MAPPING OF GEOLOGIC FORMATIONS BY THE APPLICATION OF AERIAL PHOTOGRAPHY

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SYNOPSIS

Previously generalized parent-material areas have been mapped successfully by the application of aerial photographs. This project is unique in that geologic formations have been mapped by this method.

This paper describes the geologic mapping of an area in the Ridge and Valley Province of central Augusta County, Virginia The rocks are of sedimentary origin with a few igneous intrusives, shale, limestone, and sandstone being the predominant rock types. The formations are of late Cambrian and Ordovician age. Some of the limestone formations have a high calcium content, with little impurities; others contain much chert and argilaceous material. For this reason separation of these formations was desirable.

Key formations with known physical characteristics and chemical composition produced distinctive airphoto patterns, the repetitive nature of which made possible the delineation of each formation. As an example, one formation contained much chert; upon weathering knolls and rounded hills resulted. These features stood out from surrounding topography making the formation easy to trace. Another formation high in calcium was found to occupy low topography. This too was delineated. By knowing the relative position of these key formations in stratigraphic sequence other formations thus fell into place.

Representative samples of soils and aggregates were obtained and routine tests were performed. Results of these tests were tabulated so that the extent of formations containing both suitable and unsuitable materials would be known.

This paper describes the procedure, methods, and results of the application of aerial photography to geologic mapping. The successful application of this technique has been proven. Its extension to other areas is indicated.

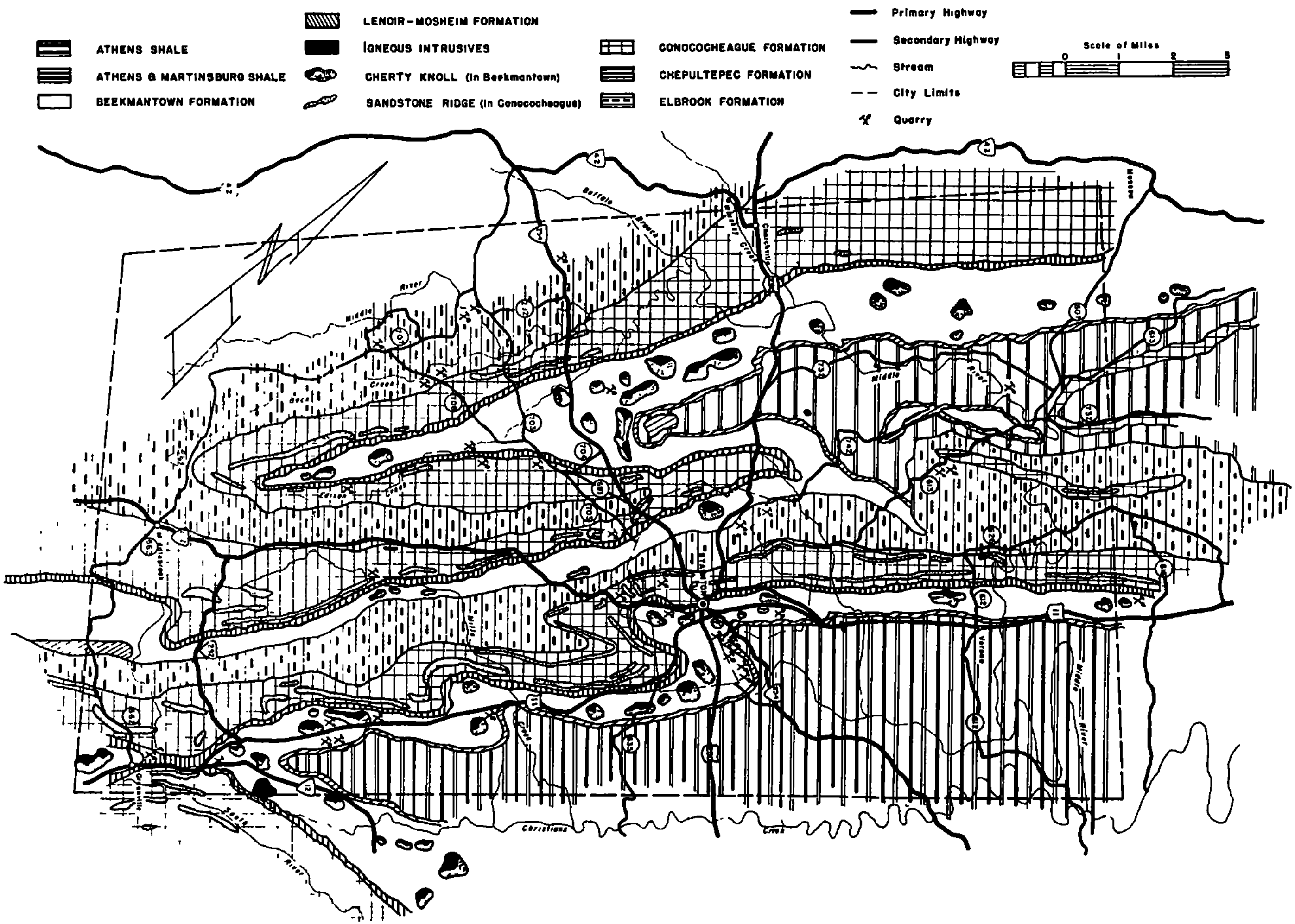
Since the year 1858 when the first aerial photograph was taken (22), aerial photopography has contributed much to the advancement of science and industry. Airphotos were used by the U.S. Coast and Geodetic Survey as early as 1920. Soon after this the United States Geological Survey began using them in making topographic maps and in 1933 airphotos were applied in soils conservation work (23). Military forces have used airphotos quite extensively and the greater portion of all military and naval intelligence is based on their interpretation (10).

Today aerial photographs have many uses. Some of the most notable are in forestry and in many phases of engineering work. Some of the engineering uses are in highway, airport, and railway locations and in highway performance studies, traffic studies, location of dams and reservior sites, drainage and watershed problems, irrigational projects, city and regional planning.

Aerial photographs have been used to some extent in geology for determining structural features (16); but principly they have been used as a base map for field work. As far as can be determined to date, airphoto interpretation has not been utilized for preparing stratigraphy maps, i.e., maps showing the extent of and naming geologic formations in the correct age sequence.

It is the purpose of this paper to demonstrate the application of airphoto interpretation to geological mapping of sedimentary strata. The project was initiated as a research problem for the Virginia Department of Highways and also as a thesis

Geologic Map of a Portion of Augusta County, Virginia



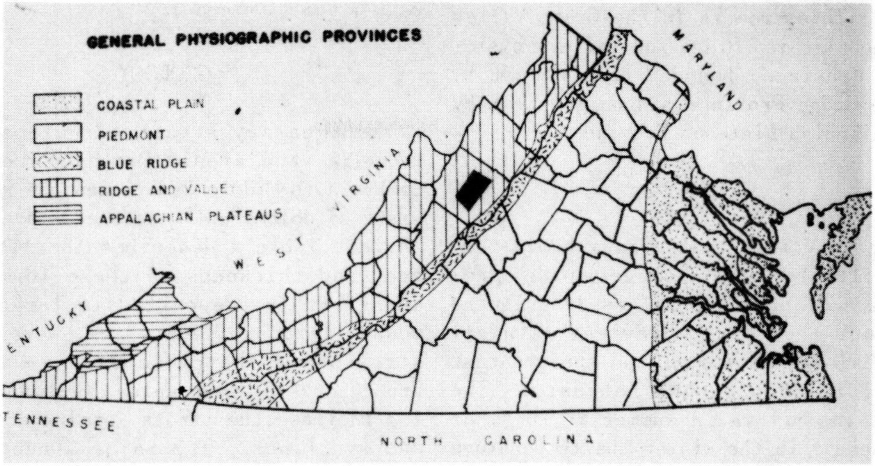


Figure 1. Map of Virginia showing relationship of area investigated to physiographic provinces.

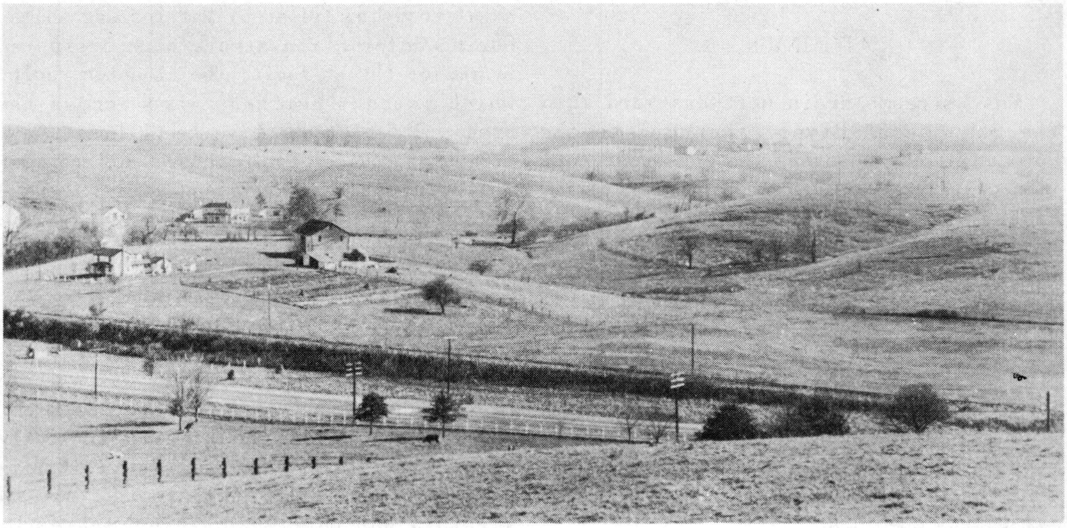


Figure 2. Typical shale topography. Notice rounded broad hills and gully system.

in partial fulfillment for a master's degree in geology at the University of Virginia.

Before beginning this study a survey of all existing literature pertaining to the investigation was made, included was geology, pedology, and airphoto techniques.

After completing this initial literature survey the airphotos were assembled as a moziac and studied to provide an overall areal picture. On this mozaic were traced generalized boundaries of areas which were strikingly different and features that were obvious. Refinement of these general borders was accomplished by stereoscopic study of individual photo pairs. Subsequent field work provided correlation of the geologic formation with airphoto patterns.

LOCATION

The area discussed in this paper is in the central portion of Augusta County and comprises approximately 200 sq. mi. (See Fig. 1.) This area is in the Great Valley of the Appalachian Ridge and Valley Physiographic Province, bounded on the east by the Blue Ridge Province and on the west by the Appalachian Plateaus Province.

CLIMATE

The county is situated in a humid-temperate climate. An average annual precipitation of about 38 in. is distributrd throughout the year. Heaviest rainfall occurs from May to August and the greatest snowfall in January and February. The average temperature in summer is 70 F. or more, whereas in the winter the temperature averages approximately 37 F. The prevailing wind direction throughout the year is southwestward, in line with the strike of the strata and of the ridges.

DRAINAGE

Most streams drain northeastward into the Shenandoah River, thence into the Potomac River; however, the southwest portion of this area is drained by tributaries of the James River. Streams of the area have a trellis regional drainage pattern, principal water courses being of subsequent origin. Perenial gullys, of resequent origin, locally form dendritic drainage patterns.

In limestone areas drainage is internal through sinkholes and caverns formed by percolating waters through bedding planes, shaly partings, points, fractures and other structural openings.

TOPOGRAPHIC FEATURES

The general relief of Augusta County is that of a broad relatively smooth valley flanked both on the east and west by high mountains. Within this so-called valley certain erosional features are distinctive. Over broad areas the terrain features are those of a sinkhole-studded plain; but locally other surface expressions included are: elongated knolls; discontinuous low ridges, rounded conical hillocks; and smoothly undulating landscape. The elevation above sea level in this area ranges from 1,200 to 2,200 ft.

GEOLOGY

Sedimentary strata of Paleozoic age underlie the area. Ranging from Upper Cambrain to Middle Ordovician the rock consists of dolomite, limestone, sandstone and shale. Table 1 describes the lithology, age, and thickness of these formations. These strata, deposited in large inland seas millions of years ago, were greatly stressed at the close of the Paleozoic Era by crustal movements. Resultant folding inclined the strata forming anticlines and synclines. The major structure developed was the Massanutten Syncline which plunges under north of Greenville, Virginia. The western limb of this syncline is exposed in the area investigated, its' axial trough is filled by Martinsburg shale. During deformation strata were disrupted by a major thrust fault, the Staunton Fault, which extends northeastward across the area. Older strata have been thrust upon strata of younger age. Subsequent erosion, following this folding and faulting, exposed resistant strata.

PREVIOUS INVESTIGATIONS

Geological work done previously in Augusta County, has been of a general nature only. One of the workers was William Barton Rogers, who with his brother H. D. Rogers, was the first to interpret correctly structural geology of the Valley of Virginia (18). In 1911 a geological map of Virginia was published by Dr. Thomas L. Watson, then director of the Virginia Geological Survey. In 1928 the current geologic map was published under the direction of G. W. Stose.

One publication of Dr. Charles Butts, on the Appalachian Valley of Virginia (2), contains a concise summary of the character of each of the formations together with a geologic map. Another of his publications on this same area consists of a descriptive text, in two parts, including illustrations of stratigraphy, geologic structure, geologic history, and index fossils (3).

A later publication by Dr. Raymond S.

Edmundson gives accurate information on the location, thickness and chemical composition of important industrial limestones and dolomites of the Appalachian Valley of Virginia (7).

DISCUSSION OF RESULTS

In studying aerial photographs stereoscopically, minute differences are observed. These differences constitute airphoto patterns of several so-called pattern elements, including: landform, regional drainage pattern, gully cross-section and gradiants, soil color tones, vegetation, man made features, and breaks in stream coarses. Much has been done in correlating airphoto pattern elements with differing material types; but for this study these pattern elements have been correlated with individual geologic formations.

The several formations of the area investigated have distinguishing features that are evident on aerial photographs. A detailed discussion of these formations with their characteristic airphoto patterns is given as follows:

1. Athens and Martinsburg formations, of middle Ordovician age, are predominantly shale and calcareous shale, the Athens containing interbedded limestone. Figure 6 shows an outcropping of this limestone. Both of these formations were found to be characterized by low subdued topography. Streams develop a meandering course and have a smooth round cross-section, indicative of a uniform soft material. (See Fig. 4.) Interstream divides are broad, rounded and very smooth. Gradients are flat and uniform. In Figure 2 may be noted this typical shale topography. Figure 3 shows this same topography as seen on an aerial photograph. Here it may be seen that the shale differs greatly from the limestone. As compared to the limestone area shale is much more dissected, the shale being a uniform softer material weathering only by surface water action and the limestone weathering mostly by solution. Figures 5 and 7 show the differences in drainage of these differing rock types. Also, in Figure 5 a break in the stream course passing from limestone to shale may be noticed. The color tones of the shale are darker than those of the adjacent areas, indicating the imperviousness of the shales (Fig. 3). These shales are bounded below by older limestone strata and may be distinguished from the other formations by the evidences mentioned above.

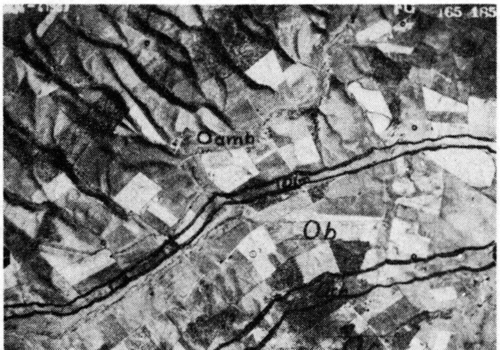


Figure 3. Airphoto showing contact of Athens and Martinsburg shale (Oamb) and Lenoir - Mosheim Limestone (Olm).

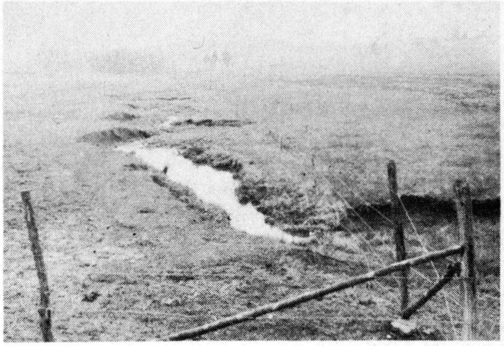


Figure 4. Photo showing meandering stream course typical of uniform soft shale.

2. The Mosheim and Lenoir formations occur conformably below the Athens shale. The Lenoir, which over lies the Mosheim is a thick-bedded, medium grained, dark-gray limestone containing thinly bedded chert. The Mosheim is a glassy-textured chemically-pure limestone.

Due to bedded chert, the Lenoir upon

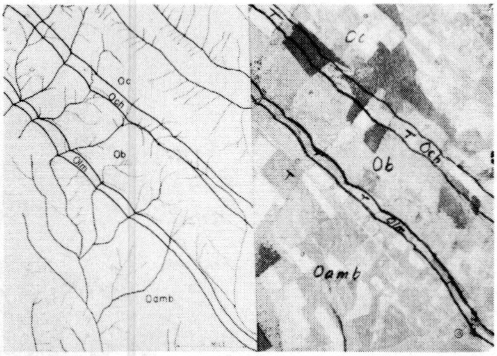


Figure 5. Drainage crossing limestone into younger shale strata. Notice stream pattern and change of stream course entering shale.

weathering resulted in low elongated knolls, as may be seen in Figure 12. These knolls have a rounded top and steep slopes. Solution is not in great evidence, however, a few scattered sink holes were noticed on top of these knolls. These probably were at the contact of the Mosheim and Lenoir, since there is a great difference in lithology. Numerous water gaps are found cutting across the strata. Streams parallel both edges of this formation and cut across the gaps. Comparing these knolls to sandstone ridges developed in a nearby formation it was noticed that the Lenoir-Mosheim knolls were more rounded and less covered by forest growth.

The Mosheim, being a high-calcium limestone, is quarried extensively for industrial lime, and it may be noticed in Figure 9 that quarries follow the strike of this strata. Due to the excessive chert content the Lenoir-Mosheim formation had color tones which were lighter than the adjacent formations as seen in Figure 10. Figure 11 shows one of the structures in this area. The strata is seen on the airphoto to bend around and change in its dip, indicating a syncline. Of interest also in the pocket of Lenoir-Mosheim within the axis of the syncline. This is due to minor local folding of the Lenoir-Mosheim formations. The break in stream course and topographic relations are the main criteria used in determining the boundaries of this formation.

Figure 6. Outcropping of Athens limestone. Note slablike structure.

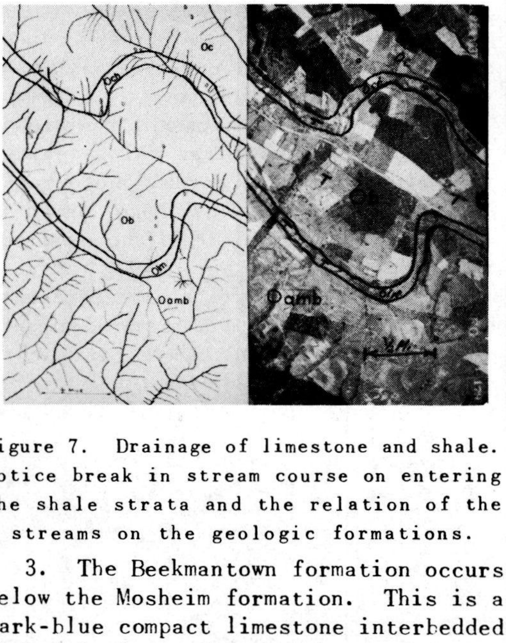


Figure 7. Drainage of limestone and shale. Notice break in stream course on entering the shale strata and the relation of the streams on the geologic formations.

3. The Beekmantown formation occurs below the Mosheim formation. This is a dark-blue compact limestone interbedded with dolomite. Great pockets of spongy chert contained in the formation results in large conical hills that stand out pronouncely above the terrain. These hills slope steeply and are covered by forest growth (Fig. 13). Streams that traverse this area develop a trellis pattern, major streams paralleling the strike with tributaries cutting in at right angles (see Fig. 14). Only a few scattered sinkholes occur in the Beekmantown, for on the whole this limestone is resistant to solution. Indicative of this are rocky streams beds. Streams that cross this formation break at

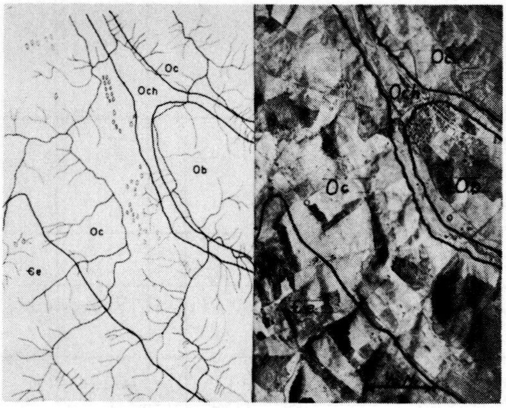


Figure 8. Drainage of limestone strata. Notice the alignment of the stream with the strike of the strata.

its boundary. Generally the color tones are medium to light in intensity.

4. The Chepultepec formation occuring below the Beekmantown, contains pure limestone and some dolomite both of which produce lower topography than adjacent strata (see Fig. 15). Streams crossing this formation break in their course at the boundaries. Major streams follow the strike of the strata either at a contact with adjacent formations or through the center of the Chepultepec. Figure 8 shows drainage crossing and paralleling the Chepultepec. Although streams usually flow in filled channels scattered outcrops of bedrock occur. An absence of solution is quite noticeable.

5. Conococheague, an upper Cambrian formation which underlies the Chepultepec, is a thick-bedded, predominantly blue limestone. Most diagnostic features, megascopically, of this formation are beds of coarse-grained sandstone and laminae of siliceous and clayey material, as seen in Figure 19. Beds of sandstone, occuring as irregularly distributed lenses, may be evident in some localities but absent in others.

Where these sandstone beds are steeply inclined, weathering makes low but long sharply crested ridges (Fig. 20). Figure 21 illustrates the steepness of some of these sandstone ridges. These ridges conform with the strike and where there is flexure within a formation the ridges also bend (Fig. 17). These ridges are thickly covered with forest growth, for they are too rocky and steep to farm (Fig. 16). Streams flow in rocky channels along the strike of the strata and occasionally across the strata thus developing a regional trellis drainage pattern. Sinkholes are numerous in certain parts of the formation. These sinkholes are in line with each other and tend to be a bit elongated (Fig. 18). Due to the internal drainage the Conococheague locally gives a mottled color.

6. The Elbrook formation occurs below the Conococheague formation. The Elbrook

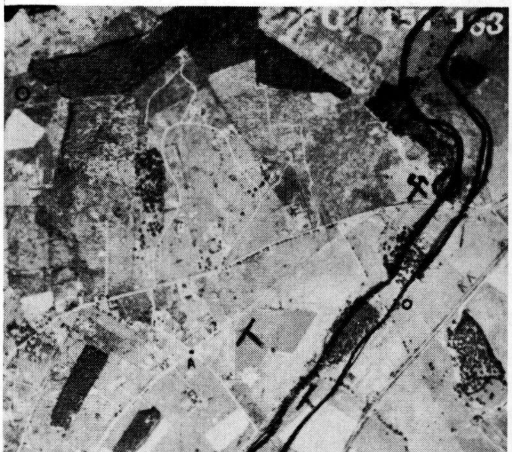


Figure 9. Lenoir-Mosheim formation (Olm). Notice the flexure in the strata and the quarries following along the border of the formation.

TABLE 1

GEOLOGIC FORMATIONS IN AREA INVESTIGATED

AGE	FORMATION	THICKNESS	LITHOLOGY
Middle Ordovician	Martinsburg Shale	1,500-3,000	Dark colored calcareous shale with interbedded limestone.
Lower Ordovician	Athens Shale	600-5,000 ±	Black fissile shale with black thin-bedded compact conchoidal limestone and argillaceous bluish limestone.
	Lenoir Limestone	50-200	Fine to medium grained dark gray limestone with thin beds of chert.
	Mosheim Limestone	50-100	Glassy (vaugnitic) textured limestone very pure limestone (chemically).
	Beekmantown Limestone	800-3,200	Interbedded dolomite and limestone - the limestone dominates the dolomite in quantity - contained in the limestone are immense pockets of spongy chert.
	Chepultepec Limestone	400-500	Chemically a rather pure limestone with intercalated beds of more or less magnesium limestone and dolomite. The limestone is commonly thick bedded, blue and finely crystalline with a few siliceous partings.
Upper Cambrain	Conococheague Limestone	1,200-2,000	Thick bedded blue limestone which forms about 75% of the formation most of the remainder being dolomite. The most diagnostic features are beds of coarse grained sandstone and laminae of siliceous and clayey material.
	Elbrook Dolomite	2,700-3,400	Interbedded clayey limestone and impure dolomite.

TABLE 2
SOIL TEST RESULTS

GEOLOGIC FORMATIONS	LIQUID LIMIT	PLASTICITY INDEX	H. R. B. SOIL CLASSIFICATION	OPTIMUM MOISTURE	OPTIMUM DENSITY	MODIFIED C.B.R.*	HORIZON	DEPTH INCHES
Elbrook Dolomite	36	10	A-4 (8)	21.8	102.3	3.5	A	0-10
	30	N-P	A-4 (4)	20.5	102	23.3	A	0-10
	36	7	A-4 (8)	23.5	95	10	A	0-10
	33	3	A-4 (4)	20.8	102	17	A	0-10
	35	6	A-4 (8)			0	A	0-10
	36	8.0	A-4 (8)	20.3	98.2	5	A	0-10
	55.20	16.28	A-7-5 (14)				B	10-50
	58	26	A-7-5 (18)	31.3	88.8	9	B	10-50
	67	18	A-7-5 (16)	30.2	88.9	10	B	10-50
	46	9	A-5 (10)	22.8	99.5	13.2	B	10-50
	51.1	18.2	A-7-5 (14)				B	8-30
	55	13.1	A-7-5 (11)				B	8-30
	32	12	A-2-6 (1)	13.2	121	23.3	C	50-
	38	11	A-6 (3)	17.7	108.8	7.5	C	50-
	35	8	A-4 (8)	20.8	100	6.7	C	50-
	52.4	4.1	A-5 (11)	25	93	16	C	30-
	43.5	14.46	A-7-6 (10)				C	36-
	48.80	23.48	A-7-6 (15)				C	36-
Conococheague Formation	24.60	9.72	A-4 (8)				A	0-10
	28.8	4.2					A	0-10
	28.4	11.8					A	0-10
	42.23	16.68	A-7-6 (11)				B	10-50
	45.40	24.65	A-7-6 (15)				B	10-50
	47.8	13.8					B	10-50
	60.20	28.62	A-7-5 (19)				C	50-
	46.30	23.76	A-7-6 (14)				C	50-
Chepultepec Formation	34.30	12.06	A-6 (9)				A	0-12
	58.84	26.81					B	12-48
Beekmantown Formation	26.0	5.39	A-4 (8)				A	0-12
	25.5	5.05	A-4 (6)				A	0-12
	34.5	14.5	A-6 (10)				B	12-36
	38	14	A-6 (9)	21.7	99.2	11.3	C	36-60
	31	9	A-4 (8)	17.1	110.2	15.8	C	36-60
Lenoir-Mosheim Formation	30.00	10.16	A-6 (8)				A	0-8
	26.4	7.65	A-4 (8)				A	0-8
	32.70	10	A-4 (8)				A	0-8
	67	38.08	A-7-6 (12)				B	8-42
	51	18	A-7-6 (12)				C	42-
	51.40	27.83	A-7-6 (17)				C	42-
	56.60	29.33	A-7-6 (19)				C	42-
Athens Formation	30.20	6.17	A-4 (8)				A	0-8
	50.70	29.37	A-7-6 (18)				B	8-40
	48.80	24.73	A-7-6 (16)				C	40-

* Modified C.B.R. is based on 95 percent standard Proctor Compaction, the rest of the test is standard.

TABLE 3

AGGREGATE TEST RESULTS

GEOLOGIC FORMATIONS	SPECIFIC GRAVITY	ABSORPTION	SOUNDLESS LOSS	LOS ANGELES GRADING	LOS ANGELES LOSS (500 REV.)	QUALITY GRADE
Conococheague	2.72	.33	O.K.	A	24.6	A
	2.81	.05	O.K.	A	22.1	A
Beekmantown	2.70	.26	O.K.	A	30.3	A
	2.81	.67	O.K.	A	22.9	A
Lenoir-Mosheim	2.73	.29	O.K.	A	28.7	A
	2.74	.19	O.K.	A	26.0	A
	2.78	-	-	B	20.0	A
	2.76	-	-	B	27.0	A
Chepultepec	2.83	-	-	B	24.0	A
Elbrook	2.81	-	-	A	14.2	A

TABLE 4

RESULTS OF ADHESION TESTS

Courtesy of Division of Tests, Virginia Department of Highways

Sample No.	GEOLOGIC FORMATIONS							
	Elbrook		Conococheague		Beekmantown		Lenoir-Mosheim	
	Percent Adhesion		Percent Adhesion		Percent Adhesion		Percent Adhesion	
	By (1) Weight	By (2) Estimate	By Weight	By Estimate	By Weight	By Estimate	By Weight	By Estimate
1	76	95	63	80	79	85	51	90
2	71	95	98	99	60	85	96	98
3	27	85	33	80	69	95	83	98
4	22	85	49	88	91	95	93	99
5	43	88	82	95	67	95	71	95
6	36	80	48	88	48	90	35	75
7	36	85	61	85	76	90		
8	16	70	50	85	76	90		
9			47	90	91	98		

(1) Tested by Type I method, see Appendix, page 34.

(2) Tested by Type II method, see Appendix, page 36

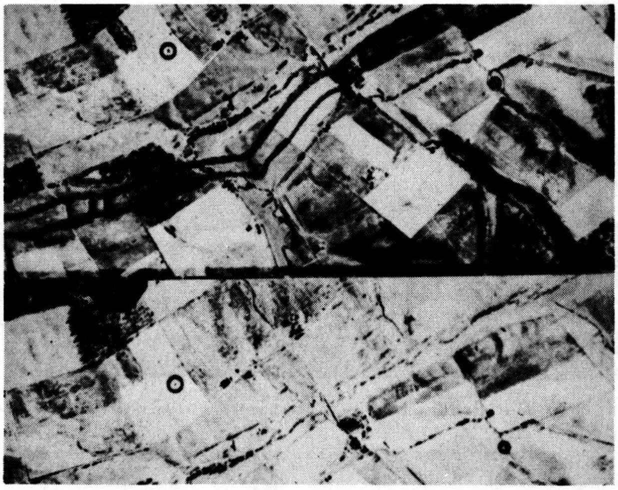


Figure 10. Stereo pair showing Lenoir-Mosheim formations. Note soil color tone is lighter than adjacent strata.

Figure 11. Synclinal structure showing the Lenoir-Mosheim formations (Olm) plunging under the Beekmantown formation (Ob). Note the pocket of (Olm) within the axis of the syncline. This is due to local folding of the Lenoir-Mosheim formations.

is predominantly a dolomite, however locally it contains considerable amount of thinly bedded argillaceous limestone or dolomite.

Due to low solubility, the Elbrook also results in ridges; however, these are not as sharply crested or as extensive as the sandstone ridges of the Conococheague. Streams have a trellis pattern and also a rocky bed. Because of the argillaceous material striations of parallel bands were noted on the airphotos.

It may be seen from this brief discussion that all of these formations have characteristic features distinguishing them from one another. Figure 23 shows characteristic topography of each formation.

The Staunton Fault extends northeastward across the area. Criteria aiding in the tracing of the fault were many. A large brecciated zone is in the fault area. Because of this zone selective erosion dominated and therefore the fault occurred in valleys and other low places. Along this fault Elbrook strata of Upper Cambrian age have been shoved up on Beekmantown

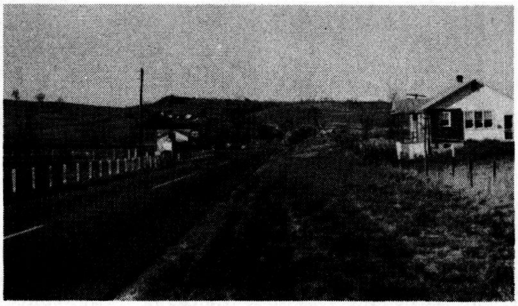


Figure 12. Lenoir-Mosheim knoll striking across a road.

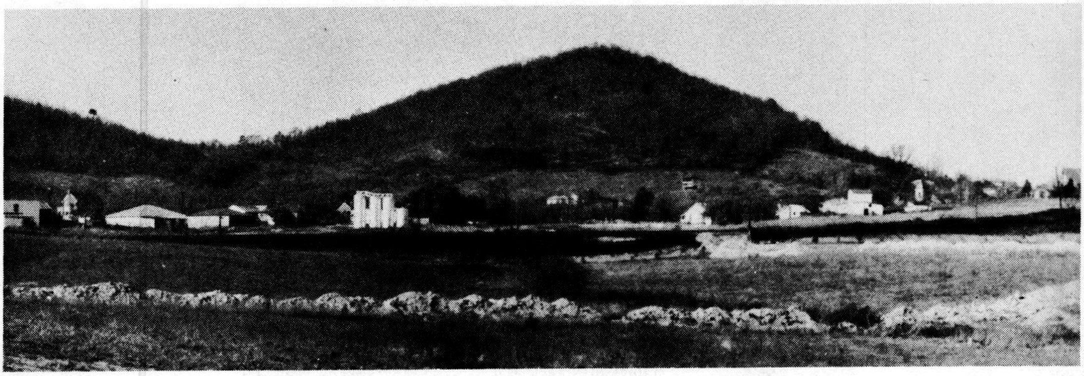


Figure 13. Knoll within the Beekmantown formation. Notice forest growth on the slopes.

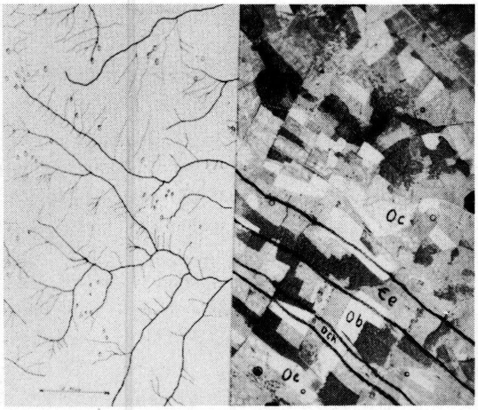


Figure 14. Drainage and airphoto showing extent of formations. Notice stream following strike of the strata.

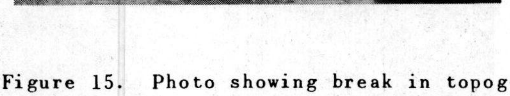


Figure 15. Photo showing break in topography between the Chepultepec limestone (Och) and Conococheague limestone (Oc) on the left and the Beekmantown limestone on the right.

Figure 16. Airphoto showing syncline plunging southwestward. Notice convergance of sandstone ridges (wooded areas) within the Conococheague limestone. (Oc).

strata of Lower Ordovician age - although the Elbrook occurs normally below the Conococheague. Airphoto patterns of these formations, as mentioned previously, aided in pointing out the horizontal trace of this fault. Figure 24 shows a structure section indicating the attitude of the fault and formations.

SOILS AND AGGREGATES

Since the geologic formations in the area investigated differ in their chemical and physical make-up, they produce distinctive and different soils upon weathering. The soils being mature in age are well developed and show distinct horizons. The following, in table form gives the geologic formations with their corresponding soils and horizons·

1. Martinsburg shale - Berks soils
   - A horizon - silt from - 0 in. to 7 in.
   - B horizon - brittle silty clay - 7 in. to 18 in.
   - C horizon - silty clay - 18 + in.
2. Athens shale - Westmoreland soil
   - A horizon - clayey silt - 0 in. to 10 in.
   - B horizon - plastic silt-clay - 10 in. to 48 in.
   - C horizon - silty clay - 48 + in.
3. Lenoir-Mosheim formation - Clarksville soils
   - A horizon - silt - 0 in. to 10 in.
   - B horizon - stiff brittle silty clay - 10 in. to 34 in.
   - C horizon - silty clay containing chert fragments - 34 + in.
4. Beekmantown formation - Clarksville soils (mentioned previously) and Frederick soils
   - A horizon - silt and clay-silt - 0 in. to 14 in.
   - B horizon - elastic silty clay - 14 in. to 50 in.
   - C horizon - crumbly elastic silty clay containing chert - 50 + in.
5. Chepultepec formation - Hagerstown soil
   - A horizon - silt and clay-silt - 0 in. to 14 in.
   - B horizon - elastic silty clay - 14 in. to 50 in.
   - C horizon - crumbly elastic silty clay - 50 + in.
6. Conococheague formation - Clarksville and Frederick soils (mentioned previously).
7. Elbrook dolomite - Frederick, Clarksville, and Hagerstown soils (mentioned previously).

Results of tests made upon soils from the various formations is shown in Table 2. Table 3 includes results of tests made on aggregate samples from the various formations. Some of the samples selected contained chert which may be detrimental to highway constructional work. It has been established that chert is a deleterious constituent in coarse aggregate for concrete. Also aggregate containing chert is conducive to stripping in bituminous material. These samples tested as Grade A. This classification is based solely on the Los Angles Abrasion Test, as used by the Virginia Department of Highways, Division of Tests, Grade A being less than 40 percent loss on abrasion after 500 revolutions.

Table 4 shows results of adhesion tests made on aggregates taken from the various formations. This test, which is reiterated in the Appendix, was developed and adopted for use by the Virginia Department of Highways, Division of Tests.

SUMMARY AND CONCLUSIONS

Geologic mapping may be accomplished by the application of aerial photography. In studying airphoto pairs stereoscopically, the interpretor sees the land surface as if flying over in an airplane. Features that are distinctly different were observed and marked on the airphoto. As the work progressed it was found that these features had a direct relationship to the geologic formation and upon their repetitive nature

Figure 17. Airphoto showing features used in differentiating geologic formations in the area investigated. Notice cherty knolls (encircled areas) in Beekmantown formation (Ob) and the sandstone ridges (also encircled) in the Conococheague formation.

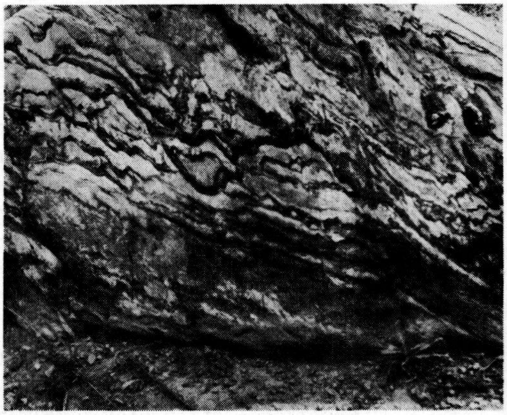


Figure 19. Thin laminae of argillaceous material within the Conococheague limestone.

made possible the delineation of each geologic formation.

A summation of the conclusions reached from this study is given as follows: (1)

Figure 18. Sinkholes within the Conococheague limestone. Notice the elongation and alignment of the sinkholes. This is typical of tilted limestone strata.

Figure 20. Sandstone ridges within the Conocochéague limestone.

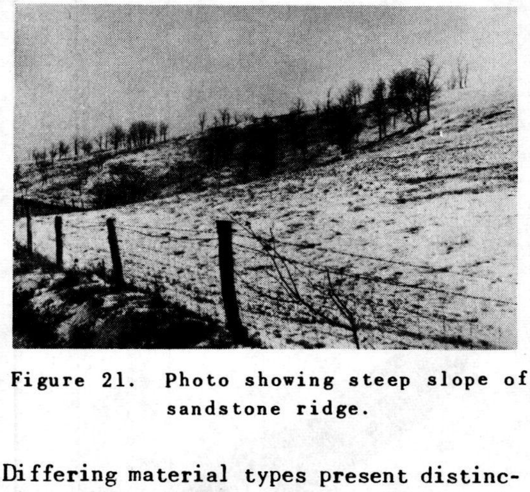


Figure 21. Photo showing steep slope of sandstone ridge.

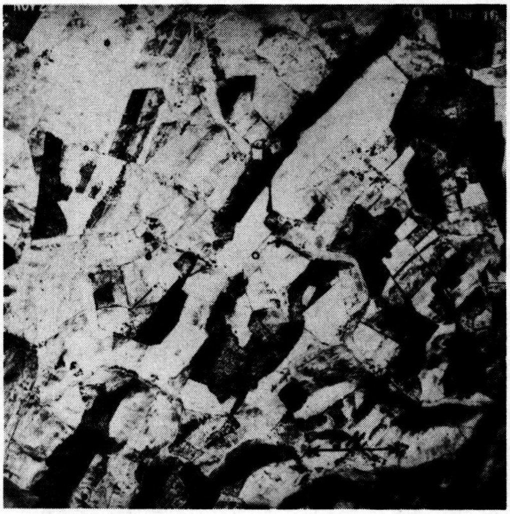


Figure 22. Element of vegetal cover. Note wooded areas trending in a relatively straight line. These wooded areas are along the steep slopes of the sandstone strata within the Conococheague formation.

Differing material types present distinctive unlike airphoto patterns; (2) There is a definite relationship of airphoto patterns to geologic formations, reoccurrence of a pattern is indicative that it's associated formation likewise repeats; (3) A much wider coverage of an area may be witnessed on an aerial photograph than can be seen on the ground, thus considerable time is saved by applying this method; (4) Local details such as folds and faults are evident on aerial photographs; (5) Aerial photographs are excellent as a base map for they contain all land features and map culture, in essence aerial photographs are minitures of the actual land surface; (6) Field checks are necessary for correlation of airphoto patterns to geologic formations; (7) If undertaken correctly this method proves as accurate as field methods when mapping out the areal extent of formations, interpretor should be well versed in airphoto techniques and in geology; and (8) Application of this method can only be made where adjacent formations differ in their physical and chemical make-up.

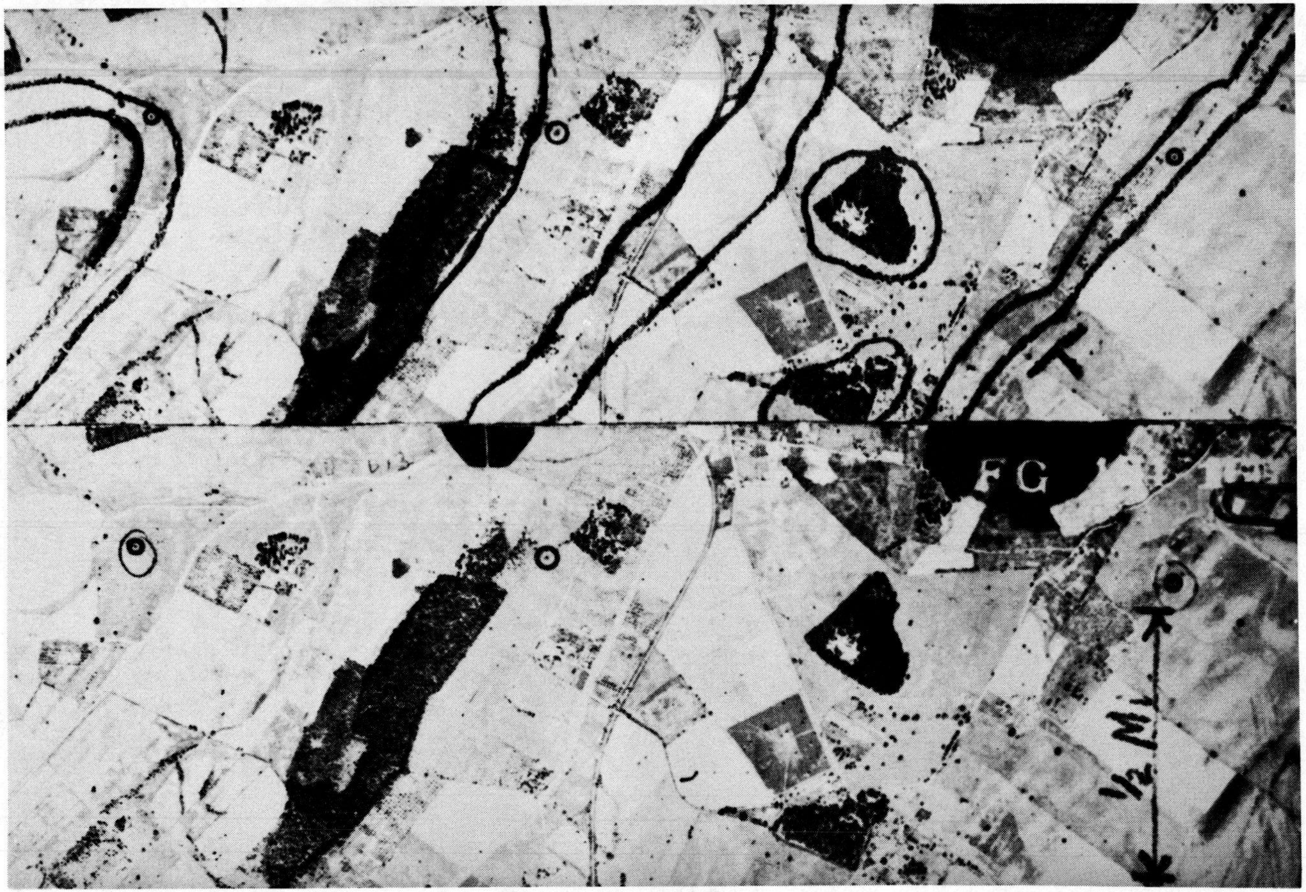


Figure 23. Stereo pair showing cherty hills in the Beekmantown formation (Ob), cherty elongated knolls in the Lenoir-Mosheim formation (Olm) and sandstone ridges in the Conococheague formation.

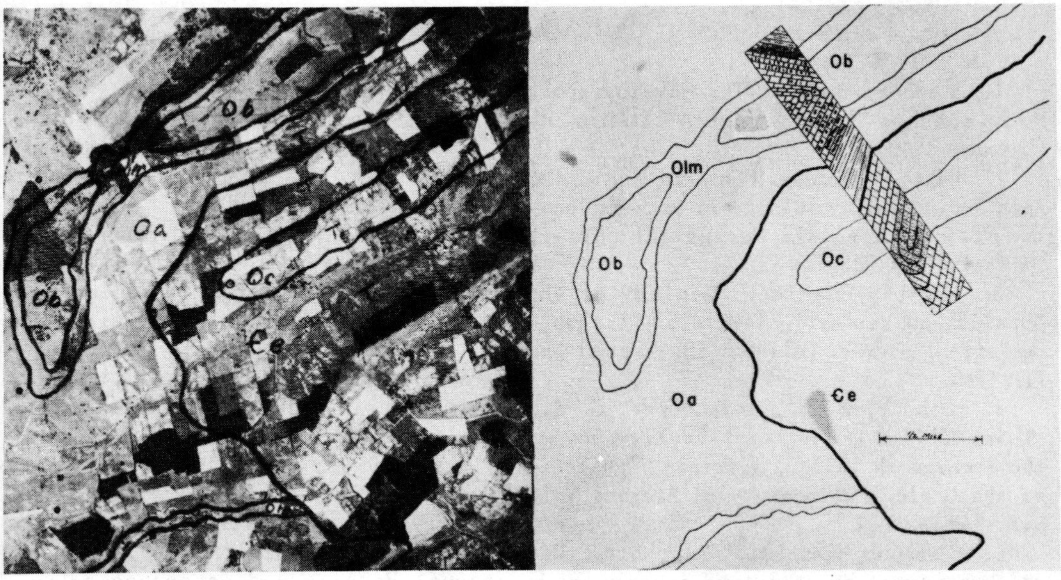


Figure 24. Airphoto showing Athens, Lenoir-Mosheim, Beekmantown, Conococheague and Elbrook formations and the Staunton Fault. Also structure section showing the attitude of these formations. Note Staunton Fault (dark line), anticlinal structure, and overturned Syncline.

Figure 25. Airphoto showing the end of the Massanutten syncline.

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APPENDIX

ADHESION TEST ON AGGREGATES

Procedure, Type I

The following is a general procedure for the Adhesion Test for Bituminous Materials, Type I. For specific information relating to mixing procedure, curing period, etc., see the notes regarding each specific type of bituminous material.

(1) Fifty grams of Shady Dolomite Aggregate,[1] washed in a distilled water[2] having a minimum pH of 6.3, air-dried for a minimum of 24 hours, and graded to a size that 100 percent passes a 3/8-in. sieve and is retained on a 1/4-in. sieve, shall be weighed into an 8-oz. seamless tin box. The aggregate shall be thoroughly mixed and completely coated with two grams of the bituminous material being tested. To insure that every particle is completely coated, the thoroughness of the mixing process shall be observed under an adequate light. At times it may be helpful to place the tin box on a hot plate for a few seconds, while mixing.

(2) The mixture shall then be transferred to a 600-cc. beaker containing 400 cc. of distilled water at a temperature of 25 C.±1.5 deg. C. (77 F.±3F.) having a minimum pH of 6.3 and allowed to remain immersed for a period of from 15 to 18 hours.

(3) The mixture shall then be removed from the beaker and placed on absorbent paper for air-drying. When dry the particles shall be immediately examined for uncoated areas. The particles containing uncoated areas shall be separated from those particles that are completely coated. Both shall then be weighed and the percentage of completely coated particles computed on the basis of total weight.

(4) Any bituminous material which under the conditions of the test fails to coat completely at least 90 percent by weight of the total shall be rejected.

NOTES ON PROCEDURE - STEP (1) WITH SPECIFIC BITUMINOUS MATERIALS -

(A) Cut-back Asphalts, RC-2a and RC-3a; and Emulsified Asphalts, (Immiscible Types) AEM-1, AEM-2, and AEM-3 - With these materials the aggregate shall be mixed at room temperature with two grams of the bituminous material which has been heated to 60 C. (140 F.) until a uniform coating results. The sample shall then be placed in a constant temperature oven at 60 C. (140 F.) and cured for a period of one hour. On removing from the oven, the sample shall be remixed for about two minutes before being placed in the distilled water.

(B) Asphalt Emulsions, AE-1, AE-2, AE-3, and AE-4 - Prior to coating, the aggregate shall be heated in a constant temperature oven for one-half hour at 130 C. (266 F.). Two grams of asphalt emulsion at room temperature shall be weighed into another tin box. The aggregate shall then be dropped into this box and mixed. After complete coating, the mixture shall be cured in a constant temperature oven at 60 C. (140 F.) for one hour. After this curing period, the sample shall be remixed for about two minutes before being placed into the beaker of distilled water.

(C) Hot Bituminous Materials, AP-0, AP-00, and OH-1 - Approximately 10 grams of the asphaltic material shall be placed in another tin box. The two boxes shall then be placed in a constant temperature oven at 130 C. (266 F.) for a one-half-hour period. Exactly 2 grams of the asphalt shall then be poured onto the aggregate in the first tin box and the materials thoroughly mixed. About two minutes should be allowed for the asphalt to set mixed. About 2 minutes should be allowed for the asphalt to set up, stirring constantly during this time. No curing period is necessary before placing the sample into the distilled water.

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[1] Samples of the Shady Dolomite Aggregate for testing purposes may be secured from the Division of Tests, Virginia Department of Highways, Richmond, Virginia.

[2] Distilled water of the proper pH shall be obtained by boiling and/or redistillation, and not by the use of an electrolyte.

Procedure, Type II

Adhesion Test for Bituminous Materials, Type II, is designed to procure a bituminous material that will satisfactorily coat and adhere to wet and cold aggregates being used under severe and adverse weather conditions. The test procedure is applicable to Rapid Curing Cut-back Asphalts RC-2a and RC-3a; and Emulsified Asphalts, (Immiscible Types) AEM-1, AEM-2, and AEM-3, and Tar RT-5.

(1) Fifty grams of the standard reference gravel[3], washed in a distilled water[4] having a minimum pH of 6.3, air-dried for a minimum of 24 hr., and graded to a size that 100 percent passes a 3.8-in. sieve and is retained on a 1/4-in. sieve, shall be weighed into an eight-ounce seamless tin box and thoroughly wetted with one gram of distilled water. The wet aggregate shall be thoroughly mixed and completely coated with three grams of the bituminous material which has been heated to 60 C. (140 F.) The mixing process shall be performed in adequate light and the bituminous material shall satisfactorily coat 95 percent of the surface area of the aggregate as determined by the visual estimation method. At times it may be helpful to place the tin box on a hot plate for a few seconds while mixing. The mixture shall then be placed in a constant temperature oven at 60 C. (140 F.) and cured for a period of one hour. On removal from the oven, the sample shall be remixed for about two minutes to insure a uniform coating of the aggregate.

(2) The sample shall then be transferred to a 600-cc. beaker containing 400 cc. of distilled water at a temperature of 37.8 C. ± 2.5 C. (100 F. ± 5 F.) having a minimum pH of 6.3 and allowed to remain immersed for a period of from 15 to 18 hr.

(3) At the end of the immersion period the sample shall be observed under water and the percentage of surface area of the aggregate remaining coated shall be evaluated by visual estimation.

(4) Any bituminous material which under the conditions of the test fails to coat 95 percent of the surface area of the aggregate originally or to retain 95 percent coating of the surface area of the aggregate by visual estimation shall be rejected.

Note: For a test on selective aggregate samples a standardized given bituminous material is used. The asphalt used was RC-2 from the Mexican Petroleum Corporation.

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[3] Samples of the standard reference gravel (Commonwealth Sand and Gravel Company) for testing purposes may be secured from the Division of Tests, Virginia Department of Highways, Richmond, Virginia.

[4] Distilled water of the minimum pH shall be obtained by boiling and/or redistillation, and not by the use of an electrolyte.