REVERSING THE CONTOURING PROBLEM, AS A STEP IN GEOLOGIC STRUCTURAL MAPPING WITH AERIAL PHOTOGRAPHS

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THE PROBLEM usually assigned the photogrammetrist is that of utilizing aerial photographs in producing a contour map. The reverse of this problem confronts the structural geologist. He must start with an existing topographic map or other source of elevation data and draw contours upon the aerial photographs. He must forego the advantages of costly equipment, mechanical and mathematical aids, and rectified prints, since it is necessary for him to execute his work at a cost of only a few dollars a square mile, which is to include the topographic contouring as only incidental to geologic interpretation, and structural contouring as well. A perfect topographic map on a perfect geodetic base is not the aim. The aim is structural contouring sufficiently accurate to reveal anticlines and synclines in approximately correct geographical location and of approximate structural relief.

Contact prints of the original uncorrected kind must be used, because as a rule they are the only ones readily available. On alternate prints he must draw the contours, reserving the other prints for the geologic data. Then by combining the pairs under the stereoscope he is enabled to estimate elevations at selected points along his outcrops and thus form the basis for the structural contouring. This article will be limited to the problem of the topographic contours.

Let us suppose that a fairly recent topographic map on a scale of one inch to the mile, and a contour interval of 25 feet, is available for the area being worked. The first task is to draw these contours on to the photographs under the stereoscope, employing reasonable care in making them fit the stereoscopic model but at the same time keeping them in agreement so far as possible with the original contouring. Any points of exact elevation, bench marks, road corners, etc., are marked on the photographs with the expectation that the final version of the contours will be made to agree with them.

The topographic map has now served its purpose, and is laid aside. From this point on, further correction and refinement of the contouring must depend on the eye, and one's knowledge of the factors involved. The contours are worked over, moving one up a little higher here, moving another down a little lower there. They are worked over until the eye no longer can find discrepancies. The final contours must satisfy several conditions, to be listed and discussed in the following paragraphs.

In the first place, each contour must appear to lie at all points in a plane. With training the eye one can become very sensitive to this. If the contour winds in and out among hills and valleys, it is easy to detect a portion that is out of this plane by being either a little too high or a little too low. This plane is not expected to look exactly horizontal, since the photographs may contain considerable tilt. This plane may be expected to appear gently warped, consistent with a certain general geometrical pattern, whose particular form for each stereoscopic pair being examined may be approximately determined by independent means.

In the second place, each successive contour must appear to lie in an approximately parallel plane—that is, the vertical interval between any two planes must appear approximately equal at all points. But here again there is an expectation of a slight progressive change of this apparent interval, the rules for which are related to those for the warping, and can be applied with sufficient approximation without undue labor.

Next, all the contours must be equally spaced vertically, except for an expectation of a progressive increase in the apparent interval with higher altitudes, an effect which occurs in addition to that mentioned in the last paragraph. This increase in apparent relief with higher altitudes accelerates, so to speak, upwards. The eye tends to compensate for it automatically, so that it is not noticed by some observers. This is because the high portions of the topography look nearer to the eyes than the low portions, and the mind associates a greater parallactic change with a given amount of relief when seen near-by than when seen far away.

In summary of the points made so far, it may be stated that the contours must be brought to the positions where they appear to the eye to be consistent with themselves. Except for the qualifications pointed out, they must look level, flat, parallel, and equally spaced. The eye with practice becomes very sensitive to deviations from these conditions, and anywhere within a distance of say a half mile will detect errors of a very few feet in actual magnitude. The final contours should contain no errors of over five feet if they are fully corrected by these tests. They will be correct from one half-mile distance to the next on across the map because of the fact that they were originally drawn to express the average contouring of a reliable topographic map.

The next factor to take into account is the amount of relief in the particular stereoscopic pair studied, compared with the average or with some standard, such as the pair having 60% overlap. It is well known that an increase in overlap beyond this figure cuts down the vertical dimension, due to the fact that there is less separation between the centers of the two photographs. Likewise, adjacent pictures taken too far apart give less overlap but more exaggeration of relief. Hence a different vertical scale must be taken into account with each pair of photographs used. A person engaged in a good deal of this contouring soon learns the apparent value of this 25 foot, or any other interval, as seen on a stereoscopic pair having 60% overlap, 50%, 70%, and other different amounts.

The apparent amount of the contour interval varies also with deviations from standard elevation at which the pictures are taken. It appears greater if the pictures are taken at a lower altitude (with larger horizontal scale), and vice versa. Hence the approximate scale in a row of pictures is checked. Three inches per mile is approximately standard. Again the experienced worker becomes familiar with the apparent value of the relief under these varying conditions, and is able to draw fairly true contours on a desired interval even without the help of a topographic map.

All the factors treated so far are of a mechanical or optical variety, inherent in the conditions in the photographs themselves. There are still other important and valuable factors controlling the contours that are inherent in the topography and physiography of the land. This article, not being of a geological nature, will not treat them in detail, but only in general principle. A contouring problem, such as has been described where the starting point is a good topographic map, can be performed without taking much heed of these factors. Such contours are bound to come out in agreement with the principles of physiography, and relate the levels of the land reliably over considerable distances. Is a hill top seen in one part of the picture higher or lower than another hill seen a mile or more away? Is a valley higher or lower than another valley separated by a ridge? Does one valley floor have a steeper or more gentle gradient than another valley? These questions were answered for you in advance by the topographers in the field who prepared the topographic map.

But suppose you have a problem of contouring on the photographs in an area supplied by a very poor topographic map, or none at all. Suppose you have a few scattered elevations furnished, or none at all. The physiographic criteria governing the horizontal plane in nature will then be relied on to largely overcome these conditions.

In the first place, what little control there is will be drawn upon the photographs as before. The contours as later developed will be made consistent with this control so far as possible, according to its degree of reliability. The next step is to draw preliminary contours on larger than the final interval in agreement with the general conditions of the physiography. If the final interval is 25 feet, these first contours might be 100 feet. After they are brought into harmony with every pertinent physiographic condition, the intervening contours may be interpolated and checked against physiographic factors, perhaps of a smaller order. Then all contours are refined and modified according to the optical principles previously described. If there is absolutely no control furnished, one should start at zero elevation at the lowest point in the area and build up. The accuracy of the contour interval will depend on one's previous experience in judging the apparent value of vertical intervals under varying conditions of percentage of overlap and scale of the photographs. If one has no knowledge of the scale of the photograph (that is, there are no section lines, and no information regarding the altitude at which the pictures were taken), one can judge this quite closely by the apparent size of trees, houses, etc.

Contours prepared in these ways with little or no control cannot be expected to be true within five or ten feet over a distance of several miles, or over a vertical range of several hundred feet. But they can be about as accurate over a limited distance as well-controlled contouring—that is, over the half-mile distance mentioned before. But the application of the physiographic principles will cut down very greatly the introduction of the accumulating errors that might be encountered over greater distances. Yet this must be accepted as an entirely successful and practicable contour map for the purpose for which it was prepared, namely as a basis for geological structural contouring. The rate at which the contouring will depart from accuracy over any distance will be a much slower rate than that of the dips of the formations being mapped. The resulting geological map, therefore, will reveal anticlines and synclines quite reliably as to their positions, and as to the approximate amount of their structural relief.