that show changes, to obtain greater detail or to check "possible" situations.

A third step, following stereo study of areas of change, would include field study of these sites, either by a complete check or by checking a sample number. For all of these purposes, the annotated index sheet serves as a location map for use in the office or in the field.

Use of this method has been made in fields other than farmland development. In areas where agricultural land is reverting to forest, airphoto comparison analysis has provided data on the acreage and the type of land that is reverting. Figure 4 illustrates the situation in an area where agricultural use is shifting rapidly to urban use. The comparison study procedure used in this field is similar to that used in land development for using both contact prints and photo index sheets.

Summary

Use of airphoto comparison methodology provides a means of obtaining data on agricultural land uses for economic analysis, with a minimum expenditure of funds, and a small number of professional personnel, in a relatively short time. The two methods allow for a choice of approach, depending on the job requirements. Or, used in combination, they are a good substitute for field mapping, particularly for large areas.

*Determination of the Angle of Dip of Seemingly Vertical Strata on Vertical Aerial Photographs**

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Introduction

Most photogeologists are familiar with the phenomenon of perspectively overturned beds in stratified rock. The impression one receives from the photographs is that the strata seem to dip in the opposite direction from the actual one. Sometimes they also appear to be considerably steeper than they actually are, without reaching an overturned position.—Also, the contrary is more or less familiar: that strata appear on the photographs to be less steep than they are in reality. However, the author has never found any written description as to how, from seemingly vertical strata, the true dip can be determined. Such a determination is simple and rapid, and does not require the use of a stereoscope. The method is described in this paper, after first determining under what conditions the strata are perspectively overturned, steepened or moderated.[1]

The Three Zones of Perspectively Overturned, Steepened and Moderated Dipslopes

In the cross section of Figure 1, O is the photographic lens; the line WW is the terrain or surface of the photographic print (film or plate); and OC is the altitude of the airplane or the focal-length f of the camera, respectively. The strata are supposed to dip with the same angle ω all over, from W to W. The beds in 1 and 4 are at the extreme margins of the vertical aerial photograph.

The widths of the projections of the dipslopes upon the print are drawn along the line XX. The projection of the slope is broadest in 1, less broad toward the left, as for instance in 2. In 3, many points of the

[1] What applies to the inclined strata is of course also valid for similar features, such as hill slopes, etc.

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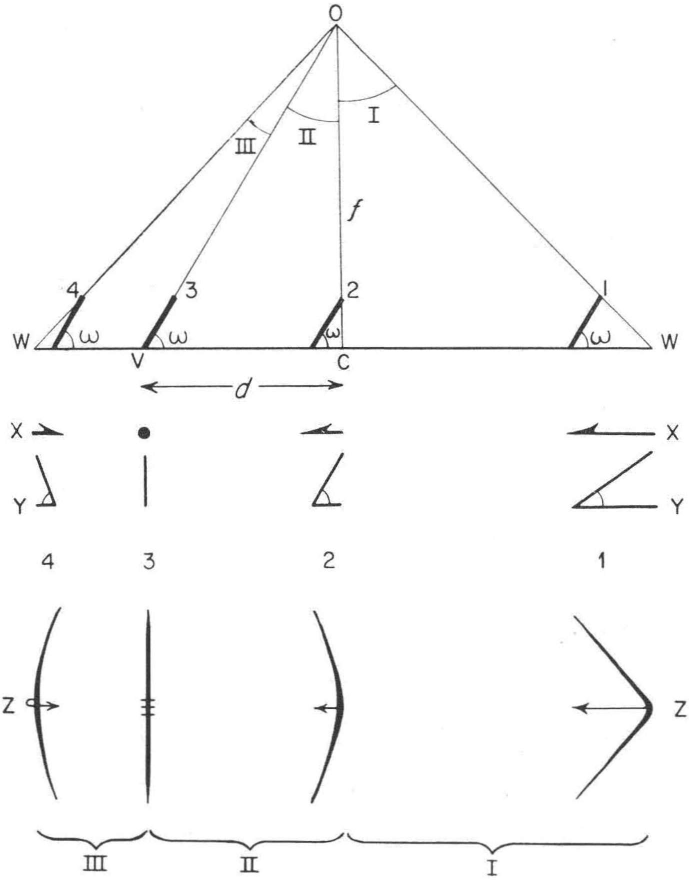

FIG. 1

slope project in one single point of the strike line. It is as if one were looking straight down along a vertical wall, and for the same reason the slope in 3 seems to be vertical. In 4 the higher parts of the slope are projected to the left of the base line. Such a slope seems to dip toward the right and is projectively overturned.

The impression that is received, concerning the angle of dip, is indicated along the line *YY*. The projections of the dipslopes upon the photographic prints are, in principle, like the ones drawn along *ZZ*.[2]

If the slope near 2 is supposed to be observed with the same angle of dip as it has in reality, then the aerial photograph can be divided into three zones which have the following characteristics: In zone 1 the slopes seem to be gentler than they are in reality. In zone II they seem to be steeper and in zone III overturned.

THE REAL DIP OF A SEEMINGLY VERTICAL BED

Let d be the distance from the center point of the photograph to the strike line of the dipslope (Figure 1), then obviously the following equation applies: $\tan \omega_0 = f/d$, Equation (1). A dislope seems to be vertical if it has an angle of dip $\omega = \omega_0$ that satisfies Equation (1). It is perspectively overturned when its angle of dip ω is greater than ω_0.

The dip that a bed must have to seem vertical at the extreme margins of a vertical photograph can be easily determined by means of Equation (1). Values are given in the following table for three representative types of photography.

Focal-length	*Size of print*	*Angle ω_0 at the photo sides*
10 cm. (Zeiss)	18 cm.	48°
8 cm.	8 cm.	64°
6 cm.	8 cm.	53°

[2] After W. E. Johnstone's paper, "A Geological Interpretation of an Air Photograph of British Somaliland," PHOTOGRAMMETRIC ENGINEERING, June 1953, the reader is supposed to be familiar with these scarp symbols.

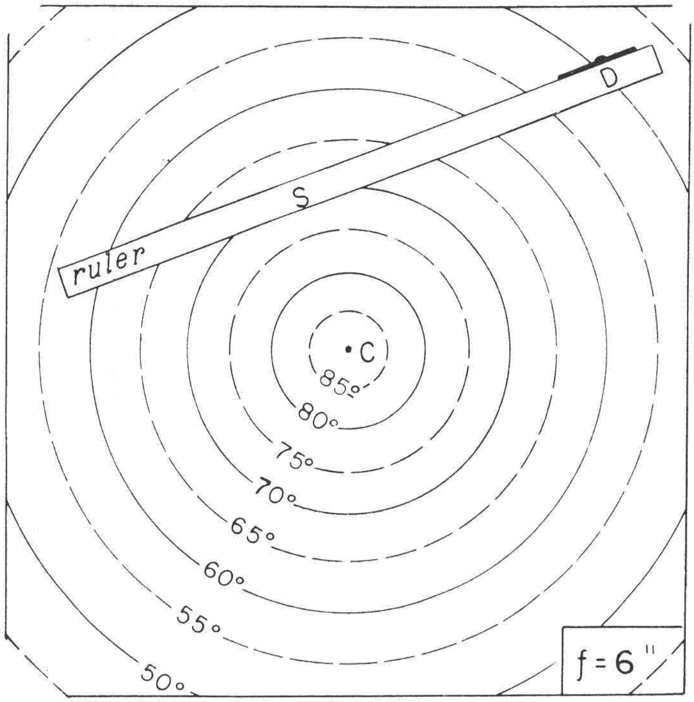

FIG. 2

From the table the conclusions can be drawn that seemingly vertical dips occur only in rather strongly tilted formations. When the photogeologist has to work in a region where this is frequently the case, it may be useful to construct a nomogram. Two different types are presented in Figures 2 and 3; each one has certain advantages over the other. It should be emphasized that the d of Equation (1) represents the distance between the center point of the photograph and the strike line of the dipslope, because in order to seem vertical it is necessary for the dipslope to coincide with the plane that can be traced between its strike line and the nodal point of the lens.

The nomogram of Figure 2 is a transparent plastic sheet provided with concentric circles, the radii of which are equal to the values of d obtained by means of Equation. (1) for successive dipangles ω (85°, 80°, 75°, etc.). With the help of a ruler held along the strike of the slope, it can be determined to which circle the prolonged strike is tangential. In this manner the true dip angle can be read or estimated (68° in the case of Figure 2).

The transparent nomogram of Figure 3 consists of two perpendicular lines corresponding to the lines DSC of Figure 2. The nomogram should be so placed on the aerial photograph that SD passes through the seemingly vertical bed and SC through the center of the photograph. The corresponding angle ω_0 is read at the center point of

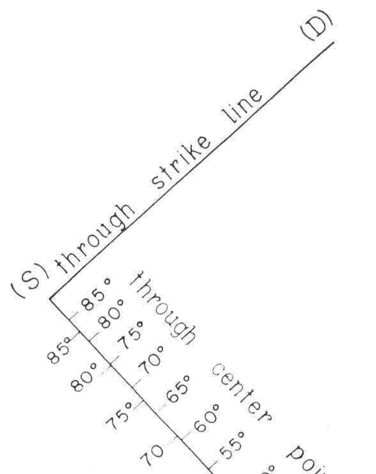

FIG. 3

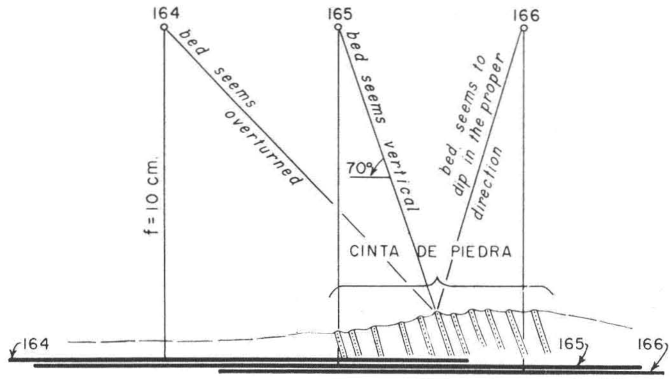

FIG. 4

the photograph (in this example 52° for 6 inch photographs). The sides *DS* and *SC* should be as long as half the diagonal of the photographs. This nomogram has the advantage over the one in Figure 2, in that it can be used for two different types of photography (for $f=6''$ and for $f=8\frac{1}{4}''$ in the case of Figure 3). Other types of universal nomograms could be constructed for use with many types of photographs, but in practice they appear to be less convenient due to the presence of many lines.

For occasional dip determinations of this kind,[3] a simple geometric construction, as indicated in Figure 5, may lead to the desired result. See also Figure 4, which represents a schematical section through the photographed area of Figure 5.

Seemingly Vertical Beds Observed by Means of a Stereoscope

Although the determination of the dip of a seemingly vertical bed is directly based upon a simple perspective geometry of aerial photography, excluding the use of a stereoscope, it may be of practical value in giving some attention to similar phenomena that can appear when photographs are examined with the help of a stereoscope.

In the following lines it is supposed that the stereoscope is used in such a way that the observed features are always in the central part of the field of vision, that is, one has to look straight down upon them and not obliquely. Moreover, only considered are those dip slopes whose strike lines are parallel to the photo-base.

A vertical section through the photographed area, perpendicular to the photo-base, and for instance halfway between the stations of exposure, will then look like Figure 1. The same three zones, I, II, III, mentioned before, this time parallel to the photo-base, can then be distinguished when the stereoscope is moved from right to left (Figure 1). The limit between I and II (zones of dips that appear less steep for the first, and steeper for the second than they actually are) passes through the photo-base if the vertical exaggeration (*Ev*) is equal to one. It will be between *C* and *W* when *Ev* is larger than 1, and between *C* and *V* when *Ev* is smaller than 1. However, the limit between zones II and III will always be in *V*, because in any event the beds will appear vertical there when ω reaches a value defined by Equation (1), whatever *Ev* may be. In a previous paper[4] the author already mentioned that too little attention has been given to this fact in some methods used for approximating dip slopes.

For those cases where the strikes of the inclined beds are not parallel to the photo-base, non-stereoscopic examination may reveal the following peculiarities. On one photograph the dip slope can appear to lie in zone III (Figure 5, photograph 164), but in zone II on the other photograph of a stereoscopic pair. Or, in zone II on one photograph and in zone I on the next one (Figure 5, photo 166). By stereoscopic vision these contrasts will somehow be overbridged and an intermediate dip will be observed, the real value of which can be determined by means of Equation (7) of the author's papers already quoted.

[3] The use of the described nomograms is rather restricted, because seemingly vertical dips are rather uncommon. But even when these are not present, perspectively overturned dips, for instance, can also be useful, and if the area is photographed several times from different points, a careful analysis of the situation may determine between which limits the angles of dip are lying.

[4] PHOTOGRAMMETRIC ENGINEERING, September 1956, p. 723, right hand column.

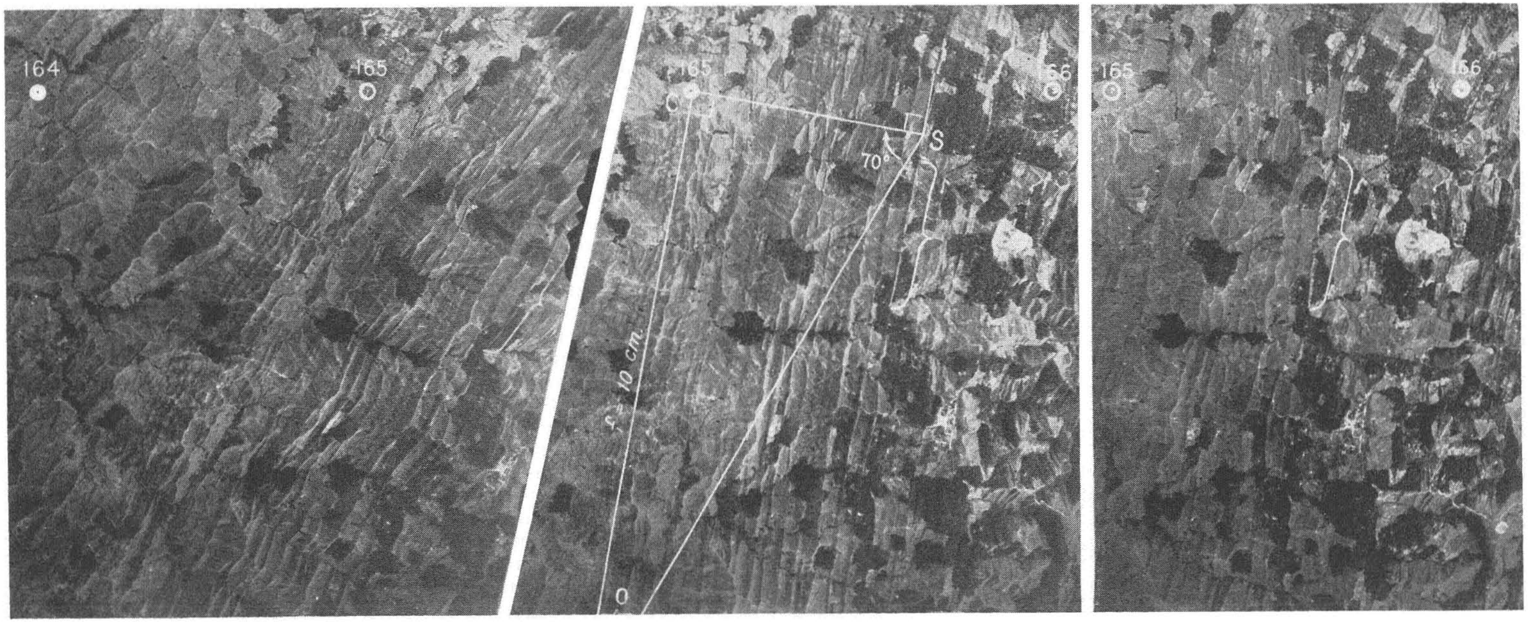

FIG. 5. This example for the construction of the dip of a seemingly vertical bed is rather interesting, because of the fact that this bed can be observed in three consecutive photographs (164, 165, 166), thanks to an unusually large forward overlap (72%), combined with considerable crab. This figure represents the parts of interest cut out from the three photographs (164, 165 and 166). The white dots are center points. The apparently vertical bed in photograph 165 permits the determination of the angle of dip at 70° by means of a simple geometric construction. The strata dip to the East appears correctly in photograph 166. In photograph 164 the bed seems to dip toward the West. Fig. 4 makes it clear that the bed is here perspectively overturned. The hard beds are sandstones belonging to a series locally called "CINTA DE PIEDRAS," which form part of the Upper Oligocene. The photographs were taken by the "Instituto Geográfico Militar" of Colombia, with a Zeiss wide-angle camera, focal-length 10 cm., east of Holguín and Obanda, at the eastern slopes of the Cauca Valley.