

## POSSIBLE OBLIQUE MINOR FAULTING IN ALASKA.<sup>1</sup>

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In the Yakutat Bay earthquakes of September, 1899, it was found that the seismic disturbances were due to movement along definite fault zones bounding a series of blocks whose edges were differentially tilted, resulting in a series of remarkable changes of level of the land.<sup>2</sup>

The blocks jostled upward along old fault lines in this renewal of growth of the St. Elias Range were themselves broken, as fresh scarps in a number of localities indicated, and on Gannett Nunatak a series of remarkably perfect step faults were observed. These we have already described<sup>3</sup> and it is in these minor faults that the possible oblique movement, with which this paper is concerned, has taken place.

In review of the topographic conditions it should be stated that a strongly-glaciated rock hill rising directly out of the fiord and made up of highly-inclined gneisses and schists is crossed by a score or two of parallel faults, usually with vertical hade, the height of the scarps varying from one inch or more to eight feet, but the average remaining under one foot and two-fifths. The movement has usually been parallel to the schistosity and the southwest is usually the upthrow side. A complete cross-section of all the faults along one line, measured under the direction of Professor Tarr in 1906, showed 29 scarps, 26 of which had an upthrow on the southwest side aggregating 30½ feet, 3 having upthrow on the northeast side aggregating 12 feet, so that the total absolute displacement along this line is 18½ feet. Along the adjacent shoreline there was practically no change of level.

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<sup>2</sup> Tarr and Martin, *Bull. Geol. Soc. Am.*, Vol. 17, 1906, pp. 29-64.

<sup>3</sup> Tarr and Martin, *Bull. Geol. Soc. Am.*, Vol. 17, 1906, p. 50 and Plates 20 and 21.

It has been conceived worthy of consideration, though the facts have not yet been tested in the field, that the movements along the fault planes in these Gannett Nunatak faults were not vertical but inclined.

As previously stated, these are minor faults. They are due to adjustment of strain in a larger fault block. The units in this larger block were of unequal size and strength. One of the units was the band of schists which make up this part of the nunatak. The adjacent units were more massive granites and gneisses. When the whole body of units making up the block was jostled by the differential tilting of the adjacent blocks, during the larger faulting which caused the earthquakes, the diversified rock units responded or resisted as their nature allowed. Granite, perhaps, adjusted itself to the new strain by slipping along minute planes, gneiss by similar movement, and each, being rigid, gave an added strain to the adjacent schistose unit. Held thus between rigid boundaries, the schist, following the direction of least resistance, slipped along its cleavage surfaces like a pack of cards. As the schist stands nearly vertical, relief would come by some sort of an upward movement, even though the strain were applied laterally in a horizontal or an oblique plane and not from below. The faulting, with a total absolute displacement of at least  $18\frac{1}{2}$  feet, would on this supposition not be due primarily to uplift; and this conclusion is supported by the lack of evidence of change of level along the coast immediately adjacent to the nunatak. The marine register is a very delicate one, and change of level due to as great uplift as that indicated by the minor faults could hardly fail to leave a definite record, as it did practically everywhere else in the region where change of level took place.

In the California earthquake of 1906 it was established that the faulting was predominantly a horizontal movement.<sup>1</sup> F. L. Ransome has recently<sup>2</sup> called attention specifically to the possibility that horizontal movement along a fault plane might produce an apparent vertical displacement, and on this basis the

<sup>1</sup> Preliminary Report of the State Earthquake Investigation Commission, p. 10.

<sup>2</sup> ECONOMIC GEOLOGY, Vol. 1, 1906, pp. 777-787.

nomenclature of faults has been subsequently discussed in this journal.

On the Gannett Nunatak the faults traverse a hillside and especial attention is, therefore, called to this as a case where an observable, apparently vertical displacement might actually have been produced by movements in a horizontal plane. In this case the hill would be thought of as broken into northwest-southeast strips, each strip being moved southeast with respect to its northeast neighbor, so that the hill slope might be said to no longer fit. Such horizontal movement would produce a similar distribution of faults to that actually found, *i. e.*, successive normal faults with upthrow on the southwest side, so that in going down hill one constantly kept going up steps. The expectable exceptions of faults with apparent upthrows (scarps) on the northeast side, due to failure of a strip to slip in the normal direction, and short cross faults, due to breaking of the long narrow strips, are found.

If this were all, the case might be considered a very pretty one, for it could be absolutely proved by going to the other side of the hill where the opposite distribution of upthrows should be found. In the observed case the investigator goes up steps as he goes down hill. If on the other side of the hill he went down steps as he went down hill, the nunatak could be definitely said to be broken into strips along which horizontal movement had caused the slopes to no longer fit, resulting in apparent, but false, vertical displacement.

Unfortunately the opposite side of the hill shows no faults at all. The larger scarps extend up to the crest and die out. On the hypothesis here considered one of two things may have happened: (1) Either the schists, along which movement is so easy, have been replaced by other, more elastic, or massive, rocks; or else (2) there has been oblique movement, parallel to the surface of the unfaulted hill slope (Fig. 65).

We cannot assume that the schists extend to the unfaulted side of the hill and that the displacement on the opposite side is the result of vertical movement, for in that case there is no excuse for the failure of both hill slopes to be faulted alike. Moreover,

the lack of evidence of change of level on the neighboring shore, as already stated, precludes the idea of uplift here. It cannot be held that the movement was entirely horizontal, for there are fault scarps on the very top of the hill.

The alternate hypotheses are either vertical uplift or subsidence of a larger block, with differential movement along the layers, dying out in short distances as a result of adjustments and tilting. If there had been such movement it is strange that here,

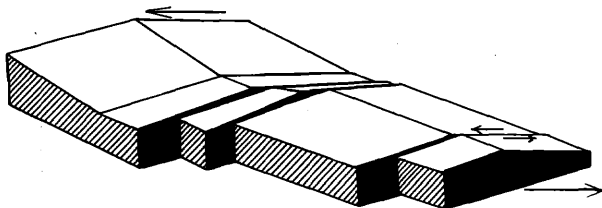


FIG. 65. Diagram illustrating oblique faulting with movement parallel to hill slope on right, producing scarps on the opposite slope and along the crest. Such movement would effect essentially no change of level in a shoreline on the right.

in one of the few places in the fiord where there is no evidence of change of level along the shore, we should find the best cases of differential movement in the entire region. If, on the other hand, the vertical throws are the result of oblique movement due to differential horizontal strain the absence of proof of uplift along the shore is readily explained.

Unfortunately this idea was not suggested on the ground and cannot therefore be tested until further observations have been made. Oblique movement seems to be the most rational hypothesis for the facts discovered; but the case has been discussed thus fully here not so much to prove this particular case as to illustrate that an observer cannot safely infer vertical movement because he finds a scarp. He may have either horizontal or an oblique movement. Unless he has a whole faulted hill for study he would have to depend on examination of the fault-plane surfaces and see the direction of slickensides, before he could come to a decision. This should be done for the faults of Gannett Nunatak.

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