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THE FLOOR OF THE SHENANDOAH VALLEY¹

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ABSTRACT. The floor of the Shenandoah Valley near Elkton, Va., is commonly supposed to be the dissected surface of the Valley Floor or Harrisburg peneplain. Actually, the principal element of the floor is a series of gravel-capped benches, formed in Pleistocene time during alternating periods of erosion and deposition, and rising step-like toward the bordering mountains away from the flood plain of the South Fork of the Shenandoah River. Unconformably beneath the gravels is residual clay, resulting from the decay of the bedrock of Cambrian and Ordovician limestone, dolomite, and shale. The clay is thickest on the southeast side of the valley, where it attains 200 feet. It probably formed during a single epoch in the Tertiary, under mild and humid climatic conditions, toward the close of a period of peneplanation—that is, near the time of completion of the Valley Floor peneplain. At one locality a small body of ancient gravel, probably of Tertiary age, lies stratigraphically between the residual clay and the Pleistocene gravels, and is unconformable with each. The Valley Floor peneplain is believed by some authors to have been formed in late Tertiary time, but the sequence of events implied by the geological materials of the Elkton area suggests that it is considerably older.

INTRODUCTION

A GREAT deal that has been written on the geomorphology of the Appalachian area has to do with land forms and surfaces, and much less has been written on the geological materials of which these surfaces are composed. This paper deals with the geological materials which compose the land forms of one area in the Appalachians, that near the town of Elkton in the Shenandoah Valley of northern Virginia. Although many details are uncertain, it is the writer's belief that the Cenozoic history was more complex than has generally been supposed, and probably different from what one would conclude from a study of the land forms alone.

In 1940 and 1941, the writer and John Rodgers, now of Yale University, mapped geologically a belt of country 20 miles along the northwest foothills of the Blue Ridge and the

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southeast edge of the Shenandoah Valley in the vicinity of Elkton, Va. The investigation was a part of the wartime strategic minerals program of the U. S. Geological Survey, and the purpose was a search for reserves of manganese ore. The investigation included study of stratigraphy and structure of the bedrock formations, of manganese-bearing residuum which overlies some of the bedrock, and of superficial deposits that overlie the residuum and bedrock. During the same period the U. S. Bureau of Mines prospected two tracts in the area by means of drill holes and shafts, and their results were studied geologically by the writer. The investigation was therefore focused on surface and near-surface geological materials, and provided an exceptional opportunity to correlate these materials with the land forms.

The economic aspects of the investigation in the Elkton area were set forth in a strategic minerals bulletin (King, 1943), and the general geology has been described in a manuscript that has recently been submitted to the Geological Survey for publication (King, 1947). This paper is a summary of one chapter in the latter manuscript.

GENERAL GEOGRAPHY AND GEOLOGY

The Elkton area lies in Page and Rockingham Counties, Va. The town of Elkton is 20 miles south of Luray and 18 miles east of Harrisonburg. The area is drained by the South Fork of the Shenandoah River, which follows the axis of a gently sloping valley—the southeastern branch of the Shenandoah Valley—from 4 to 7 miles wide, which stands at an altitude of 800 to 1,000 feet (map, figure 1). The valley is bordered on the southeast by the Blue Ridge and its fringe of foothills, whose summits rise to altitudes of nearly 4,000 feet. It is bordered on the northwest by the narrow hogback ridges of Massanutten Mountain, the highest of which reach an altitude of 3,300 feet.

The bedrock of the area consists of formations of pre-Cambrian, Cambrian, Ordovician, and Silurian age, the oldest lying to the southeast and the youngest to the northwest. Table 1, below, shows the general succession insofar as it bears on the discussion that follows:

TABLE 1

Generalized Section of Bedrock Units in Elkton Areas, Virginia.

Age	Formation	Thickness (feet)	Lithologic character	Topographic expression
Silurian	Sandstone and quartzite	500	Sandstone and quartzite	Ridge crests of Massanutten Mountain
	Martinsburg shale	2,800	Shale and sandy shale	Northwest slope of Shenandoah Valley
Ordovician	Limestone	200	Thin-bedded limestone	
	Beekmantown dolomite	3,000	Thick-bedded dolomite	Axis of Shenandoah Valley; in places overlain by thin residuum
	Conococheague limestone	2,000	Thick-bedded, argillaceous and sandy limestone	
	Elbrook dolomite	3,000	Thin-bedded dolomite	
	Waynesboro formation	1,700	Red and brown shale; thin limestone beds	Southeast slope of Shenandoah Valley; generally overlain by thick residuum
Tomstown dolomite	1,000	Dolomite, argillaceous dolomite, some shale		
Cambrian	Antietam quartzite Harpers shale Weverton quartzite Loudoun formation	2,900	White, thick-bedded quartzite above, underlain by quartzite, siltstone, and shale	Foothills of Blue Ridge; hogbacks, dip slopes, strike ridges; much talus
	Pre-Cambrian	Catoctin greenstone and underlying sediments Injection complex	Massive volcanic and plutonic rocks	Slopes and summits of Blue Ridge

The Blue Ridge is formed of massive pre-Cambrian volcanic and plutonic rocks, and its summits, standing at altitudes of 3,000 feet or more, are nearly flat or gently rolling in many places. These flat areas have been interpreted as peneplain remnants (Stose, 1919, pp. 37-38; and other authors) and have been correlated partly or wholly with the Schooley pene-

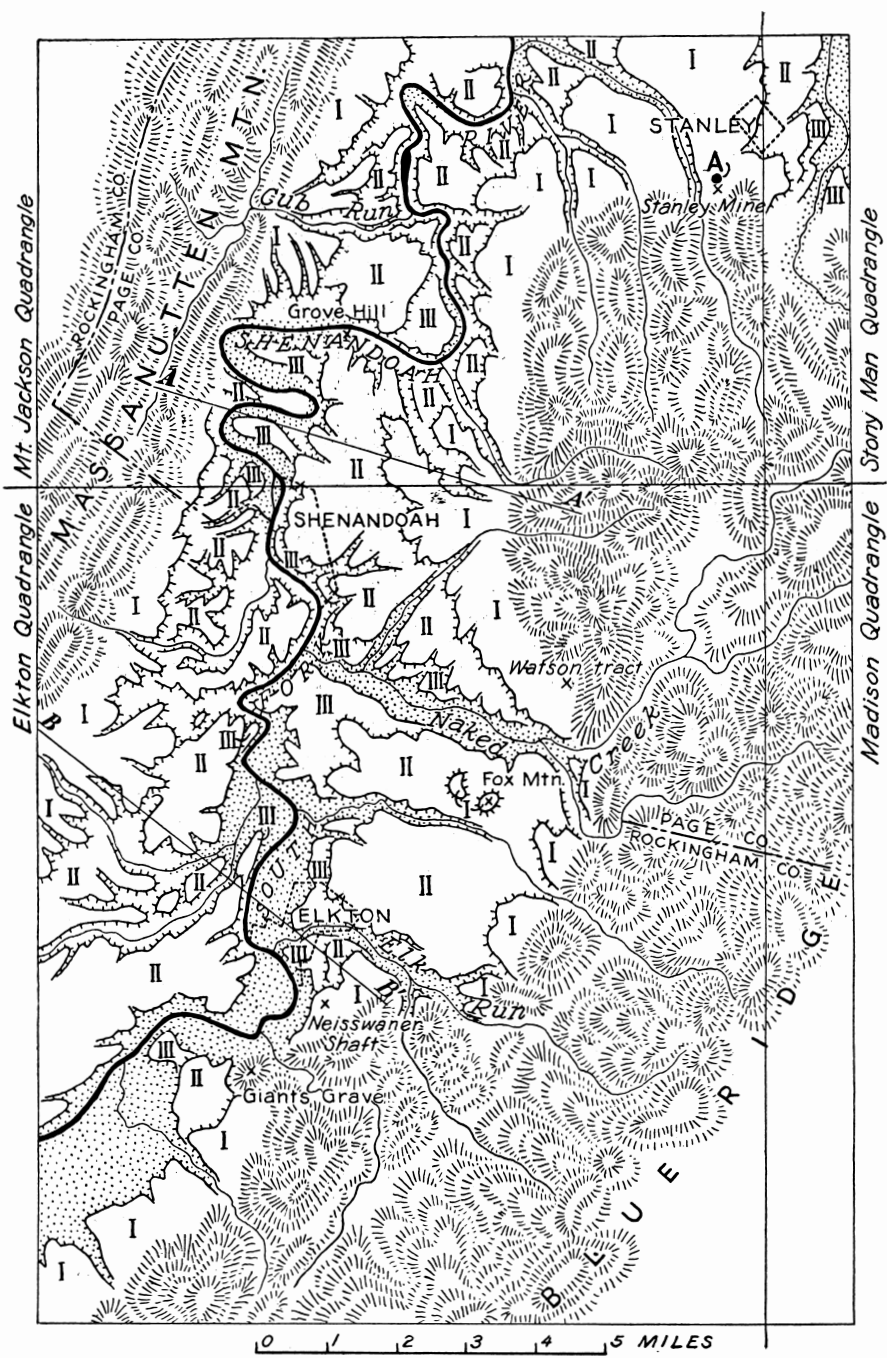
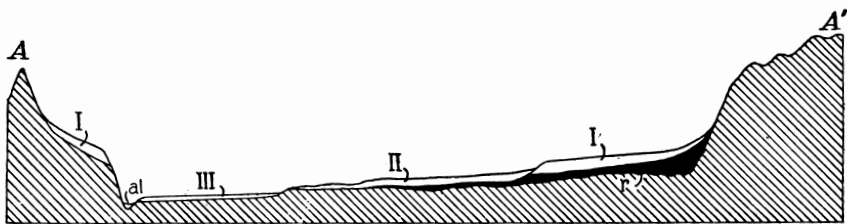
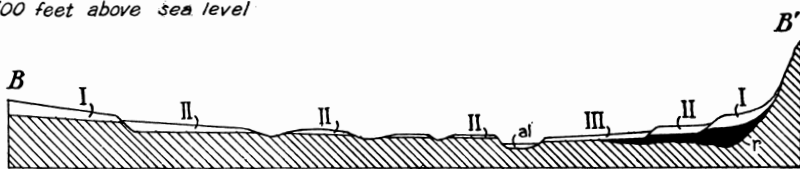


Figure 1. Map and sections of Elkton area, Virginia,



700 feet above sea level



700 feet above sea level

0 1 2 3 Miles

Horizontal scale

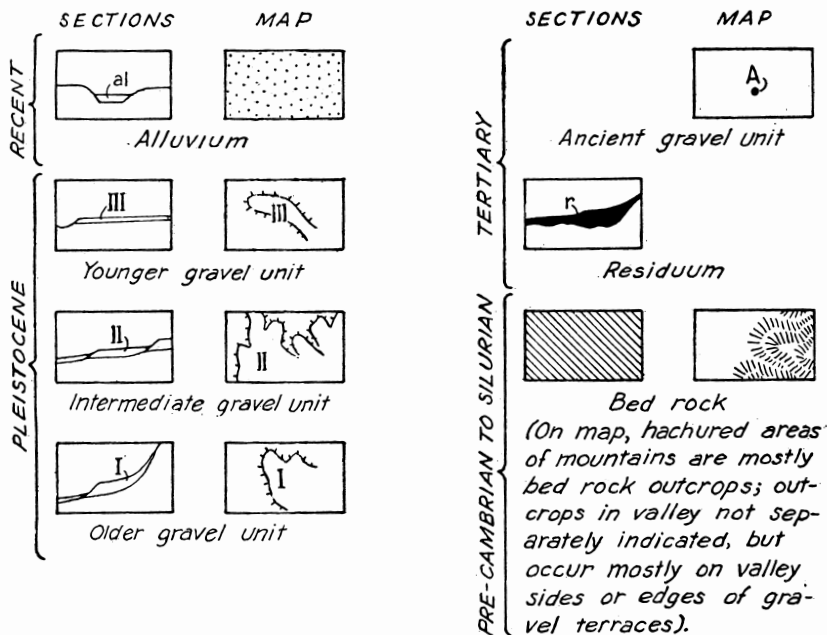
0 1000 2000 3000 Feet

Vertical scale

Horizontal scale two times that of map.

Vertical scale four times horizontal.

EXPLANATION



showing Cenozoic deposits, and localities mentioned in text.

plain. The crests of Massanutten Mountain have likewise been interpreted as controlled by a former high-level peneplain (Keith, 1894, p. 391; Spencer, 1897), perhaps the Schooley. Remnants of ancient erosion surfaces may well exist on the Blue Ridge, but it is uncertain how many are represented, as the flat summits stand at divergent heights in different places. If a surface once existed in the Massanutten Mountain area, it is now poorly preserved, for the mountain consists of ridges with knife-edged tops, without any flat summit areas. Below the Schooley level in parts of northern Virginia another surface, the Intermediate or Weverton peneplain, has been reported (Keith, 1894, p. 238; Stose, 1919, pp. 38-39). No evidence for this was seen in the Elkton area; the slopes intervening between the summit of the Blue Ridge and the floor of the Shenandoah Valley are steep and irregular, and there is no systematic arrangement of the foothill crests.

The area here called the "floor of the Shenandoah Valley" derives its name from the terms "valley floor" and "valley floor peneplain" which were used in older reports. Actually, it appears level only by contrast with the mountains which rise on either side. In detail it is a complex of rock-cut surfaces, of residuum, and of gravel deposits, standing at various heights above the flood plains of the present streams, and sloping gently from the bases of the Blue Ridge and Massanutten Mountain toward the axial stream in the center—the South Fork of the Shenandoah River (sections, fig. 1). Relief on the floor exceeds 500 feet in places. The surface and near-surface materials of the valley floor are indicated in table 2, below, and are described in more detail later in this paper. Rock outcrops occupy relatively small areas, chiefly in the stream valleys. By far the greater part of the surface is formed by the older, intermediate, and younger gravel units (table 2). The principal surface on the floor of the Shenandoah Valley has been interpreted as the Valley Floor, Harrisburg, or Shenandoah peneplain (Keith, 1894, pp. 374-376; Stose, 1919, pp. 39-40; Wright, 1934, pp. 28-31), a concept that will be examined at the conclusion of this paper.

RESIDUUM

Character.—The residuum of the area results from the decay of the rocks of the valley floor, and consists of insoluble

TABLE 2

Surface and Near-Surface Materials on Floor of
Shenandoah Valley, Elkton Area.

Age	Name of unit	Description	Topographic relations	
Quaternary	Recent	Alluvium	Gravel, sand, and clay.	Flood plains of South Fork of Shenandoah River and major tributaries.
		Younger gravel unit	Thin sheet of gravel; same composition as older gravel unit.	Terraces near river, and 50-75 feet above it.
	Pleistocene	Intermediate gravel unit	Thin sheet of gravel; same composition as older gravel unit.	Broad plains and benches on intermediate slopes of valley floor.
		Older gravel unit	Gravels, composed of pebbles and boulders, mainly of quartzite; gravel sheet thickens into coalesced alluvial fans at bases of mountains.	Narrow benches at bases of mountains, 300 to 700 feet above river.
Tertiary	Ancient gravel unit	Sand and gravel, in eroded basins in residuum, overlain unconformably by older gravel unit; mineralized.	Small areas only.	
	Residuum	Clay, waxy or silty; chaotic structure; mineralized by iron and manganese oxides.	Mainly on Tomstown and Waynesboro formations, beneath older gravel unit and near foot of Blue Ridge; thin residuum on younger formations to northwest.	

Unweathered bedrock of Cambrian and Ordovician limestones, dolomites, and shales.

material, principally waxy or silty clay, which remains after the solution of limestone and dolomite, or after kaolinization of sericite in shale (King, 1943, pp. 21-26). Mixed with the clay are sand and silt, a residue of originally sandy or silty rocks, and chert, originally in the form of concretions in the carbonate rocks. Some of the clay also contains nodules, plates, and impregnations of iron and manganese oxides, which were introduced into the clay after its formation by processes of mineralization and replacement (Stose and others, 1919,

pp. 44-45; King, 1943, pp. 32-35). These oxides form the iron and manganese ores of the area, and have been mined where concentrated in bodies of sufficient size. Much of the clay has a chaotic structure, resulting from collapse, compaction, and creep that took place during the reduction in volume of the original rock.

Thickness.—The residuum is thickest over the Tomstown dolomite and Waynesboro formation on the southeast margin of the valley, and is thin or even wanting over the younger carbonate formations along the axis of the valley (sections on fig. 1).

The volume of the residuum overlying the Tomstown and Waynesboro formations is indicated mainly by test holes and mine workings. Test holes put down by the U. S. Bureau of Mines on the Watson tract, 5 miles northeast of Elkton, showed a thickness of residuum of the Tomstown dolomite of 100 to 150 feet (section A, fig. 2). Test holes south of Giants Grave, 3 miles south-southwest of Elkton, showed a thickness of residuum of the Tomstown dolomite of 50 to 100 feet. The Neisswaner shaft, a mile south of Elkton, showed a thickness of residuum of the Waynesboro formation of nearly 200 feet (Hewett, 1916, pp. 61-67) (section B, fig. 2). The deepest residuum penetrated on the Watson tract extends down to the altitude of nearby Naked Creek, along which residuum is also exposed, and that in the Neisswaner shaft extends below the altitude of the nearby South Fork of the Shenandoah River.

The residuum of the younger carbonate formations farther out in the Shenandoah Valley is thinner. Thin bodies of residuum were noted above the unweathered Elbrook and Beekmantown dolomites in some outcrops, and somewhat thicker bodies were noted above the Conococheague limestone (fig. 3). In some places residuum is wanting, as along the east side of the South Fork of the Shenandoah River at Elkton, where unweathered Elbrook dolomite is overlain directly by gravels. The base of the residuum of the younger carbonate formations also seems to be higher with respect to the present drainage than that of the Tomstown and Waynesboro formations. Near Elkton unweathered Elbrook dolomite and Conococheague limestone are 50 feet or more above river level, whereas unweathered Waynesboro formation lies below river level in the Neisswaner shaft not far to the southeast. North of the town

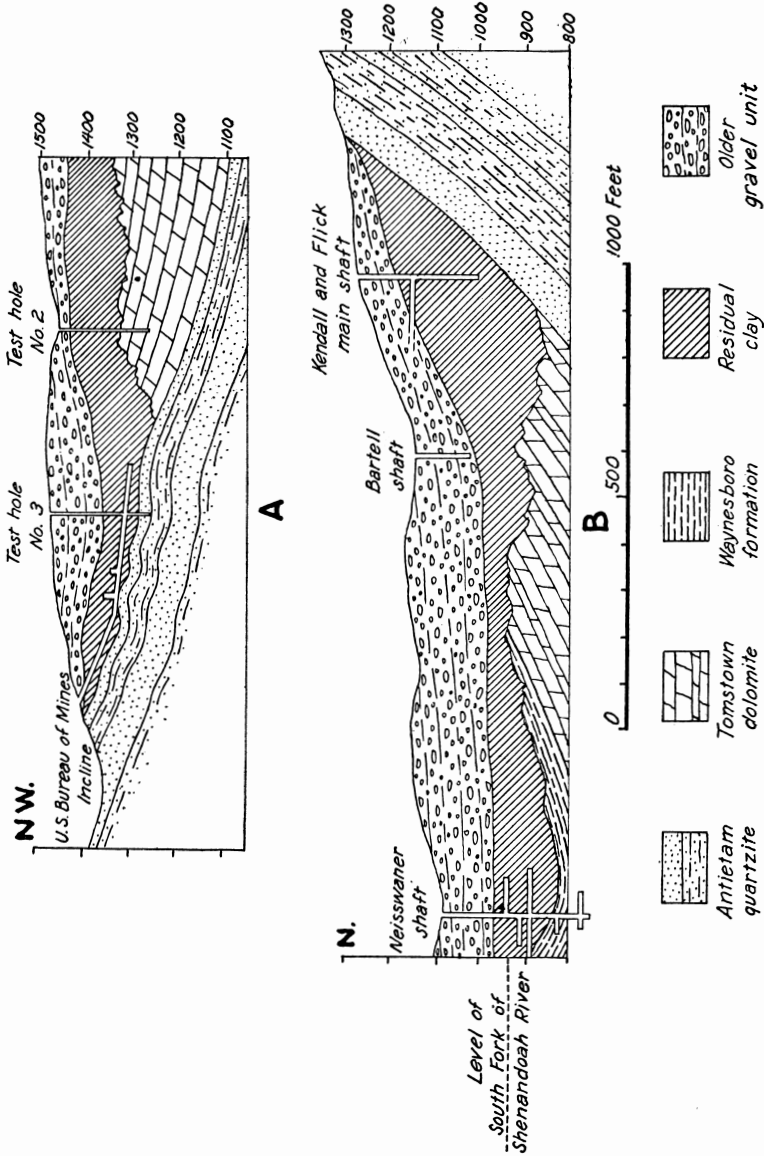


Figure 2. Sections showing inferred relations of gravel and residuum to bed rock along northwest foot of Blue Ridge. A.—On Watson tract, 5 miles northeast of Elkton. B.—Near manganese mines a mile southeast of Elkton. Section A based on Bureau of Mines drill holes and underground workings put down in 1941. Section B based on published records (Hewett, 1916).

of Shenandoah, unweathered Beekmantown dolomite extends 100 feet or more above river level.

The Martinsburg shale, northwest of the axis of the Shenandoah Valley, seems to have given rise to only small amounts of residuum, and ledges of unweathered shale extend 300 feet or more above river level.

The residuum is unconformable beneath the older, intermediate, and younger gravel units, this relation being visible in many mine workings, and in road and railroad cuts (figs. 2, 3, and 4). Open cuts of mines in residuum of the Tomstown and Waynesboro formations show coarse, cobbly or bouldery older gravels lying on the eroded surface of the residuum, and truncating the contorted structure of the residuum. The gravel contains fragments of iron and manganese oxides reworked from the residuum.

Origin.—Residuum is not being actively accumulated at the present time. Rock outcrops on valley slopes cut below the uplands of the valley floor show little or no surface accumulation of clay. Clay is no doubt being released today by weathering of carbonate rocks on the valley slopes, but under present conditions it is being carried away by erosion. The thickest accumulations of clay are beneath the upland surfaces of the valley floor, where removal by erosion would be even more active at the present time. Moreover, the clays are mineralized by iron and manganese oxides, yet many such deposits, according to Hewett (1916, p. 44)

“are situated near the top or along the slope of isolated hills or spurs, so that since dissection of the peneplain began they have received very little of the surface drainage or ground water that might contain manganese in solution.”

The unconformable relation of the residuum to the older, intermediate, and younger gravel units indicates that the collapse, compaction and creep accompanying the clay formation, and the subsequent mineralization of the clay, took place before these gravels were laid down.² It is therefore probable that the main accumulation of residuum took place before the

² In a previous report (King, 1943, p. 22) it was implied that accumulation of residuum took place during each erosion period which preceded each epoch of gravel deposition. This is now regarded as unlikely.

deposition of the oldest gravels, and it may well have been accomplished in a single epoch.

The thickest masses of residuum are those on the Tomstown dolomite and Waynesboro formation. In part this is because formations lie farthest from the axis of the valley. Their residuum would therefore be less subject to attack by later erosion than would residuum of the younger formations. However, the base of their residuum in many places extends below the level of modern drainage, and lower than the base of the residuum of formations near the axis of the valley. Very deep circulation of ground water evidently took place, for surface drainage at the time of formation of the residuum stood at a higher level than modern drainage. Along this belt of outcrop, circulating water may have been guided by the impervious beds of the Antietam quartzite which underlies the Tomstown. Similar observations and interpretations have been made by Rodgers in Bumpass Cove, Tennessee (1948, p. 15 and fig. 3).

The residuum may have accumulated in a single epoch. During this epoch, the climate may have been warmer and more humid than the present one (Hewett, 1916, pp. 46-47). Accumulation took place when the present upland areas of the valley floor lay near the grade of the streams which drained them, and when erosion was not sufficiently active to remove the residuum as it formed. In other words, conditions on the valley floor had then reached a state of peneplanation. This epoch no doubt corresponds to the time of completion of the Valley Floor or Harrisburg peneplain. The age of the Valley Floor peneplain will be considered at the conclusion of this paper.

DEPOSITS BETWEEN RESIDUUM AND OLDER GRAVEL UNIT

Lying stratigraphically between the residuum and the older gravel unit are small remnants of other deposits. Because of their position they are seldom revealed in natural exposures, but they have been uncovered in mine workings and other artificial openings. Only one remnant of such deposits was observed in the Elkton area, here termed the ancient gravel unit, but they occur widely in the southern Appalachians, as indicated below.

Ancient gravel unit at Stanley Mine.—The single observed occurrence of the ancient gravels lies in the north part of the Elkton area, in the open cut of the Stanley Mine, which is a mile southwest of Stanley at an altitude of 1,350 feet. The

deposit fills a steep-sided, eroded basin in clay residual from the Tomstown dolomite, and is overlain unconformably by coarse deposits of the older gravel unit (fig. 4). The ancient deposit consists of cross-bedded red sand, in which deeply weathered, rounded pebbles of sandstone and quartzite are

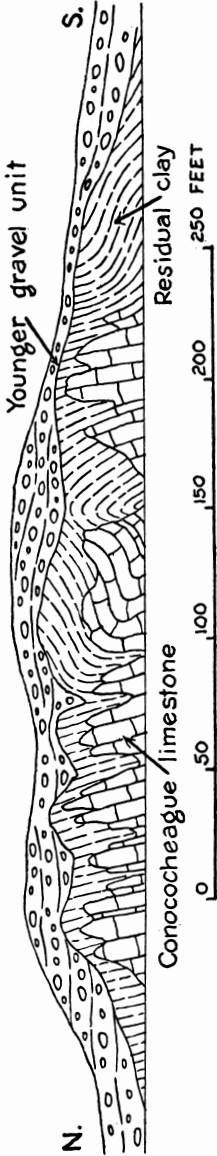


Figure 3. Section showing relation of residuum to Conococheague limestone and younger gravel unit in cut on Norfolk and Western Railway, three-fourths mile southeast of railroad station in Shenandoah.

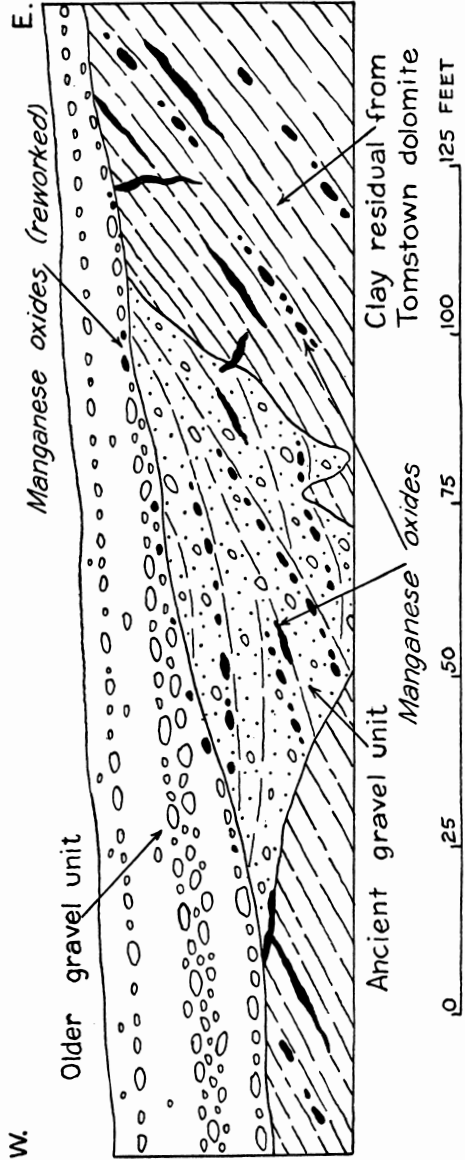


Figure 4. Section showing relation of ancient gravel unit to residuum and older gravel unit in southern open cut of Stanley Mine, 1 mile southwest of Stanley. Section is schematic, being made by combining several

embedded. Like the underlying clay, the deposit contains nodules and masses of manganese oxides that have impregnated or replaced the original sandy sediment. The overlying older gravel unit at this locality contains pieces of manganese oxides reworked from the residuum and from the ancient gravels, indicating that at least a part of the manganese mineralization of these units took place between the time of deposition of the ancient and older gravel units.

Related deposits in other areas.—Mineralized, ancient gravels occur at the same stratigraphic position elsewhere in Virginia. Manganese-bearing pebbly sand and clay have been encountered and mined at the Kennedy Mine, Augusta County (Stose and others, 1919, pp. 103-107), and at the Midvale Mine, Rockbridge County (Hewett, 1916, p. 60), southwest of the Elkton area.

At other localities in the southern Appalachians deposits at the same stratigraphic position have been worked for bauxite. One of these occurs southwest of Greenville, Augusta County, Va., and others are found in Tennessee, Georgia, and Alabama. These were intensively studied by Geological Survey field parties under the direction of Josiah Bridge during the recent war, but most of the results have not been published. One of the deposits, near Elizabethton, Tenn., was studied by the writer and his colleagues (King and others, 1944, pp. 45, 210-213), and according to Bridge resembles those elsewhere. It lies on the valley-floor upland, and consists of a mass of kaolinitic clay with a central core of bauxite, and forms a steep-sided pocket in residuum of the underlying carbonate bedrock. Lying in the kaolin are contorted lenses of lignite. The lignite at Elizabethton, and at most other deposits, has failed to yield identifiable plant remains, but according to Bridge, plant remains collected in clay and bauxite deposits in sink holes on the valley-floor surface near Anniston, Ala., and Cedartown, Ga., have been identified by R. W. Brown as of Midway (Paleocene) age.

Age of deposits between residuum and older gravel unit.—At least two types of deposits occur between the residuum and the older gravel unit—mineralized sand and gravel, and kaolinitic bauxitic lignite-bearing clay. The origin of the deposits was diverse, and perhaps also their age, for the epoch between the time of formation of the residuum and the time of deposition of the older gravels was probably a long one. As indicated

by plant remains in Georgia and Alabama, some are early Tertiary. The age of those in Virginia is unknown, but they seem most probably to have been laid down during some part of the Tertiary period.

GRAVEL DEPOSITS

Wide areas of the floor of the Shenandoah Valley are covered by gravel deposits, laid down on several surfaces that stand above the level of modern drainage. Each deposit lies on a terrace or bench, and is separated from the next by a low scarp (map and sections, fig. 1). The relations between the deposits are typically displayed southeast of Elkton, on the ridge next southwest of Elk Run, where three benches are present between the South Fork of the Shenandoah River and the adjacent mountains (section BB', fig. 1). In some other parts of the area the differentiation is less evident; the units may merge without a distinct intervening scarp, or isolated gravel patches can be assigned only doubtfully to one unit or another. In general, however, a tripartite division of the gravels seems possible, and the units are herein referred to as the older, intermediate, and younger gravel units.

Older gravel unit.—The older gravel unit, which is the highest above the present streams, forms a series of remnant benches that fringe the northwest base of the foothills of the Blue Ridge and the southeast foot of Massanutten Mountain. In addition, two gravel-capped remnants, probably of the older gravels, stand above the plain of the intermediate gravel unit well out in the Shenandoah Valley at Fox Mountain (map, fig. 1).

The upper surface of the older gravels is probably depositional. At the outer edges of the remnants the surface stands at altitudes of 1,100 to 1,200 feet, and slopes gently toward the axis of the valley. On the mountainward sides the surface rises rapidly to heights as great as 1,500 feet and assumes the form of a piedmont alluvial slope. On the Massanutten Mountain side, where Cub Run enters the Shenandoah Valley, a fine alluvial fan is developed in the older gravels.

The deposits of the older gravel unit are probably thickest beneath the piedmont alluvial slope at the edge of the mountains. On the Watson tract, close to the mountains, test holes of the U. S. Bureau of Mines show thicknesses as great as 140

feet (section A, fig. 2). Similar thicknesses are present in the shafts of the mines a mile southeast of Elkton (Hewett, 1916, pp. 61-67) (section B, fig. 2), and in Bureau of Mines test holes south of Giants Grave, 3 miles south-southwest of Elkton. Near Stanley, in the northeast part of the area, thicknesses of 50 to 175 feet of gravel are reported by Cady (1936, pp. 80-81).

The older gravel deposit consists of pebbles, cobbles, and boulders, lying in rough layers in a sandy clay matrix. Most of the fragments are quartzite, derived on the Blue Ridge side of the Shenandoah Valley from the Antietam quartzite and other Lower Cambrian formations of the foothill belt, and on the Massanutten Mountain side from sandstone of Silurian age. Most of the quartzite fragments are rounded, indicating a certain amount of transportation, but near the apices of some of the former alluvial fans are angular blocks up to 4 feet in diameter. The older gravels do not show any evidence of mineralization, deep weathering, or other marks of extreme antiquity. Most of the component boulders are fresh and strong, although in a few places they have disintegrated to such an extent that they can be crushed into sand.

Intermediate gravel unit.—The intermediate gravel unit covers the most extensive area of the three (map, fig. 1). In places, these gravels form broad plains, as in the tract northeast of Elkton, between Elk Run and Naked Creek. As with the older gravel unit, the surface of the intermediate gravels rises toward the margins of the Shenandoah Valley and away from its axis, but alluvial fans are not developed on the mountainward sides. The surface of the intermediate gravels stands at an altitude of about 1,000 feet in the south part of the Elkton area, but descends northeastward, in harmony with the gradient of the South Fork of the Shenandoah River, to an altitude of less than 900 feet in the north part.

The intermediate gravel unit, like the older gravel unit, is composed largely of rounded quartzite fragments of various sizes. Some of the fragments may have been derived directly from erosion of the parent ledges in the mountains, others were derived no doubt from reworking of fragments in the older gravels.

A significant area of the intermediate gravels lies north of Grove Hill and northwest of the South Fork of the Shenandoah

River. Along the county road east of State Highway 12 and immediately north of the river, the intermediate gravels contain large numbers of fragments readily identifiable as having been derived from the Antietam quartzite and other Lower Cambrian formations of the foothills of the Blue Ridge. In this vicinity and throughout the whole north part of the Elkton area, the South Fork of the Shenandoah River flows in a series of entrenched meanders (map, fig. 1). The locality north of Grove Hill lies northwest of the river on the inside of one of the meander loops. The presence here of fragments derived from the Blue Ridge on the opposite side of the river to the southeast suggests that the meanders did not come into existence until after the deposition of the intermediate gravels. The meanders may have formed toward the close of the period during which the intermediate gravels were deposited.

Younger gravel unit.—The younger gravel unit lies on benches between the intermediate gravels and the present flood plain of the South Fork of the Shenandoah River (map, fig. 1). The tops of the benches are 50 to 75 feet above river level. Most of the benches are small—the largest occupying an area of about one square mile—and many lie within the loops of the entrenched meanders of the river. The whole thickness of the gravels may be observed along the edges of the benches and is less than 25 feet. The younger gravels have nearly the same composition as that of the two preceding gravel units.

Origin and age of gravel deposits.—The gravel deposits of the Elkton area are part of an extensive system of gravels that covers much of the southeastern part of the Shenandoah Valley from the headwaters of the Shenandoah River northeastward beyond Luray (Butts, 1933, geologic map), yet little has been written on them, and the few interpretations that have been made regarding them are open to question. Stose (1919, p. 36) and Wright (1934, p. 31) mention the gravels briefly and suggest that the older were laid down during the closing stages of the formation of the Harrisburg or Valley Floor peneplain, and that the younger were river terrace deposits.

The older, intermediate, and younger gravel deposits seem to be closely related in origin. The cycle of which each succeeding deposit is a part began with dissection of the bed rock or residuum of the valley floor, and eventual reduction of part of the floor to a graded surface. During later stages of the

cycle, deposits accumulated on the surface previously cut. Each cycle closed with renewed cutting by the streams to new and lower levels.

The main causes of these cycles were probably fluctuations in climate. During the initial stages of a cycle, streams were capable of transporting out of the region all the material supplied to them, because of adequate volume and because erosion was not active on the adjacent mountains. During such times, the climate was probably humid, thus permitting adequate stream flow, and protection of mountain areas from erosion by the growth of vegetation. The climate during such times was probably at least as humid as at present, and perhaps more humid.

During the later stages of a cycle, streams were incapable of removing all the material supplied to them, because of inadequate volume and because of vigorous erosion on the adjoining mountains. Butts (1940, p. 509) has interpreted the times of gravel deposition as times of greatly increased rainfall, but this view is hardly tenable. Probably the climate was dry, thus reducing the volume of stream flow and the cover of vegetation on the mountains, and exposing the mountains to attack by the forces of erosion. The climate was undoubtedly different from the present and probably was much drier, for quartzite wash is not being delivered from the mountains to the valley floor today in any such quantities as it was during the time of gravel deposition.

The successive gravel deposits are so closely related in origin that they are probably not far apart in age. Moreover, none of them exhibit marks of great antiquity, such as cementation, mineralization, or deep weathering. Very probably all the gravel deposits are of Quaternary age,³ and were formed during the Pleistocene epoch. The fluctuations in climate herein suggested probably correspond to the fluctuations known to have taken place during the Pleistocene, the humid periods corresponding to glacial stages, and the dry periods to interglacial stages.

ALLUVIUM

Alluvium occupies the flood plains of the modern streams in the Shenandoah Valley, but it covers relatively small areas

³ In a previous report (King, 1943, pp. 18 and 27) the older gravels are classed as of Tertiary or Quaternary age, and the intermediate and younger gravels as of Quaternary age. There seems to be no justification for this distinction.

(map, fig. 1). From the town of Shenandoah northward the flood plain along the South Fork of the Shenandoah River is very narrow, and in places the river is enclosed by rock walls on either side. South of Shenandoah, as in the vicinity of Elkton, the alluvial areas along the river are more extensive, and in places exceed a mile in width. Here, many of the tributary streams also lie in alluvial bottoms.

The thickness of the alluvium varies. North of Shenandoah, where the South Fork of the Shenandoah River is enclosed for long distances by bedrock, riffles occur here and there in the river itself, and suggest that bedrock lies directly beneath the channel. In the broad alluvial area southwest of Elkton, bedrock is exposed in places in the channel, but at the Stonewall plant of Merck & Co., not far southeast of the river and 2 miles southwest of Elkton, water wells encounter 31, 38, 57, and 124 feet of unconsolidated deposits above the bedrock.⁴ The broad alluvial flat in the vicinity of Elkton is therefore underlain by variable thicknesses of unconsolidated deposits. Some of the thicker masses may represent buried river channels; others may be the filling of sink holes.

RELATIONS BETWEEN FEATURES OF VALLEY FLOOR

The descriptions just given indicate that the floor of the Shenandoah Valley includes a number of incompatible features, formed under contrasting conditions, and probably widely separated in time. In view of these circumstances, the earlier and simpler conception of the valley floor as a part of the Valley Floor or Harrisburg peneplain tends to disappear. Actually, the widest tracts of valley floor in the Elkton area are the depositional surface of the intermediate gravels, formed at a time by no means as remote as that assumed for the Valley Floor peneplain. The entrenched meanders of the South Fork of the Shenandoah River, commonly assumed to date from the time of formation of the Valley Floor peneplain, likewise seem to have been formed during the closing stages of the period in which the intermediate gravels were deposited. As the residuum that accumulated on the Valley Floor peneplain is now everywhere eroded and overlain unconformably by gravel deposits, it is unlikely that any remnants of the former

⁴Records of Virginia Geological Survey, through courtesy of W. M. McGill, State Geologist, September, 1947.

penneplain surface are still present in the Elkton area. The surface features of the valley are entirely those that were established during the periods of gravel deposition and later.

Both Keith (1894, pp. 374-376) and Fenneman (1938, pp. 247-248) have noted a marked increase in the gradient of the Shenandoah Valley above Front Royal, as compared with its lower or northern section. This gradient is stated to be incompatible with the slope assumed for the Valley Floor penneplain at the time of its completion, and hence to be suggestive of subsequent warping or uplift. Insofar as the Shenandoah Valley in the vicinity of the Elkton area is concerned, the gradients discussed by Keith and Fenneman are not those of the Valley Floor penneplain, but of the gravel deposits. These gradients are in harmony with the regimen of Pleistocene and modern streams, but they are out of harmony with conditions, as they are assumed to have existed, at the time of the formation of the Valley Floor penneplain and its accompanying residuum. A change in gradient has clearly taken place, either by warping or by some other means.

The history of the valley floor before the deposition of the gravels evidently occupied a long period of geologic time, even though the land surface itself was not notably lowered by erosion. First, residuum accumulated slowly as a result of rock weathering, probably in a warm and moist climate, under conditions of penneplanation. Afterwards, deposits such as the ancient gravels were laid down locally on the surface. In Georgia and Alabama, fossil plants in deposits on the valley floor surface indicate that these deposits are of early Tertiary age. The deposits in Virginia may be as ancient, but their age has not been proved. After the deposition of the ancient deposits, both their surface and that of the residuum was eroded before the older gravels were deposited. If the older gravels are Pleistocene, the events which preceded their deposition would seem to require a considerable span of Tertiary time.

According to widely accepted theories of Appalachian evolution, the shaping of the present land forms was accomplished in later Tertiary time. Johnson (1931, pp. 14-21) considers that the Schooley penneplain was not completed until middle Tertiary, and the Harrisburg penneplain not until late Tertiary. Stose, who believes that the Schooley was formed much earlier, now (1940, pp. 461-476) suggests that it was not

materially dissected until the Miocene, which would result in assigning about the same date to the completion of the Harrisburg surface. This is not the place to consider the elaborate structure of deduction on which conclusions of these and other authors have been based. The writer can only state that the dates thus assigned for the completion of the Valley Floor or Harrisburg peneplain do not seem sufficiently ancient to account for all the events which appear to have taken place on the valley floor, as indicated by the geological materials observed in the Elkton area.

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