

MEMOIRS
OF
THE GEOLOGICAL SURVEY OF INDIA

VOLUME XLVI, PART 2.

THE CUTCH (KACHH) EARTHQUAKE OF 16TH JUNE 1819 WITH
A REVISION OF THE GREAT EARTHQUAKE OF 12TH JUNE
1897. BY R. D. OLDHAM, F.R.S.

Published by order of the Government of India.

CALCUTTA: GOVERNMENT OF INDIA
CENTRAL PUBLICATION BRANCH
1926

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INTRODUCTION.

The Cutch earthquake, of the 16th June 1819, ranks among the classic earthquakes of geology, a position which it owes to various causes. In the first place it was one of the foremost rank in magnitude, whether the area over which it was felt, the violence, the extent of the region over which it was destructive, or the changes in the configuration of the surface which accompanied it, are considered. Secondly, it occurred in a region to which political events had attached special importance, and where there was a concentration of picked officers and officials, among whom were some keen observers of nature, who have left on record the results of their observations and enquiries. Thirdly, and perhaps more than either of the other causes, the interest which has always attached to this earthquake must be attributed to the graphic description and discussion, incorporated in Sir Charles Lyell's "Principles of Geology."

So much having been published, it might be thought that no useful purpose could be served by a new treatment of the subject, but all the published accounts, and summaries, date from a time when the study of earthquakes was much less advanced than now, and especially they could not consider the new discoveries and ideas which have been developed during the last quarter of a century, and have radically altered the outlook on facts, and the theoretical interpretation of them. In these circumstances a fresh discussion

of the records seemed likely to produce results which would justify the work, especially as these records happen to be unusually full and complete.

The Geological Survey Memoir on the "Geology of Kutch", by Mr. A. B. Wynne, gives references to all the literature bearing on this earthquake previous to 1872,¹ and, of later date than this, there is only the description of the Runn of Cutch by Mr. R. Sivewright,² which is of interest as describing the present condition of the region affected by the earthquake. As full references will be given in the following pages, and in the appropriate places, to the sources from which information was derived, it will be needless to give here a bibliography which would be, in the main, a repetition of Mr. Wynne's list. There are, however, some points of interest connected with the earlier reports, which could not be introduced without interrupting the continuity of treatment of the subject, and, consequently, will most conveniently be mentioned here.

Of contemporary records the most important is the description by Captain J. Macmurdo which, with some other reports from Cutch and Kathiawar, was originally published in 1822, by the Literary Society of Bombay, under the title of "Papers relating to the Earthquake which occurred in India in 1819." These were reprinted, in full, in the Philosophical Magazine and Journal for 1824, and in more or less full abstract in other scientific journals, details of which are fully given in the Bibliography of Indian Geology, by Mr. T. H. D. LaTouche.

In addition, there are several accounts, mostly reprinted from contemporary newspapers, in the Asiatic Journal and Monthly Register, Vols. VIII, IX and X of 1819 and 1820. The newspapers of that time, whether published in Bombay, Madras or Calcutta, contained notices and descriptions of the earthquake, which have been collected, so far as files are available in London, and utilised, so far as they contained information, useable for the purpose of this Memoir.

Almost a contemporary observer was Sir Alexander, then Lieutenant, Burnes, who visited the region near the Allah Bund in 1827 and 1828, some eight or nine years after the earthquake, and it is to his personal observations, and collection of evidence from still living

¹ *Mem., Geol. Surv. Ind.*, Vol. IX, Pt. 1 (1872).

² *Geog. Journ.* XXIX, 1907, pp. 518-539.

eye-witnesses, that we owe most of our knowledge of the remarkable changes which accompanied this earthquake. The results of his observations were not formally published till 1834, in the Transactions of the Royal Asiatic Society, and in the account of his travels into Bokhara, but they had been available for years previously in the form of a lithographed report. As it was from this that Sir Charles Lyell originally derived his knowledge, and as the reference in the Bibliography of Indian geology is incomplete, it may be of interest to deal with the matter more fully.

There were two distinct lithographed issues of this report. One was printed on foolscap size paper, and of this I have been unable to find any example in England. Two copies are, however, extant in Calcutta, one in the library of the Asiatic Society of Bengal and the other in the Imperial Library. As I was unable to examine these personally, I am indebted to Dr. A. M. Heron, for the information which follows. The full title is "A Memoir and Supplementary Memoir of a Map of the Eastern branch of the Indus, giving an account of the alterations in it from the bursting of the dams in 1826, and the changes brought about thereby in the Runn of Cutch, with a theory of the Runn's formation, proofs of its having been once a navigable sea, etc., and some remarks on the route of Alexander the Great: by Lieutenant Alexander Burnes, Deputy Asst. Qr. Mr. Genl. in Cutch.—*quæ loca fabulosus lambit Hydaspes*—Presented by Command of the Hon'ble the Governor in Council to the Literary Society of Bombay. Camp at Lucput, 28 March 1827, 13 August 1828" and bears the printer's mark "Gov. Litho. press Bombay."

Although I have been unable to find any copy of this issue in England, there is, in several public libraries, a lithographed memoir, printed on small-quarto sized paper. The title differs slightly being "A Memoir of a map of the Eastern branch of the Indus giving an Account of the alterations produced in it by the earthquake of 1819 and the bursting of the dams in 1826; also a theory of the Runn's formation and some surmises on the route of Alexander the Great;" the rest of the title page is identical with that of the foolscap issue. The quarto issue contains a prefatory note which mentions that the Memoir had "already been lithographed in another shape" but had been recast to enable the author to state the facts as they occurred and afterwards draw his conclusions.

This quarto issue is clearly the original from which the Memoir was printed, in the Transactions of the Royal Asiatic Society¹, under the title of "A Memoir on the Eastern Branch of the River Indus, giving an account of the alterations produced on it by an Earthquake, also a Theory of the formation of the Runn, and some Conjectures on the Route of Alexander the Great; drawn up in the years 1827-28." The printed version contains numerous verbal emendations, of the same character as those made in the title, probably made by the author on the proof sheets, but the quarto lithographed issue is followed exactly in substance, paragraph by paragraph, without addition or omission, except of one purely historical footnote, referring to the career of Futteh Mahommed, and of dates to the two parts of the Memoir.

As the prefatory note to the quarto lithographed issue indicated that it must be the later of the two, I asked that the published version might be compared with the foolscap issue in Calcutta. This was kindly done by Dr. Heron who reported that, though containing numerous phrases and sentences common to the memoir published by the Royal Asiatic Society, and the briefer account in the "Travels into Bokhara," it differed more widely from either of these than they do from each other, and could not be said to be the original of either. This report made it evident that there were material differences in the text of the two issues, and, as it seemed likely that the foolscap issue might represent the original reports, written on the spot immediately after the two visits to the Allah Bund, and might contain information which had been omitted from the later versions, I asked for a copy to be made of this issue, and am indebted to the courtesy of the Director of the Geological Survey for a type-written copy of this issue.

A comparison of the two issues confirms the conclusion that the foolscap one represents the original reports. There is less literary finish, a less orderly arrangement, if regarded as a scientific description, and an inclusion of matters which would be of interest to the Administration of the country, though of little interest to anyone else. As regards literary form, the quarto issue has been recast in the fullest sense of the word. There are, certainly, many passages identical in the two, but sentences widely separated in the one may be in juxtaposition in the other; the reports had, in effect, been

¹ Vol. III, 1835, pp. 550-588.

rewritten, though they were still given the same dates and signatures as in the original.

The second report, in the foolscap issue, has a separate title of its own, reading "A Supplementary Memoir to a map of the Eastern Branch of the Indus, with a theory of the Runn's formation founded on facts and tradition with some remarks on the route of Alexander the Great." To this report is appended, after the date and signature, a note which was written after his transfer to Bombay; this note is not dated but must have been written early in 1829.

The foolscap issue is accompanied by a map, bearing the title "Cutch, by Lieutt. Burnes, Deputy Asst. Qr. Mr. General, intended to illustrate a memoir on the Runs formation and to shew the alterations of the Eastern Branch of the Indus. Bombay April 1829." A photograph of this map shows that it had been drawn from an earlier map, of which a manuscript copy, bearing the date August 1828, is preserved at the India Office.¹ This, or another copy of the same map, was the original from which the map of Cutch in Dr. James Burnes "Narrative of a Visit to the Court of Sindh" was drawn.

No map accompanies the quarto issue or the published Memoir but in the latter a footnote is appended, saying that the map will shortly be published in a new Atlas by John Arrowsmith. The map published in this Atlas includes not only the whole of the Punjab and Sind, but all Asia lying to the westwards, and is evidently not the one referred to in the Memoir. This must have been either the map which accompanied the foolscap issue, or one similar to it, or possibly an earlier map, of which a manuscript copy is in the India Office², bearing the title "Eastern mouth of the Indus and the country between it and Puchum Island" and the date "Camp Bhooj, March 1827." This is evidently the map made by Burnes on his first visit to Allah Bund, and being of interest as an original record, is reproduced on Plate 16.

There is no imprint, on either of the lithographed issues, from which the dates, at which they were printed off, can be determined but there is some independent evidence, and a possibility of fixing the dates approximately. As regards the quarto issue, the printed list of presentations to the library of the Royal Asiatic

¹ Press mark L, viii, 23.

² Press mark U. v, 4.

Society, contains, under date Feb. 5, 1831, an entry¹ of "Lieut. Burnes' Memoir of a Map of the Eastern branch of the Indus. 4to. Bombay 1828" presented by Joseph Hume, Esq., M.P., F.R.S., M.R.A.S.; and on the title page of the copy in the library of the India Office is the endorsement "Presented by J. Hume, Esq., M.P., Feb. 5, 1831." This copy also bears, on the reverse of the title page, a partly printed partly manuscript label "Presented to *The Royal Asiatic Society of London* by *Joseph Hume, London, January 1831,*" the handwriting being different from that of the endorsement on the title page. This Joseph Hume was a native of Montrose in Forfarshire, he joined the sea service of the East India Company as assistant surgeon in 1797, was transferred to the land service in 1799, and from 1801 served with the army through the Mahratta war, holding high posts in the offices of paymaster, prize agent and commissariat. In 1807 he retired from the service and, after an interval, entered Parliament, of which he was a member almost continuously, till his death in 1855. He is said to have sat on more committees, to have spoken longer, oftener, and probably worse, than any other private member, but saw most of the causes which he advocated succeed in the end. He maintained a keen interest in Indian affairs, and would be likely to have received copies of Burnes' reports as soon as they were issued; we may consequently put the date, at which the quarto issue first reached England, as about January 1831, which would make the date of printing in India the latter half of 1830.

The list of accessions to the library of the Royal Asiatic Society also mentions² under date Dec. 5, 1829, the presentation by Lieut. Alexander Burnes of his "Memoir of a Map of the Eastern Branch of the Indus. Bombay 1829, folio. Lithog." and adds, in brackets, "since printed in the *Trans. R. A. S. Vol. III, p. 550.*" This, however, is an error, for, as has been shown above, the printed paper is the version of the quarto issue. This entry shows that a copy of the foolscap issue was received by the Society not later than the beginning of December 1829, and probably earlier, for a number of presentations are registered under the same date, which was evidently not that of receipt, but of formal registration, and probably of the meeting at which the presentations were reported and accepted. Un-

¹ *Trans. Roy. As. Soc.* III, 1833, Appendix: p. lviii. The date 1828 is evidently taken from the dates on the title page and does not necessarily represent the date of actual printing and issue.

² *Ibid.*, p. xxxv.

fortunately the Society no longer possesses any copy of either of these issues.

Copies of the foolscap issue appear to have reached Europe early in 1829, for the Bulletin of the French Société de Géographie¹ contains a verbal report on a lithographed memoir by M. Burns (*sic*), read to the Society on 23 April 1829. The report is not an abstract, yet gives enough description to show that it refers to the second part only of Burnes' report, for it is described as being a memoir presented as forming a supplement to another work, with which it presumes acquaintance, and it is added that this other memoir seems to have been devoted mainly to the origin of the Runn of Cutch, while the present one deals principally with the Indus. As it is specifically stated that the Society had not received a copy of the earlier work, it is evident that the two reports had been issued separately. The date at which the report was made to the Society, 23rd April 1829, shows that the memoir reported on must have left India in 1828, or very early in 1829, it would consequently have been a copy of the foolscap issue. Mention is also made of a map accompanying the memoir, and as this could not have been the map, dated April 1829, it must have been either an early proof, before dating, or a manuscript copy of a similar map.

These dates confirm the conclusion that the foolscap issue represents Burnes' original reports, they indicate that this issue did not appear as a whole, but that the two reports and the map were issued, as they were written, separately, at different dates, and afterwards assembled in the copies still extant.

From these facts the probable history of these two issues may be deduced. The foolscap issue was the original one, and seems to have been widely distributed in India, to the various government offices, and libraries then in existence; in addition some copies were evidently sent to Europe. The interest excited by these reports seems to have led to a demand for additional copies, and to a fresh issue being made, probably in the latter part of 1830, in which the arrangement of the matter was altered and, as official requirements had been filled, a quarto size adopted, being more convenient for unofficial use. Of this issue no copies seem to have been distributed in India, though it must have been somewhat widely circulated in Europe.

¹ Rapport verbal sur un mémoire lithographié de Bombay lu à la Société le 23 avril 1829, par M. Burns, lieutenant employé à l'état-major d'un corps anglais campé à Luckpoot. Bulletin de la Société de Géographie, 111, 1830, pp. 83-85.

Finally the memoir was published in the Transactions of the Royal Asiatic Society in 1834, in a volume bearing the date 1835 on the title-page of the collected parts.

Mention must also be made of the "Principles of Geology" by Sir Charles Lyell, the principal source from which other text books have taken their information. The first edition, published in 1830, contains only a brief account, based on the report by Captain Mac. Murdo; the second edition, of 1832, incorporates information derived from Burnes' Memoir, which is stated to be "now in the library" of the Royal Asiatic Society, London. It would be interesting to learn which of the two issues was first seen by Sir Charles Lyell; it was possibly the foolscap issue, acknowledged in December 1829, which he probably would not have seen before the first edition was passed for the press, or it might have been the quarto issue, received by the Society, in January 1831; the latter is, on the whole, the more probable. The third edition, of 1835, contains as separate, inserted, plates, a reprint of the engraving of the fort of Sindri, as it stood before the earthquake, taken from the same plate as that used in Sir A. Burnes' "Travels into Bokhara," and a map of the Runn of Cutch, apparently a reduction from Alexander Burnes' map as reproduced in James Burnes' account of his visit to the Court of Sinde. These plates were reprinted in all subsequent editions, up to the ninth edition, of 1853, in which they are replaced by woodcuts in the text, and in this change a somewhat misleading error was introduced into the map. The original map by Burnes' shows two permanently flooded areas, one round Sindri, which bears a legend that it was flooded after the earthquake of 1819, and another at the extreme eastern end of the Runn, opposite the mouth of the Luni river. In the reduced copy, inserted in the "Principles," these two flooded areas are represented, without legend on either, but in the woodcut, in the ninth and subsequent editions, there is added an index reference to the shaded areas, which makes it appear that both were submerged after the earthquake, whereas in Burnes' map this is asserted only of that round Sindri.

Apart from, and of at least equal importance with, the information derived from the descriptive accounts of observation, must be placed the admirable maps of the Survey of India, made in 1880-84. The surveyors, naturally, had no special knowledge of geology, or

of earthquakes, they were concerned only with a faithful delineation of the ground, and this they evidently accomplished with great skill and accuracy for, examining the maps in the light of special knowledge of the subject, with which this memoir is concerned, it is possible to recognise the changes, attributable to the effect of the earthquake. So important are the additions to previous knowledge, which came from a careful study of these maps, that they alone would have justified, as in fact they inspired, a revision of the records of this classic earthquake.

CHAPTER I.

THE ALLAH BUND AND CHANGES IN THE RUNN OF CUTCH.

The geological interest of this earthquake has been so largely dependent on the remarkable changes brought about in the aspect of a part of the Runn of Cutch, and, as the full import of those changes depends on an appreciation of the character and peculiarities of the region affected, it will be useful to give a brief description of the Runn, so far as it affects the subject of this memoir.

All along the north of Cutch there stretches a broad, level, salt-soaked plain. This region has been described by more than one observer, but none of these descriptions are more graphic than that of Sir Bartle Frere. "When the surface is dry," he wrote, "so imperceptible is the slope, that a shower of rain falling on the hard, polished surface, neither sinks in nor runs off, but lies, like a vast slop, on the plain, and may sometimes be seen moving along before the wind, till it gradually dries up by evaporation. Not only is there no visible change in the level, but there is a total absence of any sign of animal or vegetable life which could break the uniformity of the surface. There are no trees, no tufts of grass; and the bones of a dead camel are visible for miles, whether seen in their actual form and size, or drawn up into the likeness of towers, rocks, and houses by mirage.

"The general surface is hard and polished. It consists of fine sand and clay, with sufficient salt in it to attract any moisture which the air may possess, and to keep the surface damp when all around is arid. Hence, though sometimes covered with a saline efflorescence, the surface itself never pulverises, even in the hottest weather, and is usually so hard that a horse's hoof hardly dents it in passing."¹

Traditionally, this plain is an old inlet of the sea, now filled up, and certain places are recorded, by writers of the early half of the last century, as having formerly been sea ports; it was also recorded that anchors and other remains of sea-going craft had been found, but the evidence was somewhat uncritically accepted, in accordance with the general practice of archæology in those days. With this however, we are not concerned, and, whether or no there is truth in the

¹ *Jour. Roy. Geog. Soc.* XL, 1870, p. 185.

legend, it seems certain that the existing surface form is mainly determined by the effect of the wind, and the transport and deposit of fine-grained dust by it. Though a dead level to the eye, the surface is not actually level, nor has it a uniform slope. The only lines of levelling, of which I have seen a record, are in the Little Runn, to the east of Cutch, and there slopes of about 6 inches to the mile, or about 1 in 10,000 were found¹; in the Runn proper similar slopes probably prevail, but are not uniform or continuous, and give rise to shallow depressions where as the floods cease, water may rest for a while, gradually growing to a more and more concentrated brine as evaporation proceeds, till at last only a bed of salt remains. That there are differences in level of the surface of the Runn is shown by the fact that, on the crossings during flood time, the depth of water will vary from a few inches to some feet, and the existence of a westerly current at such times indicates that the general slope, apart from local variations, is from east to west.

The whole of the Runn lies at so low a level, and the gradient to the sea is so gentle, that large areas become flooded during the monsoon. In some text books and descriptions the statement may be found, that Cutch becomes an island when the sea level at the head of the Arabian Gulf is raised by the wind of the south-west monsoon. This assertion is rather a piece of picturesque expression than an accurate scientific statement; the sea level is certainly raised during the monsoon, apparently by about four to five feet, but the area directly submerged by this is only an insignificant fraction of the whole, and does not extend far inland from the permanent limit of dry land. The rest of the Runn is liable to flooding, but the water is in part direct rainfall on the surface, and in part flood water from the streams draining into the Runn.

The surface of the Runn is broken in places by larger or smaller patches of higher ground, which rise like islands from the level barren plain of the Runn. Some of these are rocky, others low sandy patches rising only a few feet above the level of the Runn, and carry a sparse growth of grasses, and occasional thorny shrubs or small trees. This land is known as *dhoi* (dhooee) or *bet* (beyt).

Three forms of surface are recognised in the region of the Runn. The first, known as *rann* (runn), is that which has been described above and which gives its name to the whole tract; the second,

¹ R. Sivewright. *Geog. Journ.* XXIX, 1907, p. 527.

known as *dhoi* or *bet*, is a sandy soil, free from salt, bearing a growth of grass, and occasionally stunted trees and bushes, is found round the margins of the Runn and rising, as islands of various size, from the surrounding tract of *rann*; the third, known as *kalar* (kuller) or *kara* and *lana* (laana) may be regarded as a transition between the *rann* and *dhoi*, it is less impregnated with salt than the *rann* and bears some scattered vegetation, the name *kalar* is given to the salter soil, most nearly approaching the character of *rann*, and *lana* to the higher portions with some vegetation, and more seldom flooded.¹ The distinction between *rann* and *dhoi* or *bhet* is evidently due to the fact that all vegetation on the former is killed by the periodical flooding, which keeps the surface soil impregnated with salt, while on the higher ground, which has been raised above flood level by the accumulation of wind-borne material, the salt is washed out by rain and, in the larger patches, fresh water may be found in shallow wells, though deeper excavations would find only the same salt subsoil water that underlies the *rann*.

One large area of such grass land lies south of Pachham Island, extending westwards along the north of the main land of Cutch, for a length of about fifty miles and a breadth of about fifteen. This is known as the Banni, it supports a scanty pastoral population and a few poor villages, and has not materially changed, in form or size, since the time of Burnes' survey. North of this, in the western half of the Runn, modern maps show large patches of similar land along the southern limit of the Thar desert of Sind, but a hundred years ago, and even up to the time of Wynne's survey in 1869, there was an uninterrupted stretch of *rann*, with only a few small islands of *bet* or *dhoi*.

Yet things were not always so; formerly a considerable, and perennial, river flowed down the channel, now known as the Puran, across the western Runn to the sea, by Lakhpat and the Kori creek. This river was bordered by a fertile tract, known as Saira, which, according to Sir Alexander Burnes, included the country between Lakhpat, "Saira"² and Mundhan in Cutch, extending northwards to a few miles north of where Sindri once stood. Such was the condition down to the first half of the eighteenth century after which a change took place; shortly after 1762 the then ruler of Sind constructed a bund or barrage at Mora, diverting the stream into other

¹ *Mem., Geol. Surv. Ind.* IX, p. 15.

² Sahera?

channels and leading it by canals to desert portions of his dominions. This bund did not entirely prevent the water from reaching Cutch, but reduced the amount so much that all agriculture, depending on irrigation, ceased. The Mora bund did not entirely prevent the water from reaching Cutch, but other dams, lower down stream, intercepted the overflow till, about 1802, the bund at Ali Bandar finally stopped the flow of fresh water to the sea, even when the river was in flood.¹

By this stoppage, of the flow of the Puran, the aspect of the district of Saira was changed, and a productive rice country relapsed into barren *rann*. By Sir A. Burnes, following the view of the Cutch government, the ruin of the province was attributed to the malevolence of the rulers of Sind, and the formation of these dams to a spirit of revenge for the defeat of the Sind army, at the battle of Jharra in 1762. The opinion was not unnatural, and not unjustifiable, in the then state of ignorance of the geography, and of the changes in the geography, of the Indus drainage area, but, with the more complete knowledge now available, a more cogent reason may be found.

The Puran passes, upstream, into the Eastern Narra and this into the bed of the Hakra, Wāndan or Wahind, the Lost River of the Indian Desert, which formerly carried a powerful stream to the sea. Fed by the Sutlej, possibly at one time by more of the rivers of the Punjab and, in its lower course, by the Indus, it continued to flow from the eighth at any rate till the sixteenth century. At some time subsequent to this, the Sutlej, ceasing to flow down this channel, became a tributary of the Beas and so of the Indus; the exact date and course of the change is not known, but by 1790 the severance was complete, the Hakra was merely a dry channel, and the water, which flowed by the bed of the Puran to Cutch, did not come from the old channel of the Hakra and Eastern Narra, but from an effluent of the Indus, and it was across this that the Mora *band* was formed. The upper reaches of the Hakra still carried some water, from minor streams of the outer Himalayas between the Sutlej and the Jumna, and the lower reaches, known as the Eastern Narra, were fed to a certain extent by percolation and overflow from the Indus, and by rainfall during the monsoon months.² It is to this

¹ *Trans. Roy. As. Soc.* III, 1835, p. 551.

² For details of the historic evidence of changes in the course of the rivers of the Punjab and Indus see Major H. G. Raverty, *The Mihran of Sind and its tributaries*, *Journ. As. Soc. Bengal*, LXI, Pt. i, 1892-97, pp. 155-508.

diminution of the volume of water, more than to malice, that we must look for the cause, both of the construction of the *bands*, and of the possibility of making these barriers, which could never have been built across a river of the volume indicated by Burnes' description of the former condition of the western part of the Rann. In support of this supposition we have the fact that in 1826, by some breach in the banks of the Indus, a body of water, comparable with the original flow, was discharged down the channel of the Puran and swept away all the embankments which had been made across it.¹

Whatever may have been the cause, the result was that, by the beginning of the eighteen hundreds, the country had relapsed into desert and the revenues of the district of Lakhpat, which had yielded eight lakhs of Koris, about two lakhs of rupees, from rice cultivation alone, in the latter part of the reign of Ras Laka² (1741-1760), dropped to less than a quarter of that amount in all. The old channel seems to have remained navigable, for Capt. R. M. Grindlay, accompanying a Mission to Sind in 1808, records that the journey from Lakhpat to Ali Bandar was made by boat, passing the customs station at the old fort of Sindri, of which he made a sketch reproduced in Burnes' travels, and in Lyells Principles of Geology.³

Captain Grindlay describes this fort as small, with a few huts outside and one well; the creek here had a width of about a mile and

¹ The flood took place in November 1826, at a time when the river level is normally low, and was very likely due to the failure of the head works of some irrigation canal, such as a predecessor of the present Eastern Narra canal. Burnes says that the cause was stated to "have been the pressure of water on one of the banks of the river, which had always been low, and was formerly raised by artificial means, and called the *Arrore-band*." He probably repeats a local explanation based on a traditional prophecy; the *Arrore-band* is a mythical embankment, supposed to have been made by one Saif-ul-Mulak, by which the river was diverted from a former channel, past Arrore, to the present one at Sukkur, and a local tradition maintains that this *band* will one day burst and the river once more flow in its old channel. (See H. G. Raverty, *loc. cit.* p. 486.) When the great flood of 1826 came down the old channel it was natural that the inhabitants of Cutch should look upon this as a fulfilment of the prophecy.

² Bombay Government Records, No. XV, new series, 1855, p. 46.

³ A. Burnes, *Travels into Bokhara*, Vol. III, 1834, p. 309, and 329-332. Lyell, *Principles of Geology*, chap. XXVIII. In some editions of the 'Principles' a footnote explains that the hills in the background of the sketch are an embellishment of the artist as no hills could be visible. This is not strictly true, for A. B. Wynne, who visited Sindri in Jan. 1869, mentions that the distant hills of Cutch were visible to the east, southeast and south; the statement is true enough of the sketch if, as seems to have been the case, the line of sight was north-eastwards. Very likely Captain Grindlay correctly represented the 'cold weather line' or false horizon produced by the lower dust laden layer of the atmosphere, and the engraver, not understanding what was represented, took it to be an indication of distant hills. Wynne gives a plan of the ruins of the fort, in which the features represented in the sketch can be recognised, but unfortunately the orientation of the plan is not given, though it can be inferred, approximately, from the text. (*Mem., Geol. Surv. Ind.*, IX, plate 2, and p. 45.)

a quarter, and a ferry across. The travellers who took this route were not numerous and left "no vestige of a road in the light sand, of which the dry part of the Runn is composed." So far as can be judged from the sketch, the height of the walls seems to have been about fifteen feet, the towers rising rather higher, and the height of the ground, on which it was built, could not have been more than some half-dozen feet above the water, or sea, level. It is unfortunate that no more accurate estimate of the elevation of the ground level can be formed, but at any rate it is clear that the site of Sindri must have been high enough to protect it from flooding, even when the sea level in the Kori creek was raised by the southwest monsoon.

Such were the conditions in 1819, at the time of the earthquake. A level desert country stretched northwards to the edge of the Runn, and through it passed a navigable salt water creek, following the course of an old river channel. The only contemporary account of the changes produced by the earthquake in this region is that of Captain J. MacMurdo¹; it was compiled from native information and reports, which must have originated largely from illiterate observers, probably passing through more than one repetition before reaching the writer, and relating to a region of which he had no personal knowledge, and of which not even the semblance of a trustworthy map existed. As a result the account is vague and indefinite, and gives no adequate idea of the remarkable changes which took place. He states that "the Allibund has been damaged; a circumstance which has readmitted of a navigation which had been closed for centuries" thus confusing the Ali Band, or embankment across the Puran at Ali Bandar, and the Allah Bund, produced by the earthquake, which will be dealt with further on. He reports an extensive flooding of the western Runn and states that "the goods of Sindh are embarked in craft near Ruhema Bazar and Kanjee Kacote; and which, sailing across the Bhunnee and Runn, land their cargoes at a town called Nurra on the north of Cutch."² This region, he remarks, had heretofore been dry at this period of the year. Of Sindri he reports that it was overflowed at the time

¹ Papers relating to the Earthquake which occurred in India in 1819; *Trans. Lit. Soc. Bombay*, III. 1822, pp. 90-116. Reprinted in *Phil. Mag.* LXIII, 1824, pp. 105-119, 170-177, and more or less in abstract in other places. (See Bibliography of Indian Geology by T. H. D. La Touche, 1917).

² *Phil. Mag.* LXIII, p. 116. The reference to the Banni as having been submerged is evidently due to ignorance of its true character as a relatively elevated tract: this is further indicated by his description of it as a marsh.

of the shock, the people escaped with difficulty, and the tops of the town walls were alone to be seen above the water. Numerous sand vents were formed in the Runn, vast quantities of water and mud were sent forth, and cones of sand six or eight feet in height formed, the summits of which continued to bubble for many days.

Fortunately, this contemporary account was supplemented by a more detailed and graphic one, by Lieut. (afterwards Sir Alexander) Burnes, written only eight years later and derived, like that of Captain MacMurdo, from local information, supplemented by personal examination and knowledge of the country. After reciting the condition of the country, as it was in 1819, he proceeds :

“ In this state of apathy and indifference, there occurred, in the month of June, 1819, a severe shock of an earthquake, by which some hundreds of the inhabitants of Cutch perished, and every fortified stronghold in the country was shaken to its foundation, and wells and rivulets without number were changed from fresh to salt water : but these were trifling incidents compared with the alterations which were brought about in the eastern branch of the Indus and the country bordering on it. At sunset the shock was felt at *Sindri*, the station at which the Cutch Government collected their taxes, and which is situated on the high road from Cutch to Sinde, and on the banks of what had been once the eastern branch of the Indus. The little brick fort of a hundred and fifty feet square, which had been built there for the protection of merchandise, was overwhelmed at once with a tremendous inundation of water from the ocean, which spread on all sides, and in a few hours completely flooded the country, and converted the tract, which had before been hard and dry, into an inland lake, extending for sixteen miles on each side of *Sindri*. The houses within the walls were instantaneously filled with water and the interior of the fort became a tank, in which, eight years afterwards, I found fish ; the only dry spot being where the walls actually stood, and which continued so from the bricks having fallen on one another. Of the four towers but one now remains ; the inhabitants saved themselves from destruction by ascending it, and only reached the land on the following day by boats.

“ But it was soon discovered that this was not the only alteration effected by this memorable convulsion of nature ; as the inhabitants of *Sindri* observed, at a distance of five miles to northward, a mound of earth or sand in a place where previously the soil was low and level.

It extended nearly east and west about sixteen miles, and passed completely over this channel of the Indus, separating as it were for ever, the *Phurran* river from the sea; and in fact from this period till 1826, there was no communication between the *band* which *Gholam Shah* had thrown up at *Mora*, and this natural mound which had been raised as I have described. The natives called this '*Allah-band*' or the *band* of God, in allusion to its not being, like the other dams in the Indus, the work of man."¹

The occasion for this account of the earthquake was the despatch of its author to investigate the circumstances of the great flood of 1826, for which purpose he made two expeditions, one in March 1827, the other in August 1828, and the result of his investigations, first distributed in a lithographed form, was finally published by the Royal Asiatic Society in 1833,² and forms the source from which all subsequent accounts were, directly or indirectly, derived.

Leaving Lakhpat by boat he found the channel, at a place called "Sando," shallowed to a depth of two or three feet, and above this "the waters expand into a vast inland lake, that bounds the horizon on all sides. Yet as this sheet of water is not more than four or five feet deep, it is easy to distinguish the course of the river through it by sounding, the bed being in no place, except Sando, less than two or three fathoms deep."³ The waters of this lake were, in March 1827, sweet, and at the Allah Band he found "a channel forty yards wide and about three fathoms deep, in which the waters of the real Indus were passing to the ocean; and I could not be mistaken in this as they were perfectly fresh and drinkable, and in such quantity that they had even affected the salt expanse as far down as *Lacput*, where at low tides the water becomes sweetish."⁴ On the occasion of his second visit the flow of fresh water from the Indus had been stopped, the waters of the lake had become salt as the sea, or salter, and the depth greater by two feet, due to the raising of the sea level in the Kori creek by the southwest monsoon, then at its height. These statements are quite precise and unmistakable, they show that a large area of ground must have been depressed, and, at Sindri,

¹ *Trans. Roy. As. Soc.* III, 1835, pp. 552-553.

² *Loc. cit.* 1835, 550-588.●

³ *Loc. cit.* p. 553.

⁴ *Loc. cit.* P. 554. He mentions meeting several boats which had come down from 'Wanga', showing that all the bands had been swept away as far up as that place. Incidentally it also shows that the flood came down the Eastern Nurra, and not by the distributary of the Indus, on which the Mora *band* was built.

the ground, which had been above water throughout the year, was covered to a depth of, at any rate, some four or five feet when the sea level was raised by the south-west monsoon. The amount of depression at this place must, therefore, have been at least five feet, probably about ten, if the estimate of the elevation of the ground level given above is correct, and possibly even more.

Of the Allah band he noticed, on his first visit, that the channel was a couple of fathoms deep at the entrance, that the banks were elevated about ten feet from the level of the river and composed of "soft clay mixed with shells, having all the appearance of being cut through at some late period, the sides being quite perpendicular."¹ It must be noted, in connexion with some other accounts to be noticed further on, that the figure of ten feet mentioned by Burnes refers to the height of the bund at the defined channel, which he describes as some thirty or forty yards wide, for it is said that there are marks of the "current having extended during the swell two or three hundred yards westward."

One feature noticed, and specifically mentioned, is important, and best given in his own words. "It is necessary to mention in this place that the *Allah-band* ought not to be looked upon as a narrow bar or strip of earth which had been ejected by the earthquake, for it extends very far inland, perhaps sixteen miles, and by gradually sloping towards the north, unites with the land, which renders it impossible to define its breadth with correctness."² This description fixes the cross section of the Allah Band as having a well defined southern limit, with a comparatively steep slope to the crest, whence there was a long gentle slope on the north, of some miles in width, downwards to the general level of the country.

Before passing on to consider the horizontal extent, of these displacements of the ground, it will be well to notice another examination and survey, of the region lying north of the limit of Burnes' investigation. In 1844 Captain (afterwards Sir) W. E. Baker, then 'Superintendent of Canals and Forests in Scinde' visited the Allah Band and the river channels to the north of it, and made a careful survey and levels of the district. An account of his visit was published by the Bombay Geographical Society³ but the map remained

¹ *Loc. cit.* p. 554.

² *Loc. cit.* p. 554.

³ Remarks on the Alla Bund and on the drainage of the Eastern part of the Scinde Basin, by Capt. W. E. Baker. *Trans. Bo. Geol. Soc.* VII, 1846, pp. 186-188.

unpublished till 1898 when it was reproduced, on a reduced scale, in these Memoirs.¹ In the description he states that the river channel had evidently become filled up since Burnes' visit as it was then, (11 July 1844) dry in some places, being "one foot higher than the level of the lake and seven feet above that of the salt water pools of the Pooraan." His description of the bund is as follows:

"The mound, where it is cut through by the Pooraan, is nearly four miles in width, but in other places is said to vary from two to eight miles. Its greatest height is on the borders of the lake, above the level of whose waters (on the 11th July 1844) it rises twenty and a half feet. From this elevation it gradually slopes to the northward till it becomes undistinguishable from the plain. On the surface of the mound, the soil is 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. The length of the Allah Bund has not been ascertained but it is said by the natives to extend fifty or sixty miles to the eastward. The Sindree lake,² though of inconsiderable depth near the shore, appears to be of great extent. From the elevation of the Bund, no land could be seen across it, even with the aid of a telescope, and the ruined Fort of Sindree, which still lifts its head above the waters, alone breaks the uniformity of their surface. It was asserted, however, by an agent of the Kutch Government (and with much show of probability) that the level of the water is much raised, and its extent increased, during the prevalence of the southwest Monsoon, which drives the sea water up the Koree into the lake, and that on the setting in of the north winds, a large proportion of the present expanse of water would become dry land."

Fig. 1.



Fig. 1.—Diagrammatic section through Sindree and the Allah Bund, illustrating deformation of the ground at the time of the earthquake in 1819. Vertical scale much exaggerated.

Here the description is unmistakable, and is borne out by the section, which shows the crest of the uplift somewhat over 20 feet

¹ A note on the Allah Bund in the north-west of the Runn of Cutch, by R. E. Oldham. *Mem., Geol. Surv. Ind.* XXVIII 1898, pp. 27-30.

² The word is consistently misprinted Lindree in the original.

above the level of the lake, whence the ground falls to the northwards till, at a distance of four miles, it is only a foot or so above the level of the lake, and thence slopes upwards to the north with a rise of nearly 20 feet in about 32 miles or about $7\frac{1}{2}$ inches in the mile, this being the normal gradient of the alluvial plain. On the southern face the fall of $20\frac{1}{2}$ feet is accomplished in a distance of about one third of a mile, the average slopes on either side of the elevated tract being, therefore, about 5 and 60 feet per mile respectively.

The accounts left by these two observers are definite and consistent, and sufficient proof that there was a real uplift of the ground along the line of the Allah Bund, nor would there be any need to consider this point further, but for the fact that the correctness of the descriptions has been questioned by Mr. A. B. Wynne in his *Memoir on the Geology of Kutch*¹ and by Professor E. Suess in his "Antlitz der Erde."² Wynne accepted the subsidence of the country south of the Allah Bund, as shown by the submergence of what was once dry land, but doubted the elevation of the Bund itself, considering that the appearance of uplift was deceptive, and suggesting that "if the maximum subsidence at Sindree took place along a somewhat irregular line corresponding to the place of the Allah Bund, and leaving the level of the ground to the northward but slightly, if at all, altered, then a bank or scarp, like that of the Allah Bund, might naturally result, its length being continuous with that of the depression and its height marking the amount of this depression. Seen from Sindri, within the depressed area, rising beyond the widely spreading inundation, such a bank would assume the appearance of a low hill, and present a marked feature in a view which had previously been bounded by a distant line to all appearance as level as the horizon of the sea itself."³

This explanation is plausible, and might account for the facts, so far as observation from Sindri revealed them, if there were not definite evidence to the contrary in Sir W. Baker's Survey. Wynne acknowledged that "from the amount of detail in Captain Baker's profile section it seems to have been very carefully constructed," yet doubted the correctness, on the ground that he alone of all the

¹ *Mem. Geol. Surv. India*, IX, pt. i., 1872.

² Part I, section, 1: Vol. I, p. 61 of original edition.

³ *Mem. Geol. Surv. India*, IX, 43.

observers who had visited the region made any mention of a slope on the northern side of the Allah Bund,¹ and argued that the existence of such a slope was contradicted by the conduct of the river during the flood of 1826. The argument may be put quite simply, that as, in this flood, the river resumed its old course and followed its original channel, the level of the bottom of this, after the formation of the Allah Bund, must have been lower than that of the surface of the ground north of the tract supposed to have been elevated, for if the bed of the channel had been materially raised above that of the ground to the north, the flood would have been ponded up and, in so level a country, have found its outlet round the ends, rather than across, the elevated tract. He quotes a passage from Burnes' account², to the effect that, after the stoppage of flow by the embankments across the Puran, the channel above Sindri "filled with mud and dried up," and as the estimates of the elevation at the southern edge of the Allah Bund vary from ten to twenty feet, this shows that the general slope of the country to the north could not have been materially altered at the time of the earthquake.

The whole force of the argument here lies in the statement that the old river channel to the northwards of Sindri had been filled up. The quotation is correctly made, from the account in the Travels into Bokhara, but the description is a very general one, no particulars are mentioned, no authority quoted, nor is there any indication of how far from Sindri this supposed blockage took place. That there was any such blockage near Sindri, or at the place where the Allah Bund was formed, is contradicted by Captain Grindlay's account, of his journey by boat up this river channel in 1808, in which he mentions no change in character of the channel, till the termination of the salt water navigation was reached at Ali Bandar, from whence he proceeded, by the fresh water channel above the dam, with fresh boats and some of the old ones dragged overland. Of the depth of the river channel we can only judge from Burnes' account, where he describes it as running, with a depth of two to three fathoms, through a lake of two to three feet depth, so that we may take the depth of the channel across the Allah Bund to have been at least 12 to 18 feet, and as Captain Baker's survey

¹ *Iloc. cit.* p. 36; but Burnes makes a very definite statement to the same effect, quoted above, p. 18.

² Travels into Bokhara, Vol. III, 1833, p. 312.

shows the crest of the band as about $19\frac{1}{2}$ feet above the lowest point of the surface level to the northwards, the bottom of the gap formed by the old channel would be at most only a few feet above the ground level, and may have been actually lower. In the latter case, and in the former too, the flood would naturally find an outlet along the old channel, and, once the water level topped this gap, a fresh channel would soon have been scoured out, and any flooding of the tract to the north have been drained away.

Mr. Wynne's doubts, and his attempt to find an explanation of the apparent uplift of the Allah Bund, without accepting a real uplift, may be attributed to a difficulty, which must have been very real when he wrote, of understanding how such a strange paradox as uplift on one side of a well defined line and simultaneous down-throw on the other could have been produced by a common cause. With the advance of knowledge this difficulty no longer exists, and, apart from any theoretical explanation, we have the fact that, in the Californian earthquake of 1906, precisely similar displacements, of nearly the same magnitude as in Cutch, took place simultaneously in opposite directions on opposite sides of the San Andreas fault. The character and extent of these displacements was very precisely measurable, and the only difference is that in California they were horizontal, with little or no vertical movement, while in Cutch the vertical displacements were considerable, whether accompanied or not by horizontal movement cannot be known.

It may be taken, therefore, that there are no grounds for Mr. Wynne's doubts, and less for Professor E. Suess' suggestion that nothing more took place than a local shaking down of loose sediments;¹ and accept the conclusion that there was an uplift of the ground to the north of the Allah Bund, accompanied by a depression to the south, both elevation and depression tailing off in a few miles in either direction, as is depicted in Figure 1.

For the amount of the vertical displacements which took place the most precise figures are Sir W. E. Baker's of $20\frac{1}{2}$ feet above the level of the Sindri lake, and Sir A. Burnes' of 10 feet; the latter is confirmed by the survey of 1880-81, which gives the height of the bank of the dry channel through the bund as 11 ft. but this as has been explained, does not necessarily represent the actual uplift

¹ *Das Anlitz der Erde*. I, p. 62.

of the ground, which would be more correctly given by Baker's survey and levelling. We have also an account, compiled by Lieut. S. N. Raikes, Assistant Political Agent, in 1854, in which it is stated that the height of the Allah Bund is estimated at about 18 feet.¹

We have less definite information of the depth of the depression south of the Allah Bund; in the southern part of the lake the depth is given by Burnes as two or three feet, but he says nothing of the depth of water close to the bund; on Sir W. E. Baker's section a depth of 10 feet is indicated, though nothing is said of how this was determined. Accepting this figure we may put the ground levels, after the earthquake, at about 20 feet above and 10 feet below, the level of the lake in July 1844, which would represent very closely the mean sea level at that time of the year.

The differential movement was, consequently, about 30 feet, the uplift on the north being 20 feet, less the original height of the land above water level, and the downthrow 10 feet, added to that same height. We have no precise measure of the ground level before the earthquake took place, but on Sir W. E. Baker's section the lowest point, to the north of the bund, is about a foot or so above the level of the water in the Sindri lake. We need not attribute greater precision to the survey than its author would have claimed, but it shows that the level of the ground at Sindri, before the earthquake, could only have been a very few feet above sea level and if this is taken at not more than five feet, it gives the actual uplift on the north of the dislocation as somewhere between 15 and 20 feet and the depression on the south as between 15 and 10 feet, the displacement tailing off in both directions till it becomes zero, but extending to a greater horizontal distance on the south than on the north.²

Of the lateral extension of the Allah Bund recognisable as such, the earlier accounts give little indication. Burnes mentions³ that

¹ *Sel. Rec. Bombay Govt.* No. XV, New Series 1855, p. 46.

² In a note accompanying the reproduction of Captain Baker's map (*Mem., Geol. Survey of India*, XXVIII, 1898, pp. 27-30), I took the differential movement as amounting to about 20 feet. It is not possible now to say how this figure was arrived at, but the records were not, at that time, so closely studied as they now have been, and the figure of 30 feet as the sum of the elevation and depression may be taken as very close to the reality on this section.

³ *Trans. Roy. As. Soc.* III, p. 567.

it was reported to have been traced "eastwards towards *Pacham* island, a distance of twenty-four miles; westwards as far as *Ghari* a distance of eighteen miles, which would make its whole length upwards of fifty miles." He adds "that there must be some foundation for the extent of it eastward is clear; for there is an elevated mound, about a mile broad, on the road from *Luna* to *Raoma ca bazar*, sixteen miles south of that place, in the middle of the *Runn*, which is made the halting ground in wet weather, and which was not there prior to the earthquake of 1819."

The limits of the flooded area round *Sindri* were only known to him from the facts that, on the west, the road from *Lakkipat* to *Gari* skirted the lake formed by the earthquake, and, on the east, the high road from *Cutch* to *Sind*, which formerly led through *Sindri* was necessarily sixteen miles to the east of it,¹ and was rendered more or less circuitous in proportion as the lake was made more or less full by the winds raising the water level.² *Raikes*, in his account states that a portion of the *Allah Bund* "is passed *en route* from *Raoma Bazar* in *Sind* to *Loona* in *Kutch*, though the greater portion of it remains on the right of the road or track."³ The crossing place is evidently the raised ground, used as a halting place, of *Burnes'* account, and at the point of a sharp angle in the course of the track, as shown on the survey of 1880-84, a deflexion which was necessitated by the flooded area making a direct course impracticable.

From these accounts little could have been made out, of the shape and limits of the flooded area, but for the work of the Survey of India, which, in 1880-84, mapped this region as part of the Topographical Survey of *Cutch*. On this map the course of the *Allah Bund* and the limits of the flooded area can be traced with certainty, and the whole of the important area is very conveniently published in a single sheet on the scale of 2 miles to one inch.⁴

¹ *Trans. Roy. As. Soc.* III, p. 556.

² *Ibid.* p. 563.

³ *Bombay Government Records*, No. XV, New Series, 1855, p. 46.

⁴ Comprising the four standard sheets Nos. 3, 4, 10, 11. Two editions of this sheet were published, the later carrying the Survey further west than the earlier. On the later issue some tracts of flooded ground, extending about eight miles in a north westerly direction from the *Puran*, are shown. The south western border runs about parallel with the *Allah Bund*, at a distance of three to four miles from its southern limit. These flooded areas seem to be due to an interruption of the surface slopes by the uplift of the bund.

On this the north-western end of the Allah Bund lies about 5 miles from Gari, but the dislocation may have extended beyond this, in the direction of that place, though not recognised. From the point just mentioned the bund runs, with some irregularities of course, in a general S. E. by E. direction for 16 miles, to where it is breached by the bed of the Puran, thence it bends round to an E N E course for 7 miles, when it again changes its direction to S E for about 15 miles, and throughout this length of 38 miles it marks the northern limit of the area which was flooded after the earthquake of 1819. About five miles short of the south eastern end, a narrow arm of the flooded area is crossed by the track from Luna to Rahim-ki-bazar, and here the course, of the track changes from about N N E to about N N W, on the raised patch of ground mentioned by Burnes, and named Talocha Doi on the map.

Throughout this course the Allah Bund is bordered on the south and west either by a salt bed or, in the central portion, by land which was still permanently under water in 1880. The salt bed must mark very closely the extent of the original submergence, and had been formed by evaporation from the sea water which had free access to the depressed area through a narrow channel; though dry, at the season of the year when the mapping was carried out, it was probably flooded when the sea level was raised by the south-west monsoon. The greatest length of the original lake thus indicated is about 34 miles, in a W N W—E S E direction, and the greatest width about 21 to 14 miles, along the course of the Puran. The area covered by the salt bed is about 150 square miles, but the original flooded area must have been somewhat greater than this, or about 200 square miles, a very different figure from the 2,000 suggested by Sir A. Burnes¹ and repeated by Sir C. Lyell in his Principles of Geology. It is not easy to see how this figure was arrived at; it could hardly have been a misprint for 200, as his maps all give the flooded area as a roughly-oblong outline with rounded corners and dimensions of 30 to 35 miles by 20 to 25, which would make the Sindri lake about 700, and certainly not less than 500, square miles in area. The outline as drawn on his map was necessarily conjectural, as he had no opportunity of making a detailed survey, but is inconsistent either with so large an area as 2,000

¹ Travels into Bokhara III. p. 317

square miles, or so small a one as 200, which was about the real extent of the flooded area¹.

So far only the reports of observations along or near the old course of the Puran river through the Runn have been dealt with. They indicate something which would at one time have been generally, and would still be widely, considered as sufficient to account for the earthquake, but when the condition of the northern part of the Runn is compared with what it was, at the beginning of the last century, it will be seen that the changes were spread over a larger area than is indicated by the old accounts, or has been recognised in descriptions of this earthquake.

Some indication of these displacements, other than that which produced the Allah Bund, is to be found on Burnes' map, which shows, just south of Baliari, and on the track from that place to Pachham, a small island in the Runn, bearing an inscription, varied in wording on different copies to the effect that the island was attached to the mainland before the earthquake of 1819. Sir G. Le Grand Jacob, in his account of this region, mentions the same island, but says that it was reported to have been raised from the Runn by an earthquake.² These two versions differ, but they agree that a change in the topography, indicating a change of surface level, took place.

The detailed survey of Cutch, made in the eighties of the last century, indicates much more extensive changes of level than this, whether taken by itself or in comparison with Burnes' survey. Over the greater part of the Runn the two surveys agree in representing a vast continuous stretch of *rann*; in the south the tract of sandy ground, carrying a growth of grass, known as the Banni, is somewhat larger in the later, than in the earlier, survey, but the main outlines are the same, and some small islands are marked in the Runn, which may have existed in Burnes' time and escaped his exploratory survey, or may have originated since; but there is in

¹ Some of the accounts make mention of a deepening of the channel near Lakhpat, where the water had been very shallow before 1819, but afterwards deepened to allow vessels of considerable burden to reach that place. Though attributed to the effect of the earthquake these accounts have been omitted from the text as the connexion, if any, seemed very remote. In the original report of Burnes, as reproduced in the foolscap lithographed issue, there is a definite statement that the channel was not "immediately" deepened and that "it was not till two or three years after that it was navigable for so large vessels."

² *Trans. Bombay Geol. Soc.* XVI, 1863, p. 24.

all this area no difference between the two surveys greater than would be expected from the difference in the mode of construction, and the later survey confirms the general accuracy of the earlier one, which, it must be remembered, was the first attempt at mapping a wholly unexplored region. In the north western corner of the Runn, lying to the north of the Allah Bund as described above, and of a line extending eastwards to Pachham island, and thence north eastwards to the northern edge of the Runn, the agreement disappears and a great difference between the two surveys is to be found.

On the earlier map four islands are marked along the track leading from Pachham to Baliari, with a fifth on the route to Vingur, and all the rest is shown as a continuous stretch of *rann*, but it must not be assumed from this that the five small islands were the only ones existing at that time; they were noticed and recorded because they happened to lie on one of the tracks traversed by Burnes, or his assistants; it may well be that some others existed, and escaped record, but the map may be accepted as evidence that the prevailing character of the ground, in all this region, was *rann*, and the proportion of *bhet*, was small. On the later survey the facts represented are very different, for over the whole of this area there are shown large tracts of the sandy grass grown surface, known as *bhet* or *dhoi*, and *rann* appears only as strips and patches, in the aggregate subordinate to the *bhet* land.

Had there been anything like this in Burnes' time, it is improbable that he would not have been informed of it, and given some indication on his map, instead of marking his whole area as *rann*, nor is this merely a matter of supposition for there is definite confirmatory evidence. Burnes' description of the surface of the Allah Bund shows it to have been uplifted *rann*, and the same account indicates that the whole of the tract extending northwards to Rahim ki Bazar was of the same character, but the survey of India map gives this area as grass grown waste land. On the track leading north from Pachham island we have the detailed itinerary of Sir G. Le Grand Jacob in 1852,¹ which gives a total length of *rann* traversed as 24 miles, while the *bhet* only amounted to four miles, the proportion being six to one; in 1880 the survey of India map shows a great extension of the *bhet* land, which occupies rather more than half of the total distance traversed.

¹ *Trans. Bombay Geol. Soc.* XVI, 1863, pp. 23-24.

Eastwards of this track a still more remarkable change seems to have taken place. On Burnes' original map no eastern border is shown to that northernmost island, which is said to have been joined to the mainland before the earthquake; the size is therefore unknown, but it was evidently regarded as an island of no very great extent. The Survey of India map shows this "island" as the westernmost extremity of a sandy, grass grown tract, extending some 24 miles to the eastward, joined along the whole of its northern limit to the mainland, the southern boundary of which, along the former northern margin of the Runn, is well defined; this tract is marked on the map as the Dhara Banni, and is shown as carrying trees, in places towards the eastern end. Probably parts were in existence in Burnes' time, but if the extensive and continuous tract of *bhet* land had then been in existence, it is improbable that he would have mapped the western extremity as an island surrounded by an expanse of *rann*.

The change in character of this portion of the Runn has gone on since, for the whole of this tract is marked as "æolian deposit" on Mr. Sivewright's map, published in 1907, and his description mentions that, through the agency of drifting sand, large areas shown as *rann* on Burnes' map, and so described in contemporary notes, are now areas of firm sand sustaining a scanty vegetation, while the formation of sandy islands or *bhet* is going on unceasingly.¹ The effect of deposit of sand and dust, from the air, is indubitably important, but the sharp delimitation of the area over which the change has been extensive and conspicuous, and the fact that, for about half its length, the boundary coincides with the dislocation which gave rise to the Allah Bund, suggests that an elevation of this tract was a contributory cause of the change in character which has since taken place. It has been pointed out that the cause for the difference in character, between *rann* and *bhet*, is to be found in the periodical saturation and flooding of the former by water, strongly impregnated with salt, and so destructive of vegetation, while in the latter, being raised above the saturation level, the salt is gradually leached out by successive falls of rain, and vegetation enabled to establish itself. This being so it is obvious that any general uplift of a portion of the Runn would, by facilitating drainage within the area affected, lead to an extension of the tracts

¹ *Geol. Journ.* XXIX, 1907, p.53.

over which removal of salt from the surface soil, and the consequent establishment of vegetation, could take place. Along one part of the area concerned, that which is marked by the Allah Bund, such uplift has been established and it is reasonable to suppose that a similar change took place at the time of the earthquake over the rest of it.

Fig. 2.

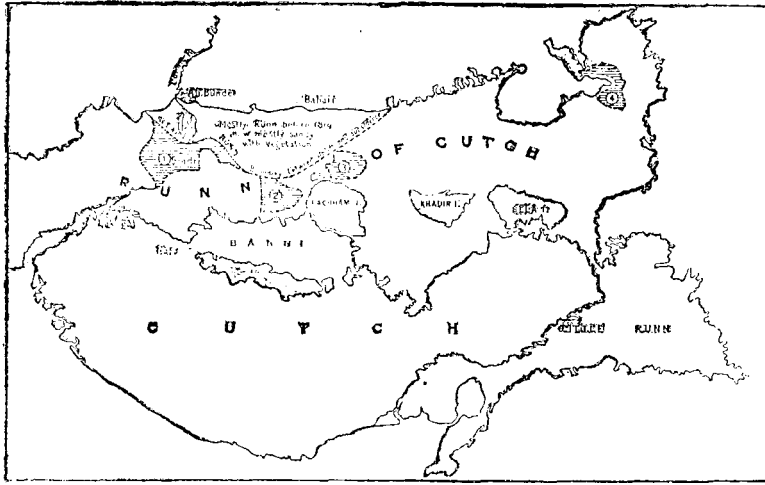


FIG. 2.—Sketch of changes in the Runn of Cutch due to the earthquake of 1819. (1) area flooded by inflow from the sea; (2), (3) areas of permanent flooding, probably due to changes of surface level in 1819; (4) similar flooded area, possibly due to changes in 1819.

From this it appears that, beyond the extent of what can be definitely recognised as the Allah Bund, the dislocation can be traced for twenty miles to the northern end of Pachham Island, and beyond that again for another thirty miles to the northern limit of the Runn. In the first named stretch, that to the west of Pachham, the uplift may have been recognisable at the time of the earthquake, though not so abrupt as further west; such, at least, is suggested by the native reports, quoted by Burnes and Baker, which give the *band* a length of fifty to sixty miles, and speak of it as extending towards Pachham. Further east the boundary of the raised area was apparently less abrupt, and may not have been noticeable at the time; in this stretch the southern boundary of the area, over which a change from *rann* to *bhet* has taken place, is less well defined, but the occurrence of some short stream valleys, along the

eastern end of the Dhara Banni, points to uplift, and the establishment of surface slopes steep enough to promote erosion.

Apart from the conclusions which may be drawn from a comparison of Burnes' map with that of the Survey of India, the latter affords evidence of changes, of which there is no other record. One of these is a dislocation of similar character to that of the Allah Bund, though on a somewhat smaller scale. The map marks a scarp running about north-west to south-east and passing about three miles to the north east of the Gainda Bet; no relative levels are given, so it was probably not many feet in height, but still enough to make the feature distinctly noticeable, and along the course of it there are, at intervals, small stream channels, of from half a mile to a mile and a half in length, draining from the higher ground, to the south-west of the scarp.¹ In this respect the feature resembles the Allah Bund proper, from which several stream beds have been cut back into the higher ground, and in this there is a remarkable contrast to the rest of the Runn; only along these two scarps are definite stream channels shown in any number; a few others occur in that area which has undergone a general uplift, but throughout the rest of the Runn no defined stream bed is marked on the detailed map of the Survey of India.

This dislocation has a traceable length of about twenty miles and, at its south-eastern end, borders a tract of more or less permanently flooded land, which will be dealt with further on, and there is some evidence that along the rest of its length, the ground level on the north-east was lowered, relatively to its original level, just as in the Allah Bund the country to the southwards was lowered concomitantly with the elevation of the *band*. In 1852 Sir G. Le Grand Jacob found the Dera Bet extending for a mile along the route followed, and separated from the mainland by about six miles of "firm level Runn;" this Dera Bet can be recognised on the Survey of India map as a promontory on the western margin of the Dhari Banni, but the country to the northwards, in 1886, consisted for more than half the way of *bhet* or *dhoi* and only rather less than three miles of *rann*, which is part of a bay in the sandy

¹ Col. G. Le Grand Jacob mentions that not far from Gainda Bet, on the road to Baliari, he crossed a "crack in the Runn, constituting a monsoon nullah, commencing apparently half a mile further west, with the slope towards the east." *Trans. Bombay Geol. Soc.* XVI, 1863, p. 24. This nulla can be recognised on the Survey of India map.

tract of the Dhara Banni ; moreover the map shows a line, indicating a change of surface level, which lies on the continuation of the western boundary of the sandy tract. The interpretation of this map, as compared with the earlier surveys and descriptions, seems to be, that before the earthquake there was an expanse of *bet* or *dhoi* land, approximately as represented by the Survey of India, that at the time of the earthquake this was depressed, either absolutely or relatively to the surrounding region, so that *rann* conditions extended over a great portion, and continued between 1827 and 1852, but by 1880 æolian deposits had again raised the surface and caused a conversion of *rann* into *bet*. If this is the true explanation, then Burnes' record, that before the earthquake the island was joined to the mainland, is the correct one, and must be accepted in preference to Jacob's version that the island was raised from the Runn.

The map also indicates another similar feature, running about south-west from the Gainda Bet to the line of the continuation of the Allah Bund ; in this case with the upthrow to the north-westwards.

Along the southern margin of this tract, which was elevated, the Survey shows signs of depression having taken place. The well known depression of the ground round Sindri has already been referred to, but some further consideration of the history of this flooded area will be of interest, and, before dealing with accounts later than those of Sir A. Burnes, it may be noted that there is some indication that the first depression, immediately after the earthquake, may have been both greater and more extensive than what remained when he made his survey. For the greater extent of the flooded area we have some suggestion in the statement, by Captain Mac-Murdo, that navigation had been re-established across the Runn, and that vessels loading near "Ruhema Bazar and Kanjee Kacote" sailed across the Runn and landed their cargoes at "Nurra" on the north of Cutch. The account is too vague for any deduction to be drawn from it, were it not for the very precise statement by Burnes that, shortly after the earthquake, the guns of Sindri were removed by boat and landed within two miles of Nara,¹ a proceeding which could only have been possible if the land then stood

¹ *Trans. Roy. As. Soc.* III, 1838, p. 557.

at a lower level than it did at the time of his survey, nine years later. These statements, and the fact that the inhabitants of Sindri had to take refuge from the flood in the tower of the fort, indicate that the initial depression may have been greater than the permanent one, and that there was a partial recovery of this in the months immediately following the earthquake.¹

However this may be, the extended flooding appears to have been of short duration², and things settled down into the condition found by Sir Alex. Burnes in 1827 and 1828, but it must be remarked that, on both his visits, the water level on the flooded area stood higher than it would normally do during the dry weather. His first visit was before the monsoon had commenced, but at that time a large body of fresh water was pouring into the lake, which was separated from the broad estuary at Lakhpat by a length of about twelve miles of river channel. No mention is made of the current in this channel, nor can any estimate be made of the gradient of the water surface, but, even if this were no more than three inches in the mile, the level of the lake must have stood at three feet above the sea level. On the second visit the inflow of fresh water had ceased, but the monsoon was at its height, and the sea level in the Kori creek raised to its maximum. On both occasions the ground at Sindri was under water, just as described by the accounts of what took place when the earthquake occurred.

The next visit of which we have record is that of the surveyor sent by Captain Grant to make a plan of Sindri and the Allah Bund in March 1838. The only account of this, which has survived, is contained in Sir C. Lyell's Principles of Geology, where a sketch of the Fort of Sindri, as it stood in March 1838, said to have been drawn by Captain Grant from the surveyor's plans, is reproduced.

¹ In the great earthquake of 12th June 1897 there was evidence of a continuance of the deformation of the surface for some months after the earthquake; See *Mem., Geol. Surv. Ind.*, XXIX, p. 158. In this case the movement continued in the same direction as that produced at the time of the earthquake; in Cutch, if there was any similar effect, it was in the nature of a partial recovery from the extreme displacement at the time of the earthquake.

² In the original report, in the foolscap lithographed issue, after stating that of the thirty-two miles which separated Sindri from Nara twenty were then covered with water, he continues: "This is, however, only the state to which it has relapsed, for two months, after the earthquake of 1819 it had attained such a height . . . that the guns of Sindree were conveyed by boat from that place to Nurra, or rather within two miles of it. It was four or five feet deep and the Natives had hoped that a free navigation would have assisted them when the road had been overflowed, but this only continued for a season, and the late swell of the Indus has left it *in statu quo* without any increase whatever."

In this sketch the ruined walls of the fort are shown as rising from an expanse of water, but this is in contradiction with the account, which distinctly states that the lagoon had diminished in area and depth, and part near the fort was dry land. This statement is probably correct, as it is confirmed by Mr. A. B. Wynne's account of his visit; it does not necessarily indicate a change in level of the land in the ten years which had elapsed since Burnes' visit, but it does conflict with the account of what took place at the time of the earthquake, and, if this is to be believed, the ground must, at first, have been depressed to a lower level than that at which it stood in 1838, and have recovered some of the depression at some date after the earthquake. The fort would naturally have been built on the highest part of the nearly level plain, so the finding of a small patch of dry land, surrounded by water, in March 1838, does not establish any change of level of the fort, relative to that of the surrounding tract of country.

The visit of Sir W. E. Baker to the Allah Bund has already been referred to; he did not visit Sindri. In 1856 Mr. Da Costa, of the Great Trigonometrical Survey, went by boat from Lakhpat to Sindri; he found water all the way, overlying salt, three or four feet thick in places. In May 1863 the channel was still practicable by boat and was used by the Surveyor of the Rao of Cutch who was sent to explore the region; but in December, 1868, when Mr. A. B. Wynne, of the Geological Survey of India, tried to visit Sindri, in the course of the Geological Survey of Cutch, he had to travel overland from Nara, as the passage by boat from Lakhpat was no longer practicable. In January, 1869, he followed the route to Rahim Ki Bazar as far as "Jerruk Dhooi," evidently Charakra Doi of the Survey of India, where he branched off and, about four miles on, reached "Ahrurai Dhooi." Leaving this at half-past twelve he struck westwards and, after a couple of miles of salt covered *rann*, entered on the mud of the Sindri basin, in which the camels sunk to their knees, and through which the guides pursued a somewhat devious course, sounding the way with sticks. After labouring through this till evening, the tower of Sindri rose to view, above an horizon of mud and half dissolved salt, but was not reached till sunset. Upon approaching the place it was found to be but a small spot, surrounded by water, about fifty yards of ankle deep transparent brine, with a sheet of white salt beneath, having to be crossed to reach the tower. Westwards of the ruin was the old river

channel, filled with brine, estimated to be 250 yards broad, extending as far as could be seen to the north and south ; all else was level Runn over which the distant hills of Cutch and Pachham could be seen to the south and east, and to the north a thin dark line of rising ground marked the Allah Bund. The depth of the river channel had evidently decreased since Burnes' visit, for some stray ponies found their way across, attracted by the camp fires, showing no sign of having had to swim.¹

This account agrees with that of the surveyor, sent in 1838, in representing the remains of the fort as standing on a patch of dry land surrounded by water, but this latter was less extensive than at the earlier date, doubtless owing to the shallow water having become filled up partly by a deposit of salt crystallised out by evaporation from the sea water, which had access through the old river channel, and partly by dust blown off the dry lands around and deposited on the flooded area. This agreement of the two accounts, shows that in 1838 as in 1869 the ground level at the old fort of Sindri lay just above the sea level during the dry weather, when the level is not raised by the wind of the southwest monsoon, thus making very improbable the statement, recorded by Sir G. Le Grand Jacob on the authority of native information, that the Allah Bund was enlarged, and the level of the Runn raised, by the earthquake of 1845.²

In the years 1880-84 a survey of this tract was made by the Survey of India and the admirable map published, which has already been referred to. On this Sindri is no longer surrounded by water, but by salt, evidently covering the ground over which Wynne waded ankle deep in brine. Eastwards of this strip of salt comes a patch of *rann* in the midst of an extensive bed of salt occupying what, in Burnes' time, was the flooded area round Sindri. South-west of Sindri a broad expanse of water is marked, some five miles or so across, and to the west of the fort a channel, about three-quarters of a mile broad, leads up to the Allah Bund, and extends for some fifteen miles along the foot of it.

At the present time even this remainder of the once extensive sheet of water has disappeared, for Mr. R. Sivewright states that

¹ *Mem., Geol. Surv. Ind.*, IX, 1872, pp. 44-47. The accounts of the visits in 1856 and 1863 are printed on pp. 36-37.

² *Trans. Bombay. Geog. Soc.* XVI, 1863, p. 65. The date there given corresponds to 1844, but a letter from Captain Nelson to the Geological Society gives the true date as June, 1845. *Quar. Journ. Geol. Soc.* II, 1846, p. 103.

no sign of the Sindri lake now exists, except some pools of brine, which are known to be rapidly decreasing in area.¹

Such is the history of the Sindri lake, but the last stage must be attributed to a gradual blocking up of the channel leading to the sea, and consequent prevention of the entry of sea water, when the sea level is raised during the monsoon, for the upper level of the great sheet of salt, formed by evaporation from the sea water entering the depression during the dry weather, could not have been raised above the water level in the Kori creek and would all be flooded when that is raised during the monsoon, if there were a channel of access from the sea.

Apart from the depression of the ground round Sindri, the Survey of India map shows two areas of more or less continuously flooded ground, one to the west and the other to the north-east of Pachham Island.² That lying to the westwards has a length of about fourteen miles and a width of about eight; the northern boundary is fairly straight with a course of about W.N.W. to E.S.E., it runs nearly along the continuation of the Allah Bund and, at the western extremity, there is marked a scarp of two to four feet in height with some small stream channels leading down to it, which may be regarded as the termination of the Allah Band, as a definite surface feature. For the rest of its course there is no definite bank, the limit of the flooded area depends on the extent to which the water level enables it to encroach upon a gently sloping surface, and, though generally in the direction of the Allah Band, the northern margin trends away from the southern limit of the uplifted region. The western margin is even straighter than the northern, running nearly due north and south, and appears to be defined by the general gentle slope of the surface of the Runn, as also are the southern and eastern margins, which follow a course roughly parallel to the general run of the boundary of Pachham and the Banni.

There is no such extensive salt bed as around Sindri, for the depression is not in communication with the sea, and lies well

¹ *Geog. Journ.* XXIX, 1907, p. 528. In the map accompanying this paper there is an error in the outline of the old Sindri lake, an arm of this being represented as crossing the Allah Bund and running some miles to the northwards. On the Atlas of India sheet a strip of *rann* is shown here, which might be taken for part of the old lake, but on the original Cutch Survey sheet it is clear that this is part of the upraised Allah Bund, which forms the northern boundary of the lake.

² The presence of water in these two areas is indicated on the map accompanying Wynne's Memoir, though there is no attempt to represent the outline of the flooded areas.

above sea level,¹ yet it seems likely that this area of flooded land may have been formed at the time of the earthquake, in a manner analogous to that which gave rise to the Sindri lake.

The other flooded area lies to the north-eastwards of Pachham Island and is of about the same dimensions as that to the west, but of more rounded outline. The south-western boundary is, in part, defined by the termination of the dislocation which has been referred to above, for the rest, the limit of the flooded area varies with the water level, and the extent to which it encroaches on the gently sloping surface of the Runn.

The occurrence of these two depressions just south of the limit of the area showing signs of uplift, indicates that the changes of surface level were similar to those so well marked further-west; the lowered area was probably continuous, though the amount of depression varied at different points along its length, as has been noticed in the case of similar changes of surface level accompanying other earthquakes, but the separation of the two flooded areas is due to the fact that the zone of depression traversed the northern end of Pachham, where the surface, before the earthquake, stood at a higher level than that of the Runn on either side.

Beyond this the dislocation cannot be traced with any degree of certainty, but there are two facts which suggest, if they do not indicate, that it may have extended for some distance eastwards of the limit to which it can be definitely traced.

The first of these is the marked change in character of the northern boundary of the Runn, just where it would be cut by a continuation of the limit between uplift and subsidence. To the westwards the boundary pursues a fairly even course, to the eastwards it abruptly changes its character and exhibits a repetition of deep embayments of the Runn into the mainland, such as would result from a comparatively recent depression of the land. There is no evidence to show the date at which this took place, but it is not impossible that it dates from 1819, and that the boundary, before that date, used to pursue the same generally even course as it does further to the west.

The second is the presence of a permanently flooded area, on the survey made about 1887, opposite the mouth of the Luni River,

¹ Some heights marked on the Survey of India Map suggest that the general level of the Runn to the west of Pachham may be some 40 feet above sea level, certainly not less than thirty feet.

A flooded area is shown in this same region on Burnes' map, but is represented as much more extensive than it was when the Survey of India mapped the same district, some sixty years later. Permanent flooding would not be looked for in this neighbourhood, where the material brought down by the Luni would raise the surface level, and the extensive submergence, depicted by Burnes, may have been brought about by some change of level in 1819, the subsequent reduction in size, of the flooded area, being due to sedimentation, and accession of dust and sand deposits from the air.

There is, consequently, evidence of a belt of disturbance running somewhat sinuously through the northern part of the Runn of Cutch, for a distance of nearly ninety miles, marked by a general uplift of the country to the north and of subsidence on the south. Near the western end the demarcation between the two areas was sufficiently abrupt to cause a visible inequality of the surface, forming the Allah Bund, which can be traced for some thirty-five miles; further east the transition between the two areas is more gradual and takes place by an imperceptible slope of the surface, which, not immediately recognisable as such, has revealed itself by the changes, which subsequently took place, in the character of the surface deposits. At the eastern end the feature ceases to be traceable, before it finally leaves the Runn, though the dislocation may have extended as far as the eastern end of the Runn. On the west the feature is still well marked where it leaves the Runn, to enter on the alluvial area of the Indus delta, in which any former indications can no longer be traced. Eighty miles, therefore, is a minimum estimate of the length of this dislocation, it may well have extended to one hundred and even more, if that part is included where the displacements underground were too small to produce any appreciable effect at the surface.

CHAPTER II.

THE EARTHQUAKE OUTSIDE THE RUNN OF CUTCH.

For details of the effect of the earthquake, as experienced in Cutch, we are mainly dependent on the account by Captain J. MacMurdo¹. It was disastrous over nearly the whole of the province, and nearly all the fortresses were destroyed. Thera, esteemed the best, had not a stone unturned, Kotheree, five or six miles from Thera, was reduced to a heap of rubbish, Mothora suffered equally as did Nulliah, Kotharee, Venjan and many other towns of the same size and description; of those which suffered less Mandvee, Moondra, Sandham, Poonree, Buchao and Adooee may be recorded as the most fortunate.² At Bhuj the shock was very severe, a large part of the town and fortifications were destroyed and 1,140 bodies recovered from the ruins. At Anjar it was as severe and the destruction, proportionately, as great.

Landslips were evidently numerous and widespread throughout Cutch. "At the moment of the shock vast clouds of dust were seen to ascend from the summits of almost every hill and range of hills. Many gentlemen perceived smoke to ascend, and in some cases fire was plainly seen bursting forth for a moment." The latter part of this statement may be ignored, it is merely a repetition of the common experience of every great earthquake, that popular rumours arise, of smoke and fire, and the outbreak of volcanic eruptions,³ but the first part is probable enough; it is what

¹ Papers relating to the Earthquake which occurred in India in 1819. *Trans. Bombay. Lit. Soc.*, III, 1820, 90—116; reprinted in *Phil. Mag.*, LXIII, 1824, 105—119, 170—177. References are here given to the reprint.

² The names of these places are given in the original spelling. Most of them can be identified in the modern maps of the Survey of India as Tera, Kothara, Mothala, Naliya, Kotera, Vinjhan, Mandvi, Mundra, Sandhan, Bachau, Adhoi. Poonree is shown, with the same spelling, on the map of Wynne's Memoir.

³ The supposed eruption of Denodar has been sufficiently disposed of by Mr. A. E. Wynne, *Mem., Geol. Surv. Ind.*, IX, p. 30. One statement by MacMurdo may be noticed, that according to the chieftain of Roha, 26 miles west of Bhuj, fire was seen to issue from a hill close to the one on which his fortress was situated, "in considerable quantities. A ball of a large size was vomitted as it were into the air, and fell to the ground, still blazing on the plain below; where it divided into four or five pieces, and the fire suddenly disappeared." (*Phil. Mag.*, LXIII, 1824, p. 115). This reads like the description of the fall of a meteorite, and the supposition is strengthened by a passage in the account of the Residency Surgeon, who states that "only one meteor (a ball of fire) has been observed since the occurrence of the earthquake, and that was on the night on which the first shock took place" (*ibid* p. 173).

would inevitably result from the formation of landslips on the steep-sided hills, and the occurrence of these is confirmed by MacMurdo's statement that the hills had not in his personal knowledge "suffered more than having had large masses of rock and soil detached from their precipices."¹

The occurrence of sand vents, which are also a phenomenon of the epicentral region, in the Runn of Cutch, has already been noticed; they were frequent and widespread throughout Cutch, where favourable conditions existed. Captain MacMurdo wrote: "The rivers of Cutch are generally dry (excepting in the monsoon), or have very little water in them. Native accounts seem to confirm the fact of almost the whole of their beds having been filled to their banks for a period of a few minutes, and, according to some, for half an hour." He had not been in the way of observing this, but had no reason to doubt it. The only definite locality mentioned is in the account of the journey of two chieftains, who had been despatched to Sandham, on the south coast of Cutch. Travelling by bullock carriage they had not felt the shock, and, after dusk, "they reached the Sandham river, in which, to their utter astonishment they found a strong stream from bank to bank; nor did they learn the cause till they reached the town." It was remarked that only rivers in valleys with sandy beds were affected. "Wells everywhere overflowed, many gave way and fell in, and in numerous places spots of ground in circles of from twelve to twenty feet diameter threw out water to a considerable height, and subsided into a slough. I saw none of these actually forming, but frequently met with them in their sloughy state."²

The account of the character of the shock, and aftershocks, also points to epicentral conditions. At Anjar, some persons were convinced that the "action of the shock" was directly upwards, he himself regarded it as mainly undulatory "although the slight motion at the commencement did certainly feel as a direct elevation of the chair attended by a blow as if under its feet." From this description it is evident that there was a very considerable vertical component in the motion of the ground. The movement was so strongly undulatory that it was no easy matter to keep one's feet. "The waving of the surface was perfectly visible and, in attempting to walk, the motion has been most aptly compared

¹ *Phil. Mag.* LXIII, p. 114.

² *Loc. cit.*, p. 115.

by a gentleman to that felt when walking quickly on a long plank supported at both ends;—when one foot was elevated, the earth either rose to meet it, or sunk away from it in its descent.”

The shock was accompanied by a violent gust of wind and a noise like that of a numerous flight of birds. The noise was not heard before, but towards the end, or even after the conclusion of the motion.¹

Aftershocks were very numerous at first. By some the earth was said to have been in almost continuous motion for ten days after the principal shock,² but apart from this, there were many shocks during the night of the 16th; at a quarter to 10 A.M., the next day, there was a shock which brought down a number of shattered buildings, besides many other lesser shocks, and, until the beginning of August, no day passed without one or more shocks. After this they became less frequent, occurring only every third or fourth day at first, and later at longer intervals till the end of November.

The epicentral region appears to have extended into Kathiawar. At Jooria, Jodiya of modern maps, the whole town is reported a ruin, the fortifications shaken from the foundation and thrown down in many places. In the open country to the west fissures opened in the ground and black sandy and gravelly soil was thrown out in places, in others a black wet earth. There were many other shocks during the night and following days. The earthquake was accompanied by a rumbling sound sometimes as of wheeled carriages and sometimes of a distant cannonade. A number of other towns in this part of Kathiawar were damaged; at Amran the fort was thrown down.³

From Porbandar Captain C. W. Elwood reported that he was walking on the ramparts with another officer at 5-45, when he heard a distant sound, like a cannonade at sea, and immediately after felt a violent shock; at the same time a stone parapet, two yards distant, was “violently agitated by a quick, short, wave-like motion” with a vibration of about a foot. He determined to descend from the rampart, which was about 20 feet high, but had to run back

¹ *Loc. cit.*, p. 107.

² *Loc. cit.*, p. 111.

³ *Loc. cit.*, p. 170; another account is reprinted, from the Bombay Courier, in the Asiatic Journal and Monthly Register VIII, 1819, p. 612; the locality is given as “Isoria” but internal evidence, and reference to the original, shows that this should be Jooria.

to the nearest ramp and, as he ran, "the sensation felt was similar to that dangerous and disagreeable one of running along an elevated and elastic plank, the ends alone of which are supported." On reaching the steps he ran down as fast as he could "each lower step apparently meeting the descending foot (which I really believe was the case, as the whole flight of steps was violently agitated)". On reaching a place of safety he was surprised to see that the works had not fallen, but noticed a cloud of dust rising from the seaward face of the fortification; after the shock was over, he went to investigate, and found that the dust was caused by the fall of towers and large portions of the curtain, leaving several breaches, some forty, and some sixty, yards wide, in five hundred yards of the walls, which he had passed along not five minutes before the shock. Few houses in the city were left uninjured, some falling so as to block the streets in which they were situated. The earth opened, and water issued from the opening, in a plain fourteen miles away.¹ The Asiatic Journal contains a diary of the same officer, showing that aftershocks were frequent, and up to 23rd June he noticed "a giddy and slight sickish or faint feeling with pains in the knees and an inclination to lay down on the earth rather than sit or stand." After the 23rd these sensations were no longer noticed, though on the 24th there was a shock, just after midnight, which threw down some houses. He attributed the sickish feeling to a rocking motion, they were confident that the earth was in a long rocking or rolling motion, though they could not observe it.²

Captain Elwood mentions that at Mangrol, eighty miles to the south-east, fifty men were reported to have been killed by the fall of walls. This indicates that the shock was comparable in violence with that experienced at Porbandar. Inland the shock seems to have been markedly less severe. Captain Elwood merely states that it "appears to have been less violent than near the sea-shore," but the *Bombay Courier*³ has further details, in an account from Porbandar, in which it is said that some *Kasids* who had felt the shock at "Gundel" (Gondal), where it had been less severe than on the coast, mention the fall of houses at many places, but saw no ruin of fortresses, though they had passed seven, "Kooteeanna" (Kutiyana) suffered severely, but not so much as Porbandar.

¹ *Phil. Mag.* LXIII, pp. 174-176.

² *Asiatic Journal*, IX, 1820, p. 164.

³ 17th July 1819.

The only other place in Kathiawar, from which I have found any report, is "Rampoor near Pullgarde" where the fort is reported as nearly demolished. If, as seems probable, this is Ranpur, twelve miles from Paliyad, it lies quite in the east of the Kathiawar peninsula.¹

These accounts show that Porbandar, at any rate, and apparently Jodiya also, must be regarded as lying within the epicentral area. Elsewhere the evidence is inconclusive, but over the rest of Kathiawar the violence of the shock was evidently less, though severe, probably reaching VII° of the Mercalli scale, over the western part of the peninsula. At Porbandar the evidence is ample, for not only have we the great violence and destruction, but also the numerous after-shocks, and almost continuous movement for several days.

There is some indication of a northerly extension of the epicentral area, in the damage reported at Baliari, Umarkot and Jaisalmer. Captain MacMurdo wrote that the damage sustained by these three places 'points out that the severity of the motion extended beyond Cutch in that particular direction,'² but gives no particulars. Baliari in 1852, according to Sir G. Le Grand Jacob,³ consisted of some mud huts and a ruined mud fort; this may well have been wrecked at the time of the earthquake, for Baliari is mentioned by Sir A. Burnes as one of the places on the Sind side of the Runn at which the Government of Cutch still maintained garrisons in 1819. This place lies close to a locality where, as there seems to have been a change of level, it is natural that the earthquake should have been severe. Of Umarkot I have been unable to find any particulars, but at Jaisalmer an account in the *Bombay Courier*, received through Bhuj, states that the shock was severely felt and the loss of lives terrible. The fort and town were reduced to ruins; a wedding was being celebrated and five hundred of those who were being feasted in the streets were smothered in the ruins of the falling houses.⁴

The account is probably exaggerated, but, after making all allowance for this, it is evident that the shock was severe at

¹ *Asiatic Journal*, VIII, 1819, p. 612.

² *Phil. Mag.* LXIII, 1824, p. 110.

³ *Trans. Bombay. Geog. Soc.* XVI, 1863, p. 24.

⁴ *As. Journ.* IX, p. 309. The name of the place is there misprinted as Jelilsbeer, but is correctly given in Vol. X, p. 435.

Jaisalmer, more so in fact than at any other place outside of Cutch and Kathiawar.

To the eastwards of Cutch, the shock was severe at Ahmedabad ; it is reported as accompanied by a sound, rumbling at first and increasing to a strong rushing noise, as the motion became violently undulating, so that it was difficult to keep on one's legs, the sensation being that of a ship at sea on a swell. The minarets of the great mosque, after standing for four hundred and fifty years, were thrown down, as were those of another mosque ; the towers of the main gate of the citadel were badly damaged, the walls of the *ad-aulat* and of the palace were rent in many places, and many private houses reduced to ruin. No deaths were reported.¹

At Kaira the *ad-aulat* (law-court) and Jain temple were injured, a good deal of damage done to buildings and two persons killed by the fall of houses.²

At Baroda the house, in which the writer was at the time, rocked so violently that he thought it would have fallen before they could get downstairs. At "Pallampore" (possibly Palanpur, twenty-five miles east-north-east of Baroda) it was accompanied by a noise in the earth like thunder.³ No mention is made of damage to buildings.

At Broach houses that were elevated, and at all loosely built, creaked like the rigging of a ship in a gale, venetians and window frames rattled violently ; a considerable lateral motion was impressed on everything that admitted of it. After this violent concussion had lasted for a minute, or upwards, it was succeeded by oscillatory motion of a more equable character, which lasted for a minute and a half. Those in palankeens or wheeled carriages did not feel the shock, a gentleman riding noticed nothing but was alarmed by seeing houses tumbling down.⁴ It is illustrative of the difficulty met with in determining the comparative violence of the shock, from descriptions by untrained observers, that there would be no indication of any damage having been wrought by the earthquake at this place, were it not for the incidental mention at the end of this description. In the *Bombay Courier* of 26th June it is stated that the ground moved like waves of the sea, so that it was the greatest difficulty to keep one's legs. Water in the well rose, many

¹ *As. Journ.* IX, 1820, p. 308.

² *As. Journ.* IX, 1820, p. 308.

³ *As. Journ.* VIII, 1819, p. 612.

⁴ *As. Journ.* IX, 1820, p. 307.

feet, with a great noise, and did not subside for an hour. Many houses were thrown down.

At Surat the shock is described as a strange trembling sensation. Wall shades shook violently and chandeliers swung, furniture was set in motion, a small table kept striking against the wall. Several houses and one side of a Parsee Pagoda fell at "Omer" (Umra) about two miles to the west.¹ The *Bombay Courier* adds that the well in the jail overflowed, the water being ordinarily four feet from the surface. The river was much agitated and water was thrown out from the tank in the bazar.

The only other place at which damage is mentioned lies much further to the east, in what are now the United Provinces. At Sultanpur the shock was "severe and awful," bungalows rocked and the huts of the soldiers were a good deal damaged. At "Jionpoor" (Jaunpur) the shock was strong, with the usual accompaniment of rattling wall-shades, swinging punkahs, and flapping doors. It was not accompanied by the rattling noise usually heard.²

At Muttra, Mainpuri and Fattehgarh, all further west than Sultanpur, the shock was felt, but described as slight. To the eastwards it is recorded from Mirzapur and Chunar, at the latter place accompanied by a noise resembling the rapid flight of birds.³

The shock was experienced in the valley of Nepal⁴ and at Calcutta two slight shocks were felt partially in some districts.⁵ This is the most easterly place at which there is any record and must be near the limit, in this direction, of the area in which the earthquake could have been felt.

To the south-eastwards of the epicentral region, the shock was reported in the local papers at Bombay, before news had come through from Cutch. The earthquake was said to have been very perceptibly felt, lasting only a minute and doing no damage, being so slight that many persons did not notice it. At Poona it was scarcely felt at all.⁶

In the interior of the Peninsula it seems to have been much less noticeable than in Upper India, and, according to Captain MacMurdo, was not felt at all in many parts of Malwa and Khandesh. This statement was probably based on enquiries, but the only

¹ *As. Journ.* IX, 1820, p. 307.

² *As. Journ.* IX, 1820, p. 184.

³ *Ibid.*

⁴ *Ibid.*, p. 310.

⁵ *Ibid.*, p. 70.

⁶ *As. Journ.* X, 1820, p. 437.

definite published information, which I have come across, is that it was so trifling at Mhow as to be noticed by only a few officers,¹ and that the shock was not felt at Amraoti, but was sensibly felt at Ellichpur, about thirty miles away, and at that place water was thrown out of the fountain in the palace.²

In Madras, reports from Masulipatam say that it caused a considerable degree of giddiness and even fainting, but little or no noise was heard. It was slightly felt at Pulicat and at Pondicherri. From "Triviar" in the Coimbatonam district probably Tiruvalur of modern maps, the Munsif wrote that at half past seven the earth was convulsed, all present became as if intoxicated and could not stand, pillars of the building shook and threatened its destruction, boxes, etc., were moved from their places, the thanadar was thrown down, as was also the peon who went to assist him. These persons, with many more in the town, experienced violent vomiting. The Pagodas and town remained in motion for about four minutes.³

It is difficult to say whether this account really represents a greater violence of shock than is suggested by the accounts from places further north or north-west, or is merely the exaggeration of a vivid imagination. The duration is longer than is given from any place remote from Cutch and Kathiawar, and the statement regarding boxes being moved from their places, if taken literally, necessitates a greater intensity of shock than was experienced by Bombay, which is about one quarter of the distance from the epicentral region in Cutch. It is probable that there was no more than a swaying, due to the slow tilting of the ground, which characterises the shock at a long distance from the centre of a great earthquake and may be noticeable by its visible effects, even where the shock is not otherwise sensible.

In a westerly direction from Cutch the extension of the shock was evidently very much less than in the opposite direction, for it seems to have been slight, and caused no damage to any of the towns in Sind. MacMurdo states that "in Sindh it was felt very partially and slightly; and similarly at Shikarpore;" he places the western

¹ *As. Journ.* X, 1820, p. 437.

² *As. Journ.* IX, 1820, p. 384. The statement indicates a gentle undulatory motion, such as is characteristic of the distant part of the seismic area of great earthquakes.

³ *As. Journ.* IX, 1820, p. 79.

limit in "the Mountains of Billoochistan" and that he "had never heard that it was experienced at Muscat." He notices that, if it had extended as far westwards, of Cutch, as it was known to have extended to the east, it should have been felt in Persia and Arabia, "we know, however, that the shock was not felt in these countries."¹

As regards Persia and Arabia no importance can be attached to the absence of information, but it is different as regards Sind. His official position required that he should maintain a constant correspondence with that country, and keep himself informed of what happened there, and had the earthquake been severe enough to cause material damage, he would not fail to have heard of it. We may be certain, therefore, that at none of the cities of Sind was the earthquake severe enough to be destructive, for had the shock been as severe as at Ahmedabad, or even at Baroda or Surat, news of it would certainly have reached Captain MacMurdo, yet Haiderabad, the capital of Sind, is not more than 170 miles from Central Cutch, and only some 90 from the Allah Band near Sindri, while Ahmedabad is fully 180, and Baroda or Surat about 240 miles. To Shikarpur, where the shock was very feebly felt, is not much over 300 miles from Central Cutch.

A brief mention may be made of the aftershocks.

As has been mentioned, tremors were almost continuous for some days at Bhuj and Porbandar. Of definite shocks, apart from the small tremors at these places, Surat reported one at half past eight on the 16th, three were noticed at Anjar before 11 o'clock, and at Surat one at 8½ o'clock.

On the 17th at Ahmedabad, between 12 and 1 A.M. and at six o'clock; a little before ten the principal aftershock was felt at Jodiya, Porbandar, Ahmedabad, Baroda Broach and Surat; at Ahmedabad shocks occurred at intervals during the day, the last at 0½ A.M. on the 18th.

On the 18th a shock was recorded at 7 A.M. at Surat and 11 A.M. and midnight at Baroda; it is noteworthy that it is definitely stated that there were no shocks or tremors at Porbandar.

On the 19th several slight shocks were recorded at 1-20 A.M. at Surat, and at midnight at Porbandar.

¹ *Phil. Mag.* LXIII, 1824, pp. 110-111.

On the 20th at Porbandar a sensible tremor at noon, repeated fifty minutes later; at Baroda two shocks, time not specified.

On the 21st at Porbandar a shock, rather strong, at 9 A.M., and a continued tremor at midnight.

On the 23rd, at Surat, 2 A.M., a strong shock set house and furniture in motion; at Porbandar tremors at midnight.

On the 24th at Porbandar between 12 and 1 o'clock at night a shock by which some houses were thrown down.

Other shocks are reported at later dates in June and July, namely, June 29th, Bhuj 2 P.M.; July 4th, Bhuj 3 A.M.; 8th, Surat 11 A.M.; 11th, Surat 5 A.M.; 15th, Bhuj 1 A.M. and 7½ P.M.; 16th, Bhuj 10 A.M.; 17th, Bhuj 10 A.M.

Such is the information extant regarding this earthquake. Considering the date, it is surprisingly abundant and complete, and even a cursory review shows that it was not one of those earthquakes with a well-defined centre of maximum intensity, which might conceivably be attributed to a single fracture, but, like the great earthquake of 12th June 1897, it had a large and irregular central area over which the earthquake had everywhere a great but varying degree of intensity. In other respects, too, it exhibits peculiarities and analogies with the 1897 earthquake, which cannot be discussed in a satisfactory manner till the record of that earthquake has been reviewed in the light of additions to our knowledge, which have been made during the last five and twenty years.

CHAPTER IV.

SUMMARY AND CONCLUSION.

Reviewing the records of the Cutch earthquake, in the light of the suggestions developed in the last chapter, the first point to be noticed is the close resemblance between the character and effect of the earthquake, in Cutch and the Ruun, to that of the 1897 earthquake in the western part of the Assam range and the Brahmaputra Valley. In the Cutch earthquake, we have no details from which a measure of the acceleration of wave-particle can be deduced, yet it is probable, from the recorded effects, that the shock was of the same order of intensity as in 1897, and, as in that case, there was no definite centre of maximum violence, but a large area over which the shock was everywhere destructive. The dimensions of this area cannot be given with precision, but they seem to have been smaller than in 1897, about two-thirds if Ahmedabad and Umarkot are included, but as great or somewhat greater if the area is extended to include Jaisalmer.

The area of destructive violence seems not to have been continuous. It spread over all Cutch and the western end of Kathiawar, but the region from Ahmedabad to Baroda and Broach, from which severe damage to buildings is reported, seems to have been separated by a tract, covering central Kathiawar, in which the shock was less severe, and little damage done. If this was so there were two separate regions of greatest violence, a feature which is common in the great earthquakes of southern Italy. In the absence of reports from the intermediate country, it is impossible to say whether there was a similar independent centre of greater intensity of shock near Jaisalmer, or whether the area of great violence of shock extended continuously from Cutch.

The permanent displacements of the ground were remarkable. The evidence is clear that they were of the same type as in the Californian earthquake of 1906, namely, displacement of the ground in opposite directions, on opposite sides of a definite line, but in Cutch the shift was vertical, whereas in California it was horizontal with very little vertical movement. The similarity in character was otherwise complete, the displacements being greatest in amount

close to the boundary between the two opposite movements, and gradually diminishing as the distance increased. In both cases they were just such as would result from elastic yielding of a block, in which a state of strain had been produced, if this strain were locally relieved by a fracture; there can be little doubt that this was the explanation in both cases, but the difference in direction, of the movement, points to a difference in the direction of deformation, by which the strain was set up.

These displacements would probably have passed unnoticed and unrecorded, had it not been that, in part, they affected a region which lay almost at sea level, and connected with the sea by an open channel, through which the waters had easy access to the tract of country which had been depressed below the sea level. They would probably not have been fully understood, and the lateral extent over which displacements took place would certainly not have been realised, but for the desert character of the country, which enabled the changes, impressed at the time of the earthquake, to be still recognisable in the careful survey, made more than sixty years later.

Apart from the extent and character of the displacements, which can be recognised as having taken place, it is noteworthy that these are confined to the outer limit of the region in which the disturbance was great and destructive. From this fact, it is natural to conclude that changes, of surface level, were not confined to the one district, in which they can still be recognised, but, as in 1897, extended over a large area, and that, had the remainder of the Runn, and especially the mainland of Cutch, been examined in the light of present knowledge, or even of that which existed half a century after the earthquake, numerous instances of permanent deformation, of the surface, would have come to light.

Consideration of the nature of the shock at the various places, from which we have records, indicates that it was distinctly more noticeable through Upper India than in the Peninsular region, south of the Indo-Gangetic plain. The minor damage reported from Sultanpur, in a region where otherwise the shock was not sufficiently severe to leave any after effects, and far distant from the limits of the region in which damage to buildings was common, was paralleled in 1897 by the minor damage at Birdha, south of Lalitpur. Other records from places in the plains, of Upper India, show that the shock was generally felt, and was noticeable even as far east

as Calcutta. Along a line further south, the shock seems to have been much slighter. The distance of Bombay from Cutch is less than half that of Sultanpur, yet the shock appears to have been much less severe, and no more so than at Mirzapur, or Chunar, at fully three times the distance. In Central India it seems to have been very slight, as witnessed by the report of its having been felt at Ellichpur, but not at Amraoti.

Here we seem to have evidence of a linear extension of the origin in an eastern direction, very much along the course of the western extension indicated in 1897, with a varying intensity of initial disturbance, though everywhere of much less intensity than in Cutch and Kathiawar.

In a southern direction, the report from the Coimbatonum district, indicating a more pronounced disturbance than was experienced at lesser distances, may be the result of an increase of intensity on a focal line extending in this direction, or possibly an independent sympathetic shock. In this connexion it may be noticed that, in the Srimangal earthquake of 8th July 1918, Dr. Murray Stuart found evidence of a sympathetic earthquake, of which he placed the centre near Madura, though in this case it was not of intensity sufficient to be felt, and was only recognised through instrumental records.¹

From this it appears that, as regards the shock which could be felt, and in 1819 there could be no question of long distance records of the disturbance which cannot be felt, observations are not consistent with the supposition of a central origin, of restricted dimensions, from which the disturbance was propagated, as elastic wave motion, decreasing in intensity with increase of distance of travel, but, as in 1897, point to a very extended origin, ramifying in narrow, or even linear, bands over the affected area, and with varying intensity of initial disturbance.

This interpretation becomes more probable when the westerly extension of the disturbed area is considered. At the north-western limit of the Runn of Cutch, where the Allah Bund was formed, the intensity of disturbance was very great, and at Umarmot it was destructive. To the westwards, in Sind, no damage was reported, and it may be accepted that no serious damage was inflicted on any of the cities of that province; and at Shikarpur the shock was

¹ *Mem. Geol. Surv. Ind.* Vol. XLVI, pt. i, 1920, pp. 49-51.

very slightly and partially felt. This seems to have been near the western limit of the area affected, which would be about 350 miles distant from Central Cutch, as compared with 1,150 to Calcutta, and 1,100 to the eastern part of the Tanjore district, in Madras.

This great discrepancy in distance, from the region of greatest violence to the farthest point at which the earthquake was just noticeable, suggests that the centre of the bathyseism may not have been directly under the centre of greatest surface shock. To make it approximately central to the disturbed area would put it about under the Satpura mountains, a position which, for many reasons, seems inadmissible; putting it under Cutch or the Runn seems to introduce as great or greater difficulties, but matters would be much simplified if the centre of the bathyseism could be placed under Ahmedabad and Baroda, or even further east, in Rewah Kanta. If this were so, the great violence of shock in Cutch would be due to local causes, which gave rise to a greater violence of episeism, in that region, than directly over the initial disturbances of the bathyseism. The records, however, are not such as to admit of profitable consideration in their bearing on this possibility.

POSTSCRIPT.

Since writing this memoir, a report on the Japanese earthquake of 1st September 1923, by K. Suda,¹ has come to hand, which confirms, in a remarkable manner, one of the conclusions drawn from the accounts of the Cutch earthquake. On p. 31 it was pointed out that the contemporary accounts indicate that the original depression of the ground, round Sindri, was partially recovered within a few weeks, or months, but the evidence, though fairly conclusive, pointed to an effect which had not been conclusively established in the case of any later earthquake. We have now proof, accompanied by definite measurements, that something similar occurred, in the case of the earthquake which led to the destruction of Tokio.

In the report on the Japanese earthquake, it is mentioned that many places on the shores of Sagami Bay were upraised at the time of the earthquake, and that the uplift had undergone considerable diminution within three or four weeks of the shock. Some of these changes were remarkable in amount; at Misaki the initial uplift was 7.6 metres, and the small island of Jogashima was joined to the mainland for three days, but, on the fourth, the land began to sink again, nearly 60 cm. on the first day, then decreasing in daily amount till, by September 26th, the uplift had been reduced to 1.4 metres. At Banda and Shirahama the initial uplift was 4.5 m., and within four weeks had decreased to 1.6 m. and 1.8 m. respectively.²

This is very like what occurred in the Runn of Cutch in 1819, and in both cases the natural interpretation is the same: that the rocks had been thrown into a state of strain, which was relieved by fracture and displacement of the surface layers on either side; then, as things settled down and the strain was relieved, part of the original elastic displacement was recovered, leaving the levels still changed, though less so than at first. In the Japanese earthquake the partial recovery of level could only be observed at some distance from any surface faulting, which may have taken place under the waters of Sagami Bay; in Cutch there is no reason to suppose that

¹ On the great Japanese earthquake of September 1st, 1923; *Memoirs of the Imperial Marine Observatory, Kobe, Japan*, Vol. I, No. 4, 1924, pp. 137-239. A summary is given, in a paper on this earthquake, by Dr. C. Davison, *Geog. Journ.*, LXV, 1925, pp. 44-61.

² Suda, *loc. cit.* p. 166, and *Geog. Journ.* p. 51.

any change took place in the relative displacement on either side of the fault, nor is such change at all likely, for the frictional resistance to movement along the fault would be too great to be overcome by the forces acting after the main shock. Away from the fault the conditions were different; it is impossible to say how deep the fault extended, but it is probable that, like others, it died out at a depth which was only a fraction, very considerably less than a half, of the thickness of the outer crust of the earth, and, if this were so, the parts of the outer layers, which had been distorted at the time of the earthquake, would tend to return to their original positions, when the forces leading to deformation had ceased to act. At the fault line, as has been pointed out, the relative levels would not change, but away from it there would be a gradual return towards the original form, leading to increased slopes near the fault and a narrowing of the elevated and depressed tracts on either side.

The sequence of events, described above, may be made clearer by the diagram in fig. 7, which is purely diagrammatic and has

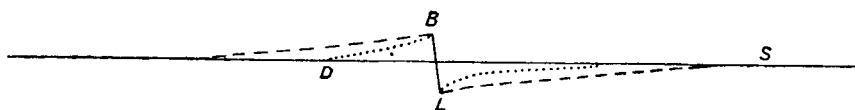


Fig. 7.

the vertical scale greatly exaggerated in comparison with the horizontal. In this the firm line, NS, represents the original slope of the ground, the broken line, NBLS, the section after the formation of the Allah Bund and the Sindri depression, and the dotted line the section after the strains, left by the deformation, had been eased by a partial return to the original levels. Moreover, if the displacement from the original levels had been unequal on opposite sides of the fault, as was almost certainly the case, the reversion towards original conditions would lead to a general uplift or depression of both sides of the fault, and so might easily give rise to a depression below the general slope of the country, at the point marked D in the diagram, such as is indicated by the area, subject to temporary flooding, shown by the Survey of India to the north of the Allah Bund.

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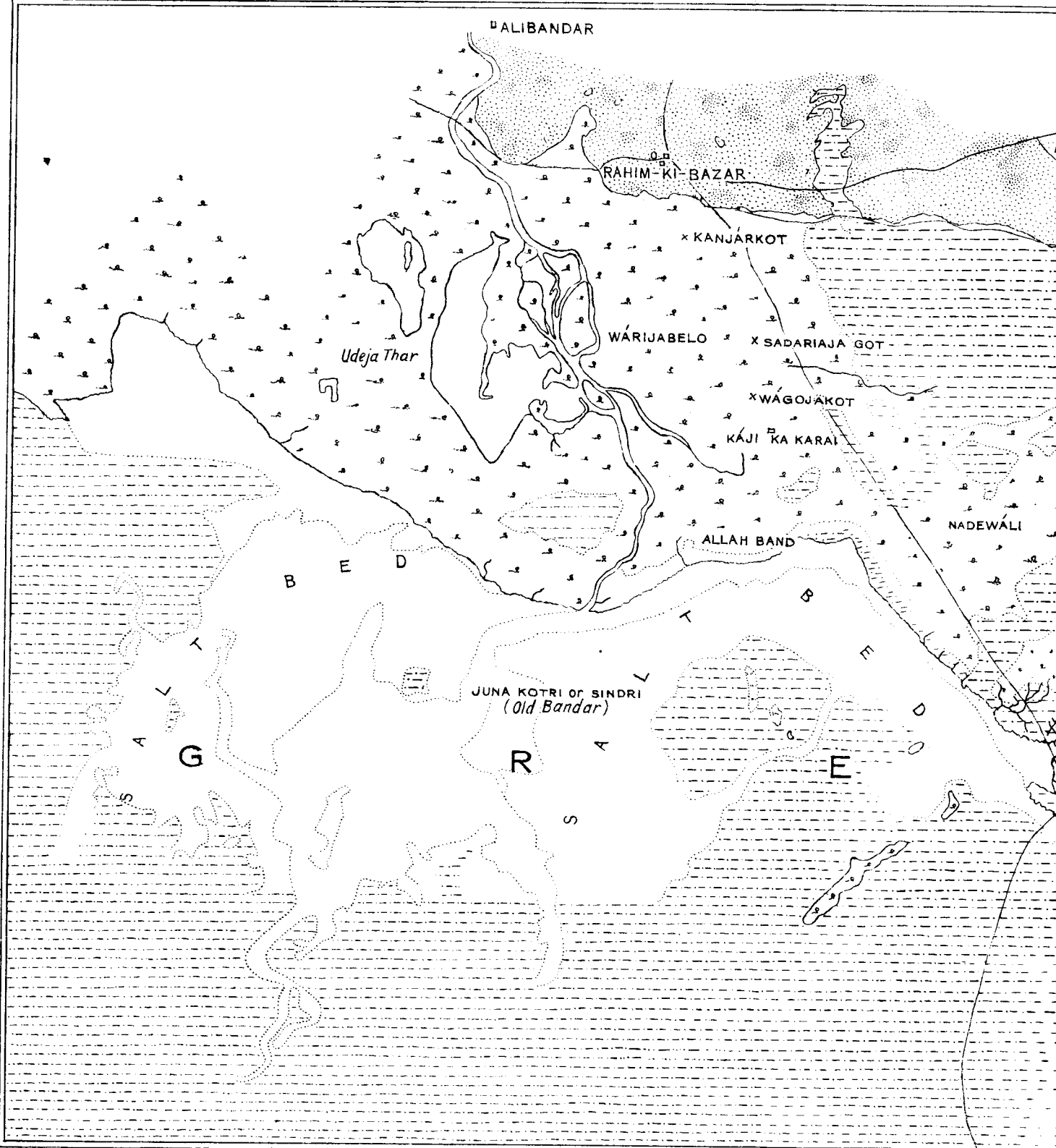
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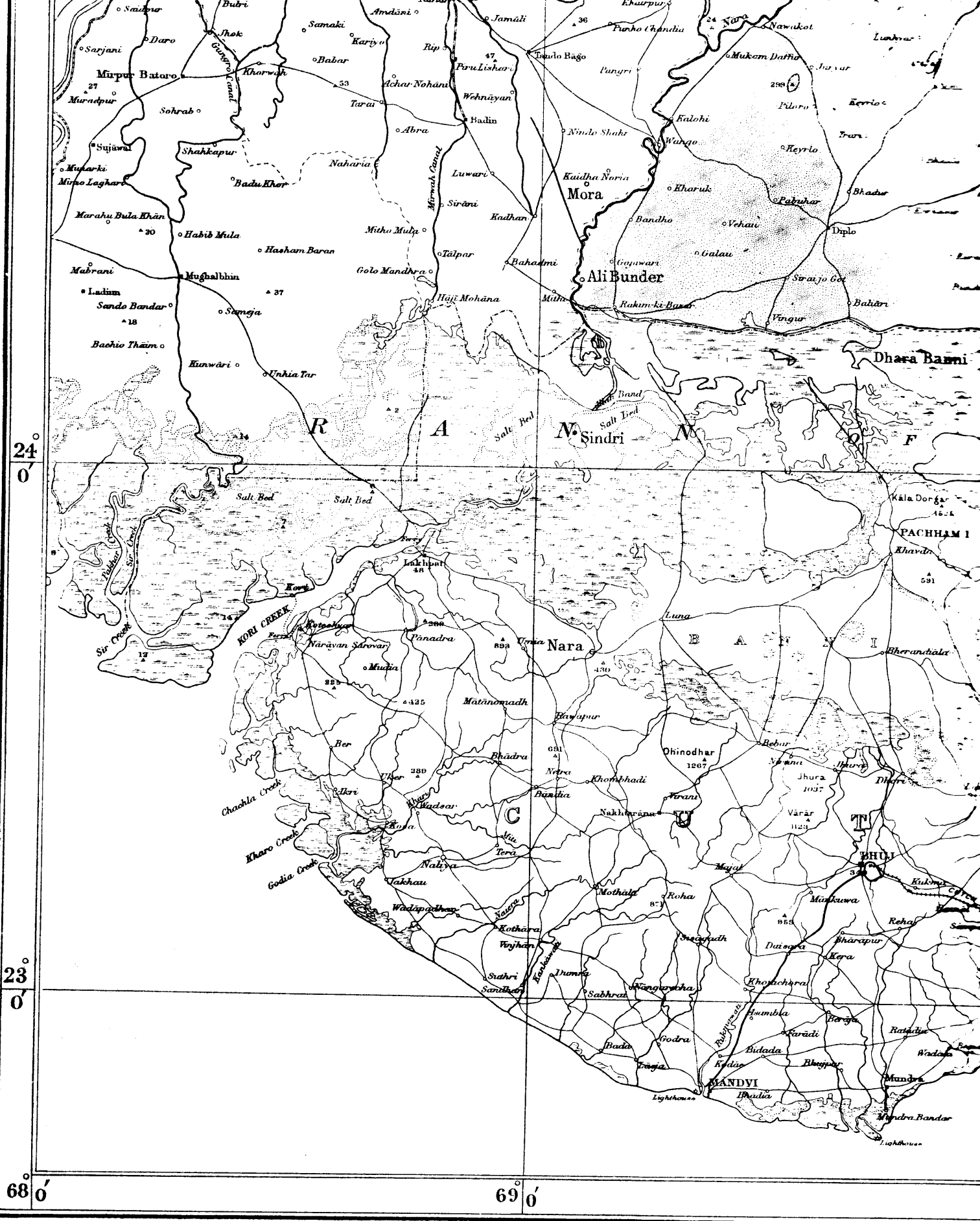
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69° 0'



24° 0'

69° 0'



24
0

23
0

68
0

69
0

Mirpur Batoro

Mora

Ali Bunder

Nara

Dhara Banni

PACHHAM I

BHULI

MANDVI

KORI CREEK

Salt Bed

Chaahla Creek

Khoro Creek

Godia Creek

Naharia

Golo Mandhra

Matanmadh

Nakhar

Wadapath

Kharpur

Taulo Bago

Nimlo Shahr

Kaidha Noria

Sindri

Salt Bed

Lakhpur

Nara

Bayapur

Banthe

Nakhar

Wadapath

Mandvi

Mukam Daffa

Filora

Keylo

Galau

Vingur

Luna

Dhinodhar

Behur

Jhura

Varar

Muskawa

Dungra

Bhidada

Ludhar

Keylo

Tran

Bahar

Bharantala

Kala Donga

Ahava

Dhara

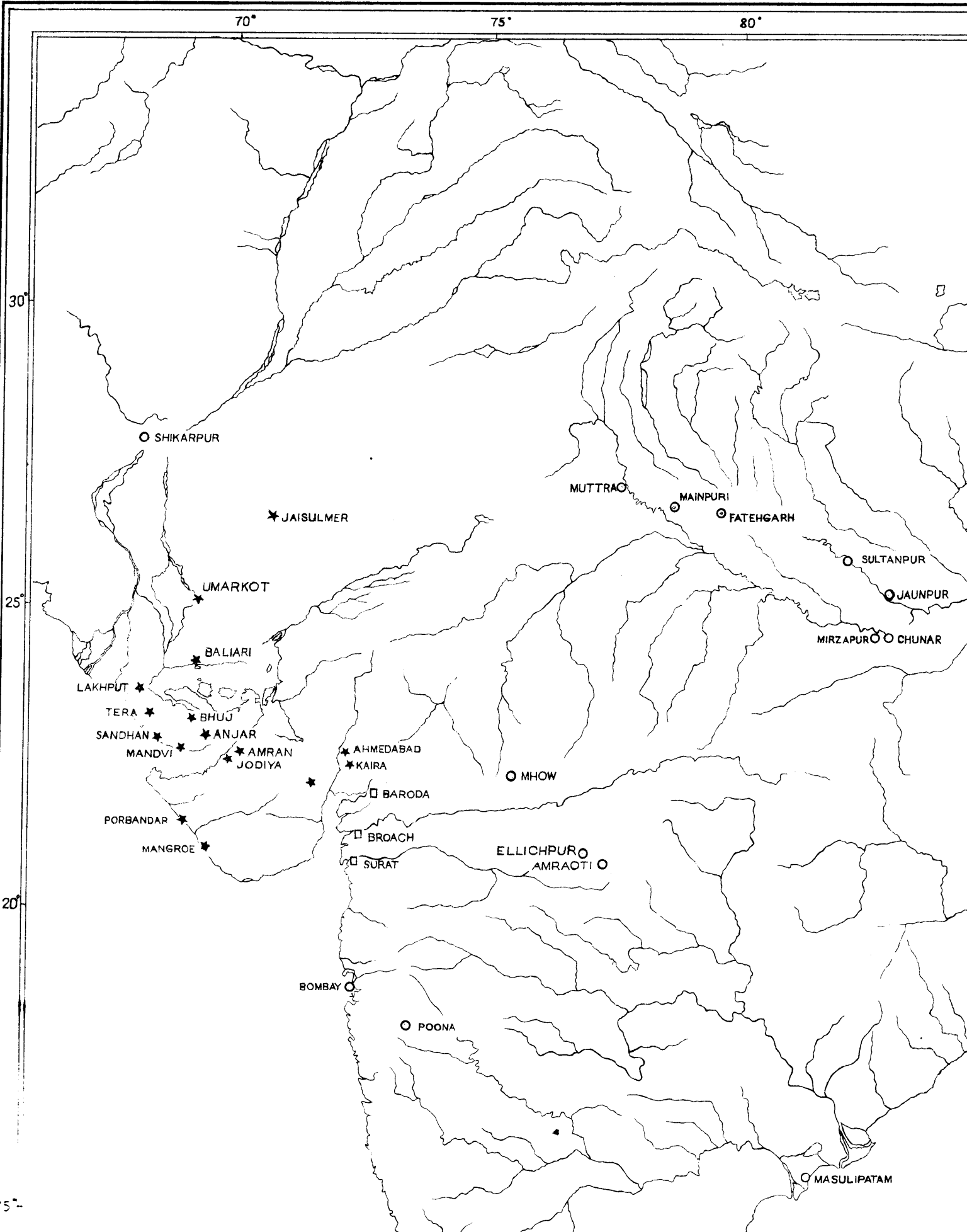
Dhara

Kulna

Reha

Bharapur

Mandvi



70°

75°

80°

30°

25°

20°

5°

SHIKARPUR

JAISULMER

MUTTRAO

MAINPURI

FATEHGARH

SULTANPUR

JAUNPUR

UMARKOT

MIRZAPUR

CHUNAR

BALIARI

LAKHPUR

TERA

BHUJ

SANDHAN

ANJAR

MANDVI

AMRAN
JODIYA

AHMEDABAD
KAIRA

MHOW

PORBANDAR

MANGROE

BARODA

ELlichPUR
AMRAOTI

BROACH

SURAT

BOMBAY

POONA

MASULIPATAM

