ART. VII.—*An attempt to determine the Amount and Rate of Chemical Erosion taking place in the Limestone (Calcareous to Trenton) Valley of Center County, Pa., and hence applicable to similar regions throughout the Appalachian Regions; by A. L. EWING.*

IN the following, the nature of the problem precludes the idea of even a close approximation to accuracy. It is claimed however that these determinations form a more reliable basis than mere estimates.

The method pursued is as follows: The amount of water flowing from a given hydrographic basin in the region under question is determined from the cross-section and velocity of the stream draining it. The amount of solids in the water is determined by evaporation; these data with the area of the basin form the basis of calculation.

The region selected is that of the Spring Creek basin which forms a considerable portion of the limestone valley of Center County. The measurements were made above the old dam below Bellefonte and below the entrance of all visible tributaries from the valley.

That a fair conception of the region may be had a brief explanation of its geology is necessary. The region under consideration forms a part of Nittany Valley. This valley, known under different names, extends through a considerable portion of the Appalachian region, and consists of the remains of a great anticlinal fold, which had it not been worn down would form an immense mountain-like plateau over 20,000 feet above its present height. As it is, the floor of the valley consists of the upturned edges of the lower Silurian limestone

eroded through a thickness of 6,000 feet. The valley is flanked on either side by the remnants of the overlying Medina Sandstone which forms monoclinical ridges from 600 to 1,000 feet above its floor. The inside slopes of these mountains are formed by the Utica and Hudson River shales.

The great amount of erosion that has taken place here is an interesting geological topic. That in early times it was mainly mechanical, caused by the steeper declivities, is undoubtedly true. The present topographical features, however, can not be explained without considering the excessive chemical erosion of the limestone. This I believe is the opinion of the geologists who have visited the region: The water from the limestone contains a large amount of calcium and magnesium salts. That from the State College well gives .2273 grams per liter of solids, over 80 per cent of which are calcium and magnesium carbonates. Sink holes, caves, etc., are common as in other limestone regions. Still, I am not aware that any attempts have been made to determine the *amount of erosion* taking place by this process, and hence the following is submitted.

Average width of stream where the measurements were taken, 22.86 meters (75 ft.). Depth, average of six measurements across the bed of the stream, .823 meters (2.7 ft.). This gives as the cross-section of the stream 18.81m² (202.5 sq. ft.). Allowance was made in these determinations for obstruction from weeds, etc.

The velocity of the stream was determined by floating surface particles and by floating a long bottle weighted with shot at various depths from .3 m. to .75 m. (the greatest depth of the stream being 1m.). The velocity of the stream was found to be 994.776 m. per hour, this giving 18.172m³, as the amount of water removed per hour. The water shows on evaporation, as average of two tests, 155.3 grams per m³, giving 2,905,974 grams the amount of solids removed per hour, or 25,456,560 kilos. per annum. As the area of limestone drained by Spring Creek is about 100 sq. miles, this gives 255.654 kilos. of solids as the amount removed per annum per sq. mile. This is equivalent to 282 tons.

A portion of the water carried off by Spring Creek, however, falls not upon the limestone area considered above, but upon the mountains bordering the valley. Probably one-fourth of the water falls upon the mountains. To show that the main part of the solids comes from the limestone, I had specimens of the water as it flows from the mountains evaporated. An average of two tests gave 16.5 grams per m³, or a little over one-tenth of the amount found in the water as it flows from the valley. Thus not more than one-fortieth of the solids in the Spring Creek *water* probably comes from the mountains.

Making this correction it still leaves 275 tons per sq. mile as the amount annually removed in solution.

A closer approximation could be made by continuing observations similar to the above through a period of time, say for one year. To get the *amount of water* carried off in a year this would be necessary. Yet it is evident that the *amount of solids carried away in solution is much more constant than the amount of water flowing through the stream*; as in times of freshet or excessive flow there is a larger proportion of surface water, while in times of diminished flow a relatively larger portion of the water reaches the stream through underground drainage and must contain more solids. Hence the above number, 275 tons per sq. mile, may be taken as a fair approximation to the amount of material actually removed per annum in this and similar regions.

According to the above determinations and assuming that the solids removed have a specific gravity of 2.8, we get as the cubic contents of the mass removed from the entire basin $9,130.5\text{m}^3$, or 91.3m^3 per sq. mile per annum, making the deduction as before of one-fortieth for the amount brought from the mountains; and conceiving the remainder to be spread evenly over the surface it would form a layer $\frac{1}{29173}$ of a meter in thickness. Hence to lower the surface to the extent of 1 m. by this process would require 29,173 years, or about 9,000 years to remove one foot from the surface.

It is safe to assume that had the rocks of this region been similar to those of the bordering mountains in their nature and power to resist dynamical agencies we should have in place of Nittany valley a mild anticlinal plateau somewhat above the mountains in elevation, say 1000 feet above the present height of the valley. The erosion in the valley then in excess of that along the mountains has been mainly chemical and at least 1000 feet of limestone has been thus removed. A simple further deduction shows that accordingly Nittany valley has been 1,000,000 years in process of formation.

The *limestone erosion* could not begin before the latter stages of the Mesozoic era, possibly not before the Cenozoic era, as sufficient time must have elapsed subsequent to the Carboniferous age to erode all formations of the Paleozoic era above the Trenton limestones. One million years seems not inconsistent with other estimates of geological time; still these calculations respecting time are an afterthought and supplementary to the main point intended to be shown in this paper, viz: the rate and amount of chemical erosion of limestone.