; Andrews and BenZion, 1997), can cause overshoot or undershoot during rupture, that may differ substantially from the static-frictionless deformation of models examined in this article. Presumably aftershocks, afterslip or post-seismic creep, would bring surface deformation closer to the static deformation field. However, if this were the case in the Sindri region, and initial subsidence at Fort Sindri were an artifact of dynamic rupture, we would expect that relaxation of the footwall would be evident also in relaxation of the hanging wall measured by Baker.

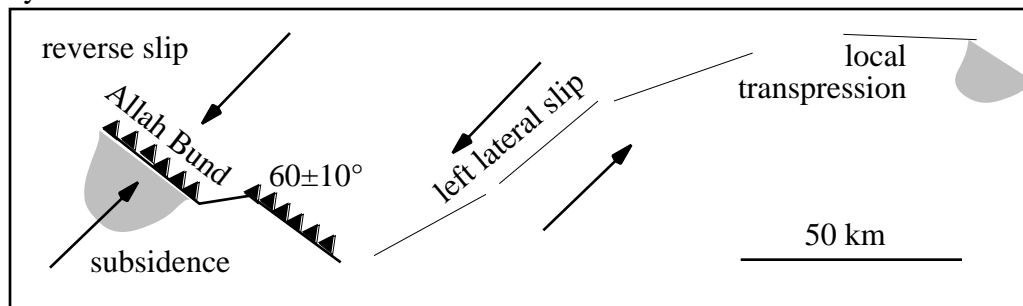


Fig. 8 Simplified sketch of inferred NE-directed convergence during the 1819 earthquake. Steep reverse slip causes uplift NE the Allah Bund (barbs). The existence and style of deformation east of Bund is speculative, because contemporary field observations are absent.

Both Baker's data and Burnes' data are obtained from isolated samples of a feature whose along-strike length and surface geometry renders approximate any simple elastic deformation model. The amplitude of slip required in each solution is considerable for along-strike dimensions of 80 km, hence Oldham's somewhat weak evidence for 150 km of along-strike slip is consistent with this aspect of the data. In addition, a down-dip width of 6 km is unexpectedly small to permit >10 m of surface rupture. Had this occurred, mean dilatational extension along each side of the fault plane would have exceeded 1000 μ strain, with a correspondingly high stress drop.

The modeling presented here is insensitive to along-strike slip, and to variations of slip along strike. It is curious that the impressive dip-slip component resulted in no surface fault scarp since it appears to have reached at least to within a few hundred meters of the surface. Presumably, for this to occur, the surface alluvium would have to have been draped over the rupture in the near-surface. It is possible, also that a fault scarp, or several scarps and fissures did occur along parts of the Bund, the details of which were not related in second-hand accounts of the event.

A curious feature of the region is the absence of a pronounced physiographic feature along the Bund (the Bund is a mound, not a mountain). This suggests that recurrence intervals are low, or that reverse slip is a relatively recent process for the Kachchh fault, which like nearby faults associated with the Kachchh rift system, are currently being reactivated in a reverse sense. The recurrence of earthquakes in the Kachchh region would appear to be accessible to paleoseismic techniques and several issues associated with the 1819 event are worthy of field investigation. For example, the 1826 flood will have deposited fresh-water sediments above the salt deposits on the floor of Lake Sindri, providing a measure of the current form of the subsidence basin. Investigations of ponding south of the Bund, along the Rann to the west and far east of the mapped expression of the 1819 Bund, would clarify the along-strike length of faulting, and its potential sinistral

component. Investigations of ponding north of the Bund might also reveal the transient strand line of the 1826 flood. Surface studies of the eastern expression of the fault might reveal evidence for left lateral slip, although many of the drainages across the scarp would have been initiated only after the earthquake.

The rate of secular strain contraction of India is not known in the Kachchh region but is immeasurably small (<0.1 μ strain per century) on the Indian Peninsula (Paul et al, 1992). If similar rates prevail in the Kachchh region, the strain contraction released by the Kachchh event would require 100 kyears for its renewal, an interval long compared to the time needed to erode the 1819 scarp, a problem common to Peninsular India earthquakes (Rajendran et al. 1996). It is therefore unlikely that future large events will recur soon near the epicentre of the 1819 Kachchh event. However, it is possible that the 1819 event may have broken a section of a larger fault system. The epicentres of large historical earthquakes are not well known. In 1534 a tsunami in the Gulf of Cambay (Logan, 1887 p. 322) was reported by the crew of Vasco da Gama's fleet when it was anchored offshore at Dabul. Hobson Jobson (Yule and Burnell, 1903) locates Dabul (Dabhul or Dabyl) between Goa and Bombay at $17^{\circ}34'N$, a location shown on early European maps of navigation around the Indian coast. If this were the near the epicentre, the event would be too far south to have been an Indus Delta event. A severe earthquake in the Indus Delta, to the east of Kachchh, occurred in 1668 in which 15,000 houses reportedly sunk into the ground (Oldham 1883). Cities along the northern Arabian Sea are much larger now than when historical earthquakes visited nearby geographic regions. In particular, Karachi, less than 200 km from Kachchh, now hosts a population of more than 12 million people. An $M>7$ earthquake within 50 km of Karachi cannot be excluded.

Conclusions

Solutions derived from subsets of data obtained 6 years, and 25 years after the earthquake share in common, coseismic reverse slip exceeding 11 m on a north-easterly, dipping fault, terminating in the shallow subsurface. The amount of slip is large for inferred planar dislocations with down-dip widths of 5-10 km, although longer down-dip widths are permitted by forms of listric faulting. It is assumed that slip was oriented NE, normal to the strike of the Allah Bund, approximately parallel to the Indo-Asian convergence direction, and to the p-axes of recent earthquakes in the region. The details of the deformation field across the uplifted Bund are inconsistent with simple elastic deformation, and it is considered possible that the deformation near Sindri was amplified by dynamic processes during rupture. The geometric moment magnitude of the event is estimated as $M=7.7\pm 0.2$, similar to a magnitude of $M=7.5\pm 0.4$ obtained from the intensity distribution.

Reverse slip on a fault dipping greater than 50° requires fluid overpressuring of the rupture plane for slip to occur. Although this is not common in the near-surface, it may be ubiquitous at mid-crustal depths in India where artificial reservoirs frequently induce local earthquakes. Moreover, the Rann of Kachchh and Indus Delta are clearly locations of sediment compaction where fluid overpressuring would not be unexpected.

Because earthquake recurrence intervals may exceed many thousands of years it is likely that future large earthquakes near the Arabian coastline of India will occur in intervening regions, and not near the epicentral regions of recent moderate events. That reverse slip can occur on a >80 km long rupture within 200 km of Karachi has important consequences for seismic hazards in that city, in view of the probable westward extension of the causal fault system.

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Appendix

The following extracts are transcribed from approximately 50 pages of handwritten minutes and letters, sent to and from the Governors Office in Bombay, concerning the 16 June 1819 Kachchh earthquake in the days following the event. Captain James MacMurdo was the British representative (Resident) in Kachchh, and in addition to these government reports, he subsequently submitted a collection of papers describing the earthquake to the Literary Society of Bombay. These were published posthumously in Volume 3 (1823. MacMurdo died from cholera at the age of 33 and an obituary appears in the same volume). Papers based on his early travels continued to surface for the next few decades and a brief history of his short career is summarized in Gosh (1977). Unlike Burnes and Baker who describe crustal deformation near Sindri 7 and 35 years respectively after the event, MacMurdo knew the area intimately before the earthquake and although he experienced the earthquake at first hand, he did so on the Kachchh mainland, and at the time these letters were written was unaware of deformation near and north of Sindri.

The data describe severe damage in Bhooj and Anjar (Mercalli Intensity X), and hint at similar damage in many villages of Kachchh. Shaking at Ahmedabad and Surat is less severe (Perhaps intensity 7) and was reported directly to Bombay. In Bombay the event is scarcely felt.

From Boards Collections 15426 to 15427 1820-1821
Volume 620 RECORD DEPARTMENT INDIA OFFICE LIBRARY. F/4/620
BOMBAY PUBLIC CONSULTATIONS, Exams Office Nov. 1820

Bombay 7 July 1819

Extract Public Letters from Bombay to East India House, London. Dated 7 July 1819

2. We are concerned to report to your Honorable Court that about twenty minutes past seven in the evening of the 16th last month, a slight shock of an earthquake was very perceptibly felt in various parts of the Island. The shock did not last above a minute and no injury appears to have been sustained from its effects, indeed the concussion was so slight that many persons did not notice it, and entertained doubts of it having taken place, but your Honorable Court will observe with regret from the enclosed documents that its consequences were very severely felt at the Northern Stations under this government, particularly at Ahmedabad and also in Cutch. At the former it has destroyed the beautiful shaking minarets of the Imra Musjed which were so long the ornament and admiration of the East, and done considerable damage to other Public and Private Buildings.
3. At Anjar the Fort wall with its towers and Guns have been levelled to the ground with three fourths of the houses in the Town, those which have been left standing have also sustained injury and the general destruction is emphatically stated by the resident to have reduced a flourishing population in one moment to wretchedness and misery. The lives lost on this occasion, as far as they could be correctly ascertained at the date of Captain McMurdo's dispatch amount to upwards of one hundred.
4. Similar damages have been done at Bhooj and we fear with an equal loss in human life.
5. We have still to learn the extent of this awful visitation, but private letters from all parts of Guzerat and Kattywar concur in stating it to have been felt with great severity through the country.
6. Since the preceding paragraphs were written we have been furnished with copies of private letters from Lt. Col. Colin Milnes of his Majesty's 65th Regiment and commanding the troops in Cutch which together with the accounts given in the Bombay Gazette of this date convey a most lamentable picture of the effects of the Earthquake.

Bombay 8 July 1819

Public Department

To Joseph Dart esq. Secretary at the East India House, London.

Sir,

In reference to the 5th paragraph of the letter from this government to the Honorable the Court of Directors of yesterday's date which has been closed and sent on the *Lady Barrington*, I am directed by the Right Honourable the Governor in Council to transmit to you for information of the Honorable Court the accompanying copy of one from the Resident at Anjar dated the 19th Ultimo detailing the particulars of the

injury sustained at that place and its vicinity from the earthquake with which they were visited on the 16th of last month and the three following days.

I have the honor to be Sir, Your obedient Servant, signed
H Newnham. Acting Chief Secretary., Bombay Castle 8 July 1819

Ahmedabad 7 July 1819

Extract Bombay Public Consultations

Read the following letter from the acting judge and Criminal Judge at Ahmedabad to Mr. Acting Secretary Newnham, dated the 17th Ultimo.

Sir,

para.1 Yesterday afternoon at 7 o'clock precisely a very severe shock of an earthquake was felt in this city, the swell came from the direction of South West, there are various opinions as to the time the shock lasted. I think it continued about two minutes.

2. Happily no lives have been lost, but the damage which has been done has been considerable. The Minarets of the Juma Musjid, the highest and most beautiful in the place were thrown down, various other Minarets outside the walls have shared the same fate, and many of the Mosques have been otherwise shattered and much injured. One of the gates of the town has also fallen. Of the Government buildings the Adawlut, has alone been affected. None of the walls have actually fallen, but they have been cracked by the shock in several places, and it will be necessary therefore to request the engineer office at this place to inspect them.

3. Several private houses have I understand been destroyed but I am not yet acquainted with the particulars on this head. I shall make enquiry concerning the damage this sustained. If it shall be found to be very heavy on a consideration of the circumstances in life of those by whom it has been sustained, the liberality of Government will not fail, I should hope, to afford some alleviation of their misfortune.

4. During the confusion occasioned by the shock, a prisoner who was in confinement for security escaped from the Gaol, the Sepoys on guard had all left the gate in the moment of alarm and he took this opportunity to pass out unobserved.

5. Several shocks have certainly been felt in the night and again very sensibly this morning.

I have the honour to be etc.

Chas. Norris

Acting Judge and Criminal judge, Ahmedabad Adawlut 1819.

Minutes 1 July: Ordered that Mr. Norris be informed that the governor in Council has great satisfaction in learning that no lives have been lost on the occasion of the earthquake felt at Ahmedabad on the 16th of last month, the effects of which were also felt at this place though in a trifling degree.

Resolved that Mr. Norris be informed that the Governor in Council approves of his having called on the Engineers office to examine the damage which the Adawlut has sustained, and to make any temporary repairs that the circumstances may render necessary. Mr. Norris will however be careful not to incur any considerable expense without previously submitting an estimate and obtaining the sanction of the government.

On the receipt of the further report on the damage sustained by private houses, he will be furnished with the instructions of the government on any suggestions that he may deem worthy of notice.

Read the following letter from the Superintendent of the Marine dated 24th. ultimo with enclosure.

To The Right Honorable Sir Evan Nepean, President and Governor in Council

Right Honorable Sir, Having received a communication from Captain J. Pruen the Commodore at Surat, under date 17th instant, reporting the circumstances which had come within his observation on the awful occasion of an Earthquake with which Surat and its vicinity had been visited, and the matter recorded in Captain Pruen's letter may not have come to the knowledge of the Right Honorable the Governor in Council, I have deemed it expeditions to transmit copy thereof for the information of your honorable board.

Henry Meriton, Superintendents Office Bombay 24 June 1819

Surat 17 June 1819

To Henry Meriton Esq., Superintendents Office Bombay 17 June 1819

I have the honor to inform you at 20 before 8 PM yesterday evening the City of Surat and for some miles round and the opposite bank of the Taply, were visited by that Phenomenon Earthquake in a very

awful degree. When it first began I was lying down on my Couch, being still an Invalid. I found the whole house in serious agitation. The furniture all in motion and a small table close to me so much so as to keep striking the wall the lamp moving from east to west with the house about 6 or 8 inches each way. I got down stair as fast as possible about three minutes had transpired before I got out of the house, and I felt myself a little giddy. I found a number of people collected outside looking with astonishment at my house, which stands alone, and which was in such agitation I expected it to fall every second. The earth under our feet was by this time convulsed and seemed as if it was floating on a long ground swell trying to break it away through, and from its very great motion I expected to see the ground crack. The shock lasted about 5 or 6 minutes and appeared to me to run from East to West. The inhabitants were much alarmed. Not a breath of wind was moving, with a clear sky, nor was there the least warning of its approach. On enquiry this morning I find several accidents have happened to houses, and at the village of Omer about 2 miles west, several Houses fell down. A Parsee Pagoda fell down in one side, and reports said one poor man was killed 10 minutes past 10 AM. We have just had another shock that lasted only one minute. I likewise felt two slight ones about 8:30 last night and at 10:10 am another shock. This shock stopped my watch, the glasses containing the oil in the lamp in two or three houses were upset. The well in the Jail whose water was about four feet below the earth was forced up to run over. The river water was likewise much agitated. A tank of water in the Bazar likewise threw its water out. Time alone will inform us whether it will be a partial convulsion of nature in the bowels of the Earth near this latitude caused by some great eruption at a far distant spot.

I have felt it part of my duty to give you Sir, this slight information, but no doubt a more able pen, will give it Government. I have only related plain and simple facts for your information I have the honour to be etc.

J. Pruen

Surat 17 June 1819.

P.S. I find that General Cook's watch stopped at 10:08 this morning.

Minutes: Ordered the Superintendent be informed that from the violence of the shocks and their long continuance it is fortunate so little damage has been sustained from the earthquake felt at Surat on the 16th Ultimo. Read the following letter from the Resident at Bhooj and Collector at Anjar to Mr. Acting Secretary Newnham dated the 17th Ultimo.

Anjar 17 June 1819

Sir, It is with sincere regret that I have to inform you that this place was visited by an earthquake yesterday evening at 10 minutes before 7 O'clock. The effects of the shock, which lasted nearly 2 minutes, have been the leveling of the Fort Wall to the ground. Not a hundred yards of the wall remain in any one spot, and guns, towers etc. are all hurled in one mass of ruin.

The destruction in the town has been distressing and awful. Not 1/4 of the houses are standing and those that do remain are all ruined. I cannot yet state the particulars of the losses, but I may in one word say that a flourishing population has been reduced in one moment to wretchedness and misery. I fear we shall have to lament the loss of upwards of one hundred people besides those hurt. Reports from the country state similar disasters in all the villages round about, and letters from Bhooj inform us that the Fort is much in the same condition as Anjar. Slight shocks continue to be felt and I shall (at) the first leisure moment, report such particulars as I may be able to collect.

I have the honor to be etc.

J. McMurdo

Ordered that our concern be expressed to Captain McMurdo at the effects produced from the earthquake felt at Anjar etc, with intimation that we are anxious to receive further accounts of the extent of the damages sustained by the adjacent country.

Recorded the following extracts of private letters from Colonel Milnes on the subject of the earthquake at Anjar.

Bhooj 17 June 1819

We are at present in a shocking state of alarm here - last evening between 6 and 7 o'clock we were visited by a dreadful earthquake - The wall that surrounded Bhooj is almost levelled with the ground and the few Towers which are left standing are merely broken remains; The houses generally unroofed; others in ruins, and most of the larger buildings including the Palace greatly injured. The wall of the Hill Fort down

in many places and a complete breach near the gateway. The right of our camp rest a short distance on the left of the latter, fronting the tower, and extends along the bottom of the hill, to a little beyond the large tower on the south most point. I am happy to say that we have had no one materially hurt- two Sepoys only bruised, who were on duty in the town, but I fear that a great many casualties have occurred there among the poor natives. Some hundreds are said to have lost their lives. There is at present so much confusion that the number cannot be ascertained.

We had several shocks during the night and they have continued at intervals this day, the last one about two hours ago, when I could scarcely keep upon my legs, The sensation is horrible while it lasts. They have suffered we understand, in the same way at Anjar.

Bhoj 18 June 1819

We still continue here in a state of doubtfulness and extreme anxiety. Every three hours we feel the Earth trembling under us but in a slighter degree. The inhabitants quitted the town yesterday, and slept out last night in the plains and about the neighbouring hills. The number of lives at present ascertained to be lost is almost 500.

I have just received a letter from Captain MacMurdo (who went to Anjar before the late events) for Dooly Bearers to assist in clearing away the streets and gates there; which he says , if not done before the rain falls, the town will be swamped. They are in wretched state there it appears.

Bhoj 19 June 1819

The last trembling we had was at 12 o'clock this day, rather severe, so that we are still kept in dread. Between 50 and 100 missing bodies have been discovered in the Town. Before this awful event took place we had not the least warning of its approach whatever. On the evening it occurred I took a short ride. The weather was delightful, a clear sky, a gentle breeze and perfectly cool, there having been a heavy fall of rain only a few days before. As I was returning home in a quick walk, some time after the Sun had set , when within about a quarter of a mile of the front of our camp I suddenly perceived something very unusual and extraordinary in the paces of my horse. His legs appeared to be in motion but he seemed to make no way whatever, at the same time, I felt a sort of dizziness in my head, and a sickness in my stomach, supposing this to proceed from the strange motion of the horse and that he was ill and might fall under me, I was thinking to dismount when my attention was distracted by an immense cloud of dust bursting out from the center of the hill Fort, which I took to be an explosion of gunpowder, and the first impression on me was that an accident had happened to the Magazine. But on casting my eyes to the left towards Bhoj, I observed the whole Town from one extreme to the other completely enveloped in a similar cloud, and on looking behind me I also observed the same appearance at no great distance in that quarter. I was then satisfied of its being dust and not Gunpowder, and concluded it to be some description of Typhoon or Hurricane, but still I was perplexed to account for its continuing so perfectly calm and serene about the spot where I was standing, and there not being the least symptom of a wind rising. I was just about moving quickly into Camp when I saw Captain Wilson, the assistant resident, who had been riding with me and from whom I had parted only a few minutes before, coming towards me from the town. He acquainted me that he was entering by one of the gateways when there was a general crash and that the whole place had fallen down. Upon this I of course knew at once the cause, but until that moment had not the most distant idea of its being an earthquake. When I go to my tent I found that the Table which had been laid out for dinner was thrown over and everything on it smashed to pieces.

The deposed Rao's mother and his Father's wives were among the sufferers in town. Some part of the Palace fell upon her, the body not yet found.

Extract Bombay Public Consultations 14 July 1819

Read the following letter from the Resident at Anjar 19 June 1819

Anjar 19 June 1819

To William Newnham esq., Acting Chief secretary to Government of Bombay

Sir 1. Since my address under the 17th instant accounts have been received from various quarters of the country.. There is every reason to believe that the shock has destroyed in a greater or lesser degree, every fort and town from Arrisir to Luckput. many of the villages round about Anjar are reduced to heaps of rubbish, and I fear that those in Cutch an Wagir generally are little less injured. Bhoj has been a great sufferer. The wall to the town level with the ground. The palace in many parts in the same state, and the private dwelling houses in ruins. The loss of lives is not exactly ascertained but the lowest calculation

makes it 500 people. The Rao's family has escaped, with the exception of the old lady, the widow of Rao Raidhan. Mandavee is stated to have suffered less than other places and is said to have lost only 125 people. Accounts from Coorbee state that town to be in ruins.

2. Our loss in Anjar has been greater than I had at first supposed. We have to lament the loss of 166 lives besides and double that number wounded, many of whom severely. Out of 4500 houses of which the town is composed, about 1500 are so completely destroyed as to not leave one stone upon another. They are overturned from the very foundation. About 1000 more are laid in ruins and so dreadful has been the shock, that of the standing some are injured and many uninhabitable. The fort cannot now bear that name, as there is no a third of it remaining in different parts, and even those are likely to fall with the first rains.

3. It is impossible to describe the misery of the unfortunate people. Their property buried in ruins, and exposed without the possibility of saving it (from) the weather. Their families, some among the ruins, and some in the open fields exposed in the same wretched condition, the calamity has been so general that not a labourer can be had for money. In the richer, and more respectable class of people, are seen sitting surrounded by their families, in the spot where their houses once stood in the most helpless and destitute situation.

4. I have not in my power to assist them materially, but what is in my power I have done. Free ingress and egress has been given to all property without taxes, and I venture to suggest to Government to continue this favour towards the people at least for some months to come. It seems impossible to levy duties from a town in ruins.

5. I have set the labouring people about cleaning the streets and making a passage for the water to escape, for if the rains were to set in with violence the lower and greater part of the town would, in the present state, be 6 feet under water.

6. I applied to the commanding officer, for the assistance of a working party, but I am sorry to say that he did not think it proper to allow the men to be employed in assisting the inhabitants. Enclosed is the correspondence for the information of the government.

7. Since writing the foregoing, 150 Dooley Bearers have been kindly sent by Colonel Milnes to our assistance.

I have the honour to be etc.

J. MacMurdo, Resident at Bhooj and Collector at Anjar.

Anjar 19 June 1819.

P.S. I have neglected to observe that the Public Buildings of every description including the judges dwelling house, offices etc. are rendered unsafe to inhabit.

Anjar 17 June 1819 MacMurdo to Morgan requesting help

To Captain James Morgan Commanding at Anjar. Sir,

1. It is of the utmost importance for the safety of the town of Anjar that the Warsamoree and Sortia gateways, and the water drains should be cleared of ruins, in order that the water may pass off, which would otherwise, in case of rain, swamp the better half of the town.

2. In consequence of the threatening appearance of the weather, and all the town people being at present too much employed in rescuing their families and small remains of property, I take the liberty to request, should you have no objection, that a proportion of the regular Sepoys be permitted to aid for a few days, for the public good by their labor, in working parties, to clear the passages for water and the gateways. I make this request with less hesitation as the dreadful misfortune has fallen with comparatively trifling weight upon the men of the Detachment.

I have the honor to be etc.,

L MacMurdo 17 June 1819

Anjar 17 June 1819 Morgan to MacMurdo denying help

To Capt, J, MacMurdo Resident etc. etc.

Sir Consistent with the military duties required of the Garrison under existing circumstances, I am concerned to say it is not in my power to comply with your request. Their duties, I am ready to allow should give way to necessities of greater magnitude, but until that is the case I conceive the employment of soldiers in occupations of the nature required, would be improper and inconsistent with the established use of the service.

I have the honor to be etc.

Thos Morgan,

Captain Commanding Anjar. 17 June 1819.

Ahmedabad 28 June 1819 Request to repair the Mosque

Sir, The Khazee of this city having the name of the Muhamedan inhabitants requested me to transmit the accompanying petition to Government to repair the Juma Muzjed. I have the honour to forward it with a translation for the purposes of being laid before the honorable board.

2. Upon a subject of this kind I can of course have little to say; there is certainly scarcely any thing that could afford so strong a contrast to the principles of the government to which we have succeeded, as an attention to the wishes of the people on this occasion, and that could excite in so lively a manner the gratitude of our subjects of all ranks and persuasions, for it must be observed that the memory of Sultan Ahmed is held in respect and veneration not only by Moosulmans but also by Hindoos, as that of their Protector and the Founder of their City.

3. There must at the same time be various considerations which must materially affect the decision of government on this question, and upon which I cannot presume to offer any observations.

4. With reference to my letter of the 17th I beg that you will inform the Hon. Board that private property has not suffered from the earthquake of the 16th in any way to make public assistance at all necessary.

Charles Norris, 28 June 1819 Ahmedabad.

Translation of the petition

“In the evening of the 16 June 1819 great alarm and apprehension was occasioned throughout the city by the shock of an earthquake. It was so severe that all the people thought that the last day was come. All the buildings and houses old and new shook like rattans and were very nearby all falling and killing thousands of men. The time however of the people was not come and God was merciful so that the earthquake ceased, but great damage was done to the public buildings. The old stone buildings, which were erected four hundred years ago or more, the stone mosques, Razahs and domes both within and without the city, the stone minarets of the mosques, remarkable for their height and beauty, which need not have fallen before the last day, have all been broken and thrown down. But the greatest loss has been in the minarets of the Iuma Muzjed, which was built by Sultan Ahmed Badshah, the founder of the city. It stands in the middle of the Bazaar, and of the city, and its minarets were the greatest ornament to the city, and to the Mosque. Both the Mosque and the minarets were the largest in the place, and the Minarets were also in this particular, remarkable, in that a person going up one them and shaking it, could communicate the motion to the other, so that people came from all quarters to admire them. Both these minarets have been thrown down by the shock and the whole city deprived of its greatest ornament and the mosque is quite deformed.”

[Another two pages follow asking the government to repair the Mosque etc. These are omitted for brevity]

Resolved that Mr. Norris be informed that government deem it proper to decline entering into any engagement for the re-erection of the Minarets of the Iumma Musjed at Ahmedabad, as the expense attending it would be considerable and the buildings themselves are more ornamental than useful.

Bhooj 23 June 1819, Read 21 July 1819,

I have the honor to report for the information of government that since I returned to Bhooj I have ascertained the damage sustained in that town to be much greater than I had supposed. The loss in lives has not been correctly ascertained, as bodies continue to be dug out from the ruins. About a thousand have already been found. The fort is in a most ruinous state, but although there is little of it entire, there are few places so completely leveled to the ground as that of Anjar. As near as can be calculated seven thousand houses have been overturned, and few or none in the city left uninjured.

The Palace which is an immense mass of building has been dreadfully shattered. All the upper parts overturned, and the pile, as low as the lower floor, rent and shook, so as to render the whole nearly uninhabitable. I am happy to say that the Rao's family has escaped without further loss than already reported. The Ex Rao is removed to tents near those of the residency, where he is guarded by a detachment of 100 Rank and File. The Rao Desul and all the females of the family, are also in tents outside of the town, where I hope to be able to persuade them to remain until some place can be made secure for their reception.

I may observe that the whole of Cutch has suffered nearly equally in regard to the loss of houses, yet I am glad to say that the proportion of lives lost in different places bears no affinity. Perhaps Bhooj has lost as many as the whole of Cutch put together. In Mandavi 116 and in Luckput 150 are said to have suffered. The Iharyjas have in some instances lost members of their families. Koteree, Thera , Koira, Mothana and Nangercha are spoken of as having experienced the most dreadful effects from the shock, but perhaps there is little difference anywhere.

A number of phenomenon are said to have occurred at the moment of the shock, but I shall only remark that which appears the most striking. The Runn and Bhunee on the north of Cutch, between that Province and the isolated district of Kouvra, which was quite dry was suddenly filled with a sheet of water, the extent of which east and west was not known, but its breadth was generally about 6 miles, and its depth gradually increased to upwards of 2.5 feet. after which, in a few hours, the waters subsided to about half that quantity. Horseman who crossed this tract on the day following the shock, describe a number of cones of soft sand elevated above the water , the tops of which were bubbling with air and water when they passed. As far as I have learned the sandy bed of every dry river in Cutch was filled for a space of time with a flood of water. These waters have the colour and taste of the soil from whence they were ejected.

The effects which this awful visitation may have on the prosperity of Cutch and consequently on our interests are very material, but I shall defer entering on the subject until the return of the Bhyant to Bhooj to their homes (wither the late event has called them) shall enable me to mature my sentiments.

J. McMurdo, 23 June 1819 Anjar.

[previous readers of the last sentence have attempted to elucidate its meaning through annotations to the syntax of the original without success]

Bhooj, 16 Sept. 1819

I have the honour to submit for the information of government an estimate of the value of the houses destroyed by the late earthquake in the town of Anjar

I have the honour etc.

J. Macmurdo

No of casts	Names of casts	Number of houses destroyed	monthly rent	value
1.	Nunowana Brahmans	92	189	50,925
2.	Bunyans	229	449	10,3975
3.	Bhojiik	3	2	400
4.	Shimalee Brahmans	95	147	40625
5.	Bhattia	113	220	65700
6.	Nagur Mettas	26	46	19,626

The list has altogether 46 lines of damage data sorted according to cast that are omitted for brevity. Monetary units are Couries. (Crores?)

46.	Bhunjia	2	1	2	150
	total	1547	2231	2	4,73,790

J. McMurdo, 16 Sept, 1819 Camp Bhooj

Bombay 15 Oct 1819

Captain Macmurdo is informed that we are concerned to find that the injury sustained by the late earthquake has been attended with so very heavy a loss to the inhabitants at Anjar as above reported.

Bombay 1 November 1819

Extract Public letters from Bombay

Para 61. A subscription having been circulated for the relief of the Hon. Company's distressed subjects at Anjar who have suffered so severely from the effects of the late earthquake, as so fully described in the dispatches from Captain Macmurdo, transmitted to your Hon., Court under the dates the 7th and 8th July last and in the one recorded as per margin (1819 consultations 21 July Folio 1211), we have taken upon

ourselves to subscribe the sum of Rupees four thousand on the part of the Honourable Company. Captain Macmurdo having been vested with the distribution of the amount.

Para 62. The value of 1547 Houses destroyed on this occasion is estimated at Couries 4.73.790 which yielded an annual rent of Couries 26,778.

(in margin: 1819 Consultations 20 October Folio)

The following entry is the first in the sequence in the India office collection, but its date is obviously related to the 1 November statement and may be a summary of it. It is written in a poor script .

Bombay 7 July 1819

The shock of an earthquake was severely felt on the 16th June 1819 at the northern Stations particularly at Ahmedabad and also in Kachchh. The sum of Rp.4000 has been subscribed on the part of the Co. for the relief of their distressed subjects at Anjar.

LONDON (to Bombay) 6 June 1821 Answer to public Letter dated 7 July 1819

Public Department Despatches to Bombay 13 Sept 1820-31 Oct 1821, Volume 45, E/4/1040 Record Department, India Office Library, London Page 653.

33. We were greatly concerned on perusing the melancholy accounts of the devastation occasioned in various parts of the territories subject to your government by the awful visitation in question, which is stated to have been felt with such severity at Anjar in Cutch, and to have at once reduced a flourishing population to wretchedness and misery and which was attended with the loss of many hundred lives.

34. The relief extended to the surviving sufferers by means of a public subscription was highly creditable to the promoters of it, and we cordially approve of your having contributed 4000 Rs. on the part of the government.

35. We cannot close this subject without expressing our entire approbation of the conduct of Captain McMurdo.

Footnote - see 8 July 1819 and also paragraph 61-62 1 Nov 1819

Extracts from the Bombay Gazette 16 June-4 August 1819

The Bombay Gazette was published weekly . It reproduces verbatim letters, but does not disclose the writer's names. The damage is concentrated along the coast of Cutch and Cambay and not so pronounced inland. No details are given for the remoter sensed locations.

Bombay Gazette 16 June 1819 no reports

Bombay Gazette 23 June 1819

Earthquake: A slight shock being felt etc..... But it appears to have been so slight a convulsion that most people doubted the evidence.

The west side of the island seems to have been most affected for we have been informed at Cambala, the undulations were distressing, and in the houses in the vicinity of the retreat, the lamps were shook violently. It was felt at Sion, and along the east side of the island but less distinctly and its duration was only of a few seconds.

This is further corroborated by the following extract of a letter from Surat dated 17 June.

"At 20 minutes past seven yesterday evening I felt a strange trembling sensation....It is strange my servants did not perceive it....I felt as if undetermined whether I should stand or lie down."

Bombay Gazette Wednesday 30th June 1819

The earthquake, We have received accounts from Ahmedabad, from Broach , Baroda and Khaira concerning this awful convulsion of nature.

Extract of a letter from Ahmedabad. **18 June 1819**

“It commenced gradually with a trembling of the earth attended with a rumbling noise: this increased every second, and was succeeded by a strong rushing noise, with a violent undulating motion, so that it was with difficulty we could keep on our legs. At this time, all the disagreeable sensation was experienced of being tossed in a ship at sea in a swell, and the rocking was so great that every moment we expected the earth to open beneath our feet.” omitted here is an irrelevant paragraph on weather.

“The rocking motion affected persons in various ways in different situations. Those indoors experienced all the horrors attending the awful suspense in which they felt themselves, the walls of the houses shook and were rent in various places, the beams and the roofs cracked and appeared ready to fall on the inmates and crush them to atoms in an instant. People in wheeled carriages were nearly thrown out by the shaking of their vehicles, and animals of all kinds in a stationary position, felt confounded and became restless. Persons in motion, on horseback, were however unconscious of the shock.

The proud minaretes of the great Mosque, the Juma Muzjid, erected by the Sooltan Ahmud, the King of Guzerat and the founder of the city of Ahmedabad, which have stood for nearly 450 years, have tumbled to the ground. The Mosque itself has sustained less injury than could have been expected, and the handsome arch which separated the minarets has escaped unhurt.

Another Muzjid, of elegant structure, which lies to the left of the road leading to the Shahee Bagh, denominated the Beebee’s or Unchunt Koonkwee ke Muzjid, has shared the same fate. A gentleman while riding out saw the minars come down: the tops were thrown to a great distance, and immediately after the stones came tumbling down one after another. The only remaining shaking minarets, which are at all worthy of notice, and much inferior to the others have, I hear, been sadly fractured. They are situated west of the city outside the walls. The mausoleums (Rozas) and places of Moohamudan worship have suffered considerably, both in the city and in the surrounding country. Hindoo temples are few in number and of recent build in the city since its conquest from the true believers seventy years ago by the Murhuttus; consequently a very small number have been damaged. The walls of the Udalhut, an old building erected by the Murhuttus and the palace of the Peshwas viceroys in Guzerat have been much injured, and the walls rent in many places. The magnificent towers also forming the grand entrance to the citadel have been much shaken, and cracked in several places, especially the one in which the flag has been placed. Many private houses have been reduced to ruins, and ‘tis most fortunate amidst all our disasters that not a single life has been lost, and but few accidents.

Between the hours of 12 and 1 the same night we experienced two or three slight shocks and another at 6. At quarter before 10 we had one more severe, which shook the houses and caused the windows and doors to rattle violently. We were now on the alert and quitted our houses in haste but the shock did not continue above a few seconds. and was trifling compared with the one of the previous night. At 10:30 we were again visited slightly and at intervals the whole of the day. The last I felt occurred at 12:20 in the night and since then I cannot say I have experienced any more, although fancy has frequently led me to pause, and expect a return of this terrible visitation.”

Omitted here are several paragraphs of non-factual information

“Reports from **Kaira** mention that the grand shock was experienced there twenty minutes after us and that it lasted only 37 seconds; two natives were killed by the falling of their homes & a good deal of damage has been done there. The Udulat hs suffered and the walls rent, the Jain temple opposite to it has also received a terrible fracture. Kaira is distant from Ahmedabad 18 or 20 miles.”

Broach 16 June 1819

“We had last night a very severe shock of an earthquake. The ground moved like the waves of the sea, and it was with the greatest difficulty I could keep on my legs. The walls of the house moved backwards and forwards. and the lamps went with a very quick motion; the water in our well rose many feet with a great noise, and did not subside for an hour, after it was over. Europeans and natives ran into the streets; many native houses were thrown down, and several boats upset by the extraordinary motion of the river. It lasted above three minutes. I never in my life felt such an awful time, every moment expecting instant death. 17th June this morning at 10 o’clock we had another slight shock for a few seconds.”

Our correspondant from **Baroda**. being a native expresses himself as follows.

“Last night I came from office, then we got Durtee Kup, ground so much shook, water jar is broken, Dinner is spoiled, all women and children, run away. No man understand this thing, only God, Lamp is cracked, Goat is gone away, all the persons is much frightened.

Bombay Gazette 14 July 1819

Earthquake 5 June 1819 in Mocha (I m not sure where this is, towards Oman?)

“its effects were to overturn tables and chairs. all over the adjacent country and in the factory at Mocha.”

Porebunder 17 June 1819

We yesterday experined in this town and fort one of the most awful scenes of nature, that of a violent and destructive shock from an earthquake.

First follows a few paragraphs describing the shaking of the walls of the fort (in a very graphic way) and then the two officers' escape, and much verbiage and verbosity, he continues...

“On reaching a spot of comparative safety, for then no place was safe, the attention was directed to a vast cloud of black dust, arising at about 300 yards distant, and from the sea face of the fort approaching the cloud of dust, I found it to proceed from the fall of 9 Towers (20-30 feet high), and large parts of the curtain, (22-25 feet high) leaving twenty one breaches of 40 and 60 yards wide. This devastation extended for 500 yards, and over a part of the fort which I had been walking on, not five minutes before.”

blah blah

“I believe there are few houses throughout this large city which have not been more or less injured: some have fallen and blocked the streets in which they were situated.

I am happy to say that not one life has been lost in this town, a circumstance which appears almost miraculaous, from the danger which existed.

The Earth opened, and water issued from the cavity, over an extensive piece of ground, in a plain, distant 14 miles hence.

blah

There has been several other shocks between 10 am and 2 pm which brought some houses down and violently shook the seats of those who were seated within doors, which caused them to run out of their houses. but these inferior alarms are not to be compared with yesterday's awful phenomenon.

blah

I am this moment informed that fifty men were killed by the fall of walls at **Mangrole** on this coast which is distant 60 miles in a SE direction.

blah.....half a Lac of Rupees damage estimated.

Porebunder 18 June same correspondent

blah

‘they say the town of **Kooteenna** has suffered but not so much as Porebunder.

Bhooj 23 June 1819

nothing new -repeat of the MacMurdo story. Probably written by MacMurdo.

“We also find that this awful phenomenon has also been witnessed at Calcutta, and singular to say on the same day that it was felt at this presidency.”

“an extract of a letter from **Allahabad** 25:30°N:

“we had a slight shock of an earthquake two or three evenings since. I never experienced so extraordinary a sensation, my first idea was that I must be extremely ill, for I felt the earth move in a way that I cannot describe and an earthquake was the last thing I thought of. I observed that my tent was shaking and that my sword which was hanging against the wall flew backwards and forwards, in a way that I could not easily account for. This is the furthest north we have yet heard of nor have we any accounts of it having extended farther south than Poonah.

Bombay Gazette Wednesday 4 August

June 16 7:20 awful to a degree

June 17 10:00 two slight ones

18 7 am rather strong

19 several slight ones

21 at 9 rather strong

23 at 2 am strong. the house and furniture in great agitation 3/4 of an hour

23/30 2 or three slight ones.

July 8 at 11 pm slight

11 at 5 slight

21 at 10 pm strong. The house etc in agitation 3/4 of a minute

Camp Bhooj 17 July

About 1 o'clock on the 15th a severe shock was felt here, the tiles came off several houses. On the evening of the 15th another (7:30) slight and nother in the morning and again this morning. 50 shocks since the 16th June.