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PETROLOGY OF POTOMAC GROUP SANDS IN FAIRFAX COUNTY, VIRGINIA

BY

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Abstract

The Potomac Group sands sampled in Fairfax County are dominantly microcline-rich lithic arkoses. Quartz averages 59%, microcline 25%, plagioclase less than 1% and lithic grains 16%. Most sands are texturally submature and medium grained. Microcline is somewhat more abundant in the deeper beds in the subsurface than in the shallow subsurface and outcrop sections, with quartz correspondingly more abundant at the surface. Zircon is the only abundant non-opaque heavy mineral in the outcrop section as well as in the shallow subsurface, but tourmaline, rutile and staurolite are also common. In contrast, the lower beds in the subsurface have a heavy mineral assemblage with zircon, garnet and apatite as the dominant species.

Several alternative explanations for the vertical variation in mineral assemblages from less to more stable types in the Potomac Group sands are possible: 1) removal of primary Piedmont apatite-bearing igneous and garnet-bearing metamorphic source rock by erosion or burial by overlapping Potomac Group sediments, 2) deep weathering of primary Piedmont source areas and destruction of less stable minerals (apatite and garnet) in Cretaceous time, 3) destruction of less stable minerals (apatite and garnet) near the surface and in the shallow subsurface by post-Cretaceous deep weathering and/or intrastratal solution.

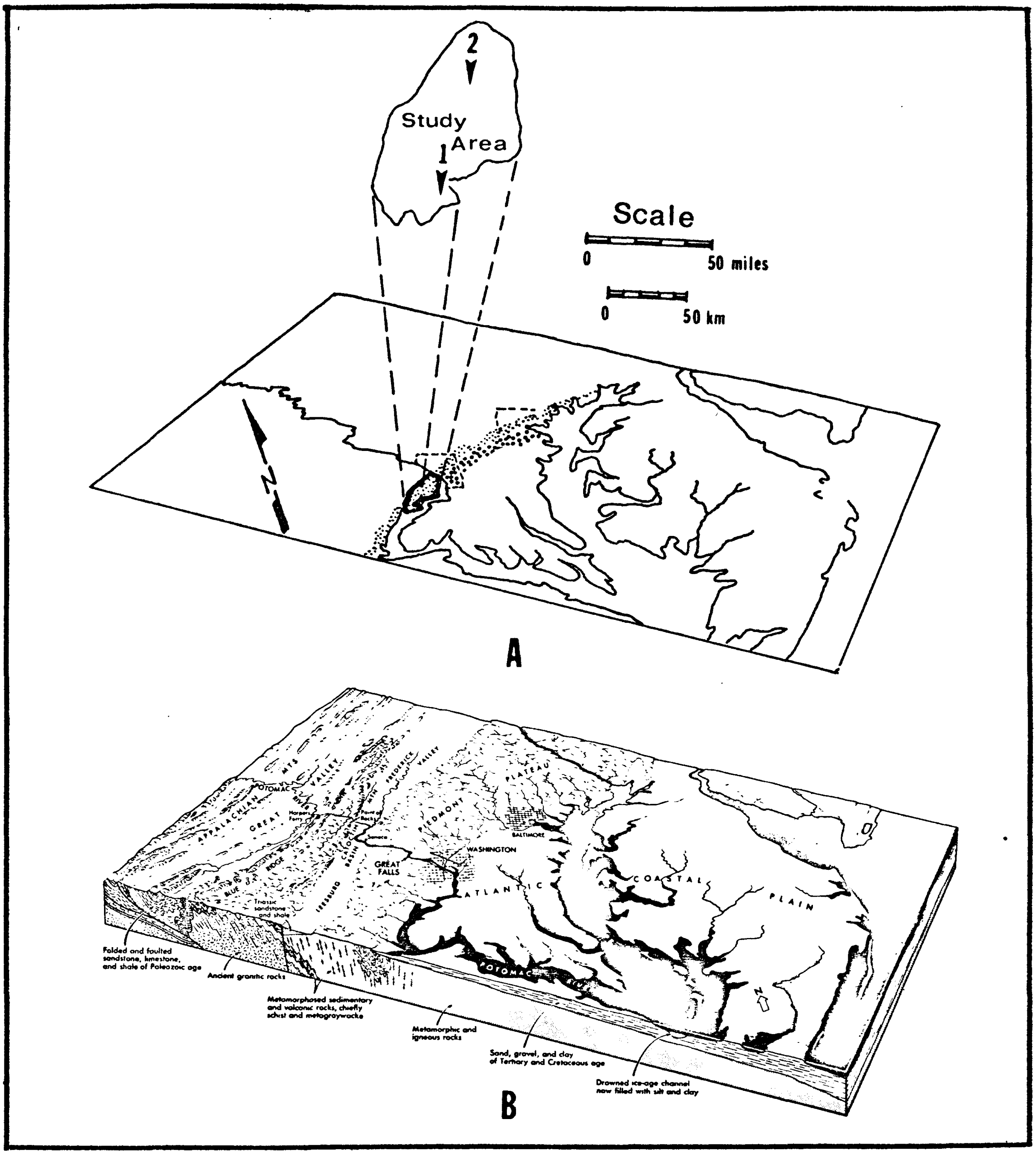

Figure 1.-- Locality index

A - Study area of Cretaceous outcrops in Fairfax Co., Va. Showing (1) U.S.G.S. well "GH" and (2) U.S.G.S. well "XI". See Figure 13 for detailed locality map. Stiple pattern indicates Cretaceous outcrop area.

B - Block diagram showing physiographic provinces and geologic features. Vertical exaggeration approximately 25x. From The River and the Rocks, 1970, U.S.G.S. and National Park Service, p. 6.

Introduction

The Potomac Group of Early Cretaceous age exposed in the eastern part of Fairfax County, Virginia is a wedge-shaped sequence of clastic sediments. It crops out in a northeast-southwest trending belt, approximately 16 km (10 miles) wide, which continues southwestward to Fredericksburg, Virginia and discontinuously to the Richmond-Petersburg vicinity and northeastward across Maryland and Delaware (Figure 1-B). Within Fairfax County, the sequence is bounded on the west by Piedmont crystalline rocks and on the east by the Potomac River, and ranges in thickness from a feather edge on the west to greater than 150 meters (500 feet) on the east.

This report describes a petrologic study of the Potomac Group sands in Fairfax County and is part of a detailed geologic investigation of the area by the U.S. Geological Survey. Field work for this study was done during July and August, 1977 and laboratory analysis continued through the fall of that year.

Methods

Sample Collection

Outcrop samples were collected at 42 localities, most of which were previously studied by Weir (1976) as part of his investigation of cross-bedding and paleocurrents in the Potomac Group. At localities where there were obvious differences in sand size material, several samples were collected in an effort to obtain a representative suite of sands. Conglomerates, clayey siltstones, and mudstones were not sampled. Most of the sites sampled were highway and railroad cuts, sand and gravel pits, or natural outcrops in gullies and stream beds (Plate 1).

Prior to this project, two wells, designated as "GH" and "XI" had been drilled by the U.S. Geological Survey (Figure 1, A-1 and A-2). Both wells penetrated to the pre-Cretaceous basement. Samples collected from these wells are included in this study.

Laboratory Techniques

Outcrop samples - Subsamples from 42 outcrop localities were studied to evaluate variations within an outcrop, as well as within individual samples (Appendix C). Samples were dried and sieved using a one phi (1Ø) set of 7 1/2 cm diameter sieves. Sieving was done primarily to separate the 4Ø to 2Ø fraction for heavy mineral analysis. This provided data of sufficient quality to calculate mean grain size and standard deviation, but not for valid estimates of skewness and kurtosis.

Heavy minerals were separated from the light minerals using acetylene tetrabromide (S.G. = 2.96), for the 4Ø to 2Ø (0.062-0.52 mm) fraction. The 3Ø to 2Ø and 4Ø to 3Ø fractions were combined because most samples had too little material in the 4Ø to 3Ø fraction to analyze it separately from the 3Ø to 2Ø fraction. Magnetic grains removed by a hand magnet were retained for later x-ray analysis. Using a micro-splitter, the non-magnetic fraction was divided and the grains were mounted on glass sides. One hundred heavy mineral grains were counted to determine the percent of opaque minerals and percent of non-opaque minerals. Additional grains were counted to bring the total non-opaque count to one hundred.

Subsurface samples - The heavy mineral composition of twenty-two samples from well "GH" and eight from the upper 24 m (78 feet) of well "XI" were studied. These samples were not sieved prior to heavy mineral separation and therefore contain an undetermined amount of material coarser than 2Ø (0.25 mm). In order to evaluate how this might affect estimates of mineralogic composition two heavy mineral samples were sieved and the heavy mineral content of three size fractions (coarser than 2Ø, 3Ø to 2Ø, 4Ø to 3Ø) was determined as well as that of the bulk sample of each (Figure 3). It is obvious that mineral abundance is not uniform in the different size fractions (e.g., garnet is much more abundant in sediment coarser than 2Ø than in finer material). Samples from the lowermost 28 m (91 feet) of well "XI" were extremely coarse, apparently as a result of recovery problems during drilling which necessitated on-site sieving to remove fines that washed into the drill hole. These samples, from the lower part of well "XI", were combined into two samples, with one representing the interval between 48-61 m (158-199 feet) and the other between 61-76 m (199-249 feet).

Results

Light Minerals

Description - Based on petrographic study of outcrop samples the dominant mineral is quartz (59 percent), most of which is the monocrystalline variety. Feldspar, mostly microcline (25 percent), is the second most abundant constituent; plagioclase generally makes up less than one percent of these sands (Plate 2).

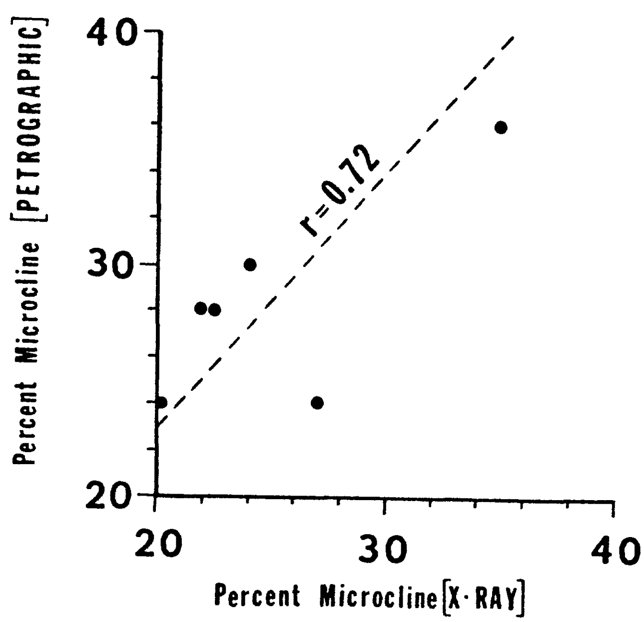

Figure 2.-- Scatter diagram of microcline per cent determined by x-ray analysis plotted against microcline per cent determined petrographically. Microcline content determined by petrographic analysis calculated exclusive of rock fragments (quartz + microcline + plagioclase = 100%).

The light mineral fraction was studied primarily by x-ray diffraction. Bulk samples were ground for 15 minutes, mounted on glass slides and x-rayed on a Picker unit at the George Washington University. Heights of principle peaks were measured for quartz (101), microcline (002), plagioclase (002), illite (001), kaolinite (001), and montmorillonite (001). Using previously prepared standard curves, the amount of quartz, microcline and plagioclase, were calculated. Because the mineralogy of the Potomac Group clays had been previously studied by Force and Moncure (1978), no attempt was made to quantify clay mineral content. Instead, a ratio (using peak heights in cm) of kaolinite: kaolinite + montmorillonite was calculated in order to evaluate relative differences in the abundance of these minerals. The same comparison was made for the clay minerals in the 4Ø fraction (collected on the pan during sieving).

Six bulk samples were impregnated with epoxy and standard thin sections made and then stained with sodium cobaltanitrate. Composition of framework (Appendix D) and matrix was determined by point counting (200 - 300 grains per thin section). Petrographic analysis was made to determine the abundance of lithic fragments and to study the relationships between framework and matrix constituents as well as for comparison with data obtained by x-ray analysis. As to the latter, the data (x-ray v. petrographic) show sufficient agreement (Figure 2) to warrant using mineralogic estimates obtained by x-ray analysis as the principal source for determining quartz-feldspar content.

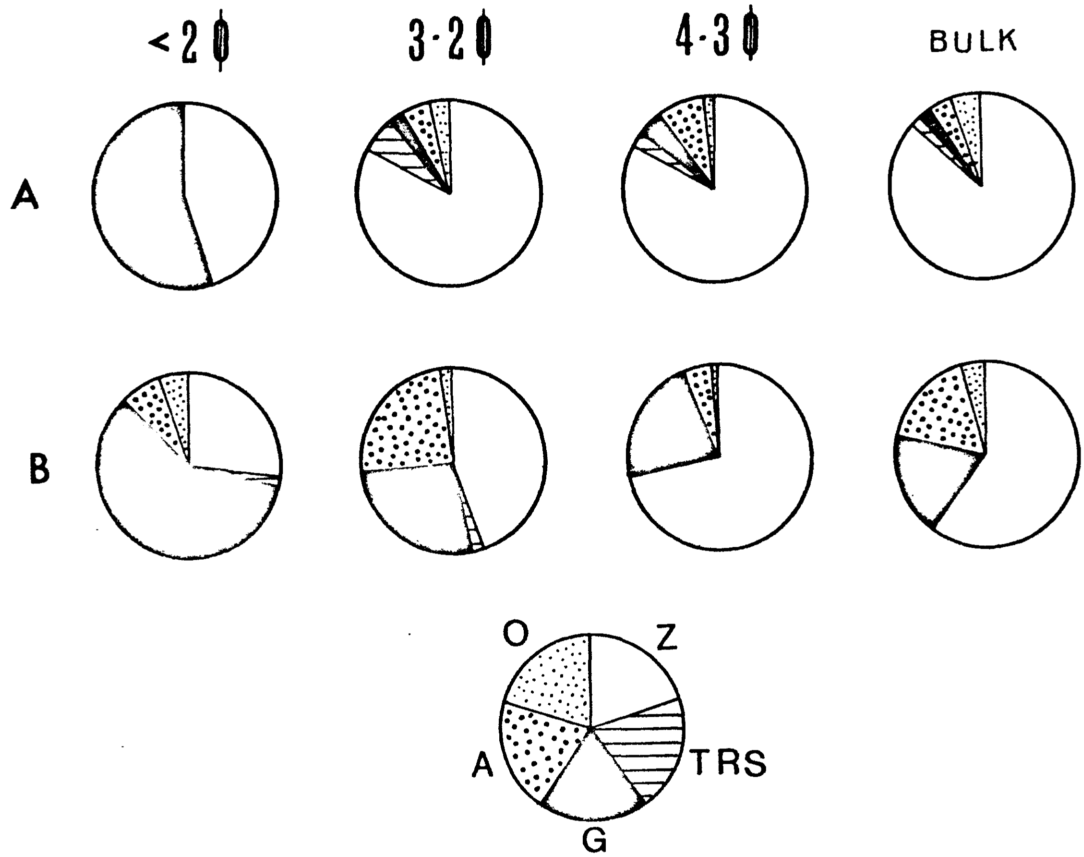

Figure 3.--Heavy mineral composition of several different size fractions.

A - Core "GH" sample taken between 105'-128', Fairfax Co.
B - Core "GH" sample taken between 373'-376', Fairfax Co.

Key: Z - zircon; RTS - rutile, tourmaline, staurolite;
G - garnet; A - apatite; O - other

Each size fraction as percent of total non-opaque heavy mineral suite: A - 2ϕ = 15%, 3ϕ-2ϕ = 61%, 4ϕ-3ϕ = 24%; B - 2ϕ = 31%, 3ϕ-2ϕ = 53%, 4ϕ-3ϕ = 16%

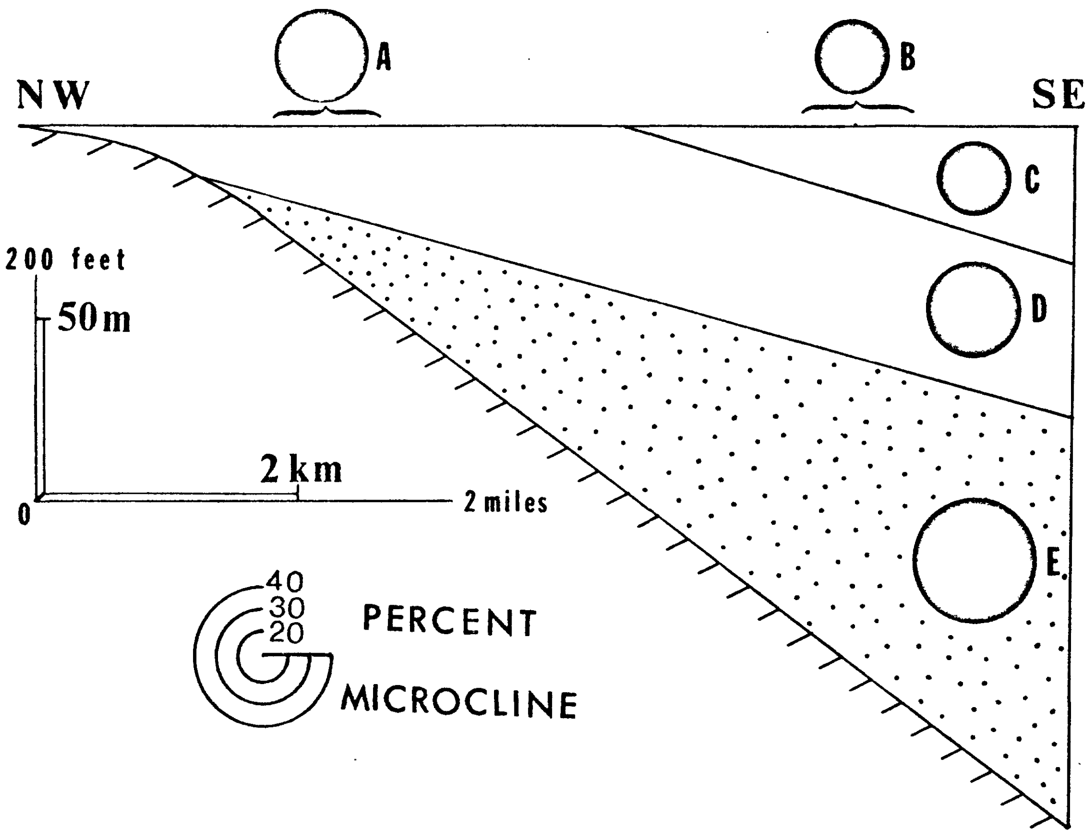

Figure 4.--A cross section showing distribution of microcline in Potomac Group, Fairfax Co. Percent microcline determined by x-ray analysis in which quartz + microcline + plagioclase = 100%. Stipple pattern is the zircon-garnet-apatite heavy mineral zone lying over crystalline basement (slash pattern). Vertical exaggeration = 100x.

A. Lower portion of exposed Potomac Group, mean = 29%, n = 9
B. Upper portion of exposed Potomac Group, mean = 26%, n = 33
C. U.S.G.S. well "GH", upper portion of zircon-rich sand, mean = 25%, n = 2
D. U.S.G.S. well "GH", lower portion of zircon-rich sand, mean = 30%, n = 2
E. U.S.G.S. well "GH", zircon-garnet-apatite-rich sand, mean = 36%, n = 2

Feldspar alteration (growth of clay minerals and vacuolization) is quite variable. Some grains are fresh, whereas most show some degree of alteration. In extreme cases high birefringent clay minerals nearly replace the whole grain; these grains are easily confused with fine grained lithic fragments (described below), and indeed some grains counted as lithic fragments may really be highly altered feldspar grains.

Sand size lithic fragments composed largely of clay minerals make up 16 percent of the light mineral fraction. Most of these grains are probably clay clasts derived from erosion and reworking of over-bank deposits by stream channel migration. Larger intraformational clasts (granule to boulder size) were noted in a number of outcrops.

Spatial variation- Microcline is more abundant in progressively older strata of the Potomac Group (Figure 4) and is accompanied by a corresponding decrease in quartz content. This trend occurs in both surface and subsurface samples. Lateral variation in outcrop is characterized by generally east-trending belts of sand which contain differing quantities of feldspar (Figure 14 in pocket).

Heavy Minerals

Description - Heavy minerals constitute 4.4 percent of the 2Ø to 4Ø fraction of exposed Potomac Group sands in Fairfax County. Of this, only 3.6 percent is magnetic, and x-ray analysis indicates that nearly half of this material is ilmenite (probably as intergrowths with magnetite). Of the non-magnetic portion, 83 percent is composed of opaque grains (mostly ilmenite and hematite) and 17 percent are non-opaque grains.

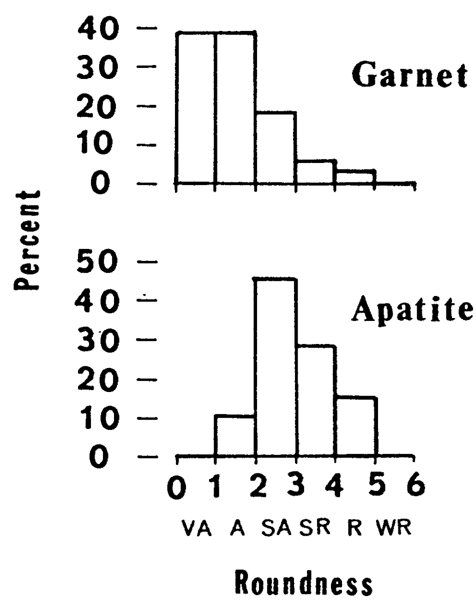

Figure 5.--Histograms showing roundness of garnet and apatite. Data from four samples. Mean roundness for garnet = 1.5; mean roundness for apatite = 2.9. Roundness values are in "Rho" (Powers, 1953; Folk, 1955).

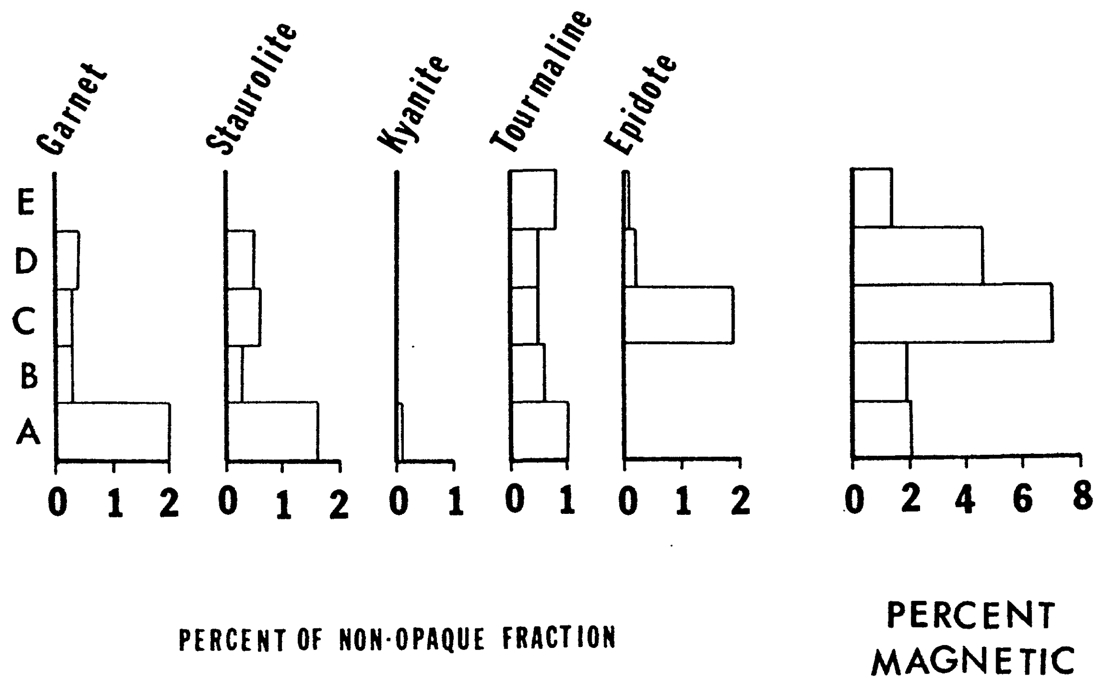

Figure 6.--Stratigraphic distribution of heavy minerals in exposed portion of Potomac Group sands in Fairfax Co. Segments A-E each represent approximately 1/5 of the total exposed section, with "A" being the oldest and "E" being the youngest; "percent magnetic" refers to the heavy mineral fraction removed with a hand magnet.

Glaser's (1969, Table 4) description of the important non-opaque heavy mineral species in the Potomac Group sands is generally applicable to the samples in this study; however, a few pertinent additions are relevant.

Zircon, the most abundant non-opaque mineral species, is quite variable in shape and color and occurs as well developed euhedra to well rounded and anhedral grains; color ranges between colorless (clear) to mauve and pale-brown. The other species are generally angular. As an example, most grains of garnet (2/3 of which are colorless) are angular to very angular (Figure 5). Even apatite, which is relatively soft and easily rounded, is dominantly subangular (Figure 5).

Spatial variation in surface samples - Although zircon is the only uniformly abundant (92 percent) non-opaque heavy mineral species, tourmaline, rutile, staurolite and garnet are present in many samples. None averages more than one percent of the total non-opaque fraction, although in some samples they are more abundant. Kyanite, chloritoid, epidote, and hypersthene are significantly less abundant than those listed above. Apatite is present (in more than trace amounts) in only one sample (AL-1), where it makes up 33 percent of the non-opaque suite.

When abundance is analyzed relative to stratigraphic position, garnet, staurolite and kyanite are seen to be more abundant in the lowermost portion of the exposed sequence (Figure 6). This contrasts with epidote and magnetitic opaques whose greatest concentration occurs midway in the exposed sequence (Figure 6).

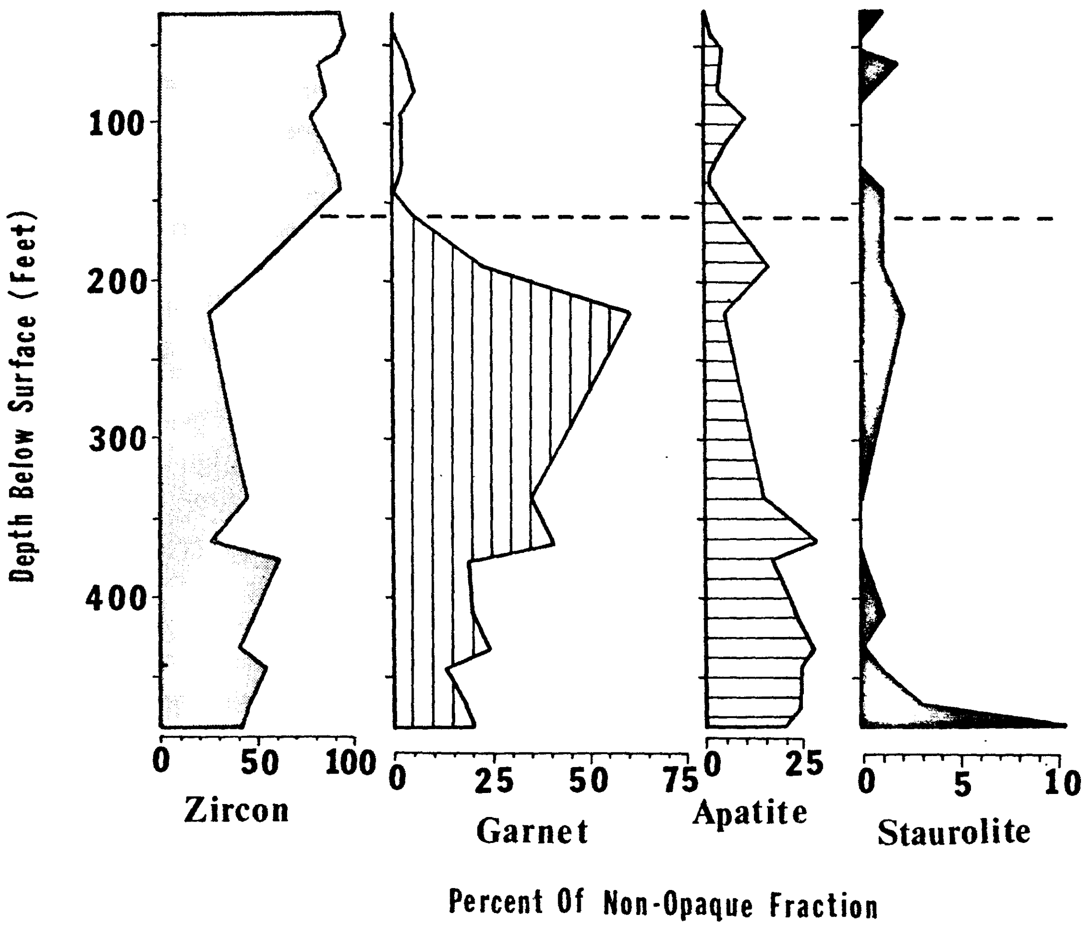

Figure 7.--Distribution of dominant non-opaque heavy minerals in U.S.G.S. well "GH", Fairfax Co. Dashed line is approximate boundary between zircon-rich suite and zircon-garnet-apatite-rich suite.

Spatial variation in subsurface samples - As with surface samples, zircon is the dominant species in the upper portion of wells "GH" (88 percent) and "XI" (95 percent), but it is relatively less abundant in the lower part of each. Tourmaline, rutile and staurolite are persistent constituents in the upper portions of these wells, ranging between zero and three percent of the non-opaque fraction which is approximately the same as in surface samples. Garnet is somewhat more abundant than in surface samples. This may be due to the fact that subsurface samples were not sieved and include heavy minerals coarser than 2∅ which are relatively rich in garnet (Figure 3). In the lower part of both wells, garnet and apatite are far more abundant than in sands higher in the section (Figure 7).

Clay Mineralogy

Clay minerals occur: (1) in clasts (ranging from a few millimeters to several decimeters), (2) as alteration products of feldspars, (3) as primary components of some lithic fragments, and (4) as interstitial material between sand grains. In some cases, the interstitial clay totally fills the space between sand grains, but much more commonly coats the quartz and feldspar grains to a thickness ranging between 1 and 30 microns. Montmorillonite seems to be the dominant clay mineral in the clasts (which are probably reworked flood plain sediments) as well as much of the interstitial material. The presence of montmorillonite is not surprising in light of the fact that clayey Potomac Group sediments in Fairfax County are largely montmorillonite (Force and Moncure, 1978). In addition to finely crystalline montmorillonite, loosely packed bundles of kaolinite

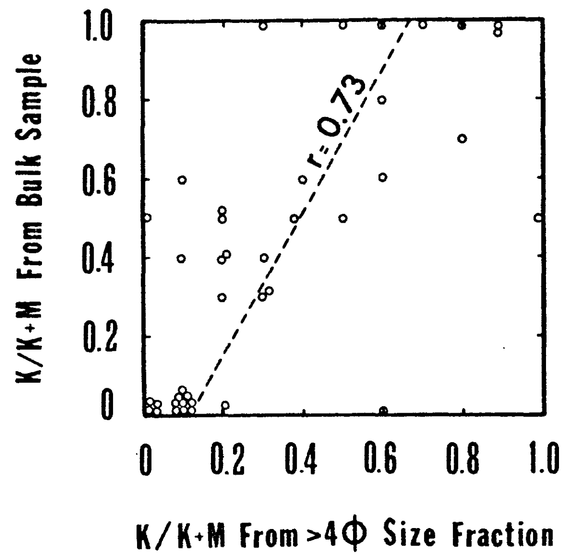

Figure 8.--Scatter diagram of kaolinite/kaolinite + montmorillonite from 4ϕ size fraction (pan) v. bulk sample. Kaolinite and montmorillonite values are "I" in cm: n = 40.

crystals (5-100 microns thick) occur interstitially between sand grains. Such an occurrence of kaolinite is generally interpreted as a precipitate from solution (Folk, 1968, p. 94; Glass, Potter, Siever, 1956, p. 752) although near surface kaolinite in Potomac Group clays in Fairfax County is thought to have replaced montmorillonite during weathering (Force and Moncure, 1978). Illite seems to be the dominant clay mineral replacing feldspar, and is also a major component in fine grained rock fragments.

The abundance of kaolinite and montmorillonite in bulk samples compared to that in the 4Ø fraction (sample collected on pan during sieving) indicates that kaolinite is relatively more abundant in the bulk sample (Figure 8). This is because the montmorillonite is finer grained and therefore concentrated in the finer than 4Ø fraction, and would indicate that the bulk sample should be used to determine clay content of these sands if quantitative data are needed.

The distribution of kaolinite and montmorillonite (Plate 3 in pocket) shows two northeast-trending belts of kaolinite-rich sands separated by a belt of sand with a montmorillonite-rich clay fraction.

Cementation

Potomac Group sands are generally poorly lithified and contain no appreciable amount of chemical cement. This may be due to clay coatings which inhibited cementation by quartz or calcite. Local induration by siderite or ferruginous cement occurs (Glaser, 1969), but was not studied during the present investigation.

Classification

Most of the sands (5 of 6) studied petrographically are classified as lithic arkoses (Folk, 1968) and are texturally submature (Appendix A) according to Folk's 1968 system of textural maturity (i.e., clay matrix less than 5 percent and standard deviation greater than 0.5ϕ). Although most sands are medium grained, the lower part of the exposed section (Figure 9-A) contains more coarse sands and fewer fine sands than the upper part (Figure 9-B). This relationship is similar to that noted by Glaser (1969, Table 2) for Potomac Group sands in Maryland.

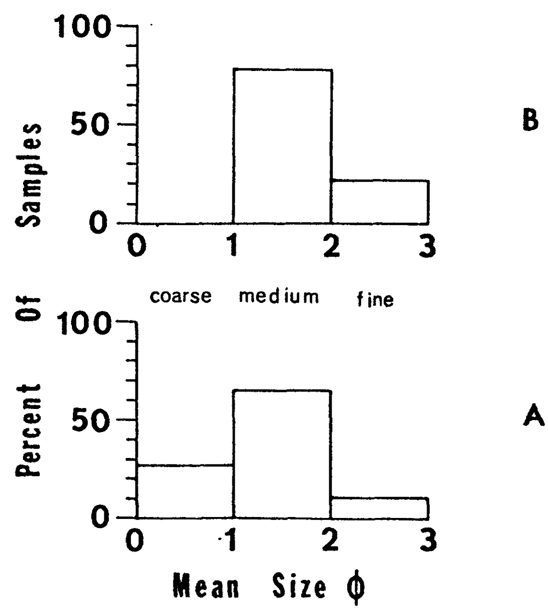

Figure 9.--Histograms showing distribution of major textural classes of exposed Potomac Group sands, Fairfax Co.

A - Lower 1/2 of exposed section
B - Upper 1/2 of exposed section

Stratigraphy

General Relationships

The basal portion of the sedimentary sequence exposed in the middle Atlantic Coastal Plain was designated as the Potomac Formation by McGee (1888) and later elevated to Group status by Clark and Bibbins (1897). Based on pollen age zones (Brenner, 1963, Doyle, 1969, 1973), these Lower Cretaceous beds range in age from Aptian (pollen Zone 1) to Lower Cenomanian (pollen Zone III). In the area around Baltimore, Maryland, the Potomac Group can be subdivided into three formations, which are, from oldest to youngest: Patuxent, Arundel and Patapsco (Minard, et. al., 1976). Sand dominates in both the Patapsco and Patuxent, although the Patapsco contains less gravel and more clay than the Patuxent. The Arundel clay is characterized by dark mudstones with abundant carbonaceous plant remains. South of the Potomac River, the Arundel Formation is not recognized and the Potomac Group is not divisible into three formations (Mixon, et. al., 1972).

Fairfax County

Although gross lithologic character does not allow a tripartite division of the Potomac Group which crops out in Fairfax County, the sharp change in heavy mineral content in the subsurface may be stratigraphically significant. The implicit assumption that litho-stratigraphic units are essentially parallel to the pre-Cretaceous surface, and therefore exposed in outcrop (Figure 10-B), need not necessarily be true. If the change from a zircon-garnet-apatite suite in the older beds, to a zircon suite in the younger beds was produced during deposition and not by later removal (intrastratal solution... a point that is discussed later) of garnet and apatite from the younger beds, a major stratigraphic boundary which dips eastward at 0.2° - 0.4° may be present. This contrasts with an eastward dip of 0.5° - 0.8° assuming parallelism of stratigraphic units to the pre-Cretaceous surface. If correct, it also means that more than half of the Potomac Group underlying Fairfax County may not be exposed and that the exposed section would be less than half as thick as previously thought (Figure 10-A).

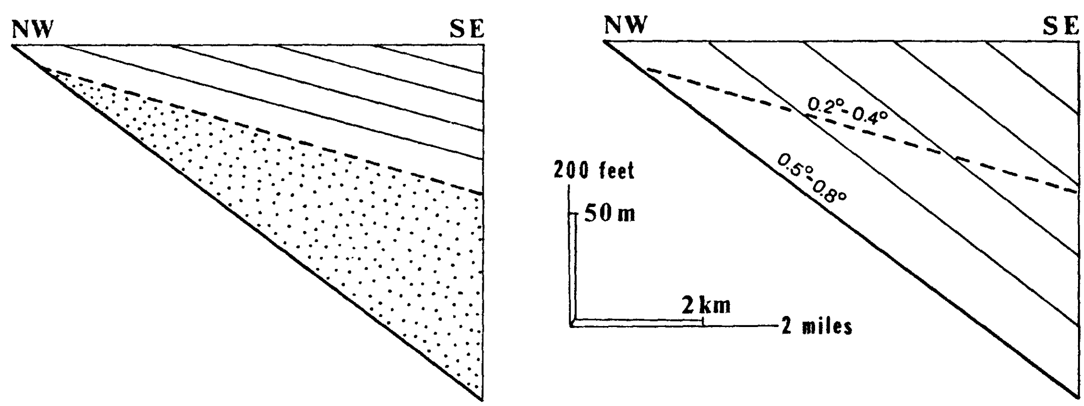

Figure 10.--Stratigraphic models for Potomac Group in Fairfax Co.

Lithostratigraphic boundaries are schemmatic and only intended to illustrate general age relationships.

A - Cross section with lithostratigraphic boundaries parallel to top of zircon-garnet-apatite heavy mineral zone (stipple pattern). Vertical exaggeration = 100x.

B - Cross section with lithostratigraphic boundaries parallel to base of Cretaceous. Dashed line is top of zircon-garnet-apatite heavy mineral zone. Vertical exaggeration = 100x.

Interpretation

Studies of the Potomac Group in Virginia and Maryland show that it is fluvial in origin (Glaser, 1969; Force, 1975; Weir, 1976). Evidence includes plant fossils, cut-and-fill structures, mudstone-clast conglomerates, lensing and intergrading of rock units and the absence of marine fossils. Paleoccurent data indicate that streams flowed nearly due east across Fairfax County during Early Cretaceous time (Weir, 1975, Figure 5).

Petrologic interpretation of Potomac Group sands in Fairfax County is based primarily on four minerals: microcline, zircon, apatite and garnet. The association of these minerals does not indicate a single source terrain. Garnet clearly points to rather high rank metamorphic rocks. Microcline and apatite generally indicate granitic rocks (Pettijohn, 1975, Table 13-1), but both can occur in metamorphic rocks (Moorehouse, 1959). Euhedral zircon occurs in granitic rocks, but rounded zircon may be derived from older sandstones or metamorphosed sandstones. The adjacent Piedmont contains all of the important minerals found in the Potomac Group sands, and was certainly the most important source of these sediments. Paleocurrent data and the angular character of mineral grains (e.g., garnet and apatite) strengthen this interpretation. Rocks west of the Piedmont (Triassic-Jurassic basin, Blue Ridge Province and Folded Appalachians) may have also contributed to the sediment pool, especially the rounded zircon.

Changes in mineral abundance within the Cretaceous sediment wedge may have been caused by (1) removal of source rock by erosion or burial by

Cretaceous sediments, (2) destruction of less stable minerals by outcrop weathering in Cretaceous time in the source area, and (3) destruction of less stable minerals by post-Cretaceous intrastratal solution or weathering.

The abrupt decrease in garnet and apatite content midway in the sequence may point to a major change in the character of rocks supplying sediment to paleostreams. Possibly, younger Potomac Group sediments (with little garnet or apatite) were derived from more intensely weathered crystalline rocks in which garnet and apatite had been totally destroyed. This could have resulted from a change in climatic conditions or from a decrease in the erosive strength of the paleostreams caused by decreased stream gradient. Cretaceous climatic change from conditions producing very little outcrop weathering (e.g., arid) to conditions of intense weathering (e.g., humid) are unlikely because feldspar content, while showing a regular upward decrease, would seem to be too great to fit into a model calling for weathering capable of nearly total removal of apatite and garnet. Decreased gradient, rendering streams incapable of eroding fresh rock beneath a deeply weathered mantle, could explain the upward decrease in garnet and apatite, and is consistent with the upward decrease in coarse sands and gravels. This does not, however, account for the abundance of feldspar in the upper beds unless we envision a source terrain where granitic rocks maintained greater relief than adjacent metamorphic rocks.

Progressive burial beneath a westward migrating edge of onlapping Potomac Group sediments could have covered the garnet-apatite rich crystalline rocks in the source terrain. This mechanism is consistent with stratigraphic model illustrated in Figure 10-A (bottom). It might also explain the few outcrop samples relatively rich in garnet and/or apatite as having been deposited by streams eroding exposed remnants of garnet-apatite rich crystallines. The slight increase in epidote and magnetite midway in the exposed section (Figure 6) might indicate an increase in the importance of source rocks west of the Piedmont (i.e., diabase and basalt in the Triassic-Jurassic sequence and greenstones in the Blue Ridge) as more and more of the main Piedmont source was buried.

Finally, we must consider whether garnet and apatite were removed from the upper Potomac Group beds by post-Cretaceous intrastratal solution. Pettijohn (1975) indicates that garnet is generally a persistent mineral species as regards weathering and intrastratal solution. In contrast, Glaser (1969) concludes that garnet, which is abundant in probable source rocks for Potomac Group sands in Maryland, is absent in these Cretaceous sediments because of garnet's relative instability. Similarly, Hester (1974) concludes that post-depositional weathering and intrastratal solution were important in removing garnet from Upper Cretaceous sands in Alabama and Georgia.

Folk (1974) claims that some varieties of garnet are relatively unstable and "rapidly dissolved in many porous sands, especially those flushed by fresh water." This combined with Back's (1966 p. A-37) observation that in the Atlantic Coastal Plain "ground-water in near-surface formations... has a low dissolved solids content because of the shorter travel path of the water in the aquifers and the prior leaching of soluble material" lends credence to the effectiveness of intrastratal solution in Potomac Group sands. Back further notes that "...a decrease in grain size of soluble material will result in a higher dissolved solids content along a particular flow path. An increase in concentration due to smaller grain size results from two different effects: (1) the smaller grains of any soluble material will go into solution more readily than coarse grains of the same material, and (2) the smaller grain size causes a decrease in permeability that requires a longer residence time to traverse the same flow distance." As previously noted, the upper part of the Potomac Group is generally finer grained than the lower portion, which may have contributed to selective removal of garnet and apatite from the upper portion by solution in ground water.

Although there is considerable circumstantial evidence favoring intrastratal solution, the facts are not totally supportive of such a conclusion. The garnet, in the Potomac Group sands (in Fairfax County) with relatively little garnet, shows no more evidence of solution etching than that in garnet-rich sands where intrastratal solution was ineffective. The same is true for apatite. This is taken as evidence against intrastratal solution as a mechanism for removal of garnet and apatite in these deposits. The abundance of microcline in garnet-apatite deficient sands would also seem to argue against intrastratal solution as a major factor in determining Potomac Group mineralogy, although the relative stability of microcline and garnet is unknown, and the true significance of abundant microcline in garnet-poor sands is unclear.

In addition, the few outcrop samples with abundant garnet and/or apatite are difficult to explain if intrastratal solution is invoked to explain the general paucity of these minerals in the exposed Potomac Group sands.

In conclusion, it is obvious that no definitive statement can be made regarding heavy mineral distribution in Potomac Group sands in Fairfax County. More data are needed from the subsurface before this problem can be resolved.

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Sample	Grain Size Data (Ø): Mean	Standard Deviation	2-3Ø/2-4Ø	Wt% <4Ø	HEAVY MINERALS: Wt.% Heavies in 2-4Ø fraction	Wt. % Magnetic	Opaque	Non-opaque	Opaques: White	Black	Red
AL- 1	1.4[illegible]	[illegible]	1.00	2.7	7.8	8.3	70	30	44	51	4
2	1.[illegible]	0.80	0.73	1.5	5.4	3.0	96	4	6	6	88
4	1.[illegible]1	0.63	0.88	1.0	12.8	2.9	90	8	88	8	10
6	1.11	0.89	0.71	2.2	3.5	2.4	90	10	48	27	25
7	1.27	1.73	0.72	4.4	1.7	35.1	76	24	59	38	3
8	0.38	0.71	0.79	0.6	1.6	2.6	87	13	85	14	1
9	1.05	0.66	1.00	0.4	4.5	2.5	76	24	89	11	0
10	1.19	0.69	0.87	0.7	0.8	2.2	60	40	70	13	17
11	1.44	1.17	0.67	4.6	1.0	1.1	62	38	77	15	8
12	1.75	0.62	0.90	0.6	5.9	3.5	91	9	59	37	4
AN- 1	0.64	0.59	0.69	0.3	10.1	1.4	88	12	45	32	23
2	1.12	1.16	0.83	2.9	3.6	1.4	86	14	67	3	30
3	0.[illegible]	0.73	0.73	0.6	1.1	2.1	79	21	51	10	39
4	1.23	0.99	0.78	3.4	-	4.8	86	14	36	15	49
5	2.[illegible]	0.79	0.85	4.2	6.5	1.4	51	49	59	8	33
6	2.4[illegible]	0.94	0.83	6.4	0.4	2.5	85	15	63	33	4
7	1.[illegible]	1.03	0.75	1.7	1.8	0	84	16	43	8	49
8	1.[illegible]	1.33	0.65	5.0	3.4	1.3	78	22	15	3	82
9	1.3[illegible]	0.93	0.85	3.1	14.9	2.0	88	12	64	0	36
10	[illegible]	0.91	0.73	0.8	2.1	2.4	86	14	47	43	10
FB- 1	0.39	0.91	0.77	1.2	2.1	2.1	89	11	96	0	4
2	1.13	0.90	0.68	1.7	2.3	3.0	86	14	83	1	16
3	1.18	0.96	0.82	2.8	2.6	0.9	80	20	91	3	6
4	0.35	0.96	0.67	2.1	3.0	1.6	83	17	89	5	6
5	1.54	0.94	0.77	3.7	5.4	1.3	82	18	87	4	9
6	0.99	1.07	0.78	3.7	1.1	1.1	93	7	50	5	45
7	1.43	0.88	0.82	2.9	12.1	1.0	88	12	93	2	5
8	0.91	0.32	0.70	1.1	5.6	1.8	87	13	79	7	14
9	1.[illegible]5	0.88	0.73	1.7	5.5	0.9	93	7	55	14	31
10	1.25	1.26	0.55	6.1	0.5	0	93	7	15	6	79
11	2.14	0.91	0.78	3.6	1.4	8.8	64	36	84	11	5
13	1.29	0.81	0.82	1.0	1.5	1.2	81	19	83	7	10
14	1.39	0.87	0.73	2.4	9.4	1.0	85	15	89	8	3
15	1.43	1.09	0.73	3.4	12.8	3.4	85	15	52	28	20
17	2.05	1.04	0.82	6.7	4.8	2.4	90	10	36	14	50
18	1.13	1.00	0.68	2.6	1.4	1.7	86	14	40	38	22
20	1.96	1.02	0.46	5.3	9.2	0.2	91	9	54	6	40
21	1.50	0.62	0.94	0.7	1.8	2.6	83	17	51	20	29
22	--	--	--	-	-	2.8	82	18	28	39	33
23	2.02	0.78	0.91	2.6	2.5	10.4	87	13	53	47	0
MV- 2	--	--	--	-	-	20.8	69	31	29	51	20
OC- 1	1.64	0.95	0.75	3.2	2.0	1.7	88	12	72	13	15
WW- 2	0.11	1.25	0.80	0.6	2.8	2.1	81	19	77	6	17
MEAN					4.4	3.6	83	17	60	17	23

Sample	HEAVY MINERALS, Non-Opaques: Zircon	Tourmaline	Rutile	Staurolite	Chloritoid	Epidote	Kyanite	Garnet	Hornblende	Apatite	Alterites & Unknowns
AL- 1	53	0	0	0	0	5	0	tr	0	33	9
2	95	0	tr	0	0	0	0	0	0	0	5
4	88	4	tr	tr	3	0	0	1	0	tr	3
6	96	0	2	0	0	1	0	0	0	0	1
7	97	0	0	0	0	0	0	0	0	0	3
8	96	1	1	0	0	0	0	0	0	0	2
9	75	0	0	0	0	0	0	21	0	0	4
10	81	0	0	2	2	0	0	8	1	0	5
11	88	1	0	9	tr	1	1	0	0	0	0
12	94	2	1	1	0	0	0	2	0	0	0
AN- 1	86	1	0	0	0	8	0	2	0	0	3
2	87	2	tr	4	2	tr	0	0	0	0	5
3	98	1	0	0	0	0	0	0	0	0	1
4	97	0	0	0	0	0	0	0	0	0	3
5	93	0	0	1	0	0	0	0	0	0	6
6	99	tr	tr	0	0	0	0	0	0	0	1
7	87	4	4	0	0	0	1	1	1	0	2
8	95	0	0	2	0	0	0	0	0	0	3
9	99	0	0	0	0	0	0	0	0	0	1
10	97	0	0	1	0	0	0	0	0	0	2
FB- 1	87	1	1	5	0	0	0	0	0	0	6
2	95	1	0	1	0	0	0	0	0	0	3
3	90	0	0	1	0	0	0	0	tr	0	9
4	96	0	0	0	0	0	0	0	0	0	4
5	96	tr	tr	0	0	0	0	0	0	0	4
6	94	0	0	0	1	0	0	1	0	0	4
7	97	tr	tr	tr	0	0	0	0	tr	tr	3
8	96	0	0	0	1	tr	0	0	tr	0	3
9	94	tr	0	1	0	0	0	0	0	0	5
10	98	0	0	0	0	0	0	1	0	0	1
11	93	0	0	0	0	0	0	0	0	0	7
13	96	0	0	0	0	0	0	0	0	0	4
14	98	tr	0	0	0	0	0	0	0	0	2
15	100	0	0	0	0	0	0	0	0	0	0
17	91	2	1	0	1	tr	0	tr	0	0	4
18	97	0	0	0	1	tr	0	0	0	0	1
20	95	2	1	0	0	0	0	0	0	0	2
21	98	0	0	0	1	0	0	0	0	0	1
22	87	2	3	5	1	1	0	0	0	0	1
23	93	2	1	0	0	0	0	0	0	0	4
MV- 2	72	5	10	4	1	0	0	0	0	0	8
OC- 1	95	2	0	0	0	0	0	0	0	0	3
WW- 2	96	2	tr	tr	0	0	0	0	0	0	2
MEAN	91.7	0.8	0.6	0.8	0.3	0.2	0.1	0.8	0.1	0.8	32

Sample	LIGHT MINERALS, Sand: Plagiocl.	Microcline	Quartz	Clay bulk: Kaolinite	Illite	Montmor.	Icm at 1K <4Ø: Kaolinite	Illite	Montmor.
AL- 1	4	31	65	0	0.5	1.1	-	-	-
2	0	32	68	0	0	0.6	0.3	0	9.8
4	2	35	63	0.6	0	0.7	-	-	-
6	0	22	78	0	0	0	2.6	1.1	9.0
7	0	22	78	0	1.9	1.2	0	1.3	10.1
8	0	19	81	0	0	1.5	1.4	0	12.2
9	2	24	74	0.4	0	0.4	0	0.6	8.9
10	2	27	71	0.5	0	0.9	3.2	0.7	22.4
11	2	24	74	0	0	0.8	2.6	0.8	13.4
12	3	29	68	1.0	0	1.4	3.3	1.0	15.0
AN- 1	2	27	71	0	0.5	1.1	0.9	1.1	25.6
2	<1	23	77	0	1.0	3.3	1.5	0.7	16.5
3	1	29	70	0	0.6	2.0	0.8	0	17.8
4	<1	29	71	0	0.6	1.8	2.0	0	25.2
5	1	27	72	0.5	0	0	4.4	1.0	8.3
6	1	31	68	0	0	0	2.6	1.2	7.8
7	4	28	68	0	1.1	1.6	-	-	-
8	0	19	81	1.1	0.3	0	5.5	0	1.9
9	0	26	74	0.8	0.5	0	6.4	1.0	2.0
10	0	30	70	0.8	0	0.6	1.7	0	17.2
FB- 1	<1	23	77	0.8	0.3	0.9	6.3	1.2	8.3
2	0	26	74	2.3	0.9	0	7.6	1.2	5.3
3	<1	26	74	1.0	0.5	1.3	3.6	1.1	12.3
4	0	28	72	1.9	0.6	1.2	4.6	0.7	3.5
5	<1	23	77	1.7	1.1	0.6	15.3	2.9	5.2
6	0	23	77	0	0	0	0	0	2.0
7	1	27	72	0	0.6	1.3	-	-	-
8	1	29	70	0	1.1	2.7	0	0.5	32.1
9	<1	22	77	1.2	0.7	1.1	3.8	0	10.9
10	0	0	100	0.6	0	0.5	2.5	0	2.3
11	1	25	74	1.0	1.0	2.9	4.3	2.0	11.8
13	0	31	69	0	0.8	4.5	1.4	0.7	24.0
14	0	20	80	0.6	0	0.5	5.9	0.7	0
15	0	22	78	0.6	0.5	0.6	0.7	0	2.7
17	0	22	78	0	1.4	6.2	0	1.8	30.0
18	0	24	76	0	0.2	0.3	1.7	0	7.4
20	0	21	79	1.9	0	0	18.6	0	2.8
21	2	33	65	0	0.5	1.3	0.7	0.6	16.8
22	0	27	73	0	0	0.5	1.2	0.5	0.7
23	4	31	65	1.3	0	0.8	2.6	0	3.3
MV- 2	0	0	100	-	-	-	-	-	-
OC- 1	0	26	74	0	0.5	3.7	1.6	0	13.6
WW- 2	0	19	81	1.3	0.8	3.6	5.4	1.3	13.5
MEAN	0.7	25.2	73.6						

APPENDIX A - Petrologic data from outcropping Potomac Group sands, Fairfax Co., Va.

		HEAVY MINERALS																		Light Minerals		
				Opaques			Non-Opaques															
	Depth below surface in feet	Opaque	Non-Opaque	White	Black	Red	Zircon	Tourmaline	Rutile	Staurolite	Chloritoid	Epidote	Kyanite	Garnet	Hornblende	Andalusite	Sillimanite	Apatite	Alterites & Unknowns	Plagioclase	Microcline	Quartz
	30-35	87	13	62	16	24	98	0	0	0	0	0	0	0	0	0	0	0	2	1	31	69
U.S.G.S.	35-48	84	16	46	13	41	94	0	1	0	0	0	0	1	0	0	0	1	3	-	--	--
well	40-45	89	11	74	13	13	97	1	0	1	0	0	0	0	0	0	0	0	1	0	33	67
"XI"	45-50	77	23	68	13	19	95	0	0	2	0	0	0	0	1	1	0	0	1	-	--	--
	50-55	83	17	46	18	36	95	1	0	0	0	0	0	0	0	0	0	0	4	-	--	--
	53-58	87	13	46	23	31	92	0	0	1	0	0	0	0	0	0	0	0	7	-	--	--
	68-73	87	13	30	37	33	90	0	0	1	0	1	0	5	0	0	0	0	3	-	--	--
	73-78	91	9	30	32	38	95	0	2	2	0	0	0	0	0	0	0	0	1	0	25	75
	100-110	--	--	--	--	--	90	6	0	1	0	0	0	3	0	0	0	0	0	-	--	--
	158-199	--	--	--	--	--	48	0	0	0	0	0	0	22	0	0	0	22	7	-	--	--
	199-249	--	--	--	--	--	8	0	0	1	0	0	0	69	0	0	0	19	0	-	--	--
	30-37	89	11	38	22	40	94	0	1	1	0	1	0	0	0	0	0	0	3	0	21	79
	37-47	92	8	48	13	39	95	0	0	0	0	0	0	0	0	0	0	1	4	-	--	--
	47-57	86	14	48	12	40	92	1	0	0	0	0	0	1	1	0	0	4	1	0	29	71
	56-67	85	15	51	18	31	82	1	3	2	0	0	0	3	0	0	0	4	5	-	--	--
	80-87	88	12	51	13	36	86	2	1	0	0	0	0	5	0	0	0	3	3	-	--	--
	87-105	86	14	59	10	31	79	3	0	0	0	0	0	2	0	0	0	10	6	1	28	72
	108-128	90	10	44	29	27	87	1	0	0	0	0	0	2	0	0	0	4	6	-	--	--
	128-136	93	7	32	39	29	92	1	1	0	0	0	0	2	0	0	0	1	3	-	--	--
U.S.S.G.	136-146	92	8	21	22	57	94	0	1	1	0	0	0	0	0	0	0	1	3	1	32	68
well	146-163	99	1	14	19	67	81	3	1	1	1	0	0	4	0	0	0	5	4	-	--	--
"GH"	179-204	86	14	16	63	21	51	1	0	1	0	0	0	24	0	0	0	16	7	-	--	--
	214-224	76	24	47	34	19	26	0	0	2	0	0	0	60	0	0	1	4	7	-	--	--
	324-353	71	29	68	18	14	45	0	0	0	0	0	0	35	0	0	0	15	5	-	--	--
	353-373	86	14	40	28	33	25	0	0	0	0	0	0	40	0	0	0	28	6	1	37	62
	373-376	47	53	15	64	21	60	0	0	0	0	0	0	18	0	0	0	17	5	-	--	--
	396-419	88	12	26	39	35	49	0	0	1	0	2	0	20	0	0	0	23	5	-	--	--
	419-447	66	34	24	50	26	40	0	0	0	0	0	0	24	0	1	0	27	8	-	--	--
	439-460	84	16	20	36	44	53	0	2	1	0	0	0	13	1	0	0	24	6	1	35	65
	460-478	72	28	10	43	47	44	1	1	3	0	0	0	18	0	0	0	24	9	-	--	--
	480-490	71	29	22	51	27	42	0	1	11	0	0	2	21	0	0	0	20	3	0	18	82
	450-508	90	10	54	33	12	47	5	1	5	0	0	1	21	0	0	0	16	4	-	--	--

APPENDIX B - Petrologic data from subsurface Potomac Group sands, Fairfax Co., Va.
Light mineral data from x-ray analysis.

		Opaques				Non-Opaques											
Sample	Subsample	White	Black	Red	Non-Opaques	Zircon	Tourmaline	Rutile	Staurolite	Chloritoid	Epidote	Kyanite	Garnet	Andalusite	Hornblende	Apatite	Alterites & Unknowns
OC-1	a	68	18		12	93	3										4
	b	58	5	25	12	97	1										2
Mean		63	12	13	12	95	2										3
	a	79	1	2	18	82	2	2	4	1	1						8
AN-2	b	63	1	30	6	97			1	1							1
	c	47	3	44	6	78	6		2	4							10
	d	44	4	26	26	90	2		1	4							3
Mean		58	2	26	14	87	3	tr	2	3	tr						5
FB-3	a	77	3	1	19	92									1		7
	b	69	1	9	21	88			2								10
Mean		73	2	5	20	90			1						tr		9
FB-5	a	73	1	7	19	98											2
	b	68	7	7	18	93	1	1									
Mean		71	4	7	18	96	tr	tr									
FB-7	a	78	3	2	16	96	tr	tr	tr							tr	3
	b	86	1	5	8	97									1		2
Mean		82	2	4	12	97	tr	tr	tr						tr	tr	3
FB-8	a	71	5	16	8	96				1							3
	b	67	7	8	18	95				1	1				1		2
Mean		69	6	12	13	96				1	tr				tr		3
FB-9	a	60	10	24	6	88	1		2								9
	b	42	15	34	9	99											1
Mean		51	13	29	7	94	tr		1								5
FB-18	a	47	16	18	19	96				2	tr						2
	b	20	50	20	10	97				1	1						1
Mean		34	33	19	14	97				1	tr						1
FB-20	a	48	7	37	8	92	2	2									4
	b	49	5	35	11	99	1										
Mean		49	6	36	9	95	2	1									2

APPENDIX C - Heavy mineral data from subsamples.

APPENDIX D - Petrographic data from six outcrop samples of Potomac Group sands, Fairfax Co., Va.

	Feldspar		Quartz			Rx. Frags.		Opaques & Fe oxide	Musc. Mica	# of grains
	Microcline	Plagioclase	Monoxt.	Composite	Chert	Shale	Other			
AL-4	28.5	1.5	47.5	1.5	0	17.0	2.5	1.5	0	200
AL-6	25.0	0.5	61.0	2.5	0	9.0	0	1.5	0	200
AN-2-b	26.0	0	52.0	3.5	1	7.0	8.5	2.0	0	200
FB-8-b	19.0	1.0	59.8	4.3	0	12.3	2.3	1.3	0.6	300
FB-9-b	27.0	0.5	59.0	3.5	0	8.5	0.5	0.5	0.6	200
FB-20-a	18.3	0	54.0	3.6	0	2.6	2.2	18.5	0.3	300
MEAN	24.0	0.6	55.6	3.2	0.2	9.4	2.7	4.6	0.3	

APPENDIX E - Summary of heavy mineral composition, Potomac Group in Virginia, Maryland and Delaware.

		Potomac Group Undivided — Data from this report					Potomac Group Divided — Data from Glaser, 1969			
		Well "XI" 30'-78'	Well "XI" 158'-249'	Well "GH" (upper pt.) 30'-163'	Well "GH" (lower pt) 179'490'	Outcrops in Fairfax Co., Va.	Patuxent Fm., Va.	Patapsco Raritan Fm., Va.	Patuxent F m., Md.-Del.	Patapsco Raritan Fm., Md.-Del.
Opaques	$\bar{x}$	85.6	-	90.0	76.1	82.7	83.0	82.3	76.8	82.2
	range	77-91	-	85-99	47-90	51-96	77-89	77-86	56-90	65-91
	σ	4.3	-	4.2	12.7	9.6	4.2	4.7	8.4	5.2
Zircon	$\bar{x}$	94.5	28	88.2	43.8	91.7	91.3	92.7	29.3	47.2
	range	90-98	-	79-95	25-60	53-100	84-97	89-95	9-56	10-84
	σ	2.6	-	6.0	10.6	8.7	4.7	3.2	13.9	16.8
Tourmaline	$\bar{x}$	0.3	0	1.2	0.6	0.8	1.5	0.7	20.4	27.0
	range	0-1	-	0-3	0-5	0-5	0-3	0-1	8-45	5-61
	σ	0.5	-	1.1	1.5	1.2	1.1	0.6	9.6	13.4
Rutile	$\bar{x}$	0.4	0	0.8	0.5	0.6	0.1	-0-	1.3	1.9
	range	0-2	-	0-3	0-2	0-10	0-1	0-4	0-3	0-6
	σ	0.7	-	0.9	0.7	1.7	0.4	-	1.1	1.4
Staurolite	$\bar{x}$	0.9	0.5	0.5	2.2	0.8	2.1	2.0	33.9	7.8
	range	0-2	-	0-2	0-11	0-9	0-5	0-4	5-62	1-21
	σ	0.8	-	0.7	3.3	1.7	2.0	2.0	17.6	5.3
Garnet	$\bar{x}$	0.8	45.5	1.9	26.7	0.8	0.1	-0-	-0-	-0-
	range	0-5	-	0-5	13-60	0-21	0-1	-	-	-
	σ	1.8	-	1.7	13.5	3.4	0.4	-	-	-
Kyanite	$\bar{x}$	-0-	0	-0-	0.3	0.05	0.1	-0-	7.6	1.2
	range	-	-	-	0-2	0-1	0-1	-	1-20	0-5
	σ	-	-	-	0.7	-	0.4	-	6.1	1.3
Apatite	$\bar{x}$	0.1	20.5	3.3	19.5	0.8	-0-	-0-	-0-	-0-
	range	0-1	-	0-10	4-28	0-33	-	-	-	-
	σ	0.4	-	2.9	6.9	-	-	-	-	-
Altered	$\bar{x}$	2.8	3.5	3.8	5.9	3.2	4.0	4.0	5.2	10.3
	range	1-7	-	1-6	3-9	0-9	1-8	1-8	2-13	2-25
	σ	2.1	-	1.6	1.8	2.3	2.3	3.6	3.7	4.8
Epidote	$\bar{x}$	0.1	-	0.1	0.2	0.4	-0-	-0-	-0-	-0-
	range	0.1	-	0-1	0-2	0-8	-	-	-	-
	σ	0.4	-	0.3	0.6	1.5	-	-	-	-
Number of samples		9		10	11	44	8	3	21	27

APPENDIX F - Summary of heavy mineral composition, Potomac Group subsurface in Maryland

	Socony-Vaccum Bethards No. 1 Well (Data from Anderson, 1948, Table 11)				Ohio Oil Co.'s L.G. Hammond No. 1 Well (Data from Anderson, 1948, Fig. 2)				Well 3S5E-30 Federal Yeast Co. Dundalk (Data from Anderson, 1948, Table 15)	
	Triassic	Patuxent	Patapsco	Raritan Magothy	Triassic	Patuxent	Patapsco	Raritan Magothy	Patuxent	Patapsco
Thickness	560'	1964'	2106'	370'	126'	891'	2111'	817'	154'	100'
Zircon	11.0	22.8	11.2	15.0	6.4	35.3	16.2	26.5	19.8	47.0
	3-16	7-49	2-31	2-36	3-10	1-91	0-80	0-89	0-60	5-70
	5.6	15.1	8.7	10.7	2.6	23.0	14.1	23.4	20.6	24.6
Tourmaline	20.8	9.6	1.0	3.7	22.9	3.9	1.1	1.0	14.1	36.4
	3-43	1-39	0-3	1-8	13-32	0-68	0-13	0-5	0-40	27-40
	17.4	10.6	1.0	2.3	8.0	9.9	6.9	1.4	12.4	5.7
Rutile	2.0	4.9	1.3	3.2	1.3	2.5	1.5	1.5	3.5	0.2
	0-4	1-11	0-5	0-6	0-3	0-20	0-10	0-8	0-10	0-1
	1.6	3.6	1.5	2.1	1.3	3.4	1.6	1.7	4.1	0.5
Staurolite	3.0	13.2	6.4	12.4	11.0	16.2	7.4	6.5	35.7	6.0
	0-15	2-58	2-15	2-38	3-19	0-64	0-27	0-16		0-30
	2.9	14.7	3.4	13.1	6.1	14.6	9.5	4.1	17.1	13.4
Garnet	25.0	30.4	8.0	3.3	38.5	34.2	12.9	5.0	-0-	1.4
	1-56	4-60	4-12	1-11	18-56	0-82	0-59	0-15	-	0-5
	22.8	20.4	2.5	3.0	12.2	25.3	10.7	4.0	-	2.1
Kyanite	-0-	0.1	0.7	2.5	-0-	0.1	0.7	1.6	16.5	4.2
	-	0-1	0-3	0-10	-	0-1	0-5	0-5	1-40	0-20
	-	0.3	0.9	2.9	-	0.3	1.2	1.7	12.8	8.8
Apatite	11.5	1.4	1.5	0.1	7.3	1.0	1.2	0.2	-0-	-0-
	4-24	0-3	0-5	0-1	0-18	0-8	1-5	0-3	-	-
	9.9	1.4	1.6	0.3	7.0	1.8	1.4	0.6	-	-
Epidote +	4.3	3.9	61.1	49.8	-0-	1.1	52.2	40.1	-0-	-0-
Zoisite +	0-16	0-34	24-82	0-78	-	0-11	0-78	0-77	-	-
Clinozoisite	7.8	9.0	17.7	27.3	-	2.5	16.7	26.4	-	-
Number of samples	4	14	12	10	8	53	168	31	13	5

Appendix G - Location of sample stations. Localities with asterisk are from Weir, (1975, Table 4). Locality map (Figure 13) in pocket.

ALEXANDRIA QUADRANGLE

AL-1* Outcrops along west bank of Pike Creek near Burgundy Village Subdivision about 1,000 ft. from mouth of creek

AL-2* Outcrops along unnamed stream about 200 ft. south of U.S. No. 1, about 0.4 mi. northeast of Penn Daw.

AL-4 Outcrop on west side of Pickett St., 500 feet south of Rt. 236.

AL-6 Outcrop behind stores on north side of Rt. 236, about 500 feet east of intersection with Gordon St.

AL-7 Outcrop along Taylor Run near intersection of Taylor Run Pkwy. and Dartmouth Rd.

AL-8 Outcrop along Taylor Run about 1,100 feet southeast of point where Rt. 7 crosses Taylor Run.

AL-9 Outcrop along south bank of Fourmile Run about 1,900 feet west of I-395 (Shirley Hwy.).

AL-10 Outcrop along south bank of Fourmile Run 900 feet west of AL-9.

AL-11 Outcrop along south bank of Fourmile Run 150 feet east of bridge (Walter Reed Dr.), and 1,400 feet west of AL-10.

AL-12 Outcrop on west side of Harrison Lane, 0.48 miles south of (Rt. 238 (Kings Hwy.).

ANNANDALE QUADRANGLE

AN-1* Outcrops on cuts and along roads of borrow pits 200-800 ft. northeast of Hayfield Road between Telegraph Road and Old Telegraph Road.

AN-2* Cut on northeast side of 7th St. between Cherokee Avenue and Virginia Street, Weyanoke Subdivision.

AN-3* Outcrops in gully along service road in quarry about 0.4 mi. northwest of junction of Hayfield Road and Old Telegraph Road.

AN-4* Outcrops along service road and power line about 700 to 1,000 ft. about 1.3 mi. northeast of junction of Hayfield Road and Old Telegraph Road.

AN-5* Cuts on west side of Richmond, Fredericksburg, and Potomac Railroad east of Loisdale Estates Subdivision, about 1.3 mi. southeast of I-95 interchange at Springfield.

AN-6* Cuts on east side of R., F., and P. RR. about 1,000 ft. south of I-495 west of Mt. Hebron Park Subdivision.

AN-7* Outcrops in gully south of Chamblis Street bicycle path (Alexandria City).

AN-8* Cuts on south side of Cherokee Road about 900 ft. southwest of Cherokee Run.

AN-9 Large outcrop south of Eisenhower Dr., 0.6 miles east of intersection with S. Van Dorn St.

AN-10 Outcrop behind warehouses south of Eisenhower Dr., about 800 feet west of AN-9, and 100 feet north of railroad.

FORT BELVOIR QUADRANGLE

FB-1* Cuts on access road to R., F., and P. RR. on east side of overpass of Pohick Road, Va. #638.

FB-2* Cuts along R., F., and P. RR. 0.5 mi. north of underpass at Newington.

FB-3* Outcrops on west side of Silver Brook Road near junction with Lorton Road.

FB-4* Cut along R. F. & P. RR. 0.3 mi. south of Lorton Road.

FB-5* Cut along R. F. & P. RR. 0.6 mi. south of Lorton Road.

FB-6* Cuts on east side of U.S. No. 1, 0.2 mi. southwest of junction with Pohick Road, Va. #638.

FB-7* Cuts on northeast side of U.S. Govt. R.R. (Ft. Belvoir Mil. Res.), about 1 mi. NE of U.S. No. 1 at Accotink.

FB-8* Ditch exposures along dirt road to Massey Cr. from Belmont Blvd., west side of Mason Neck.

FB-9* Bluff behind newly constructed (11/75) warehouses, west side of Telegraph Road, 0.3 mi. north of U.S. No. 1.

FB-10* Outcrops along service road on east side of dump on east side of Furnace Road about 1.4 mi. south of Lorton.

FB-11* Unmapped borrow pit about 800 feet east of Furnace Road, 0.7 mi. southeast of Lorton.

FB-13* Cut behind house, on east side of U.S. No. 1 about 0.5 mi. southwest of junction with Gunston Road, Va. #242.

FB-17* Outcrops near junction of dirt roads in southwestern part of Ft. Belvoir Military Reservation, about 1.8 mi. west-southwest of Accotink.

FB-18* (A) Cuts along dirt road to south-southwest in southwestern part of Ft. Belvoir Military Reservation about 0.8 mi. southwest of Accotink.

(B) Landfill cut about 1,000 ft. north of A.

FB-20* Gravel pit in southeastern part of Ft. Belvoir Military Reservation about 1.2 mi. south-southeast of Accotink.

FB-21* Ditch exposures along dirt road in northeastern part of Ft. Belvoir Military Reservation about 1.8 mi. north-northeast of Accotink.

FB-22 Outcrop on south side of U.S. Rt. 1, about 600 ft. west of entrance road to Davidson Airfield (part of Ft. Belvoir).

FB-23 Outcrop in stream bed northwest of parking lot for Woodlawn Plantation.

MT. VERNON QUADRANGLE

MV-2 Small outcrop on hill east of Whitman School athletic field.

OCCOQUAN QUADRANGLE

OC-1* Cuts on northwest side of Lorton Road about 800 ft. east-northeast of junction with Ox Road.

WASHINGTON WEST, D.C.-MD.-VA. QUADRANGLE

WW-2 Outcrop behind 1309 Veitch St., 900 feet south of Wilson Blvd. Questionable Cretaceous outcrop.