THE CIMARRON LAND-SLIDE, JULY, 1886.

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Introductory. Newspapers of Montrose and Denver, of dates about August first, contained accounts of an "earthquake" said to have occurred on Cimarron Creek in the latter part of July. These accounts referred to remarkable disturbances which had taken place in the region mentioned. Fissures were said to have been formed, ridges thrown up, the site of a former pond to have become the crest of a knoll, and forest trees to have been completely overturned. Little definite information could be gained from these stories and the truth of the whole matter was discredited by many. It chanced however that Professor Farnham of the Nebraska State Normal School stopped at Cimarron on the 28th of July, three days after the discovery of the disturbance, and he at once went to the scene. The account he furnished to the Denver Tribune-Republican of August 8th made it plain that a considerable area of country had in fact suffered a remarkable convulsion of some sort, justifying in a measure the popular idea that there had been an "earthquake." The cause of the phenomenon was not suggested by Prof. Farnham nor was it to be inferred from the descriptions, hence an examination on the part of the U. S. Geological Survey was deemed desirable. The approval of Mr. S. F. Emmons, geologist-in-charge of the Rocky Mountain Division of the Survey, was at once secured and on the 12th of August the writer reached Cimarron, in company with Mr. W. H. Jackson of Denver, who wished to take some photographs of the scene.

Position of the disturbed region. Cimarron Creek is a southern tributary of the Gunnison River which it enters mid-way in the length of the Black Cañon. The Denver and Rio Grande Railroad, having found a way through

the upper half of the cañon, is here obliged to turn up the Cimarron and then over a divide into the broad valley of the Uncompahgre, thus avoiding the impassable gorge into which the Gunnison enters just below the mouth of the Cimarron. About one mile from the Gunnison is the station Cimarron, where the Railroad turns westward to the divide. Nine miles south from Cimarron, on the western branch of the Creek, is the scene of the "earthquake."

The country lying to the southward of the Black cañon of the Gunnison is characterized by a number of streams which flow with parallel courses almost due north to their junctions with the river. Most of them rise in elevated basins directly under the highest peaks of the San Juan range, some 25 or 30 miles to the south. Cimarron Creek has two forks, both of which head under Uncompahgre Peak, and flow with approximately parallel courses to their union about two miles above Cimarron station. To the west is the Uncompahgre River and to the east, Blue Creek. The name Cebolla Creek, given to the western branch of the Cimarron, on the Hayden maps, is incorrect;—at least this name is now applied to a different stream, while the fork in question is called the Big Cimarron, in distinction from the eastern branch, the Little Cimarron. Formerly the region drained by this system of water-courses was a plateau, formed by sheets of eruptive rocks, which extended from the San Juan Mountains to, and in some places beyond, the Gunnison. This plateau has now disappeared excepting in narrow arms reaching out to the northward between the streams above mentioned. Yet the plateau feature is still so prominent topographically that the term *mesa* was used by the Hayden Survey in naming these flat-topped ridges;—thus the "Tongue Mesa" is the narrow arm left between Uncompahgre and Big Cimarron Creeks, and "Trident Mesa" is the collective name of the ridges between the branches of Cimarron, Blue, and Mountain Creeks.

These mesa remnants show the two eruptive sheets represented by the Hayden map. The upper one is massive andesite; the lower one a breccia, conglomerate, or loosely cemented fragmental bed, also of andesitic material. For the purposes of this description the structural forms of these masses are alone of importance. They rest on Upper Cretaceous clays and shales in the district traversed by the Uncompahgre and Cimarron Creeks;—on Archæan schists in the region further east. The greater part of these shales and clays belong to the Ft. Pierre Formation while under Tongue Mesa a portion of the Fox Hills is present, according to the Hayden map. Both lie horizontally.

The edges of the eruptive sheets are either cliffs or precipitous slopes, while from here down to the Creek bottoms the shales produce more gentle but uneven, wavy descents. Parts of both shale and eruptive rocks are covered by a heavy growth of timber, but a scanty covering of "sage" brush is the more general.

The scene of the so-called "earth-quake" is on the eastern slope of Big Cimarron Creek, near the northern end of the western arm of Trident Mesa, on the shaly slopes below the eruptive sheets.

Discovery and first accounts of the disturbance. In the valley bottom of the Big Cimarron are several ranches, the one situated nearest to the earth-quake ground being nearly three miles below that point and six miles from Cimarron.

The exact day of this "earth-quake" is unknown. No tremors were felt, nor noises heard, by any one, to indicate that anything unusual had happened in the neighborhood. On the 15th of July a hunter passed over the very ground now disturbed, and as late as the 18th another ranchman passed over the spot. On the 25th of July Mr. Samuel Scheldt was engaged in looking after his cattle that ranged over these slopes, and found that a considerable area of hill-side had been terribly convulsed and

very much changed in appearance. The trees, here growing quite luxuriantly, had been overturned, the earth fissured, and large masses of soil with the trees growing upon them had been broken off from the steeper slopes. In one jungle of fallen timber a bunch of cattle were imprisoned, unable to make their way out. He at once procured assistance, and the terrified cattle when liberated ran for miles before stopping. On examining the region, Mr. Scheldt and his companions found the detailed features over an area of several hundred acres very much changed. A small lake they had previously known could not be found, and apparently on its site was a ridge. Near by another sharp ridge had been thrown up some 25 feet, and one side had again sunk down, leaving a vertical wall. Everywhere the trees had been disturbed, and in some small areas none were left standing. The ground was traversed by innumerable fissures which were all shallow, owing to the soft, crumbling nature of the soil. The news of the phenomenon spread rapidly and the spot was visited by many. The explanation uniformly adopted was that the convulsions were caused by an earth-quake. Prof. Farnham was guided to the scene by Mr. Scheldt, and the earth-quake hypothesis seems to have been accepted by him. On reaching Denver he kindly gave to the writer full accounts of the disturbances as he had seen them.

Approach to the locality. In going to the "earth-quake" ground we followed a trail which led diagonally up the slope toward the end of the western fork of Trident Mesa. The Valley is here 6–8 miles wide and the eruptive sheets of the mesa are about 1,200 feet above the stream bed, some 3–4 miles to the westward.

The surface of the long slope was undulating, with many smooth-banked drains which were crossed obliquely. "Sage brush" grew thickly on the lower slopes. The banks of drains frequently exhibited outcrops of Ft. Pierre shales and the clayey soil everywhere indicated that the formation from which it was derived could not be far

below the surface; indeed slight digging in several spots brought shale or clay strata to view.

A feature of this soil, derived so immediately from the Ft. Pierre clays and shales, is the tendency to the formation of drouth-cracks during the long dry summer. These cracks are irregular in course, lacking the sharpness and curved form of ordinary mud cracks, but opening sometimes an inch or two in width, with a visible depth of nearly a foot. Their walls are crumbling. From Mr. G. H. Eldridge I learn that such cracks are sometimes so wide and deep and so numerous in certain Ft. Pierre districts of Montana, that traveling on horseback is by no means free from difficulty.

After rising some 4–500 feet above the creek the surface became more uneven, resembling many morainal districts, in the hillocks, with deep depressions or sinks between them. Ponds of water are common at this elevation. Such rough surfaces seem to be characteristic of the upper slopes of this region.

In general, the chief topographical features of the long slopes are rounded ridges which run out from the mesa arms nearly at right angles. On reaching the crest of one of these minor ridges which runs out from about the northern point of the western arm of Trident Mesa, we found ourselves overlooking the entire area disturbed.

General description of the scene. From the ridge mentioned one looks into a rudely basin-shaped area, bounded by this ridge on the north, the steep mesa slopes on the east, and another ridge two miles to the southward, while the lower or western side is open. The greater part of the basin is quite densely covered by spruce timber, with aspens here and there. The detailed topography is difficult to make out, but in general the central part is higher than the northern border along which runs one of the drainage channels. A prominent shoulder projects a short distance from the mesa, near the center of the upper basin rim. The slopes of this shoulder are very steep, but it is covered with trees.

Looking into the timbered area of this basin, evidences of such disturbances as had been described were everywhere visible. In some parts nearly all trees were overturned, and in others, when many stood erect, the various angles of inclination assumed by a few showed that these areas had also been affected in some degree.

The nearest ground disturbed was seen to be almost at the base of the northern ridge, along a line that could be traced upward to the union with the mesa. At the head of the basin the limit of confusion seemed to follow along slightly above the foot of the mesa slope. To the south, beyond the central, wooded parts of the basin, were seen bare slopes, fissured and presenting a step-like structure, as if from the dropping down of successive sections. Downward, i. e., to the westward, the limit of visible disturbance was reached in densely wooded tracts where the trees were all erect. Thus, at a glance, one saw the area affected to embrace the basin-shaped depression, while the limits were the bounding higher grounds. This area is estimated to be not less than 3 square miles in extent.

We followed up to the head of the basin and around to the central shoulder; then crossed and recrossed the most disturbed parts of the basin, examining the details of the movement. From all these observations the following views as to the nature and origin of the disturbance were derived.

Character of the movement. The close examination showed the area disturbed to be limited, in fact, on almost the very lines seen from the first point of view. The movement was a downward sliding of the whole surface, unequal in different places, apparently greatest in the upper part, and dying out gradually as distance from the upper line increased. The upper limit of movement runs along the steep mesa slope at a present elevation of 50–125 feet above the basin floor. A steep surface of freshly exposed earth and shaley rock marks the line. Above are undisturbed trees, turf or débris. At the foot of this surface is a tangle of overturned trees and bushes, half buried

in loose soil and rocks. Upon the slide surface lie a few uprooted trees, or a small patch of earth which has caught, half way down. Along the upper edge are partly detached sections, with their trees inclined at various angles.

The shoulder mentioned as projecting from the mesa out into the upper part of the basin has suffered on all its steep sides, as did the above slope; and the entire mass is divided into sections by fissures, so that it seems strange that all did not slip, piece by piece, to the basin below.

Along the northern side, near the base of the bounding ridge, runs a more or less continuous line, which is nothing less than an anticlinal fold or plication of the surface soil or turf, caused by the lateral pressure of the downward moving mass. On the outer or northern side of this fold the bushes and trees, where such exist, are simply tipped from the vertical position, corresponding to the sharpness of the plication. They are not uprooted, and in many places this side of the little ridge is unbroken, while on the basin side the downward movement has torn away nearly all of that half. A mile below the head of the slide this lateral movement is manifested very plainly by the cracking of a grassy surface, the turf from the basin side being simply shoved sideways a foot or more over the undisturbed part on the ridge side.

Cause of the Slide. Whatever the standpoint from which the scene was viewed, the uniform impression produced was to the effect that a sliding or almost a *flowing* movement had taken place in which the whole area had been involved. The movement was clearly confined to the basin area, and had taken place upon a plane very near the surface in order to produce the complete overturning of the large trees upon such gentle slopes as were for the most part concerned. The agent through whose influence the forces of gravity were enabled to produce these results was,—*water*. Only through complete saturation of the ground by water, can the degree of plasticity, evidently possessed by this moving mass, be adequately accounted for.

Direct evidences of the abundant presence of water were not so plentiful as one might expect yet they were by no means wanting. Mud streams were here and there found in which tree trunks and rocks were imbedded. In some places seen by Prof. Farnham there were columns and mounds of moist earth or mud pressed up through cracks by movements of some parts of the mass. As expressed by him: "In places the pressure from below has thrust up great columns of black, moist earth, the perpendicular sides of which are smooth as if turned up with a huge plowshare." (Tribune-Republican.) The upheaving force invoked by Prof. Farnham to account for these columns is not needed under the explanation here adopted.

As to the source from which the water needed for this saturation came, it may be said that according to the ranchmen of the neighborhood there were several small ponds or pools and one little "lake" in the wooded parts of the basin. At the present time there is no free drainage channel, and ponds which will soon become swamps, and little pools, are forming on every hand; for a considerable volume of water comes into the basin from the mesa slope above. Where the shoulder which has been spoken of as projecting into the basin joins on to the mesa, there is a small level spot occupied even now by a swamp. It has not been affected by this disturbance although some of the fissures that rend the projecting point visibly approach to within a few yards. The water from this swamp drains into the basin on the north, partly by a surface rivulet, and partly issues in a strong spring now bursting out of a freshly exposed clay slope of the shoulder adjoining. The swamp lies at the level of the line of fracture on the mesa slope and 100 feet above the tangled mass of trees in the basin below.

While these constant sources of water can be mentioned, it is highly probable that the thorough saturation necessary for such a movement of a large mass could not have been effected by the amount of water thus supplied. But ac-

cording to the testimony of the ranchmen living in the Cimarron valley a few miles distant, nearly the whole week, July 18th–25th, preceding the discovery of the disturbance, was characterized by very heavy thunder-storms in the valley above, and although little rain fell at the ranches it was thought at the time that much must have fallen on the mesa and adjoining valley slopes. The clouds hung especially heavy and low and persistently over the region of this slide. It seems quite probable, then, that the abundant rainfall of these days rendered highly plastic the soil already thoroughly moistened from local sources. A small slip may have started the movement and, by removing the resistance which held another mass in place, have paved the way to a successive slipping of section after section until the higher bounding grounds were reached.

Such a theory would allow a slight movement in the lower portions to lead to much greater displacements on the upper limit, and such seems to be in fact the case. That the slipping did occur in sections is shown by the appearance of ridges here and there in the midst of the area, which were plainly formed as was the one on the northern limit, described above. Again, the degree of disturbance is very different in different places. Certain areas seem to have moved but little. They are fissured, and some trees are partially overturned, while on all sides are courses within which no tree stands erect. In such a case one can readily conceive that the less disturbed mass was less plastic, perhaps situated on slightly elevated ground, and was only affected through the pressure from the moving masses on either side. All observed disturbances seem to be well explained thus.

Earlier land-slides of similar character. In the course of the examination evidence was obtained showing that exactly similar disturbances have occurred in some earlier epochs on the same spot or in the vicinity. On climbing to the top of the steep surface of fracture at the head of

the basin, we were surprised to find ourselves on the crest of a sharp ridge, behind which was an irregular, ravine-like depression some 10–20 feet deep. This was not a drainage channel and was plainly the result of some earlier sliding movement. A freshly opened crack ran along the bottom. Trees three or four inches in diameter were growing in this ravine, attesting to a lapse of several years since its formation.

In Professor Farnham's newspaper account of the disturbance, he speaks of dead trunks of aspens standing or lying on the site of the lake which was uplifted. Possibly these were overturned when the lake was formed, just as prostrate tree-trunks will soon be covered by the water of various small ponds which are now forming.

It seems quite possible that the irregular ridges and depressions of the slopes without this basin, such as were crossed in ascending the slopes, may have originated in landslides of this kind. Indeed, it was strongly suggested, on looking down into the Cimarron valley from high ground, that, in the remote past, landslides of this general character may have played an important part in its excavation and moulding. From one of the ranchmen in the valley it was learned that fissures several feet in width had been noticed some six or seven miles further up the Creek, though no slipping of account had taken place. These must have been formed at about the time of the great slide above described.

Comparison with other landslides. Among the authentic instances of land-slips which have been recorded in geological literature, I can find no analogon to the present case. In Switzerland, where so many fearful avalanches and "*Bergstürtze*" have occurred in historic times, solid rock is usually included in the fall. The slip may have been occasioned by the softening of some shale layer by water, but in no instance has the mass brought into motion been so purely a surface coating as in the case of the Cimarron land slide.

Mr. R. C. Hills has, however, called my attention to what seems to be a proper equivalent of this present slide. On the plains, where the cretaceous shales of the Ft. Pierre group outcrop, it is, according to Mr. Hills, no very rare thing to find that portions of the gentle slopes of shallow drains have become plastic and moved downward. This movement sometimes occurs where it would seem as if the slope were too slight to admit of the flowing of anything not highly fluid. Such cases seem to be due to a thorough saturation at times of heavy rain-fall.

The magnitude of the Cimarron land-slide makes it difficult to conceive that it has been caused by the simple agencies mentioned, but a careful consideration of all the phenomena observed does not seem to find any fact not in accord with the explanation given.