

a careful plan of the north end of the island, a general map of Ormus and the neighbouring coasts, and a very quaint bird's-eye view of the town from Astley's 'Collection of Voyages.'

With the aid of these, the principal points in Davies's drawing are easily identified. Starting from the left, we at once recognize the castle, standing at the extremity of the neck of land on which the town is situated. Next is the bridge leading over the moat which defended the fortress on its landward side. A little further on is a tall column, marked by Davies as the "church," really a brick minaret, seventy feet high, and coated with glazed tiles, which was still standing, though in a tottering condition, at the time of Captain Stiffe's visit; the mosque to which it originally belonged is said to have been destroyed by the Portuguese as being too near the castle. Round this minaret cluster the remains of the town. In the background are seen the precipitous peaks of a range of salt hills; and on the summit of the highest of these is a chapel ("monastery," Davies calls it), with a zigzag road leading up to it. At a lower level is apparently indicated a "salt vein," a feature of the island specially mentioned by Captain Stiffe, who describes the valleys as thickly encrusted with salt washed down from the hills. On the shore to the right are shown several water-cisterns, now for the most part choked with earth, and utilized for raising small crops of vegetables, etc. In front of these a number of dots indicate the presence of a sandbank, and the soundings in the roads before the town are carefully given. The writing above and below the sketch consists partly of nautical directions for safe anchorage, and partly of the continuation of the writer's journal.

Such are the main features of this interesting old drawing. Of David Davies himself little or nothing is known. Only his log-book survives, written in the queerest spelling, and illustrated by a few rough sketches, of which the present, and the one previously published, are the most important. And one may note, in conclusion, that these two drawings form a link between two island cities of the same sea whose destinies have been curiously reversed—Ormus, which was once a great commercial centre, and to-day is nothing: and Bombay, then an obscure Portuguese settlement, and now a city whose wealth and magnificence are famous throughout the world.

THE LANDSLIP AT GOHNA, IN BRITISH GARWHAL.*

THE Bireh-ganga, a small stream following a westerly course for some 20 miles, joins the Alaknanda—the main branch of the Ganges—at a

* The reports on which this article is based have been communicated to the Society by General R. Strachey, by permission of the Secretary of State for India.

point about 150 miles from Hardwar, and some 3500 feet above sea-level. Its bed lies at the bottom of a narrow valley, whose sides, everywhere very steep and in places precipitous, are partially cultivated at places along the lower levels, and covered with forest chiefly composed of evergreen oak and rhododendron higher up. The mountains that flank the valley rise to 12,000 and 15,000 feet above the sea-level, and the river-basin covers some 180 square miles. The accompanying sketch-map (Fig. 1) shows the general topography of the district. To the east, Trisúl and other snow-clad peaks rise to over 20,000 feet, and supply a large portion of the waters of the Bireh-ganga during the warmer months. The dip of the strata of the dolomitic rocks, chiefly in a south-easterly direction, is in many places greater than their natural angle of repose; and the loosening of the strata by erosive agents has been recently followed by falls of immense masses of *débris* into the bed of the stream, damming it back and forming an extensive lake. Some years ago such a similar lake was formed on this river, some 16 miles above its junction with the Alaknanda. This lake, known as the Gudyar Tal, was entirely filled up by a later slip during the rains of 1869, and the water then forced over the dam caused disastrous flooding for miles down the valley. The landslips to the effects of which attention is now directed took place two or three years ago; the largest of them was that of September 22, 1893, at a point 8 miles from the junction of the Bireh-ganga, near a village of the name of Gohna, which narrowly escaped total destruction. The summit of the spur of a hill 4000 feet above the right bank of the stream slipped down into the bed, leaving a perpendicular cliff, and forming a barrier across the gorge over 800 feet in height. Falling continued for several days with a terrific noise, darkening the sky with dust. The rocks at first did not merely slip, but were shot forward with terrific force; some blocks hurled a mile away against the opposite cliff knocked down numbers of trees. Above the barrier a lake has gradually formed by the impounding of the streams. In order to ascertain the probable date of the water reaching the top of the barrier, and the effects it is likely to produce thereafter, careful surveys of the ground have been made. A plan of the lake on December 14, 1893, and various data as to drainage areas and rainfall, are given in Fig. 2. This shows the horizontal extent of the *débris* of the landslip as it lies on the valley floor. In December, 1893, Lieut.-Colonel R. R. Pulford, R.E., Superintending Engineer of the Lucknow Circle, assisted by Mr. Joseph, Divisional Engineer of Kumaon, and by Mr. Wildeblood, District Engineer of Almora, made a full examination of the slip; and Lieut.-Colonel Pulford's report to the Hon. J. G. H. Glass, C.I.E., Chief Engineer of the Buildings and Roads and Railway Branches, gives very complete topographical information. We compile the following notes from this report and other sources:—

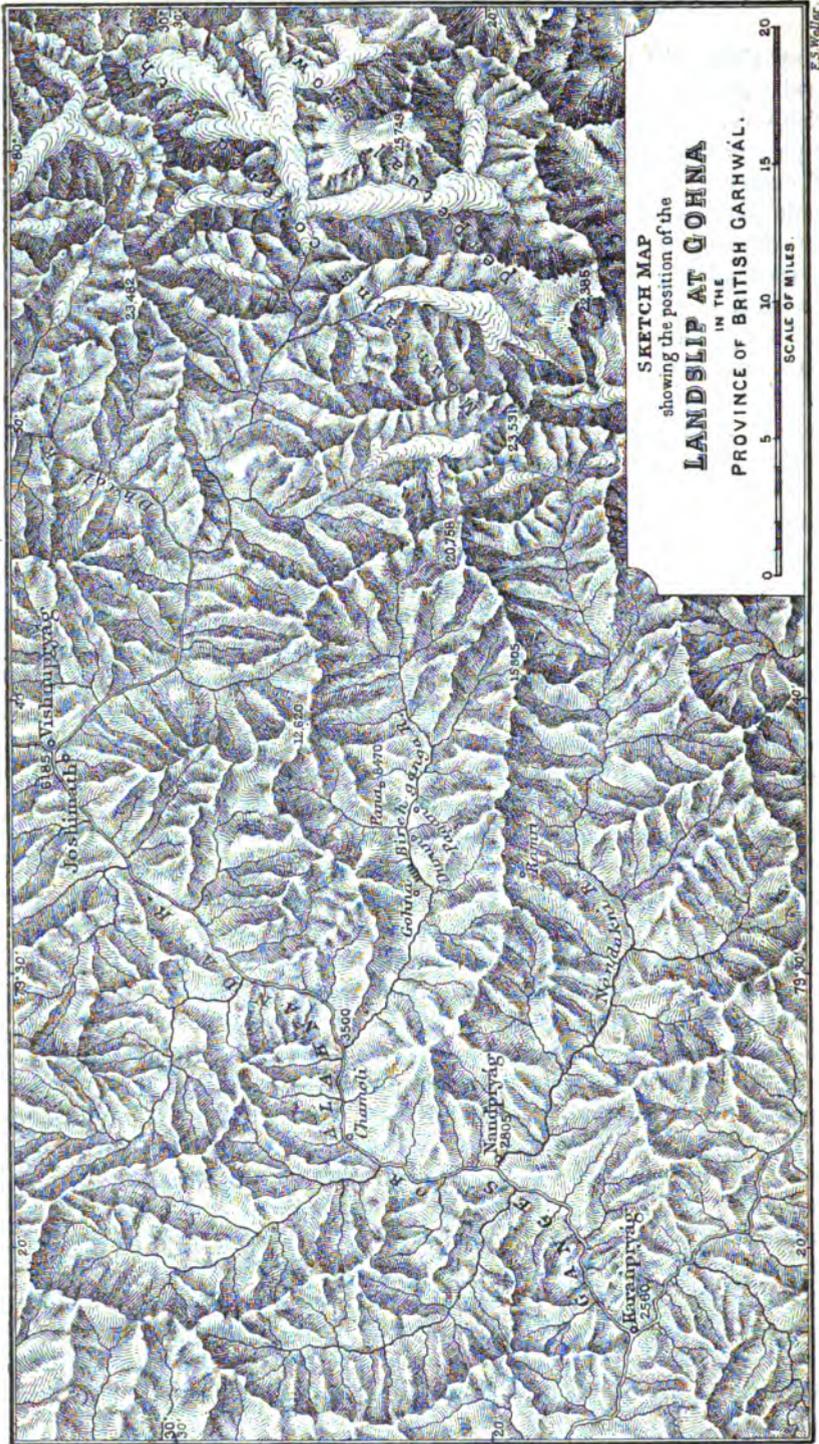
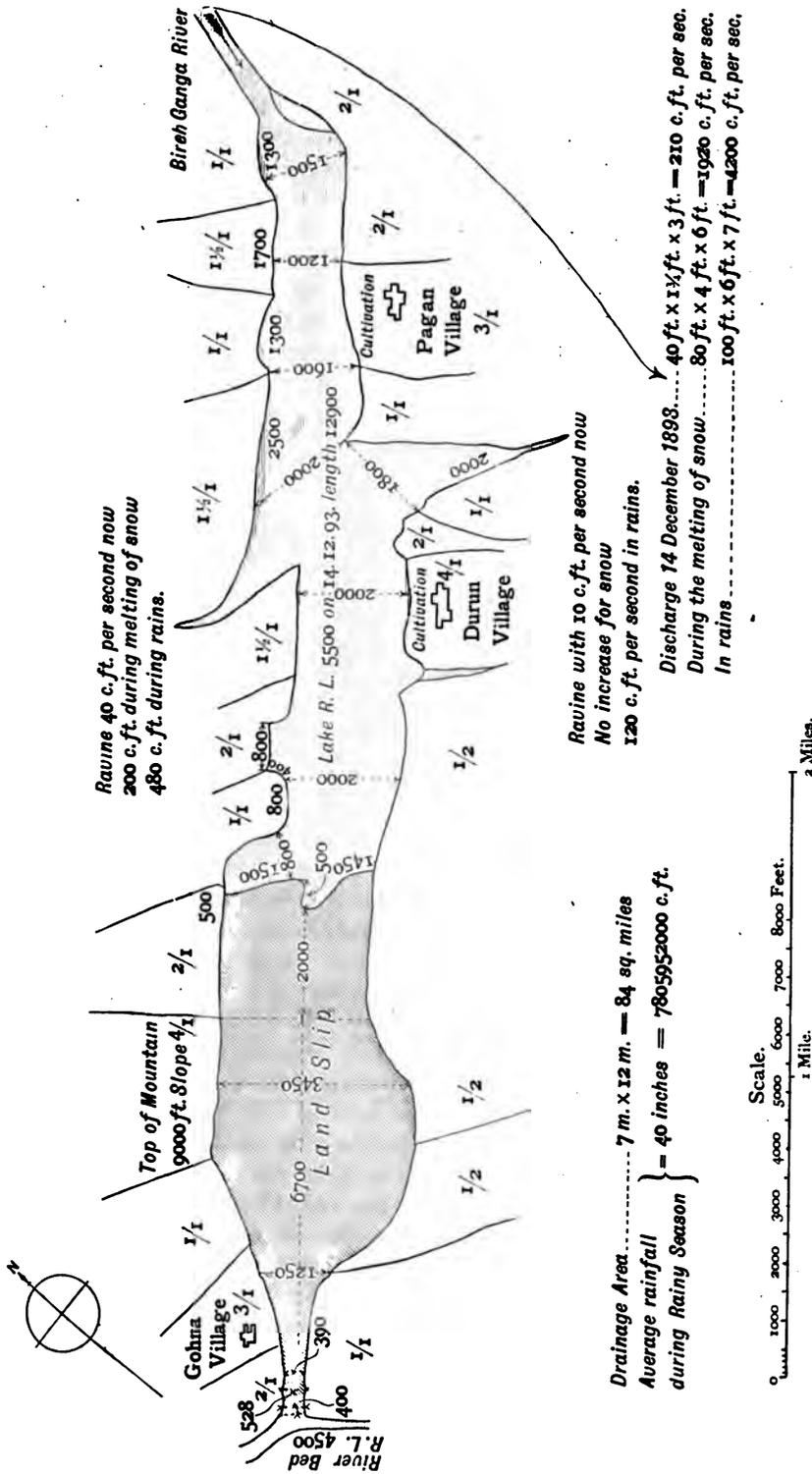


FIG. 1.—TOPOGRAPHY OF THE VALLEY.



Ravine 40 c. ft. per second now
 200 c. ft. during melting of snow
 480 c. ft. during rains.

Ravine with 10 c. ft. per second now
 No increase for snow
 120 c. ft. per second in rains.

Drainage Area..... 7 m. x 12 m. = 84 sq. miles
 Average rainfall } = 40 inches = 7805952000 c. ft.
 during Rainy Season }

Discharge 14 December 1898..... 40 ft. x 1 1/2 ft. x 3 ft. = 210 c. ft. per sec.
 During the melting of snow..... 80 ft. x 4 ft. x 6 ft. = 1920 c. ft. per sec.
 In rains..... 100 ft. x 6 ft. x 7 ft. = 4200 c. ft. per sec.

FIG. 2.—PLAN OF THE GOHNA LAKE.

The force of the fall from so great a height as 4000 feet carried the rocks and *débris* from the right bank right across the valley of the river and halfway up the steeply scarped hill on the left bank; then, its energy expended, the mass slipped down again into the bed of the river, forming a dam and a big slope up against the hill on the left bank. The consequence is that it now appears as though a portion of the dam had been formed by a slip from the steeply scarped hill on the left bank. The further slips of October, 1893, have piled up the dam on the right bank against the hill on that side, so that the top of the dam has a large depression in the centre, of 150 feet or more, between two sloping mounds of rocks and *débris*, as shown in the cross-section (Fig. 3).

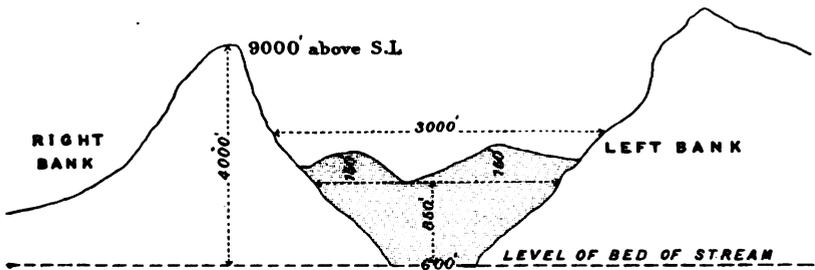
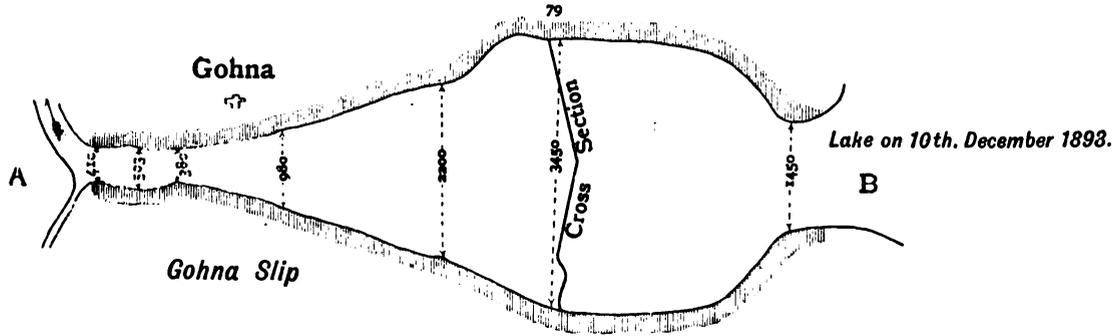


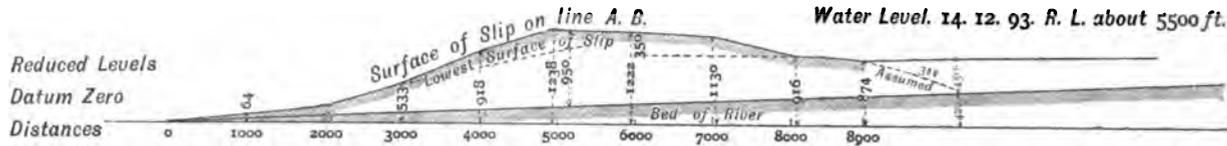
FIG. 3.—CROSS-SECTION OF LANDSLIP. THE SHADED PART SHOWS THE DAM FORMED ACROSS THE VALLEY.

The dam itself is a very massive affair, as can be seen from the plan and longitudinal section shown in Fig. 4. It is largely composed of enormous masses of rock, some of them calculated to be more than 1000 tons in weight. There is also a very large admixture of detritus from broken rock, and a thick layer of impalpable powder. The small stuff in the dam would, of course, be easily and quickly washed away by water passing over the surface. The rains of October, 1893, show a good example of this, as they have scoured out deep gullies on the outer slope. At the same time, these gullies serve to emphasize the fact that the main body of the dam is built up of large masses of rock, which would be likely to form a solid resistance to the action of water passing over it. The dam may be taken to be roughly 900 feet high, 2000 feet across at the top and 11,000 feet at the base along the valley, and 3000 feet at the top and 600 feet at the bottom across the valley. The bed of the river has a slope of about 250 feet in the mile, and, calculating from the section, the maximum depth of water in the lake formed on December 13 and 14, 1893, was 450 feet. The rate at which the water was rising during the time Lieut.-Colonel Pulford was there was 8 inches per day; but this was at the slackest



Length of Lake. 14. 12. 93. 12900 ft.

Water Level. 14. 12. 93. R. L. about 5500 ft. above Sea.



Scale. (Plan & Longitudinal Section)

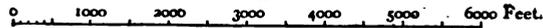


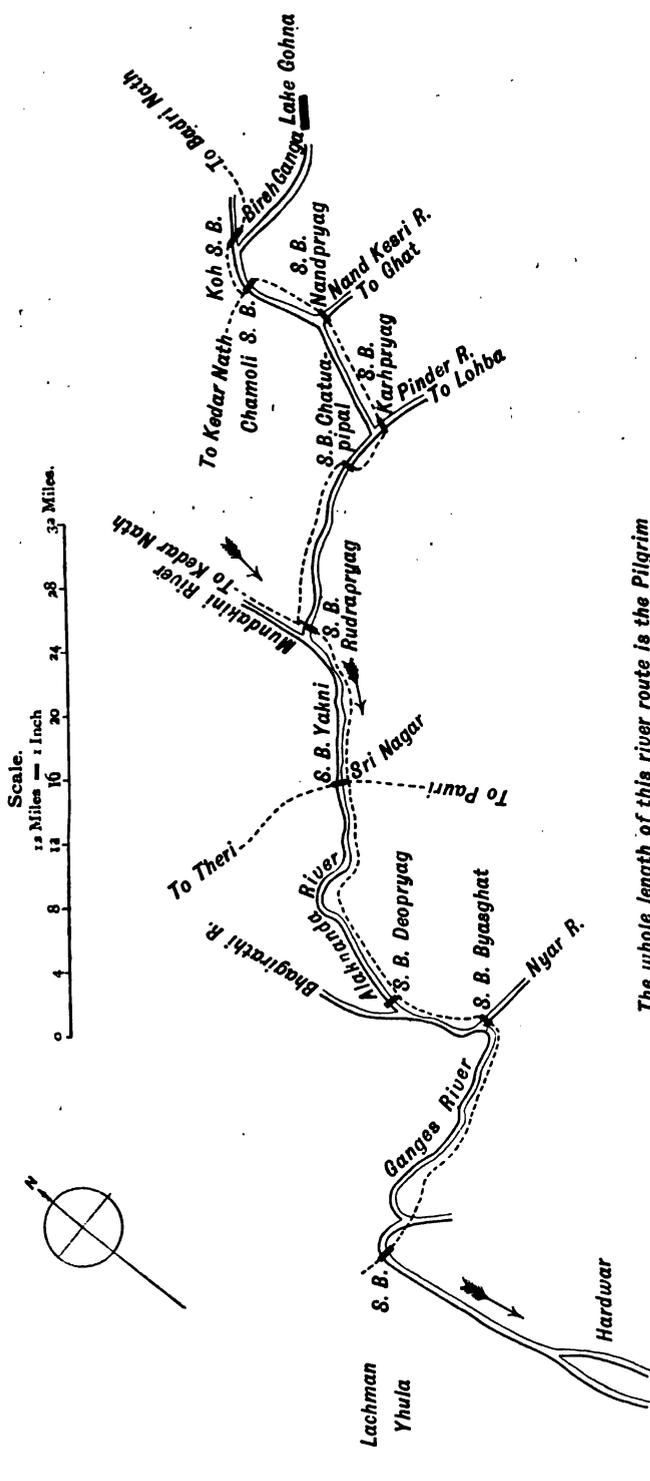
FIG. 4.—PLAN AND LONGITUDINAL SECTION OF THE DAM FORMED BY THE GOHNA SLIP.

time of the year in regard to the flow of water in mountain rivers. During the winter rains there is a large increase in the supply of water entering the basin drained by the Bireh-ganga; and during April, 1894, the snows beginning to melt would furnish a further large increase in the water impounded. Taking these several sources of additional supply into account, it should require forty-eight days after April 1, 1894, for the lake-water to rise to the top of the dam. In March the rate of rise was only 6 inches per day, and in the beginning of May the lake was still 265 feet below the top of the dam, the greatest depth as sounded by Lieut. Crookshank being 512 feet. The first rush of water passing over the barrier will necessarily be very severe, and probably at least 250 feet or so of the dam at the top will gradually be carried away. After that, it may possibly happen that the main portion of the dam will get thoroughly jammed and consolidated together, so as to form a permanent lake with a natural outfall over the broken rocks. In any case, there will be a terrific rush of water to be provided against when the lake tops the dam. So far as Lieut.-Colonel Pulford could see, the size of the dam and lake made it practically impossible to do anything in the way of letting off the water under control. The only thing which could be done was to ensure that the water would escape down the river-bed without loss of life, and with as little damage as possible to Government and private property. The bridges and villages menaced by the flood if the lake should break through its barrier are shown in detail on the plan in Fig. 5.

A meeting of engineers was held at Lucknow in January, 1894, to discuss the measures to be taken in connection with the landslip; and a note of instructions to Lieut. Crookshank, R.E., who had been ordered to proceed to the spot, was approved. Lieut. Crookshank was required to make a complete survey of the lake, dam, and valley, with contours at every 25 feet of vertical height. Bench-marks were to be erected at 10-foot vertical intervals, and the rise of water constantly noted and reported by a telegraph line to be laid up the valley from Hardwar. A skilled photographer was attached to Lieut. Crookshank, so as to secure a complete record of all changes up to and after the time of the overflow.

To prevent loss of life and damage to property, the civil authorities were to be kept fully informed of the progress of events; precautions were to be taken to preserve bridges crossing the valley between Gohna and Hardwar; and the pilgrim route near the Alaknanda, which is so much frequented during May and June, was to be closed as far as possible.

Mr. T. H. Holland, of the Indian Geological Survey, examined the ground in February and March last, and, while adding many important



The whole length of this river route is the Pilgrim Road after May to Badri Nath and Kedar Nath. The dotted line shows this route for which the many Suspension Bridges have been chiefly built.

FIG. 5.—PLAN OF RIVER BELOW THE LAKE, SHOWING PROBABLE DANGER DURING FLOOD TO BRIDGES AND TOWNS.

Hardwar 150 miles below Siip

geological facts, confirmed the conclusions arrived at by the engineers. Mr. Holland expected that the lake would begin to overflow about the middle of August, and made a somewhat lower estimate of the rapid erosion likely to follow the first overflow than did Lieut.-Colonel Pulford. He points out that the great size of the newly formed lake is in itself a safeguard against its sudden filling up by further landslips and consequent repetition of the floods of 1869. In his report published in vol. xxvii. pt. 2 of the *Records* of the Geological Survey of India, from which some of the facts stated above have been taken, he shows that fears entertained for the stability of the great mass of the dam are groundless. At its weakest point the resistance offered by the dam is nearly twenty-nine times the horizontal pressure of the water brought to bear on it (14,000 tons). The angle of repose of the dolomitic talus on the dam is about 40° , so that a section would require about four-fifths of its own weight to move it, supposing it to offer no resistance due to friction against the sides. The weakest section of the dam has therefore at least twenty-three times the necessary strength, and this estimate would be greatly increased by taking into account the weight of the innumerable dolomitic blocks on either side of the point of overflow.*

* In connection with this subject, the following telegram from the Calcutta correspondent of the *Times*, under date July 10, is of interest: "Since the beginning of the rainy season the water of the Gohna lake has been rising about 2 feet daily, and is now 160 feet from the top of the dam. As percolation has begun through the dam and is increasing with the increased pressure, the date of the overflow will probably not be before the middle of September, but as the dam seems to be composed of large blocks of dolomite to within a few feet of the top, a sudden flood or overflow is not anticipated. Nevertheless, careful precautions have been taken to ensure the safety of the inhabitants of the valley below by placing marks at three different levels above the river-bed, the highest level being the safety-line of retreat for a *maximum* flood. The villagers will be warned by telegraph from the lake of the nature of the flood, and due notice will be given as the water approaches the top. All who have visited the spot agree in thinking that there will be in any case a permanent lake more than three and a half miles long." On July 23 the lake was still 131 feet below the level of the dam, which was reported to be completely saturated.
