Technical Papers

The Physiologic Limits of Vision in Physiographic Observation

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Since the physiographic studies of Davis (*1*) and Keith (*2*) in the Appalachian-New England region near the end of the 19th century, geomorphologists have been divided into two schools of thought concerning the appearance and nature of upland surfaces. The concept of the followers of Davis seems to have been derived from his exhortation:

> Ascend a hill that reaches the general upland level, and note how even the skyline is on all sides; how moderate the unequality of the surface would be if it were not for the few mountains that rise above it, and the many valleys that sink below it. Looking around the horizon, the slightly rolling high-level surface of one hill after another approaches the plane of the circular skyline. It requires but little imagination to recognize in the successive hilltops the dissected remnants of a once even and continuous surface, beneath which the valleys of today have been eroded (*3*).

Keith (*4*) and his successors, in contrast, are convinced that the identical mountain areas consist of a number of planed surfaces separated by small vertical intervals.

The fact that two groups of workers see different features in the same landscapes, not only in the Appalachians and New England, but in the Rocky Mountains as well, creates a problem that merits attention, if only because the interpretation of geomorphic history depends on a correct description of the landforms involved. The adherents of both concepts have stressed the importance of field observation, but the proponents of multiple surfaces have also emphasized the necessity of checking field work with map study by means of "projected" (*5*) and "zonal" (*6*) profiles.

From the great reliance placed on what the eye sees in a landscape, it is evident that the physiologic limitations of the human eye as an observational instrument have never been considered in physiographic work. In fact, Davis dismissed the matter summarily: "Considerable as the inequalities of altitude are, frequent study of the maps and repeated views of the uplands from various hill-tops impress me more with the relative accordance of the altitudes than with their diversity. I cannot admit that the appearance of accordance from hill-top to hill-top is an optical deception" (*7*).

It is not the purpose of the authors to discuss the amount of relief that is admissible in "an even and continuous surface," or the external factors that impose limitations on observation, such as atmospheric phenomena and the curvature of the earth. The latter subject has been covered adequately from every angle in numerous papers and needs little comment. Nevertheless, one factor in connection with Davis' quotation should be noted. Unless there is a broad depression between the observer on a hilltop and the upland surface that he is examining, he is not looking at the same surface as that on which he is standing, but at a higher level because of the curvature of the earth.

The present study will consider factors within the eye itself that impose limitations on physiographic observation. Because of the structure of the retina, there is a definite limit to the magnitude of relief that the human eye can perceive at a given distance. The perceptive mechanism of the retina is a closely spaced array of photosensitive nerve endings, the cones. The physical limit of definition depends on the spacing of the cones. To discriminate the form of an object, its several parts must be differentiated, and this necessitates the stimulation of separate cones. Microscopic measurements (*8*) have determined the average diameter of the macular cone as .004 mm, thus establishing the smallest distance between 2 cones. The normal eye should be able to perceive form in an image made up of component elements spaced .004 mm apart.

TABLE 1

THE SNELLEN TEST TYPES (*10*)

Line on chart	Distance						Size of letters	
1	Standardized	to	60	m,	or	196.85 ft	87.0	mm
2	"	"	36	"	"	118.11 "	52.2	"
3	"	"	24	"	"	78.74 "	34.8	"
4	"	"	18	"	"	59.05 "	26.1	"
5	"	"	12	"	"	39.37 "	17.4	"
6	"	"	9	"	"	29.53 "	13.05	"
7	"	"	6	"	"	19.68 "	8.7	"
8	"	"	4.5	"	"	14.76 "	6.53	"
9	"	"	3	"	"	9.84 "	4.35	"

The eye comprises a simple lens and screen system; hence it follows that image size is determined by the eye's distance from the object. It has been found that, in order to produce a minimal image, an object must subtend a visual angle of 1′ with the retina (*9*). This is the standard of normal visual acuity. The Snellen Test Types are constructed on these principles and are accepted standards for determining visual acuity. The types consist of rows of letters that diminish in size, scaled so that at specific distances, each letter subtends a 5′ angle and each component part of a letter a 1′ angle with the retina (Table 1). Visual acuity is recorded as a fraction, the numerator denoting the distance between the type and the patient, and the denominator, the test line that he reads. The normal eye should distinguish the letters in the 6-m,

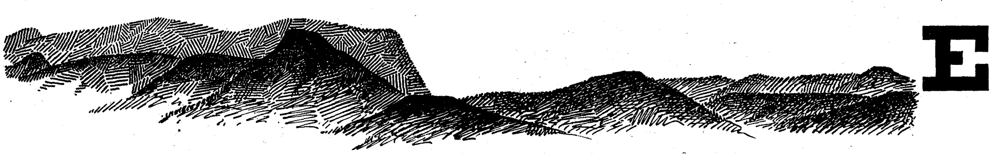

FIG. 1.

or 20 ft, line at a distance of 6 m, or 20 ft. If such is the case, it is recorded as 6/6 or 20/20. The statement "20-20" vision refers to this fraction. The chart is best illuminated by 80–100 ft-c.

By adopting the principles used in developing the Snellen Test Types, but using larger objects and greater distances, it is possible to determine the point at which individual features in a landscape cease to be differentiated. It is assumed that the illumination of the object observed is of the same order of magnitude as that used for the Snellen Type Tests for visual acuity. Furthermore, the geomorphologist is postulated to have 20/20 vision. For example, a cliff 100 ft high, at a distance of 13.06 miles, will subtend an angle of 5′, as does the letter of the Snellen "20-20" line viewed at its standard distance of 20 ft. It will be just perceived as a discontinuity of form by a person with "normal" vision. This statement must be understood as semiqualitative, as illustrated by Fig. 1 when viewed by the reader at a distance of 20 ft. In this illustration, the Snellen letter is a sharply defined black figure on a white background (*11*), which offers maximum contrast. The horizon line of the profile, on the contrary, consists of an undulating form, so that only abrupt declivities are equally conspicuous. In actuality, the sky and landscape offer a black-and-white contrast only under most unusual conditions of atmospheric clarity and lighting. When reduced illumination, haze, or subtility of contour obtains, greater changes in relief are necessary for perception.

The preceding discussion leads to a simple rule for field observation: a 100-ft cliff at 13 miles will be just perceptible under optimum conditions. At one-half the distance, a 50-ft cliff will subtend the same angle and offer similar geometric contrast. Under poor illumination, a precipice several times this scale would be necessary for discernment. With the dispersion of light caused by haze, a further allowance should be made, particularly for distant skylines. Therefore, although a horizontal surface separated from another such bench by a 100-ft cliff could be seen by a physiographer with "normal" visual acuity under ideal atmospheric conditions, it might easily be overlooked. The two surfaces, in this case, would be described erroneously as a single-planed surface of low relief. From consideration of the physical and concomitant external factors that may produce optical deception, it is apparent that descriptions of topographic relief based on the eye alone are not reliable.

The physiologic limitation of the human eye is offered as a plausible reason for different physiographic descriptions of identical upland areas. Lack of consideration and evaluation of this factor may explain why some geomorphologists have seen but one "even and continuous surface" in uplands, whereas others have identified a number of beveled surfaces separated by small vertical intervals. The former dismiss as minor (or perhaps do not see) the minute details noted by the latter.

It thus appears that "the optical deception" of hilltop accordance that Davis would not admit may very well be a fact. Like his colleagues in other fields of science, the physiographer finds that his eyes have a finite limit of reliability, and he is therefore driven to search for other methods of checking observations of topographic forms than by eye alone—namely, map analysis. Although he may be deprived of the comfort that what he sees is real, nevertheless, the foregoing simple formula may be of some assistance in determining the approximate height of features, where distances are known, by providing a scale of relief in which 100 vertical ft at 13 miles' distance will be barely perceptible under ideal conditions.

References

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Intracellular Localization and Distribution of Carbonic Anhydrase in Plants[1]

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Steemann Neilson and Kristiansen (*1*) have recently reported that in the aquatic plants *Fontinalis dalecarlica* L. and *Elodea canadensis* Mich. carbonic anhydrase is limited to the chloroplast sediment obtained by centrifuging the filtered leaf brei. This observation agrees with that of Day and Franklin (*2*), who found that carbonic anhydrase is confined to the chloroplast sediment obtained from leaves of *Sambucus canadensis* L. As Steemann Neilson and Krist-

[1] This investigation was conducted in the Plant Science Laboratories of the Division of Applied Biology, National Research Council of Canada, Ottawa. Issued as N. R. C. No. 2318.