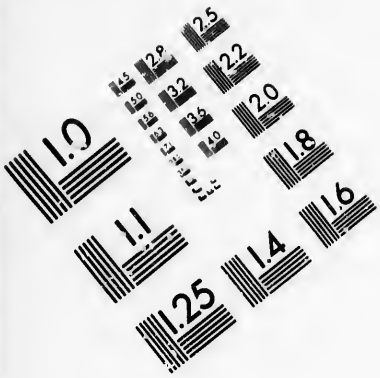

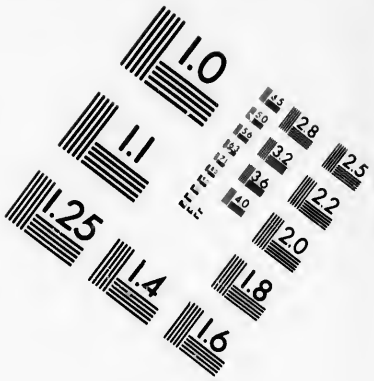

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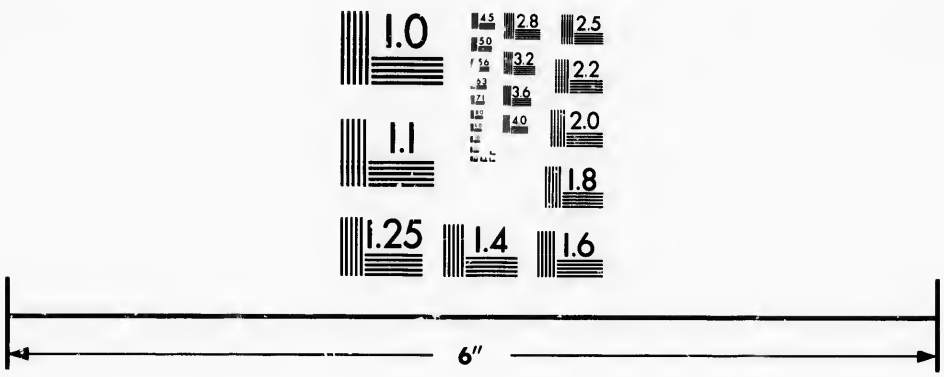

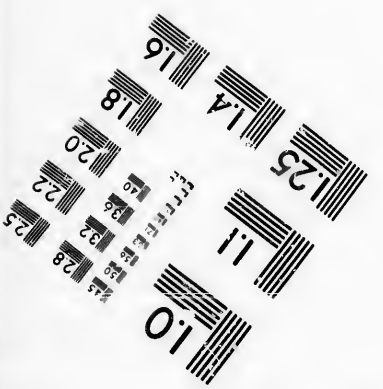

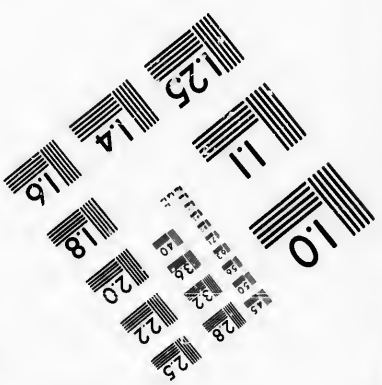

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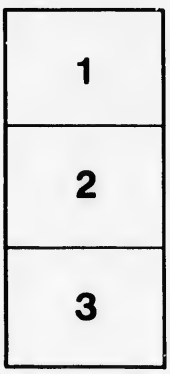

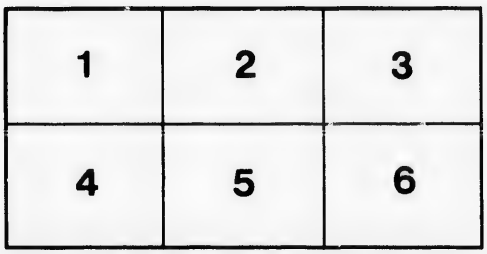

[Reprinted from the Jou. .klin Institute, May, 1898.]

Mining and Metallurgical Section.

Stated Meeting, Tuesday, January 12, 1898.

SOME ILLUSTRATIONS OF THE INFLUENCE OF GEOLOGICAL STRUCTURE ON TOPOGRAPHY.

BY BENJAMIN SMITH LYMAN.

Capt. D. G. Robinson's excellent map of the Punjab Salt Range and of the country northward finely illustrates in many places the influence of the geological structure upon the face of the country. The map was made about forty-five years ago, more particularly for military purposes, and is on the scale of a mile to the inch, with shaded topography. Certain portions of the map are especially interesting from the distinctness of the geological indications.

Near the eastern edge of the map, and about twenty miles northwest of the town of Jhilam, several ridges (*Plate 1*) bend round so as to form the northeastern end of as many concentric ellipses, with the long axis in a northeast and southwest direction. The ridges evidently consist of harder beds of rock separated by softer beds that underlie the hollows between. In the main body of the ellipse the harder rock beds seem to have so steep a dip as to make the beds perhaps nearly vertical and, therefore, nearly parallel on one side to those on the other. But where the principal ridges curve round at the northeastern end of the ellipse, a much gentler dip outwards is shown by the great steepness of the inner slopes and the comparative gentleness of the outer ones. Many of the subordinate outermost ridges have their crests worn down towards the small streams that cut across them, and thereby form sharp little peaks half way between each pair of those streams. The space in the interior of the ellipse of the principal ridges appears to be mainly filled with some level-bedded, probably old-alluvial soft formation. Yet here, too, the small streams have cut down into the steep dipping underlying rocks, and have formed numerous narrow, short valleys parallel to the main ridges. and showing the persistence of the same structure of the older beds throughout the ellipse. It is plain that the ellipse is caused by a saddle in the rocks, and that, if the rock beds of the principal ridges were restored, so as to be continuous over the central part of the ellipse, a form would result, closely resembling an overturned ship or boat, of which the prow would be towards the northeast.

Another place (*Plate 2*) within half a dozen miles east of the Indus, not far from the northwest corner of the map, and about twenty miles southwest of Attock, shows concentric ridges in a somewhat similar oval shape, forming roughly a complete ellipse half a dozen miles long, northwest and southeast, by a mile and a half wide. In this case, however, it is clear, upon careful inspection, that the rock beds do not lie in the shape of a saddle but in that of a basin. For towards the southeast end of the ellipse, and in a less degree along the northeast side, the steep escarpments on the outer side and

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
1851–57.

ORIGINAL SCALE:— 1 MILE TO AN INCH.

0 1 2 3 4 MILES 5

PLATE I.

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
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0 1 2 3 4 MILES 5

PLATE II.

the comparatively gentle slopes on the inner one show that the dips are towards the center of the ellipse. Along the southwestern side the same thing can likewise be discerned, but the dips seem to be steeper, more nearly approaching the vertical, and continue so for a couple of miles to the southwest, where the lower rock beds become gradually covered up by the overlying alluvium-like horizontal softer beds already noticed. A couple of miles northeast of the ellipse similar indications show that the rock beds form another nearly parallel basin, but the ridges are more broken up, and the geological structure is less easily made out. This basin is distinctly and narrowly closed by ridges on the northwest, but opens out towards the southeast, and the ridges become less continuous and less clear. Between the two basins the rock beds are in the form of a saddle, but very closely pressed together and broken up, so as to leave the geological structure less obvious. It appears, nevertheless, that the saddle broadens out towards the northwest.

Still another place (*Plate 3*) about twenty miles further south, has numerous nearly parallel northwest and southeast ridges, with a couple of the stronger ones bending round at the northwest to form the end of an ellipse. Here again the steep outer escarpments and gentler slopes towards the center show that the rock beds are in basin shape. Along each side of the ellipse they appear to be more nearly vertical, with the two sides rather closely pressed together. Northward from the end of the ellipse the rock beds form a saddle of somewhat irregular shape, and to the northeast another basin, the whole so compressed as to be broken up into rather disjointed parts. The alluvium-like upper soft horizontal beds also reappear here to mask the underlying harder layers.

Yet one more place (*Plate 4*) in the Salt Range itself, near its eastern end, shows a still more varied geological structure within the space of a few miles. At the point marked "Choombi pole" there is a curved nearby rectangular ridge, with steep outer slopes and gentler ones inside, indicating a small basin, broken through along the eastern side by the Bonhar River. The ridges on the east show by their slopes steep,

perhaps vertical, dips; on the west, gentler ones towards the middle of the basin, and on the northwest still gentler, with the crests formed into little peaks between the small transverse streams. To the northeast of the central basin the ridges are roughly concentric, but further on become rather sharply angular in their course, as if crushed together and broken. To the north the main river valley is very much filled up with the same alluvium-like, soft, horizontal beds already noticed, mostly covering up the harder underlying rocks, but leaving some of them visible in short ridges that betray not only steep dipping beds but a continuance of the partly crushed and broken condition of the rock beds of the neighboring hills. Yet some of the principal curves of the more disturbed rock beds are parallel to one another even at a distance of several miles. This illustration has also been used in the discussion of the paper read by Prof. J. C. Branner before the American Society of Civil Engineers last November.

It is evident that the carving out of the strongly-marked ridges and hollows in accordance with the geological structure has been effected by water—the rains and streams—leaving the harder rock beds to stand forth and the softer ones to be eaten away where not protected by overlying hard ones. In that torrid climate the water has acted mainly in its liquid form, with the help of weathering in a moist atmosphere during part of the year, but without the aid of frost to disintegrate the rocks. In some places lime rock may have been to some degree dissolved away by the waters, but their action appears to have been mainly mechanical.

The clear indication of basins and saddles within the small space of a few miles is owing partly to the fact that the succession of rock beds, originally laid down as sand, silt or the like, one on another at the bottom of the sea, and afterwards more or less consolidated, is made up of a great number of not very thick beds or masses of harder rock separated by softer beds that are likewise not in very heavy, thick masses; and partly to the fact that the whole series has been so strongly compressed and is of so yielding a character as to have been crumpled into very numerous, comparatively small waves with

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TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

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0 1 2 3 4 MILES 5

PLATE III.

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
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ORIGINAL SCALE:– 1 MILE TO AN INCH.

0 1 2 3 4 MILES 5

PLATE IV.

little basins and saddles. These folds are, to be sure, irregularly combined and in many places fractured and crushed into discontinuity. The overlying, more recent, still soft, level-bedded, alluvium-like material of the plains partially masks and obscures the geological structure of the underlying rocks, but is cut through in so many places as not to conceal it altogether. In spite of all the irregular crushing and the occasional concealment, many of the saddles and basins can be distinctly seen, or without great difficulty discerned, thanks to the mainly favorable circumstances.

In the Appalachian region of Pennsylvania the same influence of the geological structure upon the topography is observable on a much larger scale. The successive masses of harder and softer beds are much thicker, the whole series much stronger, stiffer and less readily yielding, and the basins and saddles much more extensive. The irregular crushing and breaking of these great folds is less in proportion to the whole, and the result is in the main an aggregation of comparatively simple regular waves, basins and saddles on a grand scale. The topography indicates those large forms in the same general way as the small ones we have been considering in the Punjab, and has been of great service in the study of the geology of Pennsylvania ever since the days of the first State Geological Survey. The varied topographical effects of the long, narrow basin-form and saddle-form were ably discussed by Lesley and H. D. Rogers forty years ago, when the subject was new to geologists. For the comparatively simple conditions of the Appalachians did not exist in most of the European regions where geological work had been done, and the outcrops of the different geological formations and their structure had been traced out more exclusively by means of their fossils, without regard to the topographical indications, that exist mainly in a less obvious degree.

The first impression was that the Pennsylvania topography had been produced by an immense flood of water, an ocean let loose, flowing over the land and carrying away vast quantities of earth and stones. In those days it was difficult to rid one's self of the idea that great geological changes were almost

instantaneously produced by tremendous cataclysms or even by downright supernatural means or miracles. The idea still lingers among men not familiar with geological matters that some stupendous topographical results have been effected in the twinkling of an eye by the "finger of God"—the expression cited by Prof. Branner. But all geologists now realize that the sculptured relief of the mountains and valleys, even where most astounding, even the gorge of the Niagara or the cañon of the Colorado, has been accomplished in the lapse of thousands of years by the same agents, chiefly rain and streams of water, that we see still in action about us.

It is plain that the geological indications given by the surface topography must have great value of a practical kind, and aid very much towards ascertaining both the general subterranean structure and the smaller details of either theoretical interest or economical importance. If coal or iron ore or other valuable mineral is known to occupy a particular geological horizon, a certain layer in a series of rock beds, such a series, for example, as we have in these Punjab illustrations, the place of outcrop of that horizon or layer, with the useful mineral, may in many cases be recognized merely by means of a careful study of the topography, and often the general structure, whether that of a basin or of a saddle, may be perceived; even though the surface of the ground may be so covered with loose earth and broken stone as to conceal the dips and precise character of the solid rock beds below.

The Punjab illustrations of the influence of the geological structure on the topography are interesting from their showing so clearly the small basins and saddles, with frequently very steep dips, but occasionally gentle ones, and with the repeated alternation of rather thin harder and softer rock beds, partly buried under level-bedded, soft, alluvium-like beds, in a region where the rock beds are in the main very strongly compressed and sharply folded and often broken and crushed together. The map is a striking example of the excellent geological results of faithful topographical work by surveyors who were no doubt quite unconscious of its having any significance for geology.