

11. *The PAMIR EARTHQUAKE of 18th FEBRUARY, 1911.* By RICHARD DIXON OLDHAM, F.R.S., F.G.S. (Read November 5th, 1922.)

THE Pamir earthquake of the 18th of February 1911, though of destructive violence in the central region and giving rise to long-distance records, would probably have passed without special notice had it not been for two circumstances: one, that it was accompanied by a landslip of exceptional dimensions, which dammed one of the principal drainage-valleys of the region, and gave rise to a permanent lake over 15 miles in length and 900 feet in depth; the other, that the late Prince Boris Galitzin formulated the conclusion that this landslip was the originating cause of the earthquake, and that this was an interesting and unique instance of coincidence of epicentre and hypocentre. Attention has been recently drawn¹ once more to this earthquake, and, although mistakes in Prince Galitzin's mathematical methods have been pointed out, the justice of his conclusion has been maintained; but this conclusion is so contrary to all other present knowledge of the character and behaviour of earthquakes, that a fuller examination of the evidence seemed desirable, and as this is not generally available, being published almost exclusively in the Russian language, it has seemed desirable to record the facts, so far as they are available.

Before dealing with the local observations and records of the earthquake, it will be well to refer briefly to Prince Galitzin's paper.² His conclusions were based primarily on the survey conducted in 1913 by Col. Spilko, from which it was computed that the mass of the landslip amounted to between 7 and 10 milliards of metric tons, and the height of fall was somewhere between 300 and 600 metres, from which it results that the amount of work done in falling, and set free by arrest of fall, lay between the limits of 2.1×10^{23} and 6.0×10^{23} ergs.

The next step was to estimate, from the seismographic records at Pulkovo, the amount of work transmitted past that station, and from this to compute what should have been the amount set free at the origin. The result of his computation gave 4.3×10^{23} ergs, a figure almost identical with the mean probable value obtained from the survey of the landslip, and hence it was concluded that the landslip gave rise to the earthquake.

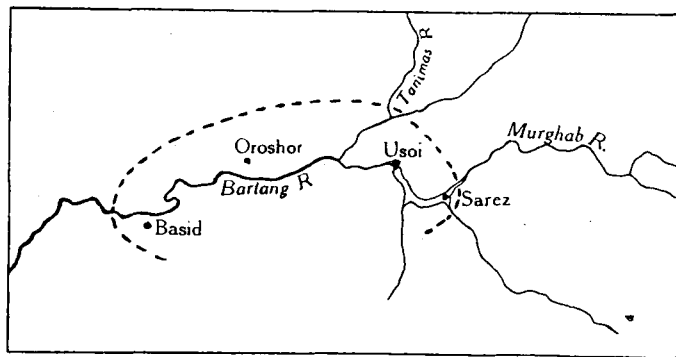
The whole calculation, however, is vitiated by the fact that, in

¹ At a geophysical discussion held in the rooms of the Royal Astronomical Society on March 3rd, 1922. [See also H. Jeffreys, 'The Pamir Earthquake of 1911, February 18, in relation to the Depths of Earthquake Foci' *Monthly Notices, Roy. Astronom. Soc. Geophys. Suppl.* vol. i (1923) pp. 22-31.]

² 'Sur le Tremblement de Terre du 18 février 1911' *C. R. Acad. Sci. Paris*, vol. clx (1915) pp. 810-14.

computing the amount of work transmitted past Pulkovo, the departure of the seismogram from the mean position was attributed to a horizontal movement of the ground, the seismograph being taken to act as a steady point; but it is well established that the record in the third phase (or long) waves, which were exclusively used in forming the estimate, is due to tilting and not to inertia: consequently the estimate, being based on an erroneous interpretation, is necessarily in error, and the real value at Pulkovo must be in defect of the adopted value to an unknown, and probably considerable, extent. Besides this, some faults have been pointed out in the formula used for computation. These considerations undermine the basis on which Prince Galitzin's conclusion was founded, and, in addition, it may be urged that, in the present very imperfect state of our knowledge of the nature and physics of

Sketch-map of the epicentral area of the Pamir earthquake of 18th February, 1911.



these surface-waves, no final conclusions can be drawn from the most exact agreement, nor from the absence of such agreement, between computation and observation. It becomes necessary, therefore, to examine the question from other aspects before accepting, or rejecting, the assertion that the landslip was determined by the earthquake.

The only account of this shock, that I have been able to find, is a report by Col. Spilko, published by the Russian Imperial Geographical Society in 1914.¹ He was primarily concerned in

¹ 'The Pamir Earthquake of 1911 & its Consequences: Chronological Reference & Report of the Works of the Military Detachment of the Pamir' by Col. Spilko, Staff Officer & Chief of the Pamir Detachment, Bull. Soc. Imp. Russ. Géogr. vol. 1 (1914) pp. 68-94, with map & plate of sections (in Russian). On account of the interest attaching to this earthquake, I have had a translation made of Col. Spilko's paper, and deposited it in the Library of the Geological Society of London, for the use of those who may be interested in the subject.

the examination of the great landslip and the lake produced by it, but incidentally gives a general account of the earthquake derived from official and other reports; reference is made to accounts and reports in newspapers, but all that is important, for the present purpose, seems to have been incorporated by him.

The earthquake took place on the night of the 5th-6th February, 1911 (O.S.), the time, as locally determined, varying from 11.15 p.m. to 1.20 a.m.¹ The central region lay close to the junction of the Tanimas with the Murghab, or Bartang, river, in about lat. 38° 15' N., long. 72° 38' E., and here the destruction, not only of villages but of roads, bridges, and all means of communication, was so complete that nearly six weeks had passed before news could reach either the military headquarters at the Pamir Post, or the civil headquarters at Khorog. Two attempts to reach the devastated region were made: Capt. Zainkin was despatched down the Murghab valley, and at Sarez found further progress impossible; while, from the Oxus valley, the official despatched by the Governor of Koshan found his progress towards Oroshor, the headquarters of the district, stopped by complete destruction of the roadway, at some place unspecified, before he could reach his destination. According to Col. Spilko's account, written two years later, the total loss of life amounted to 302 men, women, and children; details are given of separate villages and settlements, some of which I have been unable to find on any map; but the easternmost of those that I have been able to identify is Sarez, which escaped rather lightly with a loss of some houses and no deaths, and the westernmost Basid, which was almost completely destroyed. The distance between these two places is about 35 miles in a direct line; but the region over which the earthquake reached a destructive degree of violence evidently exceeded this limit, for it is recorded that the first news of the disaster that reached the Oxus valley was brought by a plucky Tajik, a resident of Basid, who descended the Bartang in a native boat (probably an inflated skin), and from this account it is evident that the destruction of the roadway and interruption of all land communication extended for some distance westwards, or downstream, from Basid. In this region, besides the destruction of buildings, of bridges, and of the galleries by which the roads were carried round the faces of cliffs, caused by the direction of the earthquake, there were numerous landslips, which will be dealt with later.

In an easterly direction the earthquake was strongly felt at the Pamir Post, where it is said to have lasted two minutes, accompanied by a subterranean rumbling, was severe enough to make all the inhabitants leave their houses, and caused clocks to stop. A second shock an hour later is reported. Some cracks were formed in buildings. At Kizil Robat the shock was felt in about the same degree, and at Rangkul and Tashkurgan (in Chinese

¹ The time, as determined from distant records, would be about 18h. 41m. Greenwich mean time, or 23h. 31m. local time.

Turkestan) it was noticed, as a slight undulation, only by a few people.

In a northerly direction it is reported that the waters of the Kara-Kul Lake surged over the eastern, low-lying, bank for a distance of about half a verst (1750 feet) leaving a bank of ice behind on their retirement. In the Alai district it was feebly felt, in about the same degree as at Tashkurgan.

Westwards the shock was severe, and caused great alarm throughout the districts of Shignan and Roshan. At Khorog a subterranean rumbling was noticed, great alarm was caused, but no damage reported. At Ishkashim the earthquake was severe, and followed at intervals by feebler ones. No damage to buildings was done.

The seismic area of this shock must have extended into Afghan territory, across the Oxus, but no records on which any reliance can be placed are available. Col. Spilko quotes reports that 300 houses were destroyed and 460 people killed in Kabul, 60 houses and 240 deaths at Kala-i-Yavun, 70 houses and 2 deaths at Konabad, and a few houses (but no deaths) at Faisabad. The first-named of these, unless some place which I cannot identify is meant, obviously cannot refer to this earthquake. The other reports, if accepted, must refer to a different earthquake, or else indicate that this, like some of the Calabrian shocks, had two distinct centres of greatest intensity; more probably, however, the reports are either greatly exaggerated, or wholly imaginary.

These accounts allow of the formation of an approximate estimate of the magnitude of the earthquake. The centre of greatest intensity lay not far from Oroshor, the headquarters of the district of the same name, or between it and the junction of the Tanimas and Murghab valleys. The central area, over which the intensity was at least VIII° R.F.,¹ extended from about Sarez on the east to beyond Basid on the west, the dimension in this direction being at least 40 miles; in the transverse direction the dimension is indeterminable, as population and communications are confined to the valleys. The outer limit of the area over which the shock was at all sensible can be fairly well fixed in an easterly direction at about 150 miles from the centre; in a southerly direction the limit was probably about the same; on the west the distance would be about 220 miles from the centre, if the earthquake was really felt at Konabad (Khanabad). As has been pointed out, however, all the reports from Afghan territory are very uncertain, and the authentic records suggest that the limit in this direction was less than on the east, possibly not more than 100 miles; on the north the limit seems to have been much the same, or about 100 miles. The actual dimensions of the region included by the II° R.F. isoseist may be put at about 250 square

¹ Col. Spilko gives the intensity as VIII° over the whole of this region; but the accounts reproduced by him and the description by Sir Aurel Stein (quoted later) show that over the greater part of it the intensity must have ranged higher, and reached at least X°.

miles, and those of the area included by the VIII° isoseist being about 40, the ratio between the two is about 6 to 1. The corresponding ratio in the case of other destructive earthquakes works out at various values, between the extremes of 12 to 1 and 3 to 1, the usual value being about 5 or 6 to 1. In this respect, therefore, the earthquake shows no abnormality, and there is nothing to suggest a radical difference in origin from other earthquakes.

Another feature which marks this earthquake as of the usual type and origin, is the occurrence of aftershocks. From the central region we have no certain records, but, both at the Pamir Post and Ishkashim, subsequent shocks are definitely reported. Great earthquakes vary extremely in the number of aftershocks and the duration of the period covered by them; in some cases the aftershocks are few and soon over, in others they are numerous and prolonged, and there is no definite relation between the magnitude of the earthquake and the number of aftershocks. In a general way, however, the greater earthquakes are followed by more numerous aftershocks than the smaller, and the Pamir one of February 1911, though it must be classed with the great world-shaking earthquakes, was, in reality, a small one of its class. To this must be added that the nature of the country and its inhabitants precludes the possibility of anything like a complete record being obtained. The published reports are sufficient to show that there were at least some aftershocks, and that in this respect the earthquake was of normal type.

So far nothing has been said of the landslips, these having been reserved for separate consideration. Of the largest of them we have fairly full particulars, in the description and survey made by Col. Spilko's expedition. This slip fell from the mountains north of the Murghab valley, just above the village of Usoi (Usaid of the Indian Survey maps), which was overwhelmed and all the inhabitants destroyed, except two, who were away on the night of the earthquake. The débris of the slip formed a heap in the valley, measuring about 19,000 feet in length along the bed of the valley, about 12,500 feet in width across the valley, and very little short of 2500 feet in maximum depth, the total bulk being about 100,000,000,000 cubic feet, and the weight about 7,500,000,000 tons. These figures are necessarily approximate, as it is not possible to determine, from the map, the exact limit of the slip, nor is the original contour of the ground known. The barrier, formed by the slip, gave rise to a lake which, at the time of Col. Spilko's survey, had attained a length of 26 versts (about 17 miles) and a maximum depth of 131 sashin (917 feet); at the time of his visit the water-level was still rising, but this was probably seasonal, for two years later Sir Aurel Stein, traversing the same route, estimated the length at 15 miles. As the upper end of the lake was very narrow, merely a flooded river-channel, when surveyed by Col. Spilko, widely differing estimates of length might easily have been made by different observers;

moreover, the narrow part would be rapidly filled up by river-deposits, so that the estimate of the later observer is in substantial agreement with the survey of the earlier, and the permanent length of the lake may be placed at about 15 miles.

The landslip itself was of the ordinary type of mountain-slip; it was a downward rush of a mass of débris, moving more as a fluid mass than as either a slide, or a fall, of separate fragments, carrying on its surface, and embedded in it, huge unbroken masses of rock measuring hundreds of cubic feet in bulk. Where this moving mass impinged on the opposite side of the valley its momentum was checked, the upper surface surged up and, not having sufficient fluidity to return, was left banked against the hillside, forming a barrier across two minor tributaries from the south, in one of which a small lakelet was formed. This much is evident from Col. Spilko's survey and description, from which it is also evident that the great slip at Usoi was by no means the only one formed at the time of the earthquake. Upstream, his survey shows several smaller landslips in the direction of Sarez, probably those that blocked Capt. Zaimkin's progress in April 1911; and, even from the accounts collected by Col. Spilko, it is sufficiently evident that there must have been numerous others farther down the valley, in the districts which were not visited by him. The information, however, would have been very scanty but for the fact that, about two years later, Sir Aurel Stein travelled down the Tanimas valley to its junction with the Murghab, and then up that valley past the great slip and the lake of Sarez, and his graphic description¹ of the condition of the country, four years after the earthquake and landslip, throws much light on what would otherwise have been obscure and doubtful.

He states that already in the Tanimas valley he had come upon huge masses of débris, which had fallen from the slopes of the flanking spurs, and spread for several miles across the open valley-bottom. On turning up the Murghab valley, progress in its narrow gorge proved very trying, owing to the results of the earthquake, which had transformed the surface of the mountain-region in a striking fashion. In these defiles huge landslides had choked up, in many places, the whole river-passage, and destroyed the tracks. The big river, once rivalling in volume the Ab-i-Panja, had altogether ceased to flow, and strings of alpine tarns had replaced it. It took three days' hard travelling, along the steep spurs and over vast slopes of débris, to get to the point, near the mouth of the Shedau lateral valley, where the fall of a whole mountain had completely blocked the river, and converted the Sarez Pamir into a lake more than 15 miles long, still spreading up the valley. Enormous masses of rock had been pushed, by the impetus of the landslip, up the steep spurs flanking the Shedau valley,

forming a huge barrage which seemed to rise 1200 feet above the level of the lake.

Some idea of the difficulty of this journey may be formed from the fact that the distance, which it took three days to cover, is less than 15 miles; while the same distance, above the barrier, was covered in one day, although the going was still bad and only practicable on foot, and by men accustomed to mountain-climbing.

The foregoing account shows that the great landslip of Usoi was not the only one that accompanied this earthquake; it was by far the largest, but there were innumerable others, many of which can only be regarded as small in comparison with the exceptionally large one, and the accounts reproduced by Col. Spilko show that, besides those seen by Sir Aurel Stein, landslips occurred, on a similar scale, at least as far downstream from the junction of the Tanimas and Murghab. In part, this extensive development of landslips must be ascribed to the unstable, or semistable, condition of the steep slopes on each side of the deep-cut valley through a lofty mountain-region. Landslips, in fact, are by no means unknown in this region, and Colonel Spilko quotes, and accepts, the statement that the Yashil Kul, in the Ghunt valley (south of the Murghab), was caused by an ancient landslip of great size; yet the simultaneous occurrence of so many landslips over so large an area, as took place on the night of the 18th of February 1911, requires some common determining cause, which is to be found in the severe earthquake, known to have coincided with the fall of these landslips.

There remains, however, the possibility that the great slip at Usoi might have been the primary cause of the earthquake, and so of the other landslips. This supposition is negated by the fact that the great slip is not situated at, or near, the centre, but on the extreme limit of the region of greatest destruction. The time of occurrence of a landslip may be determined by an earthquake, but the magnitude is very little influenced by it; in the case of those landslips, which can only be regarded as small when compared with the unusual magnitude of the Usoi slip, it may be taken as certain that slips were in preparation, and that sooner or later they would have fallen in very much the same magnitude, a magnitude determined by those initial cracks with which such mountain-slips commence. Even the great Usoi slip had probably been in preparation, in the same way, and would have come down in due course of time; its size, therefore, does not indicate a greater violence of earthquake. The position of the Usoi slip is, consequently, quite consistent with the conclusion that it, and all the other effects, were due to the earthquake as a common cause: it is not consistent with the supposition that the slip was the cause of the earthquake.

Besides the particular argument from the position of the Usoi landslip, with regard to the area over which the earthquake

¹ 'A Third Journey of Exploration in Central Asia, 1913-16' Geogr. Journ. vol. xlviii, 1916. The passages referred to in the text above are on pp. 214 et seqq.

reached a destructive degree of violence, there are some general considerations pointing to the same conclusion. It is known that in some cases earthquakes, of great violence in the central area, were only sensible for a comparatively short distance from it. The classic instance of this last-named type is the Ischian earthquake of 1883, which levelled Casamicciola with the ground, and caused 1800 deaths in that town alone, but was only felt by a few persons at Naples, not more than 20 miles away. This restriction of the seismic area is commonly attributed, and seemingly with justice, to a small depth of origin, less than half-a-mile in the Ischian earthquake, while the more extended shocks originate at a greater depth.

If we compare the extent of the Pamir earthquake of 1911 with the Ischian of 1883, both being of about the same degree of maximum violence, we are faced with very different conditions; although in both cases the maximum degree of violence was not very different, the area over which the one reached a destructive degree of violence was as great as the whole area over which the other could be felt at all. The great development of landslips in the Pamirs was due to the accidental coincidence of the epicentral area with a region where the carving of deep, narrow, and steep-sided river-valleys, through lofty mountains, had given rise to unstable conditions of the hillsides; but, apart from this, the earthquake differed in no material respect from the general run of great earthquakes, which give good records at long distances from the origin.

Of disturbances known to have originated on the surface, we have had, in the last few years, explosions of great magnitude and violence, which gave rise to surface-waves capable of record by seismographs at a distance; but, in all cases, these have been marked by the very restricted area over which the disturbance was sufficiently great to cause material damage: within a distance measurable in yards, damage, directly due to vibration of the ground, had ceased, and within a very few miles at most no vibration could be felt, even by those who were specially favourably situated. From these analogies we may conclude that, even if the fall of the Usoi landslip could have produced a shock sufficiently great to cause damage, this would have been limited to the immediate neighbourhood, and the earthquake would have ceased to become sensible before the limits of the region in which damage was actually done were reached.

The facts known of this earthquake show that it cannot have been of surface origin, but must, like other similar shocks, have had a deep-seated origin, not necessarily the 1200 or even the 200 kilometres, which have been claimed for some of the world-shaking earthquakes, but at any rate of the order of 50 kilometres or 30 miles. That it could not have been due to the fall of the landslip is evident; the landslip was determined by the earthquake and, so far as the time of occurrence is concerned, was a consequence, not a cause.

Yet it is possible that the impact of the great Usoi landslip, and of the many other great slips, which accompanied this earthquake and precipitated vast masses of rock into the valley-bottoms, may have had their effect in setting up surface-vibrations, and starting surface-waves, which were propagated afar, and left their impress on distant seismograms. In the course of the discussion, which led to this investigation, Mr. J. J. Shaw stated that the seismogram obtained at West Bromwich showed the third-phase (or long) waves, as unusually large in proportion to the preliminary tremors, which were of but small dimensions. This means that the surface-waves were of unusual size for a disturbance of the magnitude indicated by the mass-waves transmitted through the earth, and this greater development of surface-waves may not improbably have been due to the combination of wave-motion, started directly by the earthquake, with other surface-waves, originated by the landslips.