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Geochemical data for Triassic sedimentary and thermally metamorphosed  
rocks of the northern Culpeper basin, Virginia

by

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U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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## List of figures, tables, and appendices

### Figures

- Figure 1. Index map of Culpeper basin and vicinity, Virginia and Maryland, showing location of Figure 3.
- Figure 2. Index map of Newark Supergroup in eastern North America, showing location of Culpeper basin, Va.
- Figure 3. Locations of chemically analyzed Triassic-Jurassic sedimentary and thermally metamorphosed rock samples, northern Culpeper basin, Va.

### Tables

- Table 1. Three suites of thermally metamorphosed Triassic rocks sampled at intervals progressively further from the contact with intrusive Jurassic diabase.
- Table 2A. Whole-rock major element compositions of fine-grained sedimentary rocks from the northern Culpeper basin, Va. (shale and siltstone).
- Table 2B. Whole-rock major element compositions of coarse-grained sedimentary rocks from the northern Culpeper basin, Va. (sandstone and conglomerate).
- Table 3A. Whole-rock major element compositions of fine-grained contact metamorphic rocks from the northern Culpeper basin, Va. (hornfels).
- Table 3B. Whole-rock major element compositions of coarse-grained contact metamorphic rocks from the northern Culpeper basin, Va. (sandstone and conglomerate).

## Appendix

- 1A. Sample locations of sedimentary rocks from the northern Culpeper basin, Va.
- 1B. Sample locations of contact metamorphic rocks from the northern Culpeper basin, Va.
- 2A. Semiquantitative minor and trace element compositions of fine-grained sedimentary rocks from the northern Culpeper basin, Va. (shale and siltstone).
- 2B. Semiquantitative minor and trace element compositions of coarse-grained sedimentary rocks from the northern Culpeper basin, Va. (sandstone and conglomerate)
- 3A. Semiquantitative minor and trace element compositions of fine-grained contact metamorphic rocks from the northern Culpeper basin, Va. (hornfels).
- 3B. Semiquantitative minor and trace element compositions of coarse-grained contact metamorphic rocks from the northern Culpeper basin, Va. (sandstone and conglomerate).

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Geology of the Culpeper basin

The Culpeper basin (fig. 1) is a north-northeast-trending faulted trough at the inner margin of the Piedmont geologic province along the east front of the Blue Ridge. The basin is about 20 km (12.4 miles) wide and extends for about 140 km (87 miles) north from the Rapidan River near Madison Mills, Virginia, across the Potomac River and terminates near Frederick, Maryland. It is part of a belt of similar Newark rift-basin structures, all of early Mesozoic age, which lie along the east coast of North America from Florida to Nova Scotia (fig. 2).

The sedimentary rocks of the Culpeper basin are part of the Newark Supergroup, and comprise a distinctive sequence of clastic strata (Culpeper Group) ranging in age from Late Triassic to Early Jurassic (Cornet, 1977). The Triassic section is predominantly comprised of non-marine arkosic sandstone and siltstone ("red beds") with a variety of lenticular conglomerates and minor amounts of red, green and dark gray shale. The Jurassic sequence also contains red beds and lenticular conglomerates, but is characterized by a series of intercalated basalt flows and lacustrine gray and black shales.

Most of the Culpeper Group is intruded and locally metamorphosed by dikes, sills, and stocks of tholeiitic diabase (Lee, 1977, 1979, 1980; Lee and others, 1984; Lindholm, 1977a, 1979); the Hartford, Newark, and Gettysburg basins include similar igneous rocks (Puffer and Lechler, 1980). This report deals with two suites of samples in the northern part of the Culpeper basin in Virginia, one from the thermally metamorphosed aureole of sedimentary rocks adjacent to diabase, the other a basically similar suite of unmetamorphosed sedimentary rocks far removed from the thermal influence of intrusive diabase (fig. 3 and Appendix 1A and 1B).

Sampling and Analysis

The rocks discussed herein were collected by K. Y. Lee in conjunction with reconnaissance mapping in the northern Culpeper basin. Forty-three outcrop samples from Triassic sedimentary rocks (siltstone, shale, and sandstone) and 36 samples of metamorphosed clastic rocks (hornfels, granofels, metaconglomerate and quartzite) and 1 sample of limestone metaconglomerate (marble) (Appendix 1A and 1B, and fig. 3) were analyzed quantitatively for 12 major elements by atomic absorption spectrophotometry (Shapiro, 1975) (Tables 2A and 2B, 3A and 3B). Semiquantitative spectrographic measurements (Dorrszapf, 1973) were

performed for 59 minor or trace elements, including 11 rare-earth elements (REE)(Appendix 2A, 2B, 3A and 3B).

Three suites of the metamorphosed clastic rocks were sampled at intervals progressively further from the intrusive contacts (Table 1); these suites document progressive mineralogic and chemical changes reflecting change in thermal metamorphic grade. Hornfels in contact aureoles have a proximal zone 2 to 5 m wide, characterized by biotite, cordierite, plagioclase and quartz; a central zone 15 to 100 m wide consisting of cordierite, plagioclase, andalusite and quartz; and an outer zone 20 to 90 m wide of epidote, chlorite and quartz (Lee, 1982, p. 34). Granofels contains hornblende, plagioclase (mostly albite), sphene and myrmekite in a proximal zone about 10 m wide; a central zone of black tourmaline, recrystallized feldspar and fused quartz about 16 m wide; and an outer zone 10 to 30 m wide in which epidote, spot-bleached feldspar, and chlorite are common. Quartzite contains abundant andalusite in a zone 10-20 m wide and locally forms fused bands within granofels. Marble consists of calcite, andradite, diopside and serpentine with minor vesuvianite, wollastonite, magnetite, scapolite, idocrase, xonotlite and possibly colerainite in a zone 50 to 250 m wide (Lee, 1982, p. 34; Bernstein, 1976).

#### Major Element Geochemistry

Whole-rock major element analyses of the Triassic sedimentary rocks (Table 2A and 2B) show a wide range of variability; for example,  $\text{SiO}_2$  contents in siltstone and shales range from 34.8 (calcisiltite) to 72.8%, in sandstones from 48.7 (calcareous) to 79.8%. Hornfels, derived by contact metamorphism of siltstone and shale, show similar ranges in silica variation, and metamorphosed arkosic sandstones are comparable to their unmetamorphosed counterparts (Tables 3A and 3B). Although the data are not unequivocal, the major element chemistry of thermally metamorphosed rocks in proximity to the chilled margin of intrusive diabase is somewhat closer to that of diabase, particularly for  $\text{TiO}_2$ ,  $\text{Na}_2\text{O}$ , and  $\text{SiO}_2$ , than for similar metasedimentary rocks more distant from the intrusive contact (see Lee and others, 1984, for diabase geochemistry). This suggests that a limited exchange of material and mutual interreaction may have occurred between intrusive diabase and metasedimentary host rock material.

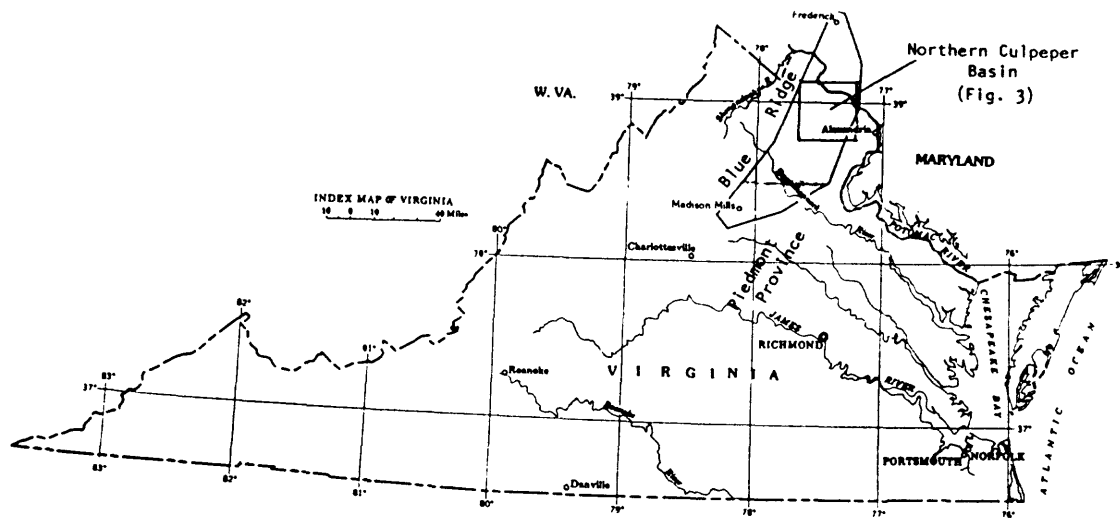


Figure 1.--Location of Culpeper basin and vicinity.

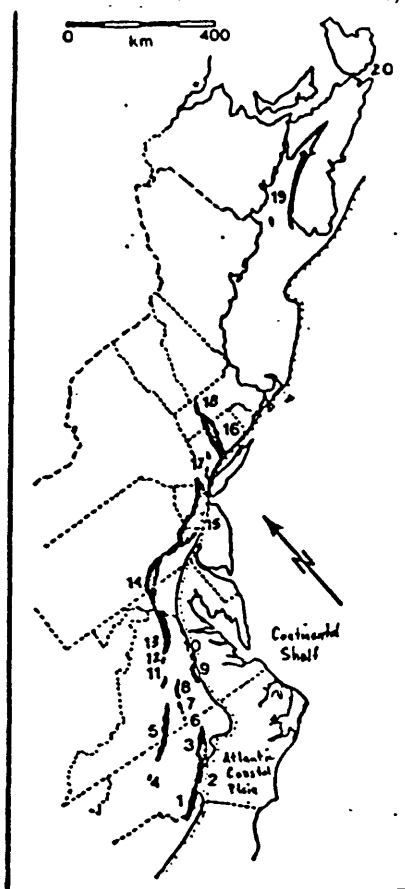


Figure 2. The Newark Supergroup of eastern North America. Exposed basins.

- |                                         |                                            |
|-----------------------------------------|--------------------------------------------|
| 1. Wadesboro (N.C.-S.C.)                | 11. Scottsville (Va.)                      |
| 2. Sanford (N.C.)                       | 12. Barboursville (Va.)                    |
| 3. Durham (N.C.)                        | 13. Culpeper (Va.-Md.)                     |
| 4. Davie County (N.C.)                  | 14. Gettysburg (Md.-Pa.)                   |
| 5. Dan River and<br>Danville (N.C.-Va.) | 15. Newark (N.J.-Pa.-N.Y.)                 |
| 6. Scottsburg (Va.)                     | 16. Hartford (Conn.)                       |
| 7. Basins north of<br>Scottsburg (Va.)  | 17. Pomperaug (Conn.)                      |
| 8. Farnville (Va.)                      | 18. Deerfield (Mass.)                      |
| 9. Richmond (Va.)                       | 19. Fundy or Minas<br>(Nova Scotia-Canada) |
| 10. Taylorsville (Va.)                  | 20. Chedabucto (Nova<br>Scotia-Canada)     |

## Minor and Trace Element Geochemistry

No conclusive statements can be made about the chemistry of sedimentary rocks and their metamorphosed equivalents in the Culpeper basin on the basis of the semiquantitative analyses reported here (Appendix 2A, 2B, 3A and 3B). However, the data for boron and barium in proximity to diabase suggest that late stage volatiles from the diabase may be the source. Also, slightly increased values for Ni, Cr and Co in hornfels at Bull Run Quarry and for Ni, Co and V in hornfels at Chantilly Quarry suggest local enrichment from nearby diabase sources. In contrast, anomalously high values for Zr at Evergreen Mills more likely reflects original heavy mineral placer accumulation in quartzite, granulite and conglomerate layers than proximity to an igneous source. Finally, scattered high values for Ag (6.2 ppm) and Cu (1350 ppm) in marble and for Pb, Zn, Cu, Ag in widely separated samples of metamorphic and sedimentary rocks apparently reflect minor veinlet occurrences and low-grade, locally mineralized areas.

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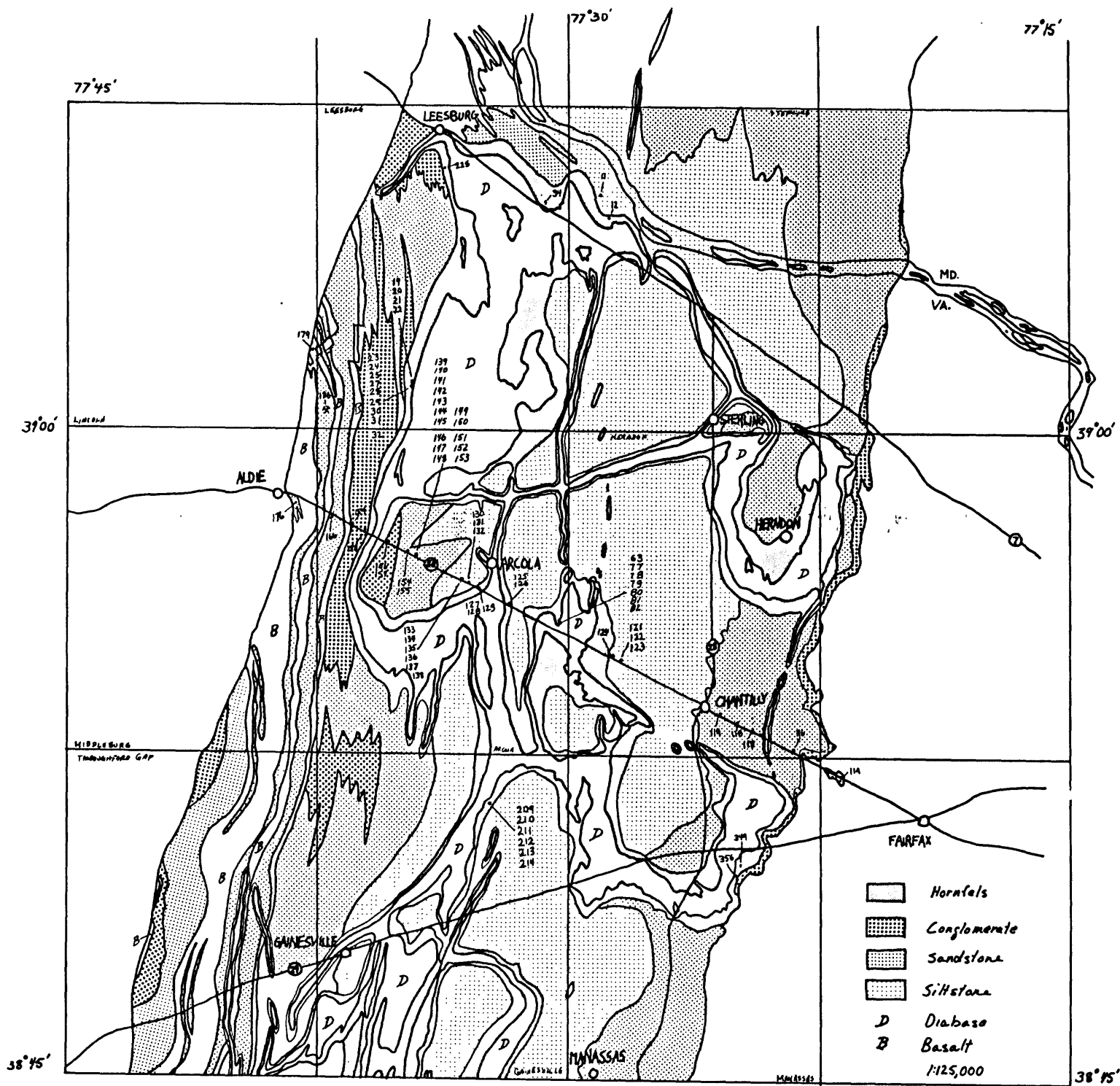
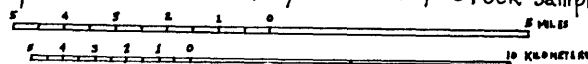


Figure 3. Locations of chemically analyzed Triassic-Jurassic sedimentary and metamorphic rock samples, northern Culpeper basin, Virginia



CHANTILLY QUARRY

Herndon Quad  
38°55'30"N. Lat  
77°30'30"W. Long

EVERGREEN MILLS

Leesburg Quad  
39°01'00"N. Lat  
77°35'30"W. Long

BULL RUN QUARRY

Gainesville Quad.  
38°51'22"N. Lat  
77°32'27"W. Long

| Sample No.   | Interval <sup>1</sup><br>(Distance) <sup>2</sup> | Lithology           | Sample No.   | Interval <sup>1</sup><br>(Distance) <sup>2</sup> | Lithology                     | Sample No.    | Interval <sup>1</sup><br>(Distance) <sup>2</sup> | Lithology  |
|--------------|--------------------------------------------------|---------------------|--------------|--------------------------------------------------|-------------------------------|---------------|--------------------------------------------------|------------|
| 82           | (27.5 M)<br>10 M                                 | Hornfels            | 32           | (59.6 M)<br>1.5 M                                | Granulite vfg                 | 209           | (14.5 M)<br>3 M                                  | Hornfels   |
| 81           | (17.5 M)<br>3 M                                  | Cordierite Hornfels | 31           | (58.1 M)<br>6 M                                  | Granulite f-mg                | 210           | (11.5 M)<br>1.5 M                                | Hornfels   |
| 80           | (14.5 M)<br>3 M                                  | Cordierite Hornfels | 30           | (52.1 M)<br>10 M                                 | Metaconglomerate (ls,qtzite)  | 211           | (10 M)<br>3 M                                    | Hornfels   |
| 79           | (11.5 M)<br>3.5 M                                | Cordierite Hornfels | 29           | (42.1 M)<br>2 M                                  | Granulite f-mg                | 212           | (7 M)<br>3 M                                     | Cordierite |
| 78           | ( 8 M)<br>4 M                                    | Cordierite Hornfels | 28           | (40.1 M)<br>1 M                                  | Granulite f-mg                | 213           | (4 M)<br>3 M                                     | Hornfels   |
| 77           | ( 4 M)<br>4 M                                    | Cordierite Hornfels | 27           | (39.1 M)<br>6 M                                  | Meta conglomerate (ls,qtzite) | 214           | (1 M)<br>1 M                                     | Hornfels   |
| 85 - Diabase |                                                  | Contact             | 25           | (33.1 M)<br>6 M                                  | Hornfels                      | Contact       |                                                  |            |
|              |                                                  |                     | 24           | (27.1 M)<br>6 M                                  | Granulite                     | 215 - Diabase |                                                  |            |
|              |                                                  |                     | 23           | (26.1 M)<br>7.5 M                                | Quartzite                     |               |                                                  |            |
|              |                                                  |                     | 22           | (18.6 M)<br>1.6 M                                | Hornfels                      |               |                                                  |            |
|              |                                                  |                     | 21           | (17 M)<br>3 M                                    | Hornfels                      |               |                                                  |            |
|              |                                                  |                     | 20           | (14 M)<br>8 M                                    | Hornfels                      |               |                                                  |            |
|              |                                                  |                     | 19           | ( 6 M)<br>6 M                                    | Metaconglomerate (ls)         |               |                                                  |            |
|              |                                                  |                     | 18 - Diabase |                                                  | Contact                       |               |                                                  |            |

Table 1 - Three suites of thermally metamorphosed Triassic rocks sampled at intervals further from the contact with intrusive Jurassic diabase.

<sup>1</sup>Interval is distance in meters between samples measured perpendicular to bedding and to paraconformable contact with diabase.  
<sup>2</sup>Distance is cumulative distance in meters away from diabase contact.

# WHOLE-ROCK MAJOR ELEMENT ANALYSES OF FINE-GRAINED SEDIMENTARY ROCKS

FROM THE NORTHERN CULPEPER BASIN, VA.

**Analysts:** Joseph L. Harris, Charles S. Ansell, Janet D. Fletcher, Floyd Brown, Herbert Kirschenbaum, Leonard Shapiro (1973, 1974, 1975)

[illegible]

TABLE 2B

## WHOLE-ROCK MAJOR ELEMENT ANALYSES OF COARSE-GRAINED SEDIMENTARY ROCKS

FROM THE NORTHERN CULPEPER BASIN, VA.

Analysts: Joseph L. Harris, Charles S. Annell, Floyd Brown, Leonard Shapiro (1974, 1975)

| Wt. %<br>Oxide<br>W#           |      | S A N D S T O N E |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |  |  |  |
|--------------------------------|------|-------------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--|--|--|
|                                |      | 114<br>182446     | 117<br>182448 | 118<br>182449 | 119<br>182450 | 132<br>182462 | 137<br>182467 | 146<br>182476 | 147<br>182477 | 148<br>182478 | 149<br>182479 | 150<br>182480 | 151<br>182481 | 152<br>182482 | 155<br>182485 | 156<br>182486 | 157<br>182487 | 159<br>182489 |  |  |  |
| SiO <sub>2</sub>               | 71.8 | 68.9              | 70.3          | 70.2          | 73.8          | 75.9          | 76.7          | 65.5          | 58.7          | 60.5          | 66.6          | 62.0          | 61.2          | 70.5          | 62.7          | 48.7          | 79.8          |               |  |  |  |
| Al <sub>2</sub> O <sub>3</sub> | 14.1 | 15.5              | 13.3          | 11.9          | 8.1           | 10.4          | 11.1          | 11.5          | 10.4          | 11.6          | 12.8          | 11.3          | 11.8          | 12.3          | 12.2          | 10.2          | 10.8          |               |  |  |  |
| Fe <sub>2</sub> O <sub>3</sub> | 4.7  | 3.5               | 4.1           | 5.0           | 4.8           | 3.4           | 3.1           | 5.2           | 4.8           | 4.7           | 7.8           | 5.3           | 4.3           | 5.2           | 4.1           | 6.5           | 3.7           |               |  |  |  |
| FeO                            | .32  | .28               | .48           | .56           | .28           | 1.0           | .28           | .80           | .72           | .88           | .68           | 1.3           | 1.6           | 1.0           | 1.4           | 1.4           | .40           |               |  |  |  |
| MgO                            | 0.85 | 0.55              | 1.1           | 0.96          | 2.3           | 0.82          | 0.58          | 0.98          | 1.1           | 0.84          | 0.93          | 1.7           | 1.8           | 1.8           | 1.8           | 2.4           | 0.27          |               |  |  |  |
| CaO                            | 0.16 | 0.14              | 0.83          | 0.78          | 0.96          | 0.15          | 0.77          | 4.0           | 8.9           | 6.9           | 0.52          | 5.3           | 5.9           | 0.83          | 4.8           | 12.1          | 0.33          |               |  |  |  |
| Na <sub>2</sub> O              | 0.01 | 4.3               | 4.6           | 4.3           | 1.7           | 2.1           | 2.9           | 2.1           | 1.9           | 1.9           | 2.3           | 2.2           | 2.1           | 3.1           | 2.3           | 2.4           | 0.5           |               |  |  |  |
| K <sub>2</sub> O               | 2.5  | 2.6               | 1.6           | 0.78          | 1.3           | 1.4           | 1.7           | 2.6           | 2.4           | 2.7           | 3.0           | 2.4           | 2.6           | 2.0           | 2.6           | 1.9           | 1.2           |               |  |  |  |
| H <sub>2</sub> O+              | 3.5  | 1.6               | 1.1           | 1.1           | 2.8           | 1.7           | 1.1           | 1.5           | 1.4           | 1.6           | 1.6           | 1.7           | 1.5           | 1.8           | 1.7           | 1.6           | 3.0           |               |  |  |  |
| H <sub>2</sub> O-              | 1.1  | .47               | .54           | .78           | .84           | .26           | .57           | .34           | .21           | .30           | .33           | .41           | .26           | .60           | .24           | .38           | .19           |               |  |  |  |
| TiO <sub>2</sub>               | 0.55 | 0.91              | 1.0           | 1.8           | 1.4           | 1.2           | 0.77          | 1.4           | 1.2           | 1.2           | 1.8           | 1.6           | 1.4           | 1.5           | 1.2           | 1.9           | 0.77          |               |  |  |  |
| P <sub>2</sub> O <sub>5</sub>  | .16  | .03               | .31           | .36           | .26           | .08           | .15           | .20           | .19           | .19           | .26           | .28           | .21           | .22           | .20           | .21           | .21           |               |  |  |  |
| MnO                            | .00  | .03               | .09           | .00           | .26           | .08           | .02           | .05           | .09           | .08           | .11           | .070          | .07           | .08           | .10           | .13           | .10           |               |  |  |  |
| CO <sub>2</sub>                | .01  | .01               | .01           | .01           | .02           | .01           | .02           | 2.9           | 6.6           | 5.1           | .07           | 3.7           | 4.5           | .08           | 3.2           | 8.7           | .03           |               |  |  |  |
| SUM                            | 100  | 99                | 99            | 99            | 99            | 99            | 100           | 99            | 99            | 99            | 99            | 99            | 99            | 101           | 99            | 99            | 101           |               |  |  |  |

TABLE 3A  
WHOLE-ROCK MAJOR ELEMENT ANALYSES OF FINE-GRAINED CONTACT METAMORPHIC ROCKS  
FROM THE NORTHERN CULPEPER BASIN, VA.

|                                |  | HORNFELS (SILTSTONE / SHALE) |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |
|--------------------------------|--|------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|--|
|                                |  | 20                           | 21     | 25     | 34     | 63     | 77     | 78     | 79     | 80     | 81     | 82     | 125    | 128    | 129    | 209    | 210    | 211    | 212    | 213    | 214    |  |  |
| wt. %                          |  | 181308                       | 181309 | 181313 | 181323 | 181868 | 181869 | 181860 | 181861 | 181862 | 181863 | 181864 | 182455 | 182458 | 182459 | 182511 | 182512 | 182513 | 182514 | 182515 | 182516 |  |  |
| Oxide                          |  | 12                           | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     | 12     |  |  |
| Mg                             |  | 63.1                         | 63.9   | 61.5   | 64.6   | 56.6   | 54.5   | 53.8   | 59.1   | 62.2   | 57.1   | 52.8   | 58.6   | 49.7   | 57.8   | 51.1   | 60.6   | 72.8   | 60.1   | 61.0   | 59.0   |  |  |
| Al <sub>2</sub> O <sub>3</sub> |  | 14.2                         | 16.2   | 14.5   | 13.2   | 20.4   | 20.1   | 19.9   | 17.5   | 17.2   | 18.2   | 17.7   | 16.8   | 12.1   | 14.1   | 18.9   | 14.5   | 10.7   | 16.9   | 16.2   | 17.2   |  |  |
| Fe <sub>2</sub> O <sub>3</sub> |  | 4.2                          | 2.6    | 3.1    | 3.4    | 5.4    | 8.6    | 8.5    | 5.9    | 5.2    | 5.8    | 5.3    | 3.3    | 1.6    | 3.9    | 6.4    | 4.4    | 3.9    | 4.5    | 5.4    | 3.8    |  |  |
| FeO                            |  | .88                          | .48    | 1.1    | 1.1    | 2.4    | 1.4    | 1.5    | 1.1    | 1.5    | 1.9    | 2.4    | 2.8    | 2.9    | 2.2    | 3.4    | 2.6    | 1.2    | 2.1    | 1.7    | 3.2    |  |  |
| MgO                            |  | 2.7                          | 2.2    | 2.3    | 3.3    | 2.6    | 2.6    | 2.5    | 3.2    | 2.4    | 2.8    | 4.3    | 4.7    | 3.2    | 2.8    | 3.9    | 3.7    | 1.3    | 2.5    | 2.7    | 3.3    |  |  |
| CaO                            |  | 3.8                          | 1.4    | 1.1    | 4.5    | .80    | 1.2    | 1.6    | 3.1    | 2.0    | 3.3    | 7.0    | 0.74   | 11.8   | 5.5    | 3.1    | 2.2    | 0.66   | 1.2    | 1.9    | 2.2    |  |  |
| Na <sub>2</sub> O              |  | 4.2                          | 6.7    | 3.9    | 4.7    | 3.6    | 3.6    | 4.0    | 3.7    | 4.2    | 4.4    | 3.1    | 2.4    | 2.3    | 2.9    | 3.6    | 5.0    | .93    | 5.2    | 4.4    | 3.4    |  |  |
| K <sub>2</sub> O               |  | 3.7                          | 2.2    | 6.8    | 3.0    | 4.7    | 4.6    | 4.8    | 3.5    | 3.3    | 3.3    | 4.7    | 2.6    | 2.0    | 2.5    | 4.3    | 1.7    | 5.1    | 4.3    | 3.6    | 3.7    |  |  |
| H <sub>2</sub> O+              |  | .68                          | .99    | 1.2    | .4     | 2.4    | 2.4    | 3.2    | 1.4    | 2.0    | 1.3    | 1.9    | 4.2    | 2.5    | 2.0    | 2.0    | 2.4    | 1.0    | 1.3    | 1.3    | 1.5    |  |  |
| H <sub>2</sub> O-              |  | .45                          | .58    | .60    | .1     | .43    | .65    | .05    | .72    | .16    | .59    | .39    | 1.3    | .31    | .29    | .62    | .39    | .08    | .10    | .06    | .15    |  |  |
| TiO <sub>2</sub>               |  | .97                          | .98    | .90    | .8     | .94    | 1.1    | 1.0    | .82    | .83    | .94    | .94    | 0.73   | 1.1    | 0.77   | 0.92   | 1.1    | 0.76   | 0.91   | 0.96   | 1.1    |  |  |
| P <sub>2</sub> O <sub>5</sub>  |  | .17                          | .14    | .13    | .1     | .18    | .15    | .27    | .15    | .12    | .21    | .27    | .27    | .21    | .19    | .27    | .18    | .15    | .21    | .23    | .20    |  |  |
| MnO                            |  | .03                          | .00    | .00    | .0     | .02    | .00    | .00    | .05    | .00    | .00    | .16    | .06    | .18    | .10    | .16    | .17    | .05    | .06    | .08    | .10    |  |  |
| CO <sub>2</sub>                |  | .10                          | .08    | .09    | .0     | .03    | .01    | .01    | .01    | .18    | .01    | .01    | .01    | .91    | 3.7    | .08    | .94    | 2.2    | .41    | .60    | .05    |  |  |
| SUM                            |  | 99                           | 99     | 100    | 99     | 101    | 101    | 101    | 100    | 101    | 100    | 101    | 99     | 99     | 99     | 99     | 100    | 101    | 100    | 100    | 99     |  |  |

TABLE 3B - WHOLE-ROCK MAJOR ELEMENT ANALYSES OF COARSE-GRAINED CONTACT METAMORPHIC ROCKS  
from  
THE NORTHERN CULPEPER BASIN, VA.

| Wt. %<br>Oxide<br>W#           | "BAKED" SANDSTONE |              |              |              |              |              |               |               |               |               | GRANULITE    |              |              |               |               |      |  |  |  |  | "BAKED" CONGLOMERATE |  |  |  |  |  |  |  |  |  |
|--------------------------------|-------------------|--------------|--------------|--------------|--------------|--------------|---------------|---------------|---------------|---------------|--------------|--------------|--------------|---------------|---------------|------|--|--|--|--|----------------------|--|--|--|--|--|--|--|--|--|
|                                | 23<br>181310      | 24<br>181311 | 28<br>181312 | 29<br>181316 | 31<br>181319 | 32<br>181320 | 126<br>182456 | 127<br>182457 | 349<br>184771 | 356<br>184773 | 19<br>181307 | 27<br>181315 | 30<br>181318 | 179<br>182497 | 225<br>184770 |      |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| SiO <sub>2</sub>               | 65.6              | 66.4         | 62.4         | 63.8         | 63.1         | 62.8         | 55.8          | 77.8          | 69.4          | 74.7          | 66.7         | 50.1         | 42.8         | 44.8          | 43.6          | 0.47 |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| Al <sub>2</sub> O <sub>3</sub> | 15.0              | 12.5         | 11.2         | 13.1         | 12.0         | 14.7         | 14.3          | 10.7          | 12.4          | 11.8          | 12.4         | 10.0         | 8.3          | 8.1           | 12.6          | .92  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| Fe <sub>2</sub> O <sub>3</sub> | 3.9               | 2.0          | 1.4          | 2.4          | .82          | 3.0          | 2.3           | 1.9           | 4.9           | 3.9           | 5.1          | 2.5          | 4.0          | 2.7           | 3.4           | 3.3  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| FeO                            | .76               | 1.4          | 1.4          | 1.4          | 1.4          | 1.3          | 2.1           | .28           | .56           | .40           | .72          | 2.7          | 2.4          | 1.7           | 5.3           | .20  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| MgO                            | 2.5               | 2.0          | 2.6          | 2.5          | 2.6          | 2.4          | 3.0           | 0.51          | 1.6           | 2.2           | 1.9          | 5.0          | 3.8          | 3.8           | 6.3           | .47  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| CaO                            | 1.0               | 4.3          | 7.7          | 4.8          | 6.9          | 3.0          | 7.7           | 0.51          | 1.0           | .93           | 2.4          | 15.7         | 19.7         | 20.4          | 16.3          | 55.2 |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| Na <sub>2</sub> O              | 5.6               | 5.3          | 4.7          | 4.4          | 4.9          | 5.3          | 5.4           | 5.5           | 5.0           | 1.9           | 5.8          | 3.8          | 1.8          | 2.5           | 1.6           | .14  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| K <sub>2</sub> O               | 2.2               | .29          | .10          | 1.0          | .00          | 1.5          | .41           | .10           | 1.3           | .71           | 1.4          | .38          | .38          | .20           | .39           | .05  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| H <sub>2</sub> O+              | .10               | 1.1          | 1.5          | 2.2          | 1.3          | 1.3          | 1.7           | .65           | 1.2           | 1.3           | .45          | 1.4          | 2.0          | 1.3           | 1.9           | .32  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| H <sub>2</sub> O-              | .81               | .32          | .46          | .48          | .44          | .30          | .38           | .22           | .97           | .15           | .08          | .56          | .72          | .70           | 1.1           | .02  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| TiO <sub>2</sub>               | .96               | .77          | .84          | .87          | .82          | 1.0          | .84           | 0.89          | 0.87          | .54           | 1.4          | .59          | .44          | .44           | 1.1           | .12  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| P <sub>2</sub> O <sub>5</sub>  | .15               | .11          | .17          | .12          | .15          | .12          | .14           | .08           | .13           | .03           | .24          | .09          | .10          | .07           | .15           | .23  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| MnO                            | .00               | .00          | .03          | .00          | .01          | .00          | .02           | .00           | .07           | .03           | .04          | .18          | .11          | .08           | .16           | .03  |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| CO <sub>2</sub>                | .05               | 3.1          | 5.4          | 2.8          | 5.0          | 2.9          | 4.8           | .02           | .05           | .05           | .05          | 5.8          | 13.0         | 11.8          | 6.0           | 37.8 |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |
| SUM                            | 99                | 99           | 100          | 100          | 99           | 100          | 99            | 99            | 100           | 99            | 99           | 99           | 100          | 99            | 100           | 99   |  |  |  |  |                      |  |  |  |  |  |  |  |  |  |

APPENDIX 1A: SAMPLE LOCATIONS OF SEDIMENTARY ROCKS,  
NORTHERN CULPEPER BASIN, VIRGINIA

| Sample No. | W-No.  | (Fm-Symbol)<br>Lithology         | Latitude(N) | Longitude(W) | USGS<br>7-1/2'<br>Quad | County  | Comments                                                                |
|------------|--------|----------------------------------|-------------|--------------|------------------------|---------|-------------------------------------------------------------------------|
| 11         | 181304 | Siltstone<br>(Trbb-gy-red)       | 39°05'22"   | 77°29'15"    | Sterling               | Loudoun | Xerox site; 1.8 km N 45°E of jct. of Rt. 7 and entrance road.           |
| 114        | 182446 | Sandstone, m-vc<br>(Trmr)        | 38°52'25"   | 77°21'52"    | Fairfax                | Fairfax | N cut face Rt. 50; about 90 m S 67°E from jct. with West Ox road.       |
| 116        | 182447 | Siltstone<br>(Trmp-dk red)       | 38°52'38"   | 77°23'16"    | Herndon                | Fairfax | N cut face Rt. 50; about 150 m S 65°E of jct. with Rugby Road           |
| 117        | 182448 | Sandstone, f-m<br>(Trmp)         | 38°53'10"   | 77°24'32"    | "                      | "       | N cut face Rt. 50; about 450 m S 65°E of jct. with SR 645               |
| 118        | 182449 | Sandstone, vf-m<br>(Trmp)        | 38°53'27"   | 77°25'18"    | "                      | "       | N cut face Rt. 50; at jct. with Chantilly road.                         |
| 119        | 182450 | Sandstone, vf-m<br>(Trmp)        | 38°53'27"   | 77°25'43"    | "                      | "       | N cut face Rt. 50; about 450 m S 65° E. from jct. of SR 657.            |
| 121        | 182451 | Siltstone<br>(Trbb-gn gy)        | 38°54'43"   | 77°28'28"    | "                      | "       | N cut face Rt. 50; 18 m S 65°E of Fairfax-Loudoun County boundary.      |
| 122        | 182452 | Siltstone<br>(Trbb-dk red)       | "           | "            | "                      | "       | 50 m N 65°W of sample no. 121 -                                         |
| 123        | 182453 | Siltstone<br>(Trbb-dk red)       | "           | "            | "                      | "       | 20 m N 65°W of sample no. 122                                           |
| 124        | 182454 | Siltstone<br>(Trbb-gy red)       | 38°54'55"   | 77°28'45"    | "                      | Loudoun | 100 m N 65°W of sample no. 123 at margin of hornfels                    |
| 130        | 182460 | Siltstone<br>(Trbb-gn gy)        | 38°56'22"   | 77°32'54"    | Arcola                 | Loudoun | N cut face Rt. 50; 750m N 65°W of jct. with SR 659; at hornfels contact |
| 131        | 182454 | Shale<br>(Trbb-dk red)           | "           | "            | "                      | "       | 8 m N 65°W of sample no. 130                                            |
| 132        | 182462 | Sandstone, vf-f<br>(Trbb)        | "           | 77°32'58"    | "                      | "       | N cut face Rt. 50; 30 m S 65°E of South Fork                            |
| 133        | 182463 | Siltstone<br>(Trbb-dk red)       | 38°56'34"   | 77°33'10"    | "                      | "       | N cut face Rt. 50; 200 m S 65°E of Powerline                            |
| 134        | 182464 | Siltstone<br>(Trbb-gn gy, ol gn) | "           | "            | "                      | "       | 8 m N 65°W of sample no. 133                                            |
| 135        | 182465 | Shale<br>(Trbb-gn gy, dk red)    | 38°56'36"   | 77°33'16"    | "                      | "       | N cut face Rt. 50; 100 m N 65°W of power line.                          |
| 136        | 182466 | Siltstone<br>(Trbb-dk red)       | 38°56'37"   | 77°33'15"    | "                      | "       | N cut face Rt. 50; 80m N 65°W of sample no. 135                         |
| 137        | 182467 | Sandstone, vf-m<br>(Trbb)        | 38°56'39"   | 77°33'22"    | "                      | "       | N cut face Rt. 50; 30 m N 65°W of power line                            |
| 138        | 182468 | Shale<br>(Trbb-dk red)           | 38°56'41"   | 77°33'25"    | "                      | "       | N cut face Rt. 50; 900 m S 65°E of jct. with SR 616                     |
| 139        | 182469 | Siltstone<br>(JTrc?-dk red)      | 38°56'53"   | 77°34'00"    | "                      | "       | N cut face Rt. 50; 180 m N 65°W of jct. with SR 616                     |
| 140        | 182470 | Shale<br>(JTrc?-dk red)          | 38°56'58"   | 77°34'08"    | "                      | "       | N cut face Rt. 50; 500 m N 65°W of jct. with SR 616                     |
| 141        | 182471 | Siltstone<br>(JTrc-dk red)       | 38°56'59"   | 77°34'09"    | "                      | "       | 180 m N 65°W of sample no. 140                                          |
| 142        | 182472 | Siltstone<br>(JTrc-dk red)       | "           | "            | "                      | "       | 10 m N 65°W of sample no. 141                                           |
| 143        | 182473 | Siltstone<br>(JTrc-gy-bl gy)     | "           | "            | "                      | "       | 5 m N 65°W of sample no. 142                                            |
| 144        | 182474 | Shale<br>(JTrc-blkish gy)        | "           | "            | "                      | "       | 6 m N 65°W of sample no. 143                                            |
| 145        | 182475 | Shale<br>(JTrc-dk red)           | 38°57'00"   | 77°34'11"    | "                      | "       | 15 m N 65°W of sample no. 144                                           |
| 146        | 182476 | Sandstone, f-m<br>(JTrc)         | "           | 77°34'12"    | "                      | "       | N. cut face Rt. 50; 530 m N 65°W of jct. SR 616                         |
| 147        | 182477 | Sandstone, vf-m<br>(JTrc)        | "           | "            | "                      | "       | 3 m N 65°W of sample no. 146                                            |
| 148        | 182478 | Sandstone, m-vc<br>(JTrc)        | "           | "            | "                      | "       | 3 m N 65°W of sample no. 147                                            |
| 149        | 182479 | Sandstone, m-vc<br>(JTrc)        | "           | "            | "                      | "       | 2 m N 67°W of sample no.148                                             |
| 150        | 182480 | Sandstone, m-vc<br>(JTrc)        | "           | "            | "                      | "       | 4 m N 65°W of sample no. 149                                            |
| 151        | 182481 | Sandstone, vf-m<br>(JTrc)        | "           | 77°34'14"    | "                      | "       | 10 m N 70°W of sample no. 150                                           |
| 152        | 182482 | Sandstone, vf-f<br>(JTrc)        | "           | "            | "                      | "       | 3 m N 70°W of sample no. 151                                            |
| 153        | 182483 | Shale<br>(JTrc-dk red)           | 38°57'00"   | 77°34'15"    | "                      | "       | N cut face Rt. 50; 960 m S 65°E of jct. with SR 600 at Lenah            |
| 154        | 182484 | Sandstone, vf-f<br>(JTrc)        | "           | "            | "                      | "       | 480 m S 65°E of sample no. 153                                          |
| 155        | 182485 | Sandstone, vf-f<br>(JTrc)        | 38°57'08"   | 77°34'53"    | "                      | "       | SR 600 at Lenah, 53 m S of jct. with Rt. 50                             |
| 156        | 182486 | Sandstone, fg<br>(JTrcg)         | 38°57'23"   | 77°35'23"    | "                      | "       | S cut face Rt. 50, 940 m N 65°W of jct with SR 600                      |
| 157        | 182487 | Sandstone, vf-f<br>(JTrcg)       | 38°57'26"   | 77°35'30"    | "                      | "       | 150 m N 65°W of sample no. 156                                          |
| 158        | 182488 | Shale<br>(JTrcg-dk red)          | 38°57'43"   | 77°36'08"    | "                      | "       | N cut face Rt. 50; 715 m S 65°E of jct. with SR 625                     |
| 159        | 182489 | Sandstone, vf-m<br>(JTrcg)       | 38°57'51"   | 77°36'34"    | "                      | "       | S cut face Rt. 50; 110 m S 65°E of jct. with SR 625                     |
| 166        | 182491 | Sandstone, f-m<br>(Jm)           | 38°58'06"   | 77°37'12"    | "                      | "       | S cut face Rt. 50; 350 m S 65°E of jct. with Rt. 15 at Gilberts Corner  |
| 176        | 182494 | Sandstone, f-m<br>(Jss)          | 38°58'19"   | 77°38'03"    | Middleburg             | Loudoun | W cut face of SR 631 about 145 m S 32°W from jct. of Rt. 50             |
| 186        | 182498 | Shale<br>(Jtr-dk red)            | 39°00'27"   | 77°37'04"    | Leesburg               | Loudoun | N face abandoned quarry on N side of Little River                       |

NOTE: Samples 114-176 inclusive along Route 50 are essentially a west-dipping ascending suite stratigraphically, from Late Triassic (114-138 incl.) to Triassic-Jurassic (139-159 incl.) to Early Jurassic (166-176) strata. Trmr, Reston Member of Manassas Sandstone; Trmp, Poolesville Member of Manassas Sandstone; Trbb, Balls Bluff Siltstone; JTrc, Catharpin Creek Formation; JTrcg, Goose Creek Member of Catharpin Creek Formation; Jm, Midland Formation; Jss, Sander Sandstone Member of Sander Basalt; JTr, Turkey Run Formation.

APPENDIX 1B: SAMPLE LOCATIONS OF CONTACT METAMORPHIC ROCKS,  
NORTHERN CULPEPER BASIN, VIRGINIA

| Sample No. | W-No.  | Lithology                            | Latitude(N) | Longitude(W) | USGS 7-1/2' Quad | County  | Comments                                                                                                                                 |
|------------|--------|--------------------------------------|-------------|--------------|------------------|---------|------------------------------------------------------------------------------------------------------------------------------------------|
| 12         | 181305 | Hornfels                             | 39°05'00"   | 77°28'45"    | Sterling         | Loudoun | Along Xerox entrance road, 1.45 km N of jct. with Rt. 7 at spot elevation 359 ft.                                                        |
| 19         | 181307 | Metaconglomerate                     | 39°01'00"   | 77°35'30"    | Leesburg         | Loudoun | S side Goose Creek, 90 m S 45°E from bridge over SR 621 at Everygreen Mills. Diabase contact 6 m below Spl. no. 19 (most metamorphosed). |
| 20         | 181308 | Hornfels                             | "           | "            | "                | "       | 8 m above 19                                                                                                                             |
| 21         | 181309 | "                                    | "           | "            | "                | "       | 3 m above 20                                                                                                                             |
| 22         | 181310 | Quartzitic hornfels                  | "           | "            | "                | "       | 1.6 m above 21                                                                                                                           |
| 23         | 181311 | Quartzite                            | "           | "            | "                | "       | 7.5 m above 22                                                                                                                           |
| 24         | 181312 | Granulite                            | "           | "            | "                | "       | 6 m above 23                                                                                                                             |
| 25         | 181313 | Hornfels                             | "           | "            | "                | "       | 6 m above 24                                                                                                                             |
| 27         | 181315 | Metaconglomerate                     | "           | "            | "                | "       | 6 m above 25                                                                                                                             |
| 28         | 181316 | Granulite                            | "           | "            | "                | "       | 1 m above 27                                                                                                                             |
| 29         | 181317 | "                                    | "           | "            | "                | "       | 2 m above 28                                                                                                                             |
| 30         | 181318 | Metaconglomerate                     | "           | "            | "                | "       | 10 m above 29                                                                                                                            |
| 31         | 181319 | Granulite                            | "           | "            | "                | "       | 6 m above 30                                                                                                                             |
| 32         | 181320 | "                                    | "           | "            | "                | "       | 1.5 m above 31 (least metamorphosed)                                                                                                     |
| 34         | 181323 | Hornfels                             | 39°05'15"   | 77°30'45"    | Leesburg         | Loudoun | N cut face of Rt. 7 at W bank of Goose Creek; 450 m S 55°E of jct. of Rt. 7 and SR 653                                                   |
| 63         | 181868 | Hornfels                             | 38°55'30"   | 77°30'26"    | Arcola           | Loudoun | W cut face of Chantilly Quarry on S side of Rt. 50; 450 m N 70°E of jct. of Rt. 50 on SR 621                                             |
| 77         | 181869 | Cordierite hornfels                  | "           | 77°30'30"    | "                | "       | W cut face Chantilly Quarry, but further E; diabase contact 4 m below Spl. no. 77 (most metamorphosed)                                   |
| 78         | 181860 | "                                    | "           | "            | "                | "       | 4 m above 77                                                                                                                             |
| 79         | 181861 | "                                    | "           | "            | "                | "       | 3.5 m above 78                                                                                                                           |
| 80         | 181862 | "                                    | "           | "            | "                | "       | 3 m above 79                                                                                                                             |
| 81         | 181863 | "                                    | "           | "            | "                | "       | 3 m above 80                                                                                                                             |
| 82         | 181864 | Hornfels                             | "           | "            | "                | "       | 10 m above 81 (least metamorphosed)                                                                                                      |
| 125        | 182455 | "                                    | 38°55'56"   | 77°31'21"    | Arcola           | Loudoun | N cut face of Rt. 50; 500 m N 63°W of jct. of Rt. 50 and SR 606                                                                          |
| 126        | 182456 | Granulite                            | "           | "            | "                | "       | "                                                                                                                                        |
| 127        | 182457 | "                                    | 38°56'21"   | 77°32'50"    | "                | "       | N cut of Rt. 50; 500m N 65°W of jct. of Rt. 50 and SR 659                                                                                |
| 128        | 182458 | Hornfels                             | "           | "            | "                | "       | "                                                                                                                                        |
| 129        | 182459 | "                                    | "           | "            | "                | "       | "                                                                                                                                        |
| 179        | 182497 | Metaconglomerate                     | 39°01'18"   | 77°31'35"    | Lincoln          | Loudoun | Abandoned quarry S of Goose Creek; 650 m N 25°W from jct. of Rt. 15 and SR 650                                                           |
| 209        | 182511 | Cordierite hornfels                  | 38°51'22"   | 77°32'27"    | Gainesville      | "       | E cut face Bull Run Quarry; 1100 m N 35°E of SR 659 bridge over Bull Run (least metamorphosed) 3m above 210                              |
| 210        | 182512 | Hornfels                             | "           | "            | "                | "       | 1.5 m above 211                                                                                                                          |
| 211        | 182513 | "                                    | "           | "            | "                | "       | 3 m above 212                                                                                                                            |
| 212        | 182514 | Cordierite hornfels                  | "           | "            | "                | "       | 3 m above 213                                                                                                                            |
| 213        | 182515 | Hornfels                             | "           | "            | "                | "       | 3 m above 214                                                                                                                            |
| 214        | 182516 | "                                    | "           | "            | "                | "       | Diabase contact 1 m below (most metamorphosed)                                                                                           |
| 225        | 184770 | Marble (Meta-limestone conglomerate) | 39°06'15"   | 77°33'52"    | Leesburg         | Loudoun | N cut of Rt. 7 bypass SE of Leesburg; 700 m N 80° W of jct. with SR 643                                                                  |
| 349        | 184771 | Tourmaline granulite                 | 38°49'15"   | 77°25'07"    | Manassas         | Fairfax | Float near diabase/qtzite contact; 530 m N 8° W of jct. of SR 659 and SR 3546 at spot elevation 369 ft                                   |
| 356        | 184773 | Granulite                            | 38°49'08"   | 77°25'33"    | "                | "       | E cut of Little Rocky Run; 1.4 km N 85°W of jct. of SR 659 and gravel road, at spot elevation 372 ft                                     |

APPENDIX 2A SEMIQUANTITATIVE WHOLE-ROCK MINOR ELEMENT ANALYSES  
of  
FINE-GRAINED SEDIMENTARY ROCKS FROM THE NORTHERN CULPEPER BASIN, VIRGINIA

Analysts: Joseph L. Harris, Charles S. Ansell, Herbert Kirschenbaum, Janet D. Fletcher, Floyd Brown, Leonard Shapiro (1973, 1974, 1975)

| PPM<br>Element<br># | Siltstone/Shale |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               | 153<br>182483 | 154<br>182484 | 158<br>182488 | 186<br>182489 |        |
|---------------------|-----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|--------|
|                     | 11<br>181304    | 116<br>182447 | 121<br>182451 | 122<br>182452 | 123<br>182453 | 124<br>182454 | 130<br>182460 | 131<br>182461 | 133<br>182463 | 134<br>182464 | 135<br>182465 | 136<br>182466 | 138<br>182468 | 139<br>182469 | 140<br>182470 | 141<br>182471 | 142<br>182472 | 143<br>182473 | 144<br>182474 | 145<br>182475 |               |               |               |               |        |
| AG                  | <0.10           | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | 0.22          | <0.10         | <0.10         | 0.11          | 0.98          | 0.10          | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10  |
| AS                  | <100.0          | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0 |
| AU                  | <6.81           | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81  |
| B                   | 44.3            | 199.0         | 63.1          | 31.7          | 84.6          | 119.0         | 52.2          | 108.0         | 129.0         | 73.1          | 54.6          | 79.9          | 126.0         | 54.4          | 103.0         | 40.0          | 56.3          | 30.1          | <10.0         | 114.0         | 63.9          | 45.1          | 44.0          | 109.0         |        |
| BA                  | 357.0           | 488.0         | 331.0         | 251.0         | 344.0         | 564.0         | 282           | 716.0         | 421.0         | 229.0         | 178.0         | 383.0         | 401.0         | 309.0         | 408.0         | 161.0         | 299.0         | 101.0         | 133.0         | 413.0         | 415.0         | 205.0         | 416.0         | 412.0         |        |
| BE                  | 1.66            | 3.87          | 2.21          | 1.48          | 2.60          | 2.32          | 2.35          | 4.04          | 2.81          | 2.18          | 1.95          | 1.80          | 2.73          | 5.33          | 2.39          | <1.00         | 1.50          |               | 1.24          | <1.00         | 3.15          | 3.54          | <1.00         | 1.76          | 3.15   |
| BI                  | <1.00           | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         |        |
| CD                  | <14.7           | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         |        |
| CE                  | 76.3            | 102.0         | 88.1          | 90.5          | 119.0         | 198.0         | 52.5          | 114.0         | 78.4          | 50.9          | 58.4          | 76.7          | 126.0         | 70.7          | 139.0         | 39.7          | 55.9          | 75.6          | 20.0          | 130.0         | 96.0          | 49.2          | 69.2          | 95.0          |        |
| CO                  | 9.63            | 22.1          | 8.56          | 5.99          | 27.3          | 28.5          | 29.9          | 22.2          | 19.6          | 7.66          | 3.98          | 11.1          | 28.5          | 7.48          | 23.3          | 3.52          | 8.99          | 10.3          | 11.1          | 13.7          | 86.1          | 7.40          | 8.97          | 18.2          |        |
| CR                  | 54.4            | 96.0          | 60.2          | 22.8          | 62.9          | 84.1          | 48.6          | 80.8          | 69.4          | 34.0          | 37.2          | 36.8          | 76.4          | 40.3          | 53.0          | 20.8          | 37.7          | 38.4          | 82.7          | 70.0          | 77.0          | 22.6          | 41.9          | 81.4          |        |
| CS                  | <3160.0         | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       |        |
| CU                  | 27.8            | 33.9          | 646.0         | 16.5          | 7.97          | 13.5          | 188.0         | 22.1          | 4.94          | 4.85          | 493.0         | 9.51          | 4.69          | 13.3          | 9.02          | 4.26          | 3.09          | <1.00         | 84.1          | 14.4          | 15.8          | 37.4          | 2.19          | 12.8          |        |
| DY                  | <3.16           | 6.60          | 5.25          | 16.3          | 11.5          | 13.2          | 5.29          | 10.0          | 5.75          | 6.82          | <3.16         | 4.47          | 3.68          | 14.2          | <3.16         | 6.48          | 7.06          | 6.81          | <3.16         | 6.28          | 6.86          | 9.61          | 6.82          | 4.98          |        |
| ER                  | <2.15           | <2.15         | <2.15         | <2.15         | <2.15         | 8.97          | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         |        |
| EU                  | 1.18            | 1.31          | 1.02          | 1.61          | 3.34          | 3.52          | 1.05          | 2.30          | 1.20          | 1.71          | 1.11          | 1.07          | 1.81          | 2.79          | 2.24          | 1.66          | 1.02          | 2.13          | <1.00         | 1.29          | 2.81          | 1.72          | 1.65          | 1.77          |        |
| GA                  | 10.7            | 20.3          | 14.2          | 2.73          | 13.8          | 22.0          | 8.71          | 22.1          | 17.6          | 4.60          | 5.03          | 8.26          | 18.3          | 4.90          | 10.3          | <2.15         | 5.42          | 6.10          | <2.15         | 16.9          | 17.4          | <2.15         | 4.75          | 20.1          |        |
| GD                  | <3.16           | 4.75          | 4.37          | 9.45          | 12.2          | 14.3          | 6.56          | 8.22          | 4.09          | 8.39          | <3.16         | 7.94          | 7.68          | 9.48          | 9.20          | 7.29          | 5.41          | 8.63          | 4.42          | 3.48          | 9.75          | 11.5          | 8.18          | 6.38          |        |
| GE                  | <1.00           | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         |        |
| HF                  | <10.0           | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         |        |
| HG                  | <147.0          | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        |        |
| HO                  | <1.00           | <1.00         | <1.00         | <1.00         | <1.00         | 4.35          | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <2.30         | <1.00         | <1.00         |        |
| IN                  | 4.64            | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          | 4.64          |        |
| IR                  | <6.81           | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         |        |
| LA                  | 38.3            | 34.2          | 26.7          | 31.6          | 56.7          | 109.0         | 35.7          | 64.8          | 30.9          | 33.7          | 20.7          | 36.7          | 47.1          | 42.2          | 49.1          | 19.1          | 25.9          | 35.8          | 14.7          | 54.5          | 45.2          | 28.4          | 33.4          | 41.0          |        |
| LI                  | <31.6           | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         |        |
| LU                  | <3.16           | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         |        |
| MM                  | 476.0           | 588.0         | 825.0         | 1920.0        | 914.0         | 679.0         | 570.0         | 511.0         | 896.0         | 1050.0        | 566.0         | 950.0         | 864.0         | 647.0         | 663.0         | 497.0         | 589.0         | 368.0         | 236.0         | 247.0         | 1150.0        | 892.0         | 1250.0        | 791.0         |        |
| MO                  | <1.00           | 3.28          | 1.47          | 4.36          | 1.92          | 3.19          | 1.52          | 2.23          | 2.93          | 1.08          | 2.18          | <1.00         | 2.00          | 1.13          | 2.50          | 1.17          | <1.00         | 1.12          | 3.61          | 2.50          | 2.53          | 1.53          | 1.37          | 3.38          |        |
| NB                  | 7.44            | 4.64          | 4.37          | <2.15         | 10.1          | 3.18          | 5.56          | 5.67          | <2.15         | 5.46          | 9.63          | 6.11          | 4.52          | 4.78          | 4.84          | 6.77          | 7.21          | 6.48          | <2.15         | 5.73          | 3.30          | 4.71          | 6.63          | 3.82          |        |
| ND                  | 48.6            | 26.3          | <14.7         | 63.3          | H             | 86.3          | 26.4          | 71.7          | 33.1          | 38.8          | 16.1          | 41.5          | 46.8          | 33.6          | 62.2          | 21.6          | 30.4          | 31.6          | <14.7         | 39.7          | 37.0          | 57.7          | 24.3          | 42.6          |        |
| N1                  | 18.0            | 32.9          | 26.8          | 32.7          | 13.6          | 32.1          | 26.8          | 32.1          | 33.3          | 21.0          | 42.0          | 28.8          | 24.0          | 52.3          | 27.0          | 6.33          | 17.8          | 34.6          | 37.6          | 25.6          | 41.8          | 11.6          | 16.9          | 33.4          |        |
| OS                  | <1.00           | <21.5         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <21.5         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <21.5         | <1.00         | <1.00         | <21.5         |        |
| PB                  | 6.92            | 22.4          | 3.37          | 12.4          | 5.89          | 8.04          | 11.7          | 10.6          | 25.1          | 5.48          | 11.8          | 6.70          | 22.5          | 11.8          | 11.1          | 4.84          | 6.75          | 2.62          | 8.32          | 18.3          | 25.7          | 4.70          | 8.29          | 11.8          |        |
| PD                  | <0.22           | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         |        |
| PR                  | 6.33            | 6.93          | 6.47          | 9.78          | H             | 16.3          | 4.99          | 10.4          | 8.70          | 5.65          | 5.75          | 7.70          | 9.57          | 7.14          | 10.5          | 4.84          | 5.11          | 6.67          | 3.09          | 9.74          | 9.23          | 8.89          | 6.37          | 8.06          |        |
| PT                  | <2.15           | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         |        |
| RB                  | <14700.0        | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      | <14700.0      |        |
| RE                  | <10.0           | <10.0         |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |        |

APPENDIX 28 SEMIQUANTITATIVE WHOLE-ROCK MINOR ELEMENT ANALYSES  
of  
COARSE-GRAINED SEDIMENTARY ROCKS FROM THE NORTHERN CULPEPER BASIN, VIRGINIA  
Analysts: Joseph L. Harris, Charles S. Ansell, Floyd Brown, Leonard Shapiro (1974, 1975)

| PPM<br>Element | Sandstone     |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |               |
|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
|                | 114<br>182446 | 117<br>182448 | 118<br>182449 | 119<br>182450 | 132<br>182462 | 137<br>182467 | 146<br>182476 | 147<br>182477 | 148<br>182478 | 149<br>182479 | 150<br>182480 | 151<br>182481 | 152<br>182482 | 155<br>182485 | 156<br>182486 | 157<br>182487 | 159<br>182489 | 166<br>182491 | 174<br>182493 |
| AG             | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.1          |
| AS             | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        | <100.0        |
| AU             | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.8          |
| B              | 62.4          | 15.6          | 30.8          | 21.9          | 88.8          | 69.7          | 62.2          | 70.2          | 53.0          | 57.0          | 72.8          | 47.8          | 47.3          | 63.7          | 55.3          | 29.8          | 62.1          | 37.6          | 16.7          |
| BA             | 377.0         | 524.0         | 3.8.0         | 2.160         | 208.0         | 235.0         | 209.0         | 388.0         | 323.0         | 1010.0        | 452.0         | 317.0         | 360.0         | 365.0         | 374.0         | 315.0         | 162.0         | 53.0          | 140.0         |
| BE             | 2.29          | 1.05          | 1.40          | 1.06          | 1.02          | 1.52          | 1.27          | 1.46          | 1.31          | 1.28          | 1.59          | 1.21          | 1.21          | 1.75          | 1.37          | <1.00         | 1.02          | 1.21          | 1.11          |
| BI             | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         |
| CD             | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         | <14.7         |
| CE             | 141           | 65.9          | 78.7          | 79.3          | 85.4          | 107           | 43.2          | 108           | 66.1          | 60.3          | 117           | 100           | 74.1          | 102           | 87.7          | 98.4          | 53.9          | 58.5          | 81.6          |
| CO             | 7.64          | 5.88          | 8.29          | 7.48          | 9.28          | 10.2          | 5.49          | 10.9          | 8.72          | 11.4          | 19.5          | 10.8          | 10.5          | 12.9          | 9.46          | 11.2          | 9.08          | 8.44          | 6.27          |
| CR             | 31.8          | 36.1          | 46.8          | 40.6          | 18.8          | 21.5          | 37.1          | 37.5          | 28.4          | 37.8          | 49.0          | 33.0          | 35.5          | 38.0          | 32.1          | 20.0          | 16.6          | 42.0          | 19.9          |
| CS             | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       | <3160.0       |
| CU             | 4.73          | 4.16          | 4.64          | 13.3          | 3.60          | 156.0         | 9.52          | 7.93          | 11.3          | 4.92          | 4.55          | 17.6          | 25.4          | 14.1          | 7.16          | 6.64          | 6.90          | 5.67          | 4.30          |
| DY             | 8.22          | 8.25          | <10.0         | 6.98          | <10.0         | 15.4          | 8.47          | 11.4          | 9.52          | <3.16         | 9.77          | 10.0          | 10.1          | 15.1          | 13.1          | <3.16         | 4.64          | 11.4          | 8.61          |
| ER             | <2.15         | <2.15         | <2.15         | 5.40          | <2.15         | 5.25          | 2.48          | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <4.64         | <2.15         | <2.15         |
| EU             | 2.86          | 2.03          | 2.03          | 1.89          | 2.54          | 3.11          | 1.36          | 2.16          | 1.77          | 1.81          | 1.99          | 2.05          | 2.05          | 2.70          | 3.17          | 1.78          | 1.01          | 2.13          | 1.83          |
| GA             | 4.73          | 7.37          | 6.10          | 5.66          | <2.15         | <2.15         | 5.03          | 6.12          | 4.14          | 7.17          | 8.91          | 6.08          | 6.04          | 7.15          | 5.96          | 3.24          | <2.15         | 9.90          | 4.60          |
| GO             | 15.1          | 3.74          | 5.98          | <3.16         | <2.15         | 16.2          | <3.16         | <2.15         | 10.6          | <3.16         | <2.15         | 10.1          | 8.42          | 9.94          | 15.1          | <3.16         | 6.29          | 4.86          | 7.31          |
| GE             | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         |
| HF             | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         |
| HG             | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        | <147.0        |
| HO             | <1.00         | <1.00         | <1.00         | 2.85          | <1.00         | 4.11          | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | 1.86          | <1.00         | <1.00         |
| IN             | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         | <4.64         |
| IR             | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         | <6.81         |
| LA             | 56.2          | 27.6          | 31.4          | 20.9          | 36.5          | 62.8          | 23.8          | 41.2          | 29.4          | 26.2          | 31.1          | 37.2          | 30.9          | 42.9          | 51.8          | 26.2          | 18.1          | 19.4          | 37.5          |
| LI             | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         | <31.6         |
| LU             | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         |
| MN             | 120.0         | 521.0         | 1100.0        | 348.0         | 2100.0        | 896.0         | 128.0         | 510.0         | 819.0         | 860.0         | 1050.0        | 571.0         | 636.0         | 903.0         | 806.0         | 1220.0        | 761.0         | 244.0         | 784.0         |
| MO             | 1.64          | <1.00         | <1.00         | 1.57          | 2.14          | 1.44          | 1.55          | 1.27          | 2.20          | 1.31          | 1.04          | 1.39          | 1.29          | 1.58          | <1.00         | 2.15          | 1.85          | 1.10          | 1.07          |
| NB             | 2.76          | 4.05          | 3.86          | 8.79          | 7.83          | 7.84          | 4.71          | 5.22          | 5.52          | 5.29          | 7.02          | 4.95          | 6.48          | 8.90          | 6.24          | 4.16          | 6.56          | 3.99          | 3.90          |
| ND             | 72.3          | 39.9          | <14.7         | 26.9          | 35.2          | 76.4          | 16.4          | 65.6          | 71.6          | 49.3          | 23.4          | 63.1          | 42.2          | 50.3          | 86.2          | <14.7         | 19.0          | <14.7         | 29.6          |
| NI             | 24.3          | 13.5          | 12.9          | 15.6          | 9.22          | 16.2          | 15.0          | 20.2          | 14.2          | 16.2          | 29.9          | 16.4          | 19.2          | 19.3          | 20.6          | 11.8          | 17.4          | 11.0          | 12.0          |
| OS             | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         | <1.00         |
| PB             | 6.51          | 7.63          | 7.46          | 8.14          | 4.43          | 2.73          | 6.11          | 7.08          | 3.54          | 3.29          | 7.18          | 6.33          | 6.19          | 32.2          | 8.09          | 6.16          | 2.34          | 5.29          | 3.68          |
| PD             | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.22         | <0.68         | <0.22         |
| PR             | 11.3          | 6.35          | 5.36          | 6.47          | 7.81          | 11.4          | 5.17          | 8.99          | 9.76          | 6.49          | 6.66          | 8.43          | 8.12          | 8.71          | 9.50          | 6.71          | 4.43          | 4.49          | 7.14          |
| PT             | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <2.15         | <6.81         | <2.15         |
| RB             | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        | <14700        |
| RE             | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         | <10.0         |
| RH             | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         | <0.10         |
| RU             | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         | <0.46         |
| SB             | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         | <68.1         |
| SC             | 8.16          | 12.0          | 16.2          | 12.5          | 6.19          | 6.33          | 9.19          | 11.1          | 17.1          | 14.8          | 12.2          | 10.5          | 11.5          | 17.6          | 11.3          | 14.7          | 4.50          | 12.3          | 11.1          |
| SM             | 6.89          | <4.64         | <4.64         | <4.64         | 5.62          | 6.82          | <4.64         | 5.37          | <4.64         | <4.64         | <4.64         | 5.34          | <4.64         | 5.46          | 5.61          | <4.64         | <4.64         | <4.64         | 5.01          |
| SN             | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | 3.35          | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         | <3.16         |
| SR             | 135.0         | 110.0         | 92.0          | 110.0         | 66.1          | 54.9          | 94.0          | 90.0          | 133.0         | 105.0         | 84.4          | 106.0         | 126.0         | 153.0         |               |               |               |               |               |

L. Harris, Charles S. Ansell, Herbert Kirschenbaum, Janet D. Fletcher, Floyd Brown, Leonard Shapiro (1973, 1974, 1975)

## HORNFELS - METAMORPHOSED SILTSTONE AND SHALE

| Element | 12     | 20     | 21     | 28     | 34     | 67     | 77     | 78     | 79     | 80     | 81     | 82     | 125    | 126    | 127    | 128    | 129    | 130    | 131    | 132    | 133    | 134    |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| MW      | 181305 | 181308 | 181309 | 181313 | 181323 | 181060 | 181069 | 181060 | 181061 | 181062 | 181063 | 181064 | 182455 | 182456 | 182459 | 182460 | 182511 | 182512 | 182513 | 182514 | 182515 | 182516 |
| Ag      | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | 0.54   | <0.10  | <0.10  | 0.22   | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  |
| As      | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 | <100.0 |
| Au      | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  |
| B       | 10.4   | <10.0  | >215.0 | <10.0  | <10.0  | >215.0 | 193.0  | >215.0 | 69.3   | 85.0   | 25.8   | 33.7   | <10.0  | 88.2   | 69.9   | 52.2   | 15.3   | <10.0  | 10.4   | <10.0  | 89.3   | 87.2   |
| Br      | 632.0  | 141.0  | 1080.0 | 105.0  | 469.0  | 190.0  | 427.0  | 508.0  | 735.0  | 606.0  | 825.0  | 842.0  | 717.0  | 253.0  | 379.0  | 282.0  | 346.0  | 196.0  | 486.0  | 923.0  | 572.0  | 505.0  |
| Ce      | 2.13   | 1.90   | 1.92   | 1.85   | 1.36   | 2.48   | 2.89   | 2.72   | 3.77   | 2.32   | 4.35   | 2.90   | 1.50   | 2.71   | 2.05   | 2.35   | 2.12   | 1.46   | <1.00  | 1.90   | 2.50   | 2.43   |
| Bi      | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  |
| Co      | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  | <14.7  |
| Cr      | 95.4   | 55.8   | <20.0  | 112.0  | 40.3   | 93.0   | 182.0  | 98.9   | 97.3   | 93.0   | 97.0   | 92.8   | 34.3   | 78.3   | 66.3   | 52.5   | 84.2   | 63.1   | 205.0  | 120.0  | 67.1   | 96.2   |
| Cl      | 13.4   | 5.99   | 2.16   | 6.05   | 9.08   | 18.8   | 23.3   | 20.6   | 23.1   | 17.3   | 31.4   | 31.4   | 24.7   | 9.97   | 16.4   | 29.9   | 18.2   | 28.6   | 7.29   | 22.9   | 24.5   | 19.3   |
| Cs      | 51.0   | 57.9   | 76.3   | 62.8   | 49.8   | 84.5   | 106.0  | 110.0  | 96.9   | 87.0   | 136.0  | 124.8  | 64.0   | 34.0   | 47.1   | 48.6   | 71.4   | 53.8   | 32.4   | 87.6   | 73.6   | 77.3   |
| Ds      | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 | <160.0 |
| Ga      | <1.00  | 6.95   | <1.00  | 23.9   | 62.6   | 3.79   | 1.45   | 27.7   | 8.29   | 6.61   | <1.00  | 23.0   | 340.0  | 45.8   | 24.1   | 188.0  | 3.53   | 15.9   | 331.0  | 32.7   | 23.4   | 2.54   |
| Hg      | <3.16  | 9.78   | 7.73   | 8.84   | 9.27   | 5.41   | 7.76   | 8.88   | 6.73   | 6.37   | 4.74   | 11.4   | 6.94   | 7.17   | 7.78   | 5.29   | 6.18   | 9.21   | 8.43   | 7.64   | 6.86   | 6.98   |
| Ir      | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  |
| Eu      | 1.55   | 1.77   | <1.00  | 1.70   | 1.17   | <1.00  | 1.27   | 1.30   | 1.40   | 1.11   | 1.32   | 1.60   | <1.00  | 1.30   | 1.20   | 1.05   | <1.00  | 1.65   | 2.24   | 1.30   | 1.16   | 1.22   |
| GA      | 11.4   | 10.7   | 12.6   | 18.5   | 12.4   | 18.2   | 24.8   | 30.7   | 35.5   | 20.5   | 32.9   | <14.7  | 4.00   | 5.83   | 9.20   | 8.71   | 17.2   | 13.1   | <2.15  | 15.9   | 15.0   | 18.0   |
| GD      | 3.65   | <3.16  | 3.99   | 5.87   | <1.00  | <3.16  | 4.12   | 9.64   | 8.59   | 4.35   | 7.08   | 5.20   | 6.03   | 6.81   | 9.67   | 6.56   | 4.81   | 6.17   | 7.25   | 5.64   | 4.62   | 3.68   |
| GE      | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  |
| HF      | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  |
| ME      | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.8 | <147.8 | <147.8 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 |
| HO      | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  |
| IN      | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  |
| IR      | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  |
| LA      | 34.7   | 25.0   | <14.7  | 57.8   | 29.1   | 29.2   | 31.1   | 32.6   | 34.6   | 26.6   | 28.3   | 38.0   | 16.3   | 24.8   | 28.1   | 35.7   | 33.0   | 30.3   | 117.0  | 37.4   | 29.1   | 28.8   |
| LI      | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  | <31.6  |
| LU      | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  | <3.16  |
| MN      | 884.0  | 327.0  | 115.0  | 287.0  | 790.0  | 795.0  | 355.0  | 294.0  | 1050.0 | 298.0  | 645.0  | 2030.0 | 1110.0 | 1700.0 | 1010.0 | 570.0  | 1360.0 | 1450.0 | 243.0  | 627.0  | 704.0  | 834.0  |
| MO      | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | 1.13   | 1.57   | 1.43   | 1.79   | 2.65   | 3.27   | 2.08   | 2.50   | 3.31   | 1.52   | 2.71   | <1.00  | 1.28   | 1.96   | 2.10   | 1.76   |
| NB      | 5.50   | 4.70   | 4.40   | 7.30   | 3.57   | 5.39   | 7.05   | 10.0   | 15.7   | 6.95   | 17.6   | 7.59   | 4.65   | 3.38   | 3.09   | 5.56   | <2.15  | 2.43   | 3.12   | 2.58   | 3.85   | 4.19   |
| ND      | 51.6   | 42.3   | <14.7  | 76.4   | 54.7   | 17.6   | 15.4   | 31.6   | 39.7   | 24.2   | 35.1   | 80.1   | <14.7  | N      | 41.6   | 25.4   | 39.8   | 40.2   | 86.8   | 41.7   | 35.7   | 38.3   |
| NI      | 22.2   | 29.7   | 13.5   | 31.7   | 16.6   | 33.4   | 35.1   | 44.0   | 43.8   | 39.4   | 52.6   | 48.3   | 10.8   | 21.3   | 22.9   | 26.8   | 31.2   | 24.8   | 9.56   | 34.1   | 28.6   | 33.1   |
| OS      | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  | <1.00  |
| PB      | 1.89   | 1.77   | 2.37   | 2.56   | 1.44   | 9.57   | 4.01   | 2.25   | 8.82   | 2.77   | 6.18   | 15.2   | 412.0  | 1.25   | 4.13   | 11.7   | 7.10   | 1.57   | <1.00  | 15.7   | 6.19   | 13.9   |
| PO      | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  | <0.22  |
| PR      | 8.48   | 3.69   | 4.81   | 9.69   | 5.73   | 5.72   | 6.18   | 7.76   | 6.72   | 6.58   | 6.67   | 9.01   | 4.21   | 7.44   | 6.63   | 4.99   | 6.82   | 6.59   | 14.9   | 7.59   | 6.67   | 6.35   |
| PT      | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  | <2.15  |
| RA      | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 | <14700 |
| RE      | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  | <10.0  |
| RH      | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | 1.00   | <0.10  | <0.10  | <0.10  | 1.00   | 1.00   | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  | <0.10  |
| RU      | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  | <0.46  |
| SA      | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  | <68.1  |
| SC      | 15.5   | 13.6   | 16.3   | 14.5   | 12.1   | 20.5   | 27.4   | 24.5   | 25.4   | 17.6   | 29.3   | 31.8   | 13.8   | 14.1   | 16.8   | 13.2   | 18.0   | 14.4   | 6.25   | 16.7   | 16.8   | 19.9   |
| SH      | <4.64  | <4.64  | <4.64  | 7.14   | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <4.64  | <10.4  | <4.64  | <4.64  |
| SN      | <3.16  | <3.16  | 4.51   | 4.17   | 3.23   | <3.16  | 4.58   | 5.48   | 5.43   | 4.29   | <3.16  | 6.96   | <3.16  | <3.16  | <3.16  | <3.16  | 3.78   | <3.16  | <3.16  | 4.61   | 4.36   | 3.80   |
| SR      | 381.0  | 60.2   | 191.0  | 148.0  | 147.0  | 146.0  | 156.8  | 259.0  | 558.8  | 323.0  | 361.0  | 554.0  | 66.7   | 251.0  | 157.0  | 86.4   | 317.0  | 98.0   | 40.2   | 223.0  | 251.0  | 247.0  |
| TA      | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.8 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 | <147.0 |
| TB      | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  | <6.81  |
| TE      | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 | <316.0 |
| TH      | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <100.0 | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  | <21.5  |
| TL      | <3.16  | <3.16  |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |

NOTES: 1. The standard deviation of any single answer should be taken as plus 50%, and minus 33%.  
2. Third significant figures, when reported, appear solely for programming convenience and should not be used in publications.  
3. The above limits apply under ideal conditions. In some cases interferences will narrow the limits.  
4. \*M denotes interference for an element which cannot be resolved by any routine method.

APPENDIX 38 SEMIQUANTITATIVE WHOLE-ROCK MINOR ELEMENT ANALYSES  
of  
COARSE-GRAINED CONTACT METAMORPHIC ROCKS FROM THE NORTHERN CULPEPER BASIN, VIRGINIA

Analysts: Joseph L. Harris, Charles S. Ansell, Herbert Kirschenbaum, Janet D. Fletcher, Floyd Brown, Leonard Shapiro (1973, 1974, 1975)

| PPM<br>Element | METAMORPHOSED SANDSTONE - GRANULITE |              |              |              |              |              |              |               |               |               | METAMORPHOSED CONGLOMERATE |              |              |              |               |               |
|----------------|-------------------------------------|--------------|--------------|--------------|--------------|--------------|--------------|---------------|---------------|---------------|----------------------------|--------------|--------------|--------------|---------------|---------------|
|                | 22<br>181310                        | 23<br>181311 | 24<br>181312 | 28<br>181316 | 29<br>181317 | 31<br>181319 | 32<br>181320 | 126<br>182456 | 127<br>182457 | 349<br>184771 | 356<br>184773              | 19<br>181307 | 27<br>181315 | 30<br>181318 | 179<br>182497 | 225<br>184770 |
| AG             | <0.10                               | <0.10        | <0.10        | <0.10        | <0.10        | <0.10        | <0.10        | <0.10         | <0.10         | <0.46         | <0.46                      | <0.10        | <0.10        | 0.27         | <0.10         | 6.12          |
| AS             | <100                                | <100         | <100         | <100         | <100         | <100         | <100         | <100          | <100          | <68.1         | <68.1                      | <100         | <100         | <100         | <100          | <68.1         |
| AU             | <6.81                               | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81         | <6.81         | <10.1         | <10.1                      | <6.81        | <6.81        | <6.81        | <6.81         | <10.0         |
| B              | 22.0                                | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         | >464          | <14.7                      | <10.0        | <10.0        | 40.6         | <10.0         | <14.7         |
| BA             | 213                                 | 50.5         | 27.7         | 132          | 10.8         | 152          | 96.7         | 67.8          | 125           | 125           | 193                        | 47.7         | 55.9         | 260          | 78.6          | 651           |
| BE             | 1.64                                | 1.44         | 1.93         | 1.25         | 2.07         | 1.64         | 1.61         | 1.42          | 1.40          | 1.47          | 1.47                       | 1.08         | <1.00        | 1.21         | <1.00         | <1.47         |
| BI             | <1.00                               | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00         | <1.00         | <4.64         | <4.64                      | <1.00        | <1.00        | <1.00        | <1.00         | <4.64         |
| CO             | <14.7                               | <14.7        | <14.7        | <14.7        | <14.7        | <14.7        | <14.7        | <14.7         | <14.7         | <10.0         | <10.0                      | <14.7        | <14.7        | <14.7        | <14.7         | <10.0         |
| CE             | 68.6                                | 42.5         | 54.0         | 41.2         | 84.6         | 102          | 116          | 189           | 75.9          | 46.8          | 89.6                       | 66.5         | 77.3         | 37.1         | <20.0         | H             |
| CD             | 7.42                                | 3.89         | 8.34         | 5.26         | 8.14         | 7.66         | 8.54         | 2.09          | 13.6          | 27.2          | <10.0                      | 10.9         | 6.94         | 7.03         | 27.7          | <10.0         |
| CR             | 61.7                                | 36.1         | 36.7         | 50.9         | 38.5         | 59.0         | 50.9         | 33.7          | 49.7          | 43.2          | 71.0                       | 22.8         | 14.9         | 18.2         | 183           | 4.42          |
| CS             | <3160                               | <3160        | <3160        | <3160        | <3160        | <3160        | <3160        | <3160         | <3160         | --            | --                         | <3160        | <3160        | <3160        | <3160         | --            |
| CU             | 54.7                                | 29.1         | 3.57         | 46.8         | 8.46         | 9.79         | 15.8         | 94.7          | 3.20          | 1.05          | 3.44                       | 22.2         | 9.71         | 30.6         | 53.9          | 1350.         |
| DY             | 14.5                                | 8.14         | 7.69         | 8.74         | <3.16        | <3.16        | 8.61         | 12.7          | 7.48          | <6.81         | <6.81                      | 7.85         | <3.16        | <3.16        | 6.18          | <6.81         |
| ER             | 7.36                                | <2.15        | <2.15        | <2.15        | <4.64        | <2.15        | <2.15        | 3.74          | <2.15         | <4.64         | <4.64                      | <2.15        | <2.15        | <2.15        | <2.15         | <4.64         |
| FU             | 2.34                                | 1.22         | 1.40         | 1.27         | 1.24         | 2.68         | 2.01         | 4.68          | 1.38          | <1.00         | 1.88                       | 1.39         | <1.00        | <1.00        | <1.00         | <1.00         |
| GA             | 11.9                                | 5.28         | 5.02         | 8.17         | 5.85         | 13.2         | 9.78         | 4.29          | 11.8          | 15.4          | 16.7                       | 2.29         | <2.15        | <2.15        | <4.16         | 2.66          |
| GO             | 4.87                                | <3.16        | <3.16        | 5.97         | <3.16        | <3.16        | 8.07         | 9.68          | 4.36          | 19.0          | 17.6                       | 3.66         | 4.88         | 6.57         | 5.88          | 23.8          |
| GE             | <1.00                               | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00         | <1.00         | <3.16         | <2.16                      | <1.00        | <1.00        | <1.00        | <1.00         | <3.16         |
| HF             | <10.0                               | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         | <21.5         | <21.5                      | <10.0        | <10.0        | <10.0        | <10.0         | <21.5         |
| HG             | <147                                | <147         | <147         | <147         | <147         | <147         | <147         | <147          | <147          | --            | --                         | <147         | <147         | <147         | <147          | --            |
| HD             | <1.00                               | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | 2.75          | <1.00         | <3.16         | <3.16                      | <1.00        | <1.00        | <1.00        | <1.00         | <3.16         |
| IN             | <4.64                               | <4.64        | <4.64        | <4.64        | <4.64        | <4.64        | <4.64        | <4.64         | <4.64         | <4.64         | <4.64                      | <4.64        | <4.64        | <4.64        | <4.64         | <4.64         |
| IB             | <6.81                               | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81         | <6.81         | <6.81         | <6.81                      | <6.81        | <6.81        | <6.81        | <6.81         | <6.81         |
| LA             | 35.6                                | 26.0         | 30.8         | 23.9         | 39.6         | 51.3         | 48.9         | 104           | 28.3          | 17.6          | 22.1                       | 19.7         | 22.3         | 24.0         | <14.7         | <14.7         |
| LI             | <31.6                               | <31.6        | <31.6        | <31.6        | <31.6        | <31.6        | <31.6        | <31.6         | <31.6         | <3.16         | 3.25                       | <31.6        | <31.6        | <31.6        | <31.6         | --            |
| LU             | <3.16                               | <3.16        | <3.16        | <3.16        | <3.16        | <3.16        | <3.16        | <3.16         | <3.16         | 165           | 369                        | <3.16        | <3.16        | <3.16        | <3.16         | <3.16         |
| MN             | 102                                 | 241          | 593          | 230          | 380          | 167          | 672          | 112           | 895           | <2.15         | <2.15                      | 1900         | 1470         | 1170         | 1340          | 119           |
| MO             | <1.00                               | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00         | 2.01          | <14.7         | <14.7                      | 1.39         | 1.93         | 1.73         | 4.55          | <2.15         |
| MB             | 7.17                                | 5.31         | 8.75         | 6.82         | 6.37         | 8.89         | 7.56         | 6.64          | 4.35          | --            | --                         | 3.02         | 4.18         | 3.11         | 2.49          | <14.7         |
| ND             | H                                   | 27.2         | H            | 37.8         | 59.0         | 77.4         | 146          | 74.5          | 35.7          | <68.1         | <68.1                      | <14.7        | <14.7        | <14.7        | <14.7         | H             |
| NI             | 22.6                                | 20.4         | 17.3         | 16.2         | 18.6         | 22.6         | 22.0         | 5.82          | 20.4          | 122           | 29.6                       | 14.0         | 10.6         | 11.9         | 40.9          | 2.01          |
| OS             | <1.00                               | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00        | <1.00         | <1.00         | <21.5         | <21.5                      | <1.00        | <1.00        | <1.00        | <1.00         | <21.5         |
| PB             | 4.32                                | 1.81         | 1.81         | 4.86         | 1.00         | 1.81         | 2.15         | 1.00          | 1.64          | 6.81          | 7.20                       | 3.04         | <1.00        | 122          | 1.50          | 37.3          |
| PO             | <0.22                               | <0.22        | <0.22        | <0.22        | <0.22        | <0.22        | <0.22        | <0.22         | <0.22         | <0.68         | <0.68                      | <0.22        | <0.22        | <0.22        | <0.22         | <0.68         |
| PR             | 7.11                                | 5.98         | 6.75         | 6.59         | 7.68         | 8.76         | 12.3         | 14.1          | 4.35          | <21.5         | <21.5                      | 9.39         | <21.5        | <21.5        | H             | <21.5         |
| PT             | <2.15                               | <2.15        | <2.15        | <2.15        | <2.15        | <2.15        | <2.15        | <2.15         | <2.15         | <6.81         | <6.81                      | <2.15        | <2.15        | <2.15        | <2.15         | <6.81         |
| RB             | <14700                              | <14700       | <14700       | <14700       | <14700       | <14700       | <14700       | <14700        | <14700        | --            | --                         | <14700       | <14700       | <14700       | <14700        | --            |
| RE             | <10.0                               | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         | <10.0         | <10.0                      | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         |
| RH             | <0.10                               | <0.10        | <0.10        | <0.10        | <0.10        | <0.10        | <0.10        | <0.10         | <0.10         | <0.68         | <0.68                      | <0.10        | <0.10        | <0.10        | <0.10         | <0.68         |
| RU             | <0.46                               | <0.46        | <0.46        | <0.46        | <0.46        | <1.00        | <0.46        | <0.46         | <0.46         | <1.00         | <1.00                      | <0.46        | <0.46        | <0.46        | <0.46         | <1.00         |
| SB             | <68.1                               | <68.1        | <68.1        | <68.1        | <68.1        | <68.1        | <68.1        | <68.1         | <68.1         | <68.1         | <68.1                      | <68.1        | <68.1        | <68.1        | <68.1         | <68.1         |
| SC             | 16.7                                | 8.41         | 12.2         | 14.0         | 10.5         | 13.8         | 16.9         | 9.29          | 8.68          | 14.1          | 21.3                       | 10.9         | 6.11         | 6.13         | 29.3          | 3.03          |
| SM             | 5.24                                | <4.64        | <4.64        | <4.64        | 5.75         | 7.54         | 7.33         | 10.1          | <4.64         | <4.64         | <4.64                      | <4.64        | <4.64        | <4.64        | <4.64         | H             |
| SN             | 6.75                                | 3.48         | <3.16        | 5.67         | <3.16        | <3.16        | 3.39         | <3.16         | 3.24          | <14.7         | <14.7                      | <3.16        | <3.16        | <3.16        | <3.16         | <14.7         |
| SR             | 106                                 | 78.9         | 130          | 173          | 83.2         | 120          | 202          | 54.9          | 39.8          | 135           | <46.4                      | 144          | 148          | 156          | 246           | 364           |
| TA             | <147                                | <147         | <147         | <147         | <147         | <147         | <147         | <147          | <147          | <464          | <464                       | <147         | <147         | <147         | <147          | <464          |
| TB             | <6.81                               | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81        | <6.81         | <6.81         | 65.9          | <46.4                      | <6.81        | <6.81        | <6.81        | <6.81         | <46.4         |
| TE             | <316                                | <316         | <316         | <316         | <316         | <316         | <316         | <316          | <316          | <464          | <464                       | <316         | <316         | <316         | <316          | <464          |
| TH             | <21.5                               | <21.5        | <100         | <21.5        | <21.5        | <21.5        | <100         | <21.5         | <21.5         | <100          | <21.5                      | <21.5        | <21.5        | <21.5        | <21.5         | <21.5         |
| TL             | <3.16                               | <3.16        | <3.16        | <3.16        | <3.16        | <3.16        | <3.16        | <3.16         | <3.16         | <4.64         | <4.64                      | <3.16        | <3.16        | <3.16        | <3.16         | <4.64         |
| TM             | <2.15                               | <2.15        | <2.15        | <2.15        | <2.15        | <2.15        | <2.15        | <2.15         | <2.15         | <3.16         | <3.16                      | <2.15        | <2.15        | <2.15        | <2.15         | <3.16         |
| U              | <215                                | <215         | <215         | <215         | <215         | <215         | <215         | <215          | <215          | <215          | <215                       | <215         | <215         | <215         | <215          | <215          |
| V              | 64.3                                | 58.8         | 63.6         | 71.3         | 62.0         | 74.6         | 65.6         | 60.8          | 67.0          | 81.4          | 132                        | 41.1         | 27.9         | 31.1         | 220           | 7.94          |
| W              | <10.0                               | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         | <10.0         | <10.0                      | <10.0        | <10.0        | <10.0        | <10.0         | <10.0         |
| Y              | 43.1                                | 22.0         | 33.2         | 32.2         | 32.5         | 40.5         | 32.8         | 33.1          | 28.2          | 12.7          | 33.5                       | 20.0         | 16.7         | 20.9         | 14.5          | 10.2          |
| YB             | 6.91                                | 3.12         | 3.99         | 3.66         | 4.40         | 5.70         | 4.81         | 6.98          | 4.69          | 1.11          | 3.93                       | 2.50         | 2.37         | 2.36         | 2.10          | <4.64         |
| ZH             | 45.5                                | 22.3         | 46.5         | 34.4         | 35.8         | 32.9         | 61.7         | <14.7         | 43.0          | 18.1          | 49.5                       | 79.2         | 74.2         | 104          | 105           | <14.7         |
| ZR             | 203                                 | 193          | 352          | 264          | 464          | 612          | 495          | 440           | 280           | 282           | 291                        | 243          | 250          | 240          | 107           | 44.6          |

- NOTES: 1. The standard deviation of any single answer should be taken as plus 50%, and minus 33%.  
2. Third significant figures, when reported, appear solely for programming convenience and should not be used in publications.  
3. The above limits apply under ideal conditions. In some cases interferences will narrow the limits.  
4. "H" denotes interference for an element which cannot be resolved by any routine method.