REFERENCES

(Asterisks refer to sources of data shown in figure 5.)

Aaron, J. M., 1971, Geology of the Nazareth quadrangle, Northampton County, Pennsylvania: U.S. Geological Survey Open-File Report 75–92, 353 p.
 Armstrong, E. J., 1941, Mylonization of hybrid rocks near Philadelphia, Pennsylvania: Geological

Society of America Bulletin, v. 52, no. 5, p. 667–693.

3. Baker, D. R., and Buddington, A. F., 1970, Geology and magnetite deposits of the Franklin

Bascom, Florence, Clark, W. B., Darton, N. H., Kümmel, H. B., Salisbury, R. D., Miller, B. L.

5. Bascom, Florence, Darton, N. H., Kümmel, H. B., Clark, W. B., Miller, B. L., and Salisbury,

6. Bascom, Florence, and Stose, G. W., 1932, Coatesville and West Chester, Pennsylvania-Delaware: U.S. Geological Survey Geologic Atlas, Folio 223, 15 p.
 7. Bayley, W. S., Salisbury, R. D., and Kümmel, H. B., 1914, Raritan, New Jersey: U.S. Geological

Bayley, W. S., Salisbury, R. D., and Kümmel, H. B., 1914, Raritan, New Jersey: U.S. Geological Survey Geologic Atlas, Folio 191, 32 p.
 Behre, C. H., Jr., 1927, Slate in Northampton County, Pennsylvania: Pennsylvania Geological Survey, 4th Series, Bulletin M9, 308 p.
 Berg, T. M., 1975, Geology of the Brodheadsville quadrangle, Monroe and Carbon Counties, Pennsylvania: Pennsylvania Geological Survey, 4th series, Atlas 205a, 60 p.
 Berg, T. M., and Dodge, C. M., compilers, 1981, Atlas of preliminary geologic quadrangle maps of Pennsylvania: Pennsylvania Geological Survey, 4th series, Map no. 61, 636 p.
 Berg, T. M., Edmunds, W. E., Geyer, A. R., Glover, A. D., Hoskins, D. M., MacLachlan, D. B., Root, S. I., Sevon, W. D., and Socolow, A. A., 1980, Geologic map of Pennsylvania: Harrisburg, Pennsylvania Department of Environmental Resources, Pennsylvania Geological Survey, 4th series, Scale 1:250.000.

Bouma, A. H., 1962, Sedimentology of some flysch deposits, a graphic approach to facies interpretations: Amsterdam, Elsevier Publishing Co., 168 p.
 Buckwalter, T. V., 1962, The Precambrian geology of the Reading 15-minute quadrangle: Pennsylvania Geological Survey, 4th series, Progress Report 161, 49 p.

Geological Survey Bulletin 67, 82 p.

17. Darton, N. H., Bayley, W. S., Salisbury, R. D., and Kümmel, H. B., 1908, Passaic, New Jersey-

New York: U.S. Geological Survey Geologic Atlas, Folio 157, 27 p.

18. Davis, R. E., Drake, A. A., Epstein, J. B., 1967, Geologic map of the Bangor quadrangle, Pennsylvania—New Jersey: U.S. Geological Survey Geologic Quadrangle Map GQ-685.

Demmon, F. E., III, 1977, Investigations of the origins and metamorphic history of Precambrian gneisses, Downington 7.5-minute quadrangle: Bryn Mawr, Pennsylvania, Bryn Mawr College, unpublished M.A. thesis, 77 p.
 Drake, A. A., Jr., 1965, Carbonate rocks of Cambrian and Ordovician age, Northampton and Proceedings of the Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western New York (Northampton and Warren and Hustorden Countries western Northampton and Marchampton and Marchampton and Marchampton

Survey Geologic Quadrangle Map GQ-595.

itoers University Press, p. 51–131

merica Special Paper 194, p. 75-109.

Bucks Counties, eastern Pennsylvania, and Warren and Hunterdon Counties, western New Jersey: U.S. Geological Survey Bulletin 1194–L, p. L1–L7.

Survey Geologic Quadrangle Map GQ-595.

—1967b, Geologic map of the Easton quadrangle, New Jersey-Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ-594.

—1969, Precambrian and lower Paleozoic geology of the Delaware Valley, New Jersey-Pennsylvania, field trip 1-A, in Subitzky, Seymour, ed., Geology of selected areas in New

rsey and eastern Pennsylvania and guidebook of excursions: New Brunswick, New Jersey

-1970, Structural geology of the Reading Prong, in Fisher, G. W., Pettijohn, F. J., Reed,

C., and Weaver, K. N., eds., Studies of Appalachian geology, central and southern: New York, lohn Wiley and Sons, p. 271–291.

-1978, The Lyon Station-Paulins Kill nappe—The frontal structure of the Musconetcon

nappe system in eastern Pennsylvania and New Jersey: U.S. Geological Survey Professional

Paper 1023, 20 p. —1984, The Reading Prong of New Jersey and eastern Pennsylvania—An appraisal of rock

relations and chemistry of a major Proterozoic terrane in the Appalachians, in Bartholomew M. J., ed., The Grenville event in the Appalachians and related topics: Geological Society of

Drake, A. A., Jr., and Epstein, J. B., 1967, The Martinsburg Formation (Middle and Upper Ordovician) in the Delaware Valley, Pennsylvania–New Jersey: U.S. Geological Survey

Drake, A. A., Jr., Epstein, J. B., and Aaron, J. M., 1969, Geologic map and sections of parts of

the Portland and Belvidere Quadrangles, New Jersey—Pennsylvania: U.S. Geological Survey Miscellaneous Investigations Series Map I–552.

Drake, A. A., Jr., Kastelic, R. L., Jr., and Lyttle, P. T., 1984, Geologic map and sections of parts

Drake, A. A., Jr., and Lyttle, P. T., 1980, Alleghanian thrust faults in the Kittatinny Valley, New Jersey, in Manspeizer, Warren, ed., Field studies of New Jersey geology and guide to field

——1985, Geologic map of the Blairstown quadrangle, Warren County, New Jersey: U.S. Geological Survey Geologic Quadrangle Map GQ-1585.

Drake, A. A., Jr., McLaughlin, D. B., and Davis, R. E., 1961, Geology of the Frenchtown

Geological Survey Geologic Quadrangle Map GQ-593.

Drake, A. A., Jr. and Morgan, B. A., 1981, The Piney Branch Complex—A metamorphose

Epstein, J. B., 1973, Geologic map of the Stroudsburg quadrangle, Pennsylvania-New Jersey: U.S.

rips: Newark, New Jersey, Rutgers University Press, p. 92-114.

Geological Survey Geologic Quadrangle Map GQ-1047

Geologic Quadrangle Map GQ-1645

Geologic Quadrangle Map GQ-1637. Lyttle, P. T., unpublished data.

Markewicz, F., unpublished data.

University Press, p. 2–39

Ratcliffe, N. M., unpublished data.

Groundwater Report W14, 111 p.

Science, v. 278, no. 4, p. 518-542.

of the Portland and Belvidere quadrangles, New Jersey: U. S. Geological Survey Miscellaneous Investigations Series Map I-1530.

quadrangle, New Jersey-Pennsylvania: U.S. Geological Survey Geologic Quadrangle Ma

fragment of the Central Appalachian ophiolite in northern Virginia: American Journal of Science, v. 281, no. p. 484–508.

— in press, Geologic map of the Saylorsburg quadrangle, Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ-1638.

in press, Geologic map of the Wind Gap quadrangle, Pennsylvania: U.S. Geological Survey

Epstein, J. B., and Epstein. A. G., 1969, Geology of the Valley and Ridge Province between

ed., Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions: New Brunswick, New Jersey, Rutgers University Press, p. 132–205.

41. ——1972, The Shawangunk Formation (Upper Ordovician (?) to Middle Silurian) in eastern Pennsylvania: U.S. Geological Survey Professional Paper 744, 45 p.

*42. Epstein, J. B., and Sevon, W. D., 1978, Preliminary geologic map and sections of the Kunkletown quadrangle, Pennsylvania: U.S. Geological Survey Open-file Report 78–392.

*43. Epstein, J. B., Sevon, W. D., Glaeser, J. D., 1974, Geology and mineral resources of the Lehighton and Palmerton quadrangles, Carbon and Northampton Counties, Pennsylvania: Pennsylvania Geological Survey Atlas 195 c and d, 460 p.

*44. Eroolish A. L. and Olsen, P. F. 1984, Newark Supergroup, a revision of the Newark Group in

Froelich, A. J., and Olsen, P. E., 1984, Newark Supergroup, a revision of the Newark Group in

Glaeser, J. D., 1966, Provenance, dispersal, and depositional environments of Triassic sediments

168 p. (reprinted 1974).

Hague, J. M., Baum, L., Herrman, L. A., and Pickering, R. J., 1956, Geology and structure of the Franklin-Sterling area, New Jersey: Geological Society of America Bulletin, v. 67, no. 4, p.

Hall, Leo M., 1976, Preliminary correlation of rocks in southwestern Connecticut, in Page, L. R.

Houghton, H., unpublished data.
 Kastelic, R. L., Jr., 1980, Precambrian geology and magnetite deposits of the New Jersey Highlands in Warren County, New Jersey: U.S. Geological Survey Open-file Report 80–789,

Annual Report of the State Geologist, 1896, p. 25–88. Kümmel, H. B., and Weller, Stuart, 1902, The rocks of the Green Pond Mountain region: New

Jersey Geological Survey, Annual Report of the State Geologist, 1901, p. 1–51.

Lash, G. G., 1978, The structure and stratigraphy of the Pen Argyl Member of the Martinsburg Formation in Leigh and Berks Counties, Pennsylvania: U.S. Geological Survey Open-file

Geologic Quadrangle Map GQ-1577.
—in press, Geologic map of the Hamburg quadrangle, Pennsylvania: U.S. Geological Survey

quadrangle, Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ-1598. MacLachlan, D. B., 1967, Structure and stratigraphy of the limestones and dolomites of Daupl

County, Pennsylvania: Pennsylvania Geological Survey, Atlas 187cd.

1985, Geologic map of the Kutztown quadrangle, Pennsylvania: U.S. Geological Survey

T., and Drake, A. A., Jr., unpublished data.
T., Lash, G.G., and Epstein, J. B., 1986, Bedrock geologic map of the Slatedale

County, Pennsylvania: Pennsylvania Geological Survey, 4th series, Bulletin G44, 168 p

County, Pennsylvania: Pennsylvania Geological Survey, Atlas 187ab, 71 p.

——1983, Geology and mineral resources of the Reading and Birdsboro quadrangles, Berks

North America, Newark Supergroup)—Stratigraphy, structure and correlation: New Jersey Academy of Science, The Bulletin, v. 25, p. 25–51.

-1980b, Triassic and Jurassic formations of the Newark basin, in Manspeizer, Warren, ed

Field studies of New Jersey geology and guide to field trips: Newark, New Jersey, Rutgers

Tertiary formations of the New Jersey Coastal Plain, in Subitzky, Seymour, ed., Geology of

selected areas in New Jersey and eastern Pennsylvania and guidebook of excursions: New

basement rocks of Ramapo seismic zone, New York and New Jersey, and their relationship

to current seismicity, in Manspeizer, Warren, ed., Field studies of New Jersey geology and

Jersey and eastern Pennsylvania: New Brunswick, New Jersey, Rutgers University Press, p.

quadrangles, Carbon and Monroe Counties, Pennsylvania: Pennsylvania Geological Survey,

eastern Pennsylvania and guidebook of excursions: New Brunswick, New Jersey, Rutgers

Line gabbro-peridotite complex, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., and Weaver, K., N., eds., Studies of Appalachian geology, central and southern: New York, John Wiley

Rima, D. R., Neisler, Harold, and Longwill, Stanley, 1962, Geology and hydrology of the Stockton Formation in southeastern Pennsylvania: Pennsylvania Geological Survey, 4th series,

Sevon, W. D., 1969, Sedimentology of some Mississippian and Pleistocene deposits of northeastern Pennsylvania, in Subitzky, Seymour, editor, Geology of selected areas in New

-----1975, Geology and mineral resources of the Christmans and Pohopoco Mountain

Sims, P. K., 1958, Geology and magnetite deposits of the Dover District, Morris County, New

Jersey: U.S. Geological Survey Professional Paper 287, 162 p.

Smith, B. L., 1969, The Precambrian geology of the central and northeastern parts of the New Jersey Highlands, in Subitzky, Seymour, ed., Geology of selected areas in New Jersey and

University Press, p. 35–47.

Southwick, D. L., 1970, Structure and petrology of the Harford County part of the Baltimore-State

Spencer, A. C., and Kümmel, H. B., Wolff, J. E., Salisbury, R. D., and Palache, Charles, 1908,

Franklin Furnace, New Jersey: U.S. Geological Survey Geologic Atlas, Folio 161, 27 p.
79. Stose, G. W., 1908, The Cambro-Ordovician limestones of the Appalachian Valley in southern

80. Sumner, J. R., 1977, Geophysical investigation of the structural framework of the Newark-Gettysburg Triassic basin, Pennsylvania: Geological Society of America Bulletin, v. 88, no.

81. Swartz, C. K., and Swartz, F. M., 1941, Early Devonian and late Silurian formations of southeastern

Pennsylvania: Geological Society of America Bulletin, v. 52, no. 8, p. 1129–1191

U.S. Geological Survey, 1967, Engineering geology of the Northeast Corridor, Washington, D.C., to Boston, Massachusetts—Coastal Plain and surficial deposits: U.S. Geological Survey

Miscellaneous Geologic Investigations Series Map I–514–B.

*83. Van Houten, F. B., 1969, Late Triassic Newark Group, north central New Jersey and adjacent Pennsylvania and New York, in Subitzky, Seymour, ed., Geology of selected areas in New

-1980, Late Triassic part of Newark Supergroup, Delaware River Section, west-c

trips: Newark, New Jersey, Rutgers University Press, p. 264–276.

85. Wagner, M. E., and Crawford, M. L., 1975, Polymetamorphism of the Precambrian Baltimo

Gneiss in southeastern Pennsylvania: American Journal of Science, v. 275, no.6, p. 653–682.

86. Wherry, E. T., 1910, Contributions to the mineralogy of the Newark Group in Pennsylvania: Wagner Free Institute of Science, Transactions, v. 7, p. 5–27.

Willard, Bradford, and others, 1959, Geology and mineral resources of Bucks County, Pennsylvania: Pennsylvania Geological Survey, 4th series, Bulletin C9, 243 p.
 Wise, D. V., 1970, Multiple deformation, geosynclinal transitions and the Martic problem in

Pennsylvania, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., and Weaver, K. N., eds., Studies of Appalachian geology, central and southern: New York, John Wiley and Sons, p. 317–333.

*89. Wood, G. H., Jr., 1974a, Geologic map of the Nesquehoning quadrangle, Carbon and Schuykill

Wood, G. H., Jr., and Bergin, M. J., 1970, Structural controls of the Anthracite region Pennsylvania, in Fisher, G. W., Pettijohn, F. J., Reed, J. C., and Weaver, K. N., eds., Studies

92. Wood, G. H., Jr., Trexler, J. P., and Kehn, T. M., 1969, Geology of the west-central part of the

93. Wright, T. O., and Stephens, George, 1978, Regional implications of the stratigraphy and structure

94. Young, D. A., 1971, Precambrian rocks of the Lake Hopatcong area, New Jersey: Geological Society of America Bulletin, v. 82, no. 1, p. 143–157.

——1974b, Geologic map of the Tamaqua quadrangle, Carbon and Schuykill Counties, Pennsylvania: U.S. Geological Survey Geologic Quadrangle Map GQ-1133.

n Appalachian geology, central and southern: New York, John Wiley and Sons, p. 147–160

Southern Anthracite field and adjoining areas, Pennsylvania: U.S. Geological Survey

of Shochary Ridge, Berks and Lehigh Counties, Pennsylvania: American Journal of Science,

Jersey and eastern Pennsylvania and guidebook of excursions: New Brunswick, New Jersey,

Jersey, in Manspeizer, Warren, ed., Field studies of New Jersey geology and guide to field

Pennsylvania: Journal of Geology, v. 16, p. 698–714.

Rutgers University Press, p. 314–347

rofessional Paper 602, 150 p.

New Jersey Geological Survey, 1973, Geologic overlay of topographic sheet 22: Trenton, N.J.

Owens, J. P., and Sohl, N. F., 1969, Shelf and deltaic paleoenvironments in the Cretaceous-

Brunswick, New Jersey, Rutgers University Press, p. 235–278.

Perry, W. J., Jr., 1978, Sequential deformation in the Central Appalachians: American Journal of

Science, V. 278, no. 4, p. 518–542.
 Postel, A. W., 1940, Hydrothermal emplacement of granodiorite near Philadelphia: Proceedings of the Academy of Natural Science of Philadelphia, v. 92, p. 123–152.
 ——1951, Problems of the pre-Cambrian in the Phoenixville and Honey Brook quadrangles, Chester County, Pennsylvania: Pennsylvania Academy of Science, v. 25, p. 113–119.
 Quick, A. N., 1960, Structural geology of the Hackettstown in 5-0 minute quadrangle, New Jersey:

New York, New York University, unpublished M.S. thesis, 50 p.

*70. Ratcliffe, N. M., 1980, Brittle faults (Ramapo fault) and phyllonitic ductile shear zone in the

uide to field trips: Newark, New Jersey, Rutgers University Press, p. 278-312.

Department of Conservation and Economic Development.

Olsen, P. E., 1980a, The latest Triassic and Early Jurassic Formations of the Newark Basin (easter

-1979, Geology and mineral resources of the Temple and Fleetwood quadrangles, Berks

50. Kümmel, H. B., 1897, The Newark System; report of progress: New Jersey Geological Survey,

eastern North America, in Contributions to stratigraphy: U.S. Geological Survey Bulletin 1537-A, p. A55-A58.

in the Newark-Gettysburg Basin: Pennsylvania Geological Survey, 4th series, Bulletin G43

ed., Contributions to the stratigraphy of New England: Geological Society of America Memo

Delaware Water Gap and Lehigh Gap, Pennsylvania, field trip 1-B, in Subitzky, Seymour,

ed., Geology of selected areas in New Jersey and eastern Pennsylvania and guidebook o

967, Geologic map of the Riegelsville quadrangle, Pennsylvania-New Jersey: U.S.

-1967a, Geologic map of the Bloomsbury quadrangle, New Jersey: U.S. Geological

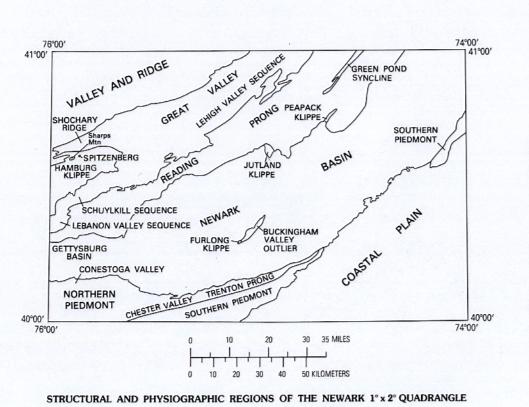
Chadwick, G. H., 1908, Revision of "the New York series": Science, v. 28, no. 5, p. 346–348.
Crawford, W. A., Robelen, P. G., and Kalmbach, J. H., 1971, The Honey Brook anorthosite:
American Journal of Science, v. 271, no. 4, p. 333–349.

Darton, N. H., 1890, The relation of traps of the Newark System in the New Jersey region: U.S.

quadrangle and part of the Hamburg quadrangle, New Jersey: U.S. Geological Survey Professional Paper 638, 73 p.

and Knapp, G. N., 1909, Philadelphia, Pennsylvania-New Jersey-Delaware (Norristown Germantown, Chester, and Philadelphia quadrangles): U.S. Geological Survey Geologic

1909, Trenton, New Jersey-Pennsylvania: U.S. Geological Survey Geologic Atlas, Foli



DESCRIPTION OF MAP UNITS Note: A variety of Holocene deposits and Pleistocene glacial sediments are present throughout the quadrangle, and Pleistocene and Tertiary terrace deposits of gravel, sand, and clay are common along the area of the Fall Line. None of these units are shown on the map.

COASTAL PLAIN

The Coastal Plain is a gently seaward-sloping surface on poorly consolidated sediments of Tertiary and Cretaceous age. These rocks form a southeastward-thickening, gently tilted prism of strata which exceeds 755 m (2,480 ft) in thickness along the coast, and thins to a feather edge along the Fall Line where they unconformably overlap the Southern Piedmont and Newark Basin. Whereas the oldest Cretaceous clastic sediments are mostly nonmarine, the overlying units are mostly marginal marine in origin. Cohansey Sand (Pliocene (?) and Miocene)—Well-sorted, crossbedded, medium grained, partly arkosic quartz sand; some dark, massive, carbonaceous, kaolinitic, and illitic silty clay; crossbedded gravel in channels with pebbles of quartz and quartzite; and mino orphic rock fragments which are less than 5 cm (2 in) in diameter. As much as 46 n (150 ft) thick, thinning toward the Fall Line Kirkwood Formation (Miocene)—Moderately well sorted, fine-grained, micaceous quartz sand, locally clayey or silty with local thick beds of clayey silt and fine-pebble gravel. Lower tact unconformable. 30-76 m (100-250 ft) thick Manasquan Formation (Eocene)—Thick-bedded to massive, silty and clayey glauconition and quartzose sand; interbedded silty clay and clayey silt. Apatite pellets and siderite ragments locally abundant. 15–61 m (50–195 ft) thick Vincentown Formation (Paleocene)-Partly clayey, glauconitic quartz sand. 15-30 m (50–100 ft) thick

Hornerstown Sand (Paleocene)—Massive, poorly sorted, fine- to medium-grained locally very silty and clayey glauconite and guartz sand with some phosphate pellets and Red Bank Sand (Upper Cretaceous)-Very thick bedded, medium- to coarse-grained durated, quartz, feldspar, and glauconite sand and fossiliferous sandy silt. As much lavesink Formation (Upper Cretaceous)—Dark-gray, thick-bedded, clayey and silty, uconite sand, with organic matter, pyrite, and local thick shell beds. As much as 14 m Mount Laurel Sand (Upper Cretaceous)—Medium-grained, poorly to moderately sorted, eldspathic quartz sand. Abundant borings filled with glauconite sand and thin-bedder lark, micaceous and carbonaceous silt and clay alternating with medium-bedded, ligh colored, micaceous, glauconitic quartz sand with discontinuous layers of gray siderite oncretions. As much as 15 m (50 ft) thick Wenonah Formation (Upper Cretaceous)-Generally dark, thick-bedded, fine- to

edium-grained, poorly to moderately sorted, carbonaceous, pyritic, very silty and clayey, artzose glauconite sand. 21–30 m (70–100 ft) thick Marshalltown Formation (Upper Cretaceous)—Dark, fine-grained, massive, fossiliferous, very silty and clayey, quartzose glauconité sand with common mica, feldspar, pyrite, and carbonaceous matter. 5–6 m (15–20 ft) thick Englishtown Formation (Upper Cretaceous)-Light-colored, well-sorted, fine- to medium-grained, crossbedded, glauconitic, feldspathic, and micaceous guartz sand, an interbedded clayey silt and sand with numerous siderite concretions. 6-46 m (20-150 ft) Woodbury Clay (Upper Cretaceous)—Dark-gray, massive to crudely laminated, onaceous, pyritic, partly glauconitic, micaceous, very clayey (dominantly illitic) silt. As ferchantville Formation (Upper Cretaceous)—Dark, clayey, micaceous, quartzose, conaceous silt with interbedded gravel containing reworked siderite concretions; thickedded glauconite and quartz sand. 6-30 m (20-100 ft) thick agothy Formation (Upper Cretaceous)—Dark, micaceous, pyritic, kaolinitic, clayey silt nt-colored quartz sand with large lignitized logs. Lower contact is unconformable but is buried by surficial deposits and precise location is poorly known on Staten Island d in Brooklyn, N.Y. 3-61 m (10-200 ft) thick

Raritan Formation (Upper Cretaceous)-Massive, crossbedded quartz sand; thickded clayey silt; laminated clay and silt; and minor gravel. About 61 m (200 ft) thick Potomac Formation (Upper and Lower Cretaceous)-Moderately well sorted, dded, quartzose sand; gravelly sand with quartz and quartzite pebbles as much as 3 cm (5 in) long; and black, red, white, and yellow, massive, kaolinitic and illitic, crudely atified, lenticular clay. 76–244 m (250–800 ft) thick. Lower contact unconformable Il Coastal Plain sediments (Tertiary and Cretaceous)—Shown in cross section only.

NEWARK AND GETTYSBURG BASINS The Newark basin, and west of the Schuylkill River, the Gettysburg basin, form a rolling lowland underlain by a thick succession of sedimentary rocks and basalt flows of Early Jurassic and Late Triassic age. Jurassic diabase dikes, sills, and stocks cut and metamorphose older rocks in the basin. The rocks generally di gently to moderately to the north toward a large fault zone that forms the basin boundary, although ma pen folds with axes at high angles to the strike of the faults have been mapped. The rocks form a north ward-thickening wedge with a composite thickness that may exceed 10,000 m (33,000 ft); however, not all of the units are preserved in one area. Several generations of folds may affect the rocks of the basin but do not appear to affect the older pre-Triassic rocks outside the basin. The basin may have forme as a pull-apart structure with significant strike-slip movement along the larger faults. This could accour or local horsts and grabens within the basin, possible sequential development of different parts of the basin, the compressional regime that produced the folds and local thrust faults, as well as decoupling of the folds within the basin from structures outside the basin. Some of the gently dipping listric normal faul may represent reactivated segments of Paleozoic thrust faults, but with the opposite sense of movement. Limestone conglomerate (Rcl), quartzite conglomerate (Rcq), and unclassified conglomerate (Rc) may be partly Jurassic in age. Figure 1 shows stratigraphic and intrusive relationships.

Diabase (Lower Jurassic)—Dikes, sills, and sill-like intrusives. Dark-gray to black, fineto coarse-grained (except very fine to fine-grained near chilled borders), diabase compos largely of calcic plagicclase and augite. Some of the dikes are several miles long and as much as 0.8 km (0.5 mi) wide; some may have been intruded along faults. Generally deeply weathered. Larger bodies, as much as 520 m (1,700 ft) thick, interpreted as sills or discordant sheets with oval or ringlike outcrop patterns. Shales and siltstones surrounding these bodies have been thermally metamorphosed to a purplish-red, lightgray, and dark-gray, indurated, brittle, and fine-grained hornfels with quartz, plagioclase, sericite, biotite, cordierite, epidote, chlorite, magnetite, hornblende, pyroxene, tourmaline, nepheline, cancrinite, and zeolite in a zone averaging about 610 m (2,000 ft) wide. Th width of this zone depends on the thickness of the intrusive, its topographic expression,

NEWARK SUPERGROUP* Conglomerate (Lower Jurassic)—Generally poorly exposed conglomerate and onglomeratic sandstone with clasts of quartz, sandstone, conglomerate, granite, netamorphic rocks, limestone, and basalt; clasts may be more than 15 cm (6 in) in iameter. Overlies Boonton Formation, Hook Mountain Basalt, and Towaco Formation Jb Boonton Formation of the Brunswick Group (Lower Jurassic)—Lower part is red, gray, own, and black, blocky, partly dolomitic siltstone; locally contains hopper (salt crystal asts pseudomorphic after gypsum, glauberite, and halite. Overlain by red, well-bedde

and thick-bedded siltstone and sandstone and thin beds of gray-green siltstone. Bed o icrolaminated, gray, calcareous siltstone with fossil fish near the top, 1 m (3.3 ft) thick with thin, gray and brown pebble-conglomerate beds as much as 0.5 m (1.6 ft) thick eptile and arthropod fossils also present. Northeast of Morristown, N. J., includes thick sequences of red-, gray-, and brown-matrix conglomerate and breccia. More than 500 m (1,640 ft) thick Hook Mountain Basalt of the Brunswick Group (Lower Jurassic)—Two tholeiitic basalt ows composed mainly of aphanitic to finely crystalline plagioclase and augite. In places, the flows contain vesicles near the top. As much as 110 m (361 ft) thick Towaco Formation of the Brunswick Group (Lower Jurassic)—Red, gray, and black, to coarse-grained sandstone, siltstone, and conglomerate in fining-upward cycles. Medial black and gray, microlaminated, calcareous siltstone containing diagnostic pollen, sh, and dinosaurs. Cycles average about 35 m (115 ft) in thickness with maximum (ness of unit 340 m (1,115 ft) Preakness Basalt of the Brunswick Group (Lower Jurassic)—At least three tholeitic

lt flows, with some pillows and basaltic breccia resembling aa. Columnar with paracteristic platy prismatic joint pattern. Locally, thin red siltstone (Jps) separates the Feltville Formation of the Brunswick Group in New Jersey and upper part of the artly crossbedded, fine- to coarse-grained feldspathic sandstone; gray and black siltstone in fining-upward cycles; and a laterally continuous, gray, laminated limestone. Lower ha contains a unit of black to white laminated limestone, calcarenite, graded siltstone, and crossbedded siltstone and sandstone about 1–10 m (3–39 ft) thick. Fossiliferous, with reptiles, arthropods, abundant fish, and diagnostic spores and pollen. About 170–600 m 558–1,969 ft) thick. Only lower 215 m (705 ft) preserved near Reading, Penn. Orange Mountain Basalt of the Brunswick Group in New Jersey and Jacksonwald of the Brunswick Group in Pennsylvania (Lower Jurassic)—The Orange fountain Basalt comprises at least two tholeiitic, pillowed pahoehoe, and columnar basa lows, with thin interbedded volcaniclastic rocks that are about 1-4 m (3-13 ft) thick, in the irst Watchung Mountain of New Jersey. The Jacksonwald Basalt (Wherry, 1910; also lled the Jacksonwald Basalt Member of the Brunswick Formation by MacLachlan, 1983. km (5.6 mi) east of Reading, Penn., and another flow 8 km (5 mi) south of Flemingtor

J., may be the same extrusive unit. Probably between 100 and 200 m (328 and 656 Passaic Formation of Olsen (1980a) of the Brunswick Group in New Jersey and lower part of the Brunswick Group in Pennsylvania (Lower Jurassic and Upper Triassic) edominantly gravish-red to reddish-brown, evenly to irregularly bedded, thin- to thick ded shale, siltstone, very fine to coarse-grained sandstone, and red-matrix glomerate. Generally becomes coarser in the northeastern half of the basin in New Jersey. Mudcracks, ripple marks, crossbeds, and burrows are common. Contains detrital cycles of medium- to dark-gray and olive- to greenish-gray, thin-bedded and evenly bedded shale and siltstone (Rpg, Rblg), similar to the rocks in the underlying of Lambertville, N. J., but are not shown on the map (Olsen, unpub. data, 1983). Greenish and brownish, fine- to coarse-grained, arkosic sandstone grades in places to quartzite fanglomerate (Rcq), and contains some interbedded red beds and impure limestone or careous shale. Locally contains dinosaur footprints. Individual cycles as much as 76 m 250 ft) thick; some cycles are too thin to show on this map. Lower contact with the Lockatong Formation (RI) gradational through about 500 m (1,640 ft) and is mapped where thickness of red beds is dominant over thickness of gray and black beds. Interfingers laterally with the Lockatong (RI) and Hammer Creek (Rh) Formations. Where the uni rades laterally into the Lockatong, lower contact is either conformable and gradational o older rocks of the Newark Supergroup, or is unconformable on basement rock Contains reptiles, arthropods, pelecypods, plant impressions, spores, and pollen. The Jurassic-Triassic boundary lies within the uppermost 100 m (328 ft). The maximum

thickness may exceed 6,000 m (19,685 ft) in the western part of the basin and is about

Hammer Creek Formation (Upper Triassic)—Red, brown, and less abundant light-gray, very fine to coarse-grained and conglomeratic, thin- to thick-bedded sandstone, with som crossbedding, lensing, channeling, and ripple marks, and thin- to medium-bedded red shale and siltstone with ripple marks and mudcracks. Contains beds with abundant red and gray, thick- to very thick bedded conglomeratic sandstone with clasts of quartz, quartzite, sandstone, limestone, and shale as much as 25 cm (10 in) long (Rhc). The contact between the Hammer Creek Formation (Rh) and the lower part of the Brunswick Group (JRbI) is arbitrarily placed in the Schuylkill River area. Thickness of the entire Hammer reek Formation may be as much as 2,800 m (9,187 ft) Lockatong Formation (Upper Triassic)-Predominantly laminated to thick-bedded

gray and black siltstone and shale; rich in fossils, including plants, reptiles, fish, and agnostic spores and pollen. Unit composed of alternating detrital and chemical-lacustrine cles. Detrital cycles: lower part laminated, medium-dark-gray to black, calcareous, pyritic siltstone and shale overlain by platy to massive, disrupted (mudcracked and burrowed lark-gray, calcareous siltstone, ripple-bedded siltstone, and fine-grained sandstone: more common in the lower Lockatong. Averages about 5.2 m (17.1 ft) in thickness. Chemica cycles: Lower part platy, medium-dark-gray to black, dolomitic siltstone and marlstone with hrinkage cracks and lenses of puritic limestone, overlain by massive, gray or red, analcime and carbonate-rich, disrupted siltstone. Average thickness about 3.2 m (10.5 ft). Lowe contact of Lockatong gradational, placed at base of lowest continuous black siltstone bed ontains interbedded, reddish-brown, sandy siltstone in units from about 3 to 82 m (1 tockton Formation (Tks) as well as up into the Passaic Formation (JTkp) and lower part of the Brunswick Group (JRbI). Wedges out between the Stockton (Rs) and Hammer Creek (Rh) Formations west of the Schuylkill River. Maximum thickness about 1,180 m Stockton Formation (Upper Triassic)—Light- to medium-gray and light-yellowish-gray or pale-reddish-brown, thin- to thick-bedded, fine- to coarse-grained sandstone, arkose

nd arkosic conglomerate with pebbles of quartz, quartzite, feldspar, shale, limestone, and etamorphic rocks locally more than 8 cm (3 in) long; grayish-red to moderate-reddishown, and light- to medium-gray siltstone and shale, bioturbated by roots and burrows; and gravish-red to reddish-brown, thin- to thick-bedded, very fine to medium-grained arkosic sandstone, generally fining upward with abrupt lateral lithic changes. These roc contain channels, ripple marks, mudcracks, crossbeds, pinch-and-swell structures, and minor burrows. Purplish siltstone near the middle and top. Well-bedded, gray and graygreen, fossiliferous siltstone present locally in upper Stockton. Locally contains retone breccia filling solution cavities in Ordovician-Cambrian limestones. Local gray and buff, thick-bedded to crudely bedded, arkosic conglomerate and arkose with subangular to rounded pebbles of quartz, quartzite, limestone, and underlying basemer rocks as much as 8 cm (3 in) long in a red, arkosic sand to silty shale matrix (Rsc). Units containing conglomerate average about 100 m (320 ft) in thickness. Lower contact The Hammer Creek (Rh) is a partial lateral correlative and un overlies this unit. Maximum thickness is 1,830 m (6,000 ft) in the center of the basin, hinning in all directions to less than 250 m (820 ft) near Hoboken, N.J. In Montgomery ounty and eastern Chester County, Penn., the Stockton is divided into three members Upper shale member (Rsu), red shale and siltstone with some fine-grained, arkosic sandstone. 18-305 m (60-1,000 ft) thick. Middle arkosic member (Fism), fine- to nedium-grained, arkosic sandstone with red shale and siltstone, 518-1,280 m (1,700 4.200 ft) thick. Lower arkosic member (RsI), medium- to very coarse grained, arkosic sandstone and conglomerate, with fine-grained, arkosic sandstone and red shale and siltstone. 168-823 m (550-2,700 ft) thick Limestone conglomerate (Upper Triassic)—Subangular, medium- to dark-medium-gray limestone and dolomite clasts as much as 1 m (3.3 ft) in diameter (derived from

Cambrian limestones in the immediate area) and rare gneiss pebbles and cobbles in a matrix of red, partly arkosic sandstone and siltstone. Generally becomes finer grained Quartzite conglomerate (Upper Triassic)—Rounded pebbles, cobbles, and boulders, as much as 30 cm (1 ft) long, of white, light-gray, and reddish quartzite, and lesser calcareous sandstone in a matrix of red, partly arkosic siltstone and sandstone. Source from Silurian rocks to north. Generally becomes finer grained southward. About 305 m (1,000 ft) thick Unclassified conglomerate (Upper Triassic)—Conglomerate and conglomeration ndstone with rounded to angular quartzite, limestone, gneiss, and basalt clasts as much as 1 m (3.3 ft) long. As much as 305 m (1,000 ft) thick in places

VALLEY AND RIDGE PROVINCE The Valley and Ridge province can be divided into lithotectonic units, each comprising a group of prmations with their own deformation and erosion characteristics. Incompetent rocks, such as the Marcellus Formation and the top of the Martinsburg Formation, are zones of detachment separating the

thotectonic packages. Alleghanian deformation, dominated by a thrust system of imbricate splays, has

produced a series of northeast-trending, northwest-verging, upright to overturned folds. Many of the anticlines may be directly related to blind thrusts at depths. Figure 2 shows stratigraphic and facies Pl Llewelyn Formation (Upper and Middle Pennsylvanian)—Very light gray to grayishblack, light-brownish-gray, greenish-gray, and grayish-orange, very thin to thick bedded siltstone and shale with abundant plant debris; evenly bedded to lenticular, partly channeled, graded, crossbedded, and rippled, fine- to coarse-grained sandstone and conglomerate; evenly bedded to lenticular, partly channeled, graded, crossbedded, an rippled conglomeratic sandstone with quartz and quartzite pebbles; and less abundant chert and metamorphic rock fragments as much as three inches in diameter with numerous anthracite coal beds. Lower contact sharp and placed at base of shale or underclay benea he Buck Mountain (No. 5) coal bed (not identified on the map). 275–625 m (900–2,050

Pottsville Formation (Middle and Lower Pennsylvanian)—Light- to dark-gray and olive ray to yellowish-brown, thin- to very thick bedded, planar-bedded and crossbedde tabular to lenticular conglomerate; fine- to coarse-grained sandstone with quartz an quartzite pebbles as much as 20 cm (8 in) long; minor pebbles of other metamorphic and sedimentary rocks; less abundant shale and siltstone with plant debris; and several beds of anthracite coal. Lower contact at top of highest red bed of underlying Mauch Chunk Formation (IPMm). 250–450 m (820–1,475 ft) thick Mauch Chunk Formation (Lower Pennsylvanian and Upper Mississippian)—Gravisi to pale-red, light- to dark-gray, and olive-gray, laminated to thick-bedded, planar-bedde and crossbedded, partly lenticular and channeled, very fine to medium-grained sandstone some shale and siltstone, and minor conglomerate with quartz and quartzite pebbles more than 8 cm (3 in) long. Mudcracks, ripple marks, and raindrop impressions are commo Lower contact is gradational and placed at base of lowest red bed above gray beds of the underlying Pocono Formation (Mp). About 950 m (3,100 ft) thick Mp Pocono Formation (Lower Mississippian)—Light- to medium-gray, thin- to very thick pedded, quartzitic conglomerate with quartz pebbles and minor amounts of chert and quartzite pebbles as much as 8 cm (3 in) long; structureless and crossbedded, mediumrained sandstone: and minor thin, lenticular beds of light- to dark-gray siltstone and shale ith abundant plant debris. Lower contact sharp and unconformable. 225-305 m (820-

Spechty Kopf Formation (Lower Mississippian and Upper Devonian)-Light-olive gray to gravish red-purple, discontinuous, generally massive and unsorted, polymictic conglomerate; quartzite, schist, slate, gneiss, quartz, and siltstone pebbles generally as much as 10 cm (4 in) in diameter; some larger clasts. Locally grades up into partly laminated, light-olive-gray, shaly and pebbly siltstone and shale; white, planar-bedded rippled, very thin to thin-bedded, well-sorted sandstone with some load casts; an medium-gray, poorly bedded, fine- to coarse-grained, conglomeratic sandstone with quartz and chert pebbles as much as 2.5 cm (1 in) in diameter. Lower contact is an irregular nformity with basal diamictite resting on red or gray rocks of the underlying Catskil Catskill Formation (Upper Devonian) Dcd Duncannon Member—Grayish-red and medium-gray, fine- to very coarse grained, partly massive and crossbedded, very thick sandstone beds with scoured bases; fissile to

very thick bedded siltstone and shale with burrows and roots: and minor, massive, partly crossbedded conglomerate with red and white quartz and quartzite pebbles and cobbl as much as 15 cm (6 in) long, in fining-upward cycles. Thick, red, basal conglomerate rest on greenish-gray siltstone of underlying Clarks Ferry Member (Dccf). 152-296 m (500-97) Depg Poplar Gap Member—Poplar Gap Member of Berg (1975) is here adopted for use by the J.S. Geological Survey. Medium-gray, light-olive-gray to greenish-gray, fine-to very coarse grained, very thin to very thick bedded, planar-bedded and crossbedded sandstone and conglomeratic sandstone with quartz pebbles as much as 2.5 cm (1 in) long; pale-to gravish red, medium- to thick-bedded shale, siltstone, and sandstone with burrows and plan fragments; and some discontinuous, dark-gray siltstone beds as much as 0.6 m (2 ft) thick. Base at bottom of lowest red bed above conglomerate of the Packerton Member (Dcp). Grades southwestward into the Clarks Ferry Member (Dccf) and Berry Run and Sawmill Run Members (Dcbs), 259-518 m (850-1,700 ft) thick Clarks Ferry Member-Greenish-gray, olive-gray, bluish-gray, brownish-gray, at gravish-red, fine- to very coarse grained, thin- to very thick bedded, rippled, planar-bedde and crossbedded sandstone and minor conglomerate with pebbles of quartz, sandstone, and argillite; and minor greenish-gray and olive-gray, flaggy siltstone. Basal conglomerate with abrupt contact on red siltstone and fine-grained sandstone of underlying Berry Run

fember (Dcbs). 122-276 m (400-904 ft) thick Berry Run and Sawmill Run Members, undivided Berry Run Member—Light- to medium-gray, yellowish- to olive-gray, greenish-gray, brownish-gray, and grayish-red, very fine to very coarse grained, laminated to very calcareous sandstone; medium-light- to greenish-gray, dark-bluish-gray and grayish red, laminated and flaggy siltstone; and minor greenish-gray and dark-reddish-brow shale; partly in fining-upward cycles. Basal sandstones form topographic high next to valleys underlain by gray and red siltstone of Sawmill Run Member. 300-335 m (980–1,100 ft) thick Sawmill Run Member—Greenish-gray, olive-gray, brownish-gray, medium-gray, and grayish-red, very fine to medium-grained, laminated to very thick bedded crossbedded, planar-bedded, and irregularly bedded, partly calcareous sandstone with some plant fossils; pale- to dusky-red, olive-gray, brownish-gray, and greenishgray, laminated to thin-bedded shale. Basal contact placed at bottom of red siltston

overlying gray sandstone of Packerton Member (Dcp). Forms valleys. 43–130 m (140–425 ft) thick Packerton Member-Medium-gray, olive-gray, greenish-gray, brownish-gray, and minor ravish-red, generally fine to medium grained, but ranging to conglomeratic calcareous, thin- to very thick bedded sandstone with some plant debris and fossil fish ragments; minor conglomerate with quartz, sandstone, and siltstone pebbles as much as 2.5 cm (1 in) long and shale clasts as much as 15 cm (6 in) long; and lenses of olive-gray shale. Lower contact at base of gray sandstone, or locally, at base of grayish-red, onglomeratic sandstone overlying red shale of Long Run Member Long Run Member-Grayish-red to grayish-red-purple and minor greenish-gray, aminated to thick-bedded siltstone and shale with minor ripple marks, burrow mudcracks, roots, and dark-yellowish-orange, ferroan dolomite nodules; and medium-to nedium-dark-gray, greenish- to olive-gray, and grayish-red, laminated to thick-bedded planar-bedded and minor crossbedded, silty, limonitic, and micaceous sandstone with some channeled bases with rare quartz-pebble conglomerate, load casts, ripple marks, le chips, bivalves, crinoid columnals, and plant fragments. Many fining-upward cycle

ase placed at bottom of lowest red bed above gray rocks of Beaverdam Run Member cbr). 634 to about 1,000 m (2,080-3,280 ft) thick Beaverdam Run Member—Light- to medium-dark-gray, light-olive- to greenish-gray, and oderate-brownish-gray, laminated to thick-bedded, planar-bedded and cross very fine to fine-grained, limonitic, micaceous, partly silty sandstone; a few thin, granuleonglomerate zones; some load casts, ripples, channeled bases of sandstones, burrows, and shale chips; and generally thin-bedded siltstone and shale. Several beds are liferous with Tentaculites, crinoid columnals, brachiopods, pelecypods, and plant fragments. Base placed at top of uppermost red bed of underlying Walcksville Member Dcw). 61–351 m (200–1,150 ft) thick; thins southward and eastward by intertonguing th the underlying Walcksville Member Valcksville Member—Grayish-red to medium-brownish-gray, and olive- to greenish-gray ited and ripple-laminated to massive, bioturbated, partly mudcracked siltstone and silty shale with irregular ferroan dolomite nodules and some rootlets; and medium-to moderate-greenish-gray, grayish-red-purple, very fine to medium-grained, planar-bedden nd crossbedded, thin- to thick-bedded, limonitic sandstone; and a few thin, shale-chip onglomerates. Beds are mostly in fining-upward cycles. Lower contact placed at base o rst red bed above non-red rocks of the Towamensing Member (Dct). 76-762 m (250 500 ft) thick; thickens eastward and southward mensing Member-Medium-light- to medium-dark-gray, and olive- to greenish-gray,

ery fine to medium-grained, thin- to thick-bedded, generally flaggy, planar-bedded an less abundantly crossbedded and rippled, partly graded, limonitic sandstone with some load casts; and lesser light-olive- to medium-greenish-gray and dark-gray, laminated to thin-bedded and ripple-bedded siltstone and silty shale. Locally contains brachiopods crinoid columnals, pelecypods, *Tentaculites*, and plant fragments. Lower contact place nation (Dtr) 58-183 m (190-600 ft) thick Valcksville and Towamensing Members, undivided—Shown in cross section only. oplar Gap and Packerton Members, undivided—Shown in cross section only. Includes Clarks Ferry, Berry Run, Sawmill Run, and Packerton Members, undivided—Shown in ross section only. Includes units Dccf, Dcbs, and Dcp Trimmers Rock Formation (Upper Devonian)—Medium- to medium-dark-gray, and

are olive-gray, laminated to thin-bedded, planar-bedded and cross-laminated, siliceous,

blocky, graded siltstone to fine-grained sandstone and silty shale with some burrows, load

asts, groove casts, scour-and-fill structure, ball-and-pillow structure, wavy laminations,

of ridge-forming sequence. 183-396 m (600-1,300 ft) thick

aser bedding, brachiopod, crinoid, bryozoan fossil debris, and plant fragments. Lower

transitional and placed at base of dominantly siliceous siltstones which are bottom

Mahantango Formation (Middle Devonian)—Medium-dark- to dark-gray, poorly bedded and laminated to thin bedded, bioturbated, shaly siltstone and silty shale. Fossil are diverse and scarce to abundant in different parts of the formation. Many fossiliferous intervals, at least four of which have been traced for many kilometers; mappable bryozoans, corals, trilobites, gastropods, and others), slightly calcareous and noncalcareous, medium-light- to dark-gray, silty shale and shaly siltstone. These biostromes range from about 3 to 20 m (10 to 65 ft) thick. Near the top of the formation is the Nis Hollow Siltstone Member, a medium-light- to medium-dark-gray and olive-gray laminated to thin-bedded, siliceous, slightly fossiliferous, blocky siltstone to very fin grained sandstone interbedded with dark-gray shale. The Nis Hollow is as much as 17 m 56 ft) thick, but cannot be identified west of the New Ringgold 7.5-minute quadrangle Near the base of the Mahantango in the New Ringgold quadrangle is a poorly exposed very fine grained graywacke that may be the easternmost feathered edge of the Montebello Sandstone Member. The lower contact of the Mahantango is gradational through 30 to 60 m (100 to 200 ft) of siltstone and shale. Thickness is 360–785 m (1,180–2,575 ft) Marcellus Shale (Middle Devonian)-Medium-dark-gray to grayish-black, laminated to

poorly bedded, sparingly fossiliferous (depauperate brachiopod fauna) shale and silty shale. Lower part, as much as 60 m (200 ft) thick in the east and less than 21 m (70 ft) thick in the west, consists of medium- to medium-dark-gray, laminated to thin-bedd calcareous, shaly siltstone and argillaceous limestone (Stony Hollow Member) above, and medium-dark-gray to grayish-black shale (Union Springs Member) below. The Tioga Ash ed, a pyritic, micaceous, tuffaceous shale occurring in three thin beds, is exposed at and 9 m (28 ft) of the base in the Lehighton quadrangle uttermilk Falls Limestone through Esopus Formation, undivided—Ranges from 81 168 m (265 to 550 ft) thick. See figure 2 for stratigraphic relations and thicknesses of Buttermilk Falls Limestone (Middle Devonian)-Medium- to medium-dark-gray very thin to thin-bedded, irregularly bedded, fossiliferous, fine-to very coarse grained cherty limestone and argillaceous limestone with abundant crinoid columnals as much as $2.5\,\mathrm{cm}$ (1 in) in diameter in lower part; deeply leached in western exposures. Contains Tioga Ash Bed, about $7.6\,\mathrm{m}$ ($25\,\mathrm{ft}$) below top and $34\,\mathrm{cm}$ ($1.1\,\mathrm{ft}$) thick near Palmerton Sandstone (Middle and Lower Devonian)-Very light to medium-dark gray, medium- to very coarse grained, generally massive sandstone and conglomeratic sandstone with quartz pebbles as much as 2 cm (0.75 in) long Schoharie Formation (Middle and Lower Devonian)—Medium-gray to gravish-black. aminated to very thick bedded, slightly cherty, fossiliferous, calcareous siltstone with Esopus Formation (Lower Devonian)—Medium- to dark-gray, well-cleaved, generally minated to poorly bedded siltstone with abundant Taonurus Schoharie and Esopus Formations, undivided (Middle and Lower Devonian)lostly weathered, medium-light- to dark-gray, laminated to thin-bedded, blocky partly cherty, siliceous siltstone to fine-grained sandstone with Taonurus. Lower

contact with Ridgeley Sandstone (Doh) is unconformable Oriskany Group through Helderberg Group, undivided (Lower Devonian)—Ranges nm 55 to 125 m (180 to 410 ft) in thickness. Lower contact with Rondout and Deck Formations (Sdp) gradational. See figure 2 for stratigraphic relations and thicknesses of Ridgeley Sandstone of the Oriskany Group—Light- to medium-gray, fine- to very coarse grained, evenly to unevenly bedded, thin-bedded, fossiliferous (spiriferid orachiopods), calcareous sandstone and conglomerate with quartz pebbles as much as 2 cm (0.75 in) long, with minor siltstone, arenaceous limestone, and chert Shriver Chert of the Oriskany Group-Medium-dark-gray, calcareous, fossiliferous Port Ewen Shale of the Helderberg Group-Medium-dark-gray, fossiliferous irregularly bedded to laminated, burrowed, well-cleaved, calcareous shale and Minisink Limestone of the Helderberg Group—Medium- to dark-gray, argillaceous fine-grained, fossiliferous limestone and calcareous shale New Scotland Formation of the Helderberg Group-Medium-dark- to dark-gray, well-cleaved, cherty, fossiliferous, calcareous and silty shale and argillaceous imestone, deeply leached in western exposure Coeymans Formation of the Helderberg Group-Medium- to dark-gray, fine- to very coarse grained, irregularly bedded, very fine to thick-bedded, argillaceous and arenaceous, partly cherty, fossiliferous, burrowed, partly biohermal limestone, and edium-gray, fine- to coarse-grained and pebbly, fossiliferous, crossbedded and

olanar-bedded, calcareous sandstone and conglomerate with quartz pebbles as much as 2.5 cm (1 in) long Dbe and Doh combined. Shown in cross section only uttermilk Falls Limestone through Coeymans Formation, undivided (Middle and vonian)—Generally similar to Dbe and Doh to east except that units are generally deeply weathered and thinner. Limestone content of the Coeymans Formation decreases westward. Therefore this unit may not extend west of the Lehighton 7.5-minute uadrangle, but could be represented by rocks of the Andreas Red Beds of Swartz and artz (1941). Definitive discrimination of the New Scotland Formation, Oriskany Group choharie and Esopus Formations, and Palmerton Sandstone west of the Lehighton minute quadrangle has not been described. Unit ranges from about 15 to 136 m (50 to 45 ft) in thickness. See figure 2 for stratigraphic relations and thicknesses of individual unit Rondout Formation and Decker Formation through Poxono Island Formation, individed (Upper Silurian)—About 53 to 280 m (175 to 920 ft) thick. Lower contact gradational and placed at top of predominantly red sequence of underlying Bloomsburg Red Beds (Sb). See figure 2 for stratigraphic relations and thicknesses of individual units Rondout Formation-Light- to medium-dark-gray, very fine to medium-grained medium- to dark-gray, very fine grained, laminated, mudcracked dolomite Decker Formation-Medium-light- to medium-dark-gray, calcareous, fine- to coarsegrained, thin-bedded, crossbedded to planar-bedded to flaser-bedded, fossiliferous ued sandstone: calcareous conglomerate with quartz pebbles as much as 1 m (0.5 in) in diameter; calcareous siltstone; fine- to coarse-grained, arenaceous mestone; calcareous shale; and medium- to greenish-gray, mudcracked dolomite Becomes more conglomeratic to the southwest Andreas Red Beds of Swartz and Swartz (1941)—Pale- to gravish-red and light- to greenish-gray, very fine to very coarse grained and conglomeratic, thin- to thic ded, massive and crossbedded sandstone with quartz pebbles as much as 2.5 cm (1 in) in diameter: and burrowed shale and siltstone. May correlate with either the oeymans Formation or upper part of the Decker Formatic Bossardville Limestone-Medium- to dark-gray and olive-gray, very fine to fine-

grained, laminated to thin-bedded, wavy-bedded, graded, fossiliferous (mainly leperditiid ostracodes), argillaceous, and partly dolomitic limestone; and olive-gray calcareous shale with mudcrack polygons more than 5 m (15 ft) deep and some plomite intraclasts as much as 2.5 cm (1 in) in diameter Poxono Island Formation-Pale-green to greenish-gray, and medium- to dark-gray; partly mudcracked, ostracode-bearing, laminated to thick-bedded, calcareous shale very fine to fine-grained dolomite; and argillaceous limestone with dessication breccia locally at the top and pale-red, interbedded shale near the bottom Buttermilk Falls Limestone through Poxono Island Formations, undivided (Middle nian through Upper Silurian)—Shown in cross section only. Includes units Dbh an rp. Applies only to central part of Valley and Ridge province on map. See figure 2 for Buttermilk Falls Limestone through Poxono Island Formation, undivided (Middle Devonian through Upper Silurian)—Rocks of the Ridgeley Sandstone of the Oriskany Group, Andreas Red Beds of Swartz and Swartz (1941), Decker Formation, Bossardville Limestone, Poxono Island Formation, and possibly the New Scotland Formation are recognized in scattered outcrops. The Buttermilk Falls Limestone is probably present under over. Continuation of the Palmerton Sandstone, Esopus Formation, and Schohari Formation from the northeast into the westernmost part of the Newark 1° x 2° quadrangle is uncertain. Thickness about 53–69 m (175–225 ft). See figure 2 for stratigraphic relations loomsburg Red Beds (Upper Silurian)—Grayish-red to dark-reddish-brown, pale-red o grayish-red-purple, and greenish-gray to pale-green, crossbedded and planar-bedded laminated to thick-bedded shale, siltstone, very fine to coarse-grained sandstone, and minor conglomeratic sandstone with cut-and-fill structures, mudcracks, ferroan dolomite nodules, local fish scales, and red mudstone intraclasts as much as 8 cm (3 in) long. Many fining-upward cycles. Lower contact gradational, very irregular in places, and placed at base of lowest red bed above gray rocks of the Shawangunk or Clinton Formation. 244 Shawangunk Formation (Silurian and Upper Ordovician (?))—Three members of the

Shawangunk Formation extend southwestward into the Slatedale 7.5-minute quadrangle To the southwest of the quadrangle, only the Lizard Creek and the Minsi Members maintai Sandstone. The arbitrary boundary between the Shawangunk and the Clinton-Tuscarora stherefore placed in the Slatedale 7.5-minute quadrangle Fammany Member (Middle Silurian)—Medium- to medium-dark-gray, planar-bedde crossbedded, thin- to thick-bedded, fine- to coarse-grained and conglomerati quartzite with quartz and argillite pebbles as much as 5 cm (2 in) long, and minor beds of dark-gray argillite. Lower contact gradational. 0–249 m (0–816 ft) thick. Grades laterally to the southwest into the Lizard Creek Member (SsI) in the Kunkletown 7.5-minute Lizard Creek Member (Middle Silurian)-Light- to dark-gray and light-olive- to darkgreenish-gray, very fine to coarse-grained, laminated to very thick bedded, planar-bedded, crossbedded, flaser-bedded, rippled, partly channeled, burrowed quartzite with flattened argillite cobbles as much as 10 cm (4 in) in diameter; minor dark-grayish-red-purple, fine grained, burrowed, hematitic quartzite, interbedded with medium-light- to dark-gray and olive- to greenish-gray, laminated to thin-bedded, flaser-bedded, burrowed siltstone and shale; scattered thin beds contain collophane, siderite, and chlorite nodules, quartz pebble as much as 0.6 cm (0.25 in) long, and Lingula and eurypterid fragments. Lower contact transitional and placed at base of lowest argillite in sequence containing abundant argillite above quartzites of underlying member. 82–427 m (270–1,400 ft) thick; thins southwestward and is replaced by the Clinton Formation (Sc) southwest of the Slatedale

.5-minute quadrangle

Minsi and Weiders Members, undivided (Lower Silurian and Upper Ordovician) Minsi Member-Very light to dark-gray and light-olive- to greenish-gray, partly burrowed, planar-bedded and crossbedded, thin- to thick-bedded, fine- to coarsegrained, partly conglomeratic quartzite with pebbles of quartz and chert not more tha cm (2 in) in diameter and cobbles of shale as much as 18 cm (7 in) in diamete minor medium-dark- to dark-gray and greenish-gray, laminated to thin-bedded locally mudcracked siltstone and shale. Local Arthrophycus. Lower contact placed top of uppermost bed of the Weiders Member containing quartz pebbles more than 5 cm (2 in) long or, northeast of the Kunkletown 7.5-minute quadrangle, in sharp hick. These two units are not recognized southwest of the Slatedale 7.5-minute quadrangle and the combined unit in that area is called Tuscarora Sandstone (SOt) Weiders Member-Medium-light- to medium-dark-gray and greenish-gray, planar bedded and crossbedded, thin- to thick-bedded, medium- to very coarse grained quartzite; conglomerate with quartz and chert cobbles as much as 17 cm (6.5 in) in ameter and shale cobbles as much as 20 cm (8 in) in diameter; and rare, greenish gray, laminated to thin-bedded argillite. Lower contact with Martinsburg Formatio nconformable. 0-67 m (0-220 ft) thick. Pinches out southwest of Slatedale 7.5 minute quadrangle (where it is equivalent to part of the Tuscarora Sandstone) and northeast of the Kunkletown 7.5-minute quadrangle ammany through Weiders Members, undivided (Silurian and Ordovician)—Shown in ross section only. Includes units Sst, Ssl, and SOsw Clinton Formation (Middle Silurian)—Gray, green, and red sandstone, siltstone and

hale laterally continuous with and lithically similar to the Lizard Creek Member of the

Shawangunk Formation (SsI), except that it contains more red beds. Lower contact gradational. About 396–427 m (1,300–1,400 ft) thick uscarora Sandstone (Lower Silurian and Upper Ordovician)—Gray quartzite laterally nuous with and similar to the Minsi Member of the Shawangunk Formation. Lower contact abrupt and unconformable. About 76 m (250 ft) thick GREEN POND SYNCLINE The Green Pond syncline is a narrow, northeast-trending, faulted syncline containing a thin, but fairly plete section of Paleozoic sediments, located in the middle of the external massif of the Reading The very narrow southwestern end of this structure is located in the Newark 1° x 2° quadrangle rong. The very narrow southwestern end of this success. The Paleozoic rocks sit unconformably upon the Proterozoic basement. However, the Paleozoic section the Paleozoic rocks sit unconformably upon the Proterozoic basement. However, the Paleozoic section is cut by a number of thrust faults, and in places the contact between the basement and cover rocks may be structural. In places, folds in the Paleozoic section are decoupled from the older basement rocks. Ma f the Paleozoic rocks correlate with thicker units in the Valley and Ridge Province (see the Correlation of Map Units) showing that these rocks once were present between the two areas, a distance of more

han 25 kilometers. A significant strike-slip component of movement is possible on the normal faults in Bellvale Sandstone (Middle Devonian)—Bellvale Flags of Darton (1894) is herein dopted for use by the U.S. Geological Survey as Bellvale Sandstone. Medium-gray, flaggy sandstone, black shale and siltstone, sandier in upper part. Grades upward into re st north of the Newark 1° x 2° quadrangle. About 610 m (2,000 ft) thick Marcellus Shale (Middle Devonian)—Very dark gray, sparsely fossiliferous shale, more ty in upper part. About 180 m (590 ft) thick onnelly Conglomerate, Esopus Formation, and Kanouse Sandstone, undivided —Total unit thickness about 117 m (383 ft) Connelly Conglomerate—Connelly Conglomerate of Chadwick (1908) is herein adopted for use by the U. S. Geological Survey. White to light-gray, fossiliferous conglomerate and quartz-pebble conglomerate. Lower contact unconformable.

Esopus Formation—Light- to dark-gray, fossiliferous (*Taonurus*) siltstone and fine-grained sandstone; dark-gray to black mudstone and siltstone. Lower contact Kanouse Sandstone-Light-gray, thick-bedded, fine conglomerate with quartz pebbles as much as 10 mm (0.4 in) long, sandstone in lower part grades upward into sparsely fossiliferous sandstone. About 15 m (49 ft) thick Decker and Poxono Island Formations, undivided (Upper Silurian)-Total unit thickness about 144 m (473 ft Decker Formation-Very thin to thin-bedded, fossiliferous, gray to greenish-gray, calcareous siltstone and medium-gray dolomite, with interbedded olive-gray sha Local sandstone and conglomerate beds near base. Lower contact conformable Poxono Island Formation-Medium-gray, greenish-gray, grayish-yellow-weather laminated to thin-bedded, mudcracked, and burrowed dolomite, interbedded with greenish-yellow, medium-grained, thin- to thick-bedded, crossbedded sandstone; and green, purple, and bluish-gray, laminated to very thin bedded, silty shale and green siltstone. Lower contact gradational. About 106 m (348 ft) thick High Falls Formation (Upper Silurian)—Grayish-red, nonfossiliferous, silty shale with in sandstone common in lower half. Lower contact probably transitional. About 91–107

Green Pond Conglomerate (Upper Silurian)-Gray and reddish-gray sandstone and

conglomerate with predominantly white quartz and minor gray, green, red, and yellow chert, red shale, and red sandstone cobbles as much as 7.6 cm (3 in) long. Lower contact unconformable. About 300–425 m (984–1,394 ft) thick LEHIGH VALLEY AND SCHUYLKILL SEQUENCES The Great Valley of Pennsylvania and New Jersey is a northeast-trending lowland bounded by Blue untain-Kittatinny Mountain on the northwest and the highlands of the Reading e Lehigh Valley sequence, within the Great Valley, comprises a thick section of Ordovician clastics a thinner section of Ordovician and Cambrian carbonates, and a very thin Cambrian quartite at its bas of these rocks have been multiply deformed, perhaps by a continuum of deformation between Tacor nd Alleghanian time. These rocks contain a large number of thrust faults concentrated at severa tratigraphic levels. These include: 1) the entire lower thin-bedded slate member of the Martinsburg Formation (Omb), 2) the incompetent Jacksonburg Limestone (Oj) which sits stratigraphically on top of the much more competent, dolomite-dominated Beekmantown Group, and 3) the base of the Allentown Dolomite (OCa) or Leithsville Formation (Cl). The lowest unit in both sequences, the Hardyston Quartzite (Ch) almost always decoupled from the rest of the cover rocks during thrusting an acted as a thin veneer welded on top of the thrust slices of Proterozoic basement. In the Topto uadrangle, the rocks of the Lehigh Valley sequence are structurally overlain by the Schuylkill sequence. he Schuylkill sequence differs from the Lehigh Valley sequence in Pennsylvania by: 1) the absence of the cement limestone facies of the Jacksonburg Limestone (Oi), 2) having a thick, continuous belt on the comment of the Control of the Stonehenge Formation (Oo), 3) the presence of the Stonehenge Formation (Os), and 4) the stonehenge Formation (O mappable members in the Allentown Dolomite (O€a). Since the Jacksonburg Limestone (Oi) and the Allentown Dolomite (OCa) are not subdivided on this map, the Lehigh Valley and Schuylki sequences are not separated on the correlation chart. The rocks of the Schuykill sequence are, in tur cturally overlain by the rocks of the Lebanon Valley sequence in the Birdsboro quadrangle. The rocks

of the Lebanon Valley sequence appear, at least in part, to be slightly deeper water, and perhaps farther Pen Argyl Member (Upper Ordovician)—Dark-gray to grayish-black, thin- to thick bedded, evenly bedded slate, commonly more than 3 m (12 ft) and in places 6 m (20 ft) thick; rhythmically interlayered with carbonaceous slate, sandy slate, and very fine to medium-grained graywacke with parallel lamination, lenticular bedding, convolute bedding, and sole marks. Units in fining-upward sequences (turbidite-flysch). Quarried extensively for slate ("soft slate" of Pennsylvania quarrymen). Upper contact unconformable and site of a regional decollement. Lower contact is gradational and is placed where graywacke is in excess of about 5 percent of local sequences and supplies abundant float. Though present in eastern Pennsylvania, the Pen Argyl is overlapped by the Shawangunk Formation (Sst, Ssl, SOswm) just west of the Delaware River and sent in northern New Jersey. Thickness ranges from 1,000-2,100 m (3,280-6,900 ft) Ramseyburg Member (Upper and Middle Ordovician)-Medium- to dark-gray slate that Iternates, in part cyclically, with light-to medium-gray, thin- to very thick bedded graywacke and graywacke siltstone (turbidites). Graywacke comprises about 20 percent of member, but may make up more than 50 percent of some thick parts of the section, and less than 5 percent in others. Slates are generally thick bedded at the top and thin to medium bedded at the bottom of the member. Lower contact is placed at the base o lowest conspicuous graywacke bed, generally recognized by abundant float, but contact may be transitional through several hundred feet, where discontinuous and lenticular graywacke beds are present in the underlying Bushkill Member (Omb). Thickness ranges Bushkill Member (Middle Ordovician)—Medium- to dark-gray, laminated to thin-bedde slate containing thin beds of quartzose slate, graywacke slitstone, and carbonaceous slate in fining-upward sequences. Bed thickness does not exceed 15 cm (6 in) throughout member, and is generally less than 5 cm (2 in), except for graywacke beds that probable are less than 30 cm (12 in) thick in discontinuous units near the top of the member. Lower contact transitional through 1 m (3 ft). Formerly quarried for slate ("hard slate" belt of

ennsylvania quarrymen). Minimum thickness is about 1,525 m (5,000 ft) Jacksonburg Limestone (Middle Ordovician)-The upper part, referred to as the cement rock" facies, is a dark-gray to almost black, fine-grained, thin-bedded, argillaceous limestone. Contains beds of crystalline limestone in places. Upper contact gradation Lower contact gradational in eastern Pennsylvania and main outcrop belt of northern N Jersey, but is unconformable and marked by a conglomerate in the Paulins Kill lowland of New Jersey. Thickness ranges from 100–300 m (330–1080 ft). The lower unit, referred to as the "cement limestone" facies, is a light- to medium-gray, medium- to coarse-grained largely well bedded calcarenite and fine- to medium-grained, high-calcium limestone. the western edge of the map, the lower contact is sharp but conformable, but becomes unconformable approaching the Delaware River. Continuing northeastward through Ne Jersey, the lower contact is marked by beds of dolomite pebble- to boulder-conglomerate and the magnitude of this hiatus becomes greater with this unit progressively resting on older units in the Beekmantown Group. Thickness ranges from 20-130 m (65-430 ft) Ontelaunee Formation of the Beekmantown Group (Middle and Lower Ordovician)-Medium- to thick-bedded, medium-dark-gray, fine- to coarse-grained dolor cherty at the base, grading into medium- to thick-bedded, medium-gray, fine- to medium ained dolomite that contains beds of medium-grained calcilutite at the top in some places Unit only sporadically present east of Northampton, Penn., and generally absent in New Jersey except as cobbles in the overlying conglomerates of the Jacksonburg Limestone Lower contact is gradational. Thickness ranges from 0–200 m (0–650 ft) Epler Formation of the Beekmantown Group (Lower Ordovician)—Very fine grained to cryptogranular, light- to medium-gray limestone and fine- to medium-grained, light- to dark-medium-gray dolomite. Upper part of unit is absent in much of New Jersey. Lower onglomerates where the Ontelaunee Formation (Oo) is absent. Thickness is about

Rickenbach Dolomite of the Beekmantown Group (Lower Ordovician)-Fine- to coarse-grained, light-medium- to medium-dark-gray dololutite, dolarenite, and dolorud Upper part generally thin-bedded and laminated; lower part characteristically thickbedded. Lower contact gradational. In some places in New Jersey, this unit is present a cobbles in the overlying conglomerates of the Jacksonburg Limestone (Oj) where both the Ontelaunee (Oo) and Epler (Oe) Formations are absent. Thickness is about 220 m (720 Stonehenge Limestone of the Beekmantown Group (Lower Ordovician)-Mediumlight- to medium-gray, fine-grained, thin-bedded limestone marked by silty or sandy laminae with subordinate beds of orange- to buff-weathering, irregularly laminated ar mottled dolomite. The silty laminae are the residue left after extensive non-seam-suture pressure solution. Dolomitic beds, generally near the base of the unit, are sparse in the western part of the map area, but increase in abundance eastward through Pennsylvania. In Pennsylvania, this unit is found in the Schuylkill sequence, but not in the Lehigh Valle sequence. In New Jersey, it reappears, and the amount of thin- to medium-bedd lomite may equal the amount of thin-bedded limestone. Throughout the map area, the presence of chert is rare. In some areas, particularly just east and west of the Delaware River, the formation has not been recognized. In the same region, the Rickenbach Do (Or) increases in thickness, and it is possible that dolomite of Stonehenge age occurs there. If so, it is difficult, if not impossible, to distinguish from the Rickenbach without the presence of fossils. Therefore, for the purposes of this map, the Stonehenge is considered to missing from the central portion of the map area. Thickness ranges from 0-100 m (0-320Allentown Dolomite (Lower Ordovician and Upper Cambrian)-Very fine to mediumgrained, light- to medium-dark-gray, alternating light- and dark-gray-weathering

calcarenite, oolitic calcarenite, calcirudite, algal stromatolite, dolomicrite, and scattere beds and lenses of orthoquartzite. Lower contact is gradational. The Ordovician-Cambrian oundary is within this unit, very close to the upper contact. Thickness is about 575 r Leithsville Formation (Middle and Lower Cambrian)—Interbedded, light-medium-grav fine- to coarse-grained dolomite and calcitic dolomite, light-gray to tan phyllite, and ver thin beds and stringers of quartz and dolomitic sandstone. Lower contact is gradational where present, but is commonly marked by numerous thrust faults making thickness estimates difficult. However, where the lower contact is gradational, the unit is approximately 330 m (1,000 ft) thick Hardyston Quartzite (Lower Cambrian)-Fine- to medium-grained, white to dark-gray light-buff-and reddish-gray-weathering, fine- to medium-grained, thin- to medium-bedded, commonly massive, but in some places thinly laminated and crossbedded, Scolithusbearing, feldspathic quartzite interbedded with arkose, quartz-pebble conglomerate, an silty shale or phyllite. Lower part commonly consists of quartz-pebble conglomerate with a matrix of coarse, feldspathic sandstone and minor dark-gray argillite. Lower contact generally unconformable and abrupt. Thickness ranges from 0 to 30 m (100 ft) in Ne

Jersey, but thickens both southwestward toward the Schuylkill River to 20–40 m (70–125 ft) and southward to the Buckingham Valley where it reaches 270 m (900 ft) SPITZENBERG AND SHARPS MOUNTAIN OUTLIERS These two small erosional remnants in the Great Valley north of Hamburg, Penn. contain reworked ediments of both the Hamburg klippe and the Lehigh Valley sequence. These rocks rest unconformably nd perhaps with structural discontinuity, on rocks of the Hamburg klippe and unconformably beneat Tuscarora Sandstone (SOt). Although difficult to prove, these rocks may have been deposited after he rocks of the Hamburg klippe were folded during the Taconic orogeny and may represent the youngest dovician clastics in the area. Sandstones and conglomerates of Spitzenberg and Sharps Mountain (Late Ordovician)—At Spitzenberg, the unit consists of medium- to coarse-grained, medium to thick-bedded, poorly to well-sorted, crossbedded, red- and green- weathering

conglomeratic sandstone, interbedded with a thick-bedded, polymict conglomerate. clasts include green chert, milky-white calcilutite and laminated to cross-laminate calcisiltite, red and maroon shale, brown sandstone and siltstone, and clasts of the same red sandstone that is interbedded with the conglomerate. Conodont biostr that the clasts are youngest at the bottom of the unit and oldest at the top. At Sharps Mountain, the sandstone is common, although it weathers differently (to a greenish-white and the conglomerate is absent. These rocks are unconformable on, and possibly in thrust are a partial source for this unit both at Sharps Mountain and Spitzenberg. At Sharps Mountain, the unit is unconformably overlain by the Tuscarora Sandstone (SOt). Thrusting may be localized at this contact. Thickness is 60 m (200 ft) ROCKS OF THE SHOCHARY RIDGE AREA

This group of Ordovician clastic rocks crops out over a fairly small area in the Great Valley of eastern ennsylvania. It is entirely fault bounded, and sits structurally on top of all three members of the artinsburg Formation (Omp, Omr, Omb), and lies structurally beneath the Windsor Township rmation (Owd, Ows, Oww, Owc, Owr) of the Hamburg klippe. The eastern end of the Shochary Ridge outcrop belt coincides almost exactly with the eastern end of the Hamburg klippe. It is likely that ne rocks of Shochary Ridge are derived from the Windsor Township Formation (Gre aburg klippe and were transported in Taconic time as a thrust sheet beneath the two major slices of he klippe. The Eckville and Kistler Valley faults, bounding the Shochary Ridge area on the north and south, respectively, are probably Alleghanian in age. The rocks of the Shochary Ridge area formed as a local, northward-prograding deltaic fan. The source of these clastics was the advancing accretionar prism of the Greenwich slice of the Hamburg klippe. These rocks are roughly the same age as the slightly thick-bedded (5–75 cm, 2–30 in) calcareous, pyrite-rich, graywacke turbidites intert

nantly northeast or southwest) currents within a very long northeast-trending basin Shochary Sandstone (Upper and Middle Ordovician)-Medium-dark-gray, thin- to with medium-dark-gray, light-olive-brown-weathering slate, calcisilitie, and minor thin beds of conglomerate. The amount of graywacke ranges from 10 to 20 percent with rare instances of 50 percent, particularly near the top of the exposed section, and beds become thick-bedded with rare parallel laminations. Graywacke beds contain abundant fauna lebris. Sedimentary structures in some turbidites obliterated in places by bioturbation Rusty-weathering channels filled with coarse-grained sandstone, abundant shelly faun and pyrite are common in light-olive-brown-weathering graywackes. Graywackes. contain rare clasts of rounded chert. Approximately 1,520 m (5,000 ft) thick. Upper part of unit not present due to faulting and erosion. Unit is structurally and unconformably overlain by the Tuscarora Sandstone (SOt). Lower contact transitional over 15 m (50 ft, with underlying New Tripoli Formation (Ont) and is placed where sandstones commonly make up less than 10 percent and beds are less than 5-10 cm (2-4 in) thick New Tripoli Formation (Middle Ordovician)-Medium-dark-gray, light-olive-brownand calcisiltite beds (as much as 50 cm, or 20 in thick). The calcisiltite beds are mo commonly 2–5 cm (1–2 in) thick and are more resistant to weathering, giving the rock a ribbed appearance. This characteristic contrasts markedly with the ribbon slate of the Bushkill Member (Omb) of the Martinsburg Formation, which weathers more evenly Shelly fossil debris is common, especially near the upper contact of the unit, but not abundant. The contact between the Bushkill (Omb) and this unit is not a gradual facies change in this area, but is a thrust fault representing significant structural telescoping. Lowe

contact not exposed because of faulting of both Taconic and Alleghanian age. Approximate minimum thickness is 1,500 m (4,900 ft)

LEBANON VALLEY SEQUENCE This group of rocks is exposed only in a small area at the west edge of the map in Pennsylvania. This nce has affinities with rocks in the Conestoga Valley of the Piedmont Province, but is distinct from the Lehigh Valley sequence present throughout the Great Valley, in that it is missing the unconform at the base of the Jacksonburg Limestone (Oj). In addition, the carbonates of the Lebanon Valle sequence are generally a slightly deeper water facies of the same units in the Lehigh Valley and Schuylki sequences, and perhaps have travelled a greater distance along northward- or northwestward-mov ust faults. The rocks of the Lebanon Valley sequence rest structurally on top of the rocks of the Schuylkill sequence. Only the units not exposed in the Lehigh Valley and Schuylkill sequences are separately described below. See correlation chart for relations between the three sequences Annville Limestone (Middle Ordovician)-Medium-gray, light-gray-weathering, highcalcium limestone with thick beds exhibiting wavy bedding. The upper contact i commonly marked by thrust faults and the lower contact is apparently gradational. hickness ranges from 0 to 34 m (0 to 110 ft) Beekmantown Group, undivided (Middle and Lower Ordovician)-Due to the poor exposure of these rocks and the present lack of fossil data, no attempt has been made to Richland Formation of the Conococheague Group (Upper Cambrian)—Medium-gra hick-bedded dolomite and limestone. Limestone beds commonly have silty and sand laminae. Beds commonly contain nodules and stringers of brownish-gray chert and colitic and cryptozoon layers. Discrete dolomitic sandstone beds are also present. Lower contact is gradational. Unit is only partly exposed and minimum thickness is 530 m (1,700 ft) Millbach Formation of the Conococheague Group (Upper Cambrian)-Light-gray, -bedded limestone and lesser dolomite. Thickness is approximately 100 m (330 f Buffalo Springs Formation of the Conococheague Group (Upper Cambrian)-Finegrained, light-blue-gray, thickly and massively bedded limestone grading downward into a fine- to medium-grained, light-gray, yellowish- to light-olive-gray-weathering dolomite interbedded with fine- to medium-grained, dirty-white to pinkish-gray to medium-gray limestone, and thin, light-olive-gray-weathering, sandy or silty limestones. In the unit as a whole, limestone is more common than dolomite. The dolomites commonly are algalaminites with occasional cryptozoon structures. Lower contact is gradational with the underlying Zooks Corner Formation (€zc). North of the Newark-Gettysburg basin, a partial section is less than 300 m (1,000 ft) thick; south of the basin in the northern ontit may reach 400 m (1,300 ft) Zooks Corner Formation (Middle (?) Cambrian)—Very fine grained, medium-gray, thinthick-bedded, silty to sandy dolomite with common shaly partings interbedded with less common ripple-laminated, grayish-blue limestone and medium-bedded, crossbedded sandstone. Lower beds overlie and partially interfinger with the Ledger Dolomite (Clg). North of the Newark-Gettysburg basin, a partial section has a thickness of probably less than 100 m (360 ft). South of the basin, in the northern Piedmont, the thickness is 150 Includes rocks of €bs, €zc, €lg, and €k HAMBURG KLIPPE This structurally and stratigraphically complex group of far-travelled rocks is located in the Pennsylvania Great Valley and resembles the Taconic allochthon of New York State. The klippe is divided into two tectonic slices: 1) the Greenwich slice, an accretionary prism of sediments displaying scaly cleavage that

composes the Windsor Township Formation, and 2) the Richmond slice, a sequence of rise and slope deposits that composes the Virginville Formation. Although emplaced by thrust faults during the Taconic orogeny, these faults have been obscured by later Alleghanian folds and faults. Although the klippe was thrust on the rocks of the Lehigh Valley and Schuylkill sequences in Taconic time, some rocks of the ehigh Valley and Schuylkill Valley sequences were later thrust on top of the rocks of the Hamburg klippe. Windsor Township Formation (Middle and Lower Ordovician) Dreibelbis Member-Medium- to very thick bedded, partly graded, fine- to coarse-grained, locally conglomeratic, somewhat calcareous graywacke sandstone interbedded with dark greenish- to light-olive-gray, fissile to poorly cleaved mudstone, siltstone, and shale. Characterized by the predominance of partial Bouma (1962) sequences Ta and Tae, wit esser Tb-e, Tc-e, and Td-e sequences. The Dreibelbis has probably been incised into he Weisenberg Member (Oww). Minimum thickness about 1,200 m (3,937 ft) Switzer Creek Member-Medium- to thick-bedded, massive, medium-to coarse-grained to conglomeratic graywacke interbedded with lesser amounts of dark-greenish-gray mudstone and shale. Graywacke is rich in carbonate grains and pebbles, which weather to very distinctive, rotten and porous, limonite-stained rocks. Partial Bouma (1962) sequences Ta and Tae predominate. The Switzer Creek has probably been incised into ne Weisenberg Member (Oww). Minimum thickness about 914 m (3,000 ft) Weisenberg Member—Light-olive-gray to grayish-olive, fissile to poorly cleaved shale and gray, silicified shale, mudstone, and argillite. In some places, thin-bedded siltstone and rraywacke sandstone, and debris flows of chert and silicified mudstone are interbed with the shale and mudstone. Soft-sediment slump folds are common. Local channels contain a very distinctive conglomerate with chalky-white-weathering feldspar grains and rare volcanic rock fragments. This conglomerate is best exposed 0.3 km (0.2 mi) east of Werleys Corner in the Slatedale 7.5-minute quadrangle. Minimum thickness about 1,737

Polymict conglomerate—Light-green to medium-dark-gray and dark-greenish-gray pelitic matrix containing clasts ranging in size from less than a cm to at least 3 m (10 ft). Clast lithologies include graywacke, carbonate, siltstone, shale, and chert. All clasts are derived Red beds-Dusky-red, grayish-yellow to light-green, locally silicified mudstone and argillite, interbedded with very thin to thick-bedded siltstone, sandstone, black calcilutite to calcarenite, and chert. Carbonate is found locally as clasts and megaclasts within a matrix of varicolored shale and argillite. This unit is found locally within the Dreibelbis (Ow Virginville Formation (Middle Ordovician to Upper Cambrian) Moselem Member (Middle Ordovician)—Grayish-black to brown, thin-to thick-bedded nudstone and shale interbedded with dark- to dark-greenish-gray, silicified argillite; minor light-gray to black, thin-bedded, ribbon limestone; black shale; and orange-vellowthering dolostone. Minor amounts of thin- to medium-bedded, carbonate-clas conglomerate. This unit is the youngest member of the Virginville, but structurally underlies he Onyx Cave (Evo) and Sacony (Evs) Members, although the only exposed fault Onyx Cave Member (Upper Cambrian)-Grayish-black to medium-light-gray, thin- to

thick-bedded calcarenite, peloidal limestone, quartzose limestone, and calcareous quartzite; very thick bedded, structureless carbonate-clast conglomerate, thinly nterbedded with black lime, mudstone, and shale to argillaceous ribbon limestone, thin laminated black shale and dark-yellowish-brown-weathering dolostone. Lower contact conformable with the underlying Sacony Member (\mathfrak{Cvs}), except where this unit has been thrust over the Moselem Member (\mathfrak{Ovm}). About 90 m (300 ft) thick Sacony Member (Upper Cambrian)—Grayish-olive- to pale-blue-green, locally grayishd, thick-bedded, structureless, micaceous siltstone and sandstone interbedded with grayish- to pale-blue-green micaceous shale and mudstone. Minor amounts of light-gray to light-green, silicified shale and black mudstone. Lower contact is not exposed. Minimum JUTLAND KLIPPE These rocks resemble some of the rocks found within the Greenwich slice of the Hamburg klippe in

Pennsylvania. Unlike the Taconic allochthon and Hamburg klippe, which occur on the foreland side of the external massifs of the Berkshires and Reading Prong, the rocks of the Jutland klippe occur on the Jutland klippe lower unit A (Ordovician)-Interbedded red and green shale; silty sandstone; silty shale; pink hematite-stained shale; sandstone; and micritic limestone. r contact is placed where sandstone, siltstone, and sparry and micritic carbonate rocks (found throughout the Jutland klippe, but more rarely in this lower unit) become much more common. Lower contact absent due to faulting. Minimum thickness estimated at 1 Jutland klippe upper unit B (Ordovician)—Gray, manganese-bearing shale is abundant and restricted to this upper unit. Also present are interbedded red and green shale interbedded dolomite and green shale, limestone conglomerate, interlaminated limeston and shale, interbedded fine-grained sandstone, siltstone and shale, and yellow, red, gree and gray shales interbedded with chert. Sandstone, siltstone, and sparry and micriti

carbonate rocks occur throughout the klippe, but are much more abundant in this unit though graptolites are found in both units, conodonts are found only in this unit. Th Peapack klippe is made up entirely of rocks of this unit. Upper contact not present FURLONG KLIPPE OF THE BUCKINGHAM VALLEY OUTLIER A small area of Taconic-like rocks is found in the Buckingham Valley Paleozoic-Proterozoic outlier in middle of the Newark basin. Like the Jutland klippe, these far-travelled rocks occur on the hinterland ide of the Reading Prong external massif. The presence of the Buckingham Valley outlier may be du n part, to pull-apart tectonics that formed local highs or "horsts" through compression during t mation of this part of the Newark basin and, in part, to earlier folding of Taconic thrust sheets of the nt that put these rocks at the crest of an anticline.

Undivided Taconic-like rocks of the Furlong klippe (Cambrian (?))—Fissile to slatv plack, blue, purplish and gray phyllite. Minimum thickness is approximately 60 m (200 ft No contacts with any surrounding units are exposed. However, since these rocks resemble Taconic allochthon rocks, it is very possible that they have been thrust over the nearby Lehigh Valley-like Paleozoic rocks of the Buckingham Valley outlier, much as the Hamburg klippe was thrust over the Lehigh Valley sequence to the northwest PROTEROZOIC ROCKS OF THE READING PRONG All of the rocks of the Reading Prong are allochthonous and represent an imbricate stack of thrust sheets that have been thrust over the Paleozoic rocks of the Great Valley. These thrusting events probably took place both during Taconic and Alleghanian times and perhaps as a continuum in between, however, most of the movement probably occurred late in the Paleozoic. The Proterozoic rocks have undergone at least one high-grade Proterozoic metamorphism and two low-grade Paleozoic metamorphisms. These rocks primarily include the layered sequences of the Losee Metamorphic Suite and of the interlayered

calcareous and quartzofeldspathic gneisses. They also include intrusive rocks of the Byram Intrusive Suite and pyroxene granites with related quartz-poor rocks. There is no stratigraphic order for the units given low. For relations among these rocks, see figure 3 Chestnut Hill Formation (Late Proterozoic (?))—Interbedded sequence of arkose ferruginous quartzite, quartz-pebble conglomerate, sericite-talc-chlorite schist, and metarhyolite. Occurs only locally in several areas near the Delaware River yroxene granite and related quartz-poor rocks (Middle Proterozoic)-A very egeneous group of rocks consisting of pyroxene granites ranging in composition from granodiorite to alkali-feldspar granite, and other quartz-poor rocks ranging in composition from monzodiorite to quartz-alkali-feldspar svenite and alkali-feldspar svenite. Fairl abundant northwest of the Green Pond syncline in New Jersey. Many of these rocks contain what appears to be a primary flow foliation. These rocks differ from the Byram Intrusive Suite by having mesoperthite (largely antiperthitic) as the primary feldspar. higher iron-to-magnesium ratio, and more calcium. Genetic relations with the Byram

Byram Intrusive Suite Alaskite, microperthitic and microantiperthitic (Middle Proterozoic)-Th microperthitic alaskite comprises light-pink to light-gray, medium- to coarse-grained foliated alaskite and gneissoid alaskite composed largely of microperthite, quartz, and oligoclase. Contains bodies of amphibolite, hornblende granite, and potassic-feldspa gneiss that are too small to map. The microantiperthite alaskite erthite alaskite in that the principal feldspar is microantiperthite. This unit weathers Hornblende granite and associated biotite granite (Middle Proterozoic)-Pink to lightgray, medium- to coarse-grained, gneissoid granite, foliated granite, and sparse granite biotite. In granite gneiss phases, microperthite has typically recrystallized. Rock contains free microcline and oligoclase. Includes bodies of alaskite, amphibolite, and potassicfeldspar gneiss that are too small to map Metasedimentary Layered Sequence

Marble (Middle Proterozoic)-Fine- to medium-grained, white to grayish-white calcite marble and medium-gray, greenish-gray-weathering dolomite marble. Much of the dolomite marble largely altered to serpentine, tremolite, and talc. Probably found at many erent stratigraphic levels and not confined to one age Biotite-quartz-plagioclase gneiss (Middle Proterozoic)—Light- to medium-dark-gray to pale-yellowish-brown, fine- to medium-grained, well-layered gneiss of variable composition but always containing conspicuous biotite. Some phases contain garnet as r) magnetite. Unit differs from oligoclase quartz gneiss (YIo) in its heterogeneity and well defined layering, and from potassic feldspar gneiss (Ymk) in that most of the feldspar is plagioclase. Also included in this unit are light- to light-greenish- to pin1 sh-gray, medi roperthite, monoclinic potassic feldspar, sericitized oligoclase, and sillimanite otassic feldspar gneiss (Middle Proterozoic)—Grayish-pink, pinkish-gray, light-gray or t-greenish-gray, fine- to medium-grained gneiss and minor granofels that have poor to biotite and (or) magnetite and, more rarely, garnet and sillimanite. Unit contains local interlayers of biotite-quartz-plagioclase gneiss (Ymb) and feldspathic quartzite. In places, unit has been partly mobilized to form sheets and irregular bodies of alkali-feldspar grani Pyroxene gneiss (Middle Proterozoic)—Greenish-gray to light-grayish-green, mediumgrained, well-layered to nearly massive, granoblastic gneiss composed principally of diopsidic pyroxene and plagioclase and lesser quantities of homblende, quartz, biotite, and

magnetite. At some places unit contains relict patches of marble

Losee Metamorphic Suite Oligoclase-quartz gneiss (Middle Proterozoic)-Light-greenish-gray to grayish-green lium-fine- to medium-coarse-grained, poorly foliated, granoblastic gneiss and mino granofels. Composed principally of oligoclase and quartz. Minor amounts of biotite magnetite, and typically shredded and chloritized augite. Unit contains sparse to moderate Albite-oligoclase granite (Middle Proterozoic)—Medium- to coarse-grained, light-green to dull-white, gneissoid granite composed principally of albite, oligoclase, quartz, and minor amounts of sodic homblende, or more rarely augite or magnetite. Rock is thought to be an anatectic phase of oligoclase-quartz gneiss (Ylo) Albite pegmatite (Middle Proterozoic)—Light-greenish-gray, or more rarely moderateorange-pink, coarse-grained rock composed principally of albite, quartz and lesser amounts of microperthite. Locally contains masses and large crystals of sodic homblende and, more rarely, pyroxene and magnetite. Some phases are syenitic. Rock is thought to be a coarse-grained phase of the albite-oligoclase granite (YIa) Hexenkopf Complex Hornblende-augite-quartz-andesine gneiss (Middle Proterozoic)-A strongly sericitized, chloritized, and silicified gneiss containing hornblende, augite, quartz, andesi and lesser amounts of epidote, biotite, sphene, garnet, apatite, magnetite, pyrite, chlorite, and zircon. In many places it is strongly veined by albite pegmatite (YIp) and microperti alaskite (Yba). Rock is probably a metamorphosed gabbro or diorite. Composes about 6 Epidote-augite-hornblende-plagioclase gneiss (Middle Proterozoic)—Grayish-olive dense, massive, well-foliated gneiss containing sparse amounts of biotite, sphene, and magnetite, and widely varying amounts of quartz. Rock appears to be a metamorphosed d altered pyroxenite. Composes 25 percent of complex Quartz-garnet-augite granofels (Middle Proterozoic)—Medium-fine- to medium-grained, equigranular, highly siliceous granofels containing quartz, garnet, augite, and plagioclase and chlorite. Composes about 15 percent of complex Rocks of Uncertain Origin and Relative Age Amphibolite (Middle Proterozoic)-Light- to dark-gray to nearly black, fine- to mediumgrained rock composed principally of hornblende and andesine. Some phases contain augite and, more rarely, hypersthene or biotite. Much of rock is probably metavolcanic and ome may be metasedimentary Amphibolitic migmatite and related hybrid rocks (Middle Proterozoic)-Mixed rock mposed of irregular knots, lenses, veins, and layers of microperthite alaskite (Yba) i amphibolite (Ya). In some areas, this rock is a mixture of albite-oligoclase granite (Yla) and phibolite. Both types of mixed rock are intruded by veined gneiss and permeation gneiss. In the Trenton Prong, that narrow belt of Proterozoic rocks of the northern lmont that is found north of the Huntingdon Valley fault, hybrid rocks are, in some places, interlayered amphibolite and a light-colored felsic gneiss, and, in other places are comogenized completely to a felsic gneiss of intermediate composition. In some place the unit is very rich in graphite, contains lenses of marble, and may represent a partia migmatized Pickering Gneiss (Ypgn). Although this unit is found both in the Reading and Trenton Prongs, it is likely that the protolith has a larger proportion of igneous rocks in the ading Prong and of sedimentary rocks in the Trenton Prong Quartz diorite (Middle Proterozoic)-Light- to dark-gray, medium- to coarse-grained rock composed principally of andesine or oligoclase, quartz, and hypersthene. Some phases contain augite and (or) biotite. Unit has a charnockitic affinity and is thought to be a partly mobilized, amphibolite-rich phase of oligoclase-quartz gneiss (Ylo). Unit contains small bodies of albite-oligoclase granite (Yla) and amphibolite

THE PIEDMONT PROVINCE The Piedmont is divided into northern and southern parts (see fig. 4). The boundary between the two is the Huntingdon Valley fault south of the Trenton Prong and its unnamed continuation to the west that marks the southern boundary of the Octoraro Phyllite (£Zo). The Proterozoic rocks of the Piedmont are distinctly different in these two regions, suggesting that this fault may represent an important suture. The two terranes were probably joined before the late Proterozoic or earliest Paleozoic, because the Peters Creek Schist (£Zpc) occurs on both sides of the extension of this fault in Maryland. In addition metadiabase dikes of possible Late Proterozoic to early Paleozoic age intrude both regions. Both the northern and southern Piedmont are structurally complex, and are characterized by folded and imbricately stacked thrust sheets and duplexes of probable Taconic age. Figure 4 shows stratigraphic and Metadiabase dikes—Fine-grained and more commonly porphyritic, dark-charcoal-gray, slightly metamorphosed diabase containing augite, plagicclase, and minor hornblende, zoisite, and biotite. Intruded after high grade Proterozoic Y metamorphisms, and before lower grade Paleozoic (Taconic) metamorphism. Found to intrude many different Middle Proterozoic gneisses throughout the Piedmont and may intrude both the Peters Creek Schist (CZpc) and Octoraro Phyllite (CZo). It is possible that these dikes are roughly the

same age as the Catoctin Formation of the central and southern Appalachians Paleozoic and Late Proterozoic Cover Rocks of the Northern Piedmont Many of the Paleozoic cover rocks of the northern Piedmont show distinctive differences in lithology and thickness going from Welsh Mountain and the Barren Hills in the north to the Chester Valley in the south. These differences are discussed below. Conestoga Limestone (Lower Ordovician to Middle Cambrian)—Upper part consists medium- to bluish-gray, light-gray-weathering, fine- to medium-grained, thin-bedded (2-10 cm, 1-4 in), highly micaceous limestone with argillaceous, shaly partings parallel to regional cleavage that give the unit a finely laminated appearance. Near the base of the upper part, beds increase in thickness to 25 cm (10 in), and the unit becomes slightly coarser grained. The upper part of the unit has a maximum thickness of 110 m (36 but may be partially repeated by faulting. In addition, the upper contact is marked by a thrust fault bringing the Octoraro Phyllite (£Zo) over the Conestoga, perhaps truncating part of this unit. The lower part consists of very light gray to white, medium- to coarse grained, medium- to thick-bedded dolomite interbedded with dark-gray to bluish-black thin-bedded, medium-grained limestone and dark-gray, fine-grained, thin-bedded dolomite. The lower part has a maximum thickness of 100 m (320 ft), but, like the uppe part may be repeated by numerous faults that are difficult to detect. The contact between the upper and lower parts is the locus of significant thrust faulting, which in some areas inserts thin slivers of Octoraro Phyllite (€Zo) within the Conestoga. The lower contact is thought to be an unconformity with the Conestoga overlying the Elbrook Formation (€e) within the area of this map. However, to the southwest of the mapped area the Conestoga werlies older Cambrian units (specifically, the Ledger Dolomite (Elg), the Kinze Formation (Ck), and the Antietam Quartzite and Harpers Phyllite (Cah). This supposed inconformity may also be the locus of thrusting Elbrook Formation (Upper and Middle Cambrian)-Light-blue, fine-grained, thinpedded limestone which weathers to a shaly, light-yellowish-brown or buff limesto interbedded with cream-colored to pure-white, fine-grained, thin-bedded, laminate dolomitic marble. In the Chester Valley, white marble beds predominate and are thicker here than to the north and west. Concentrations of mica are left as a pressure-solution

residue parallel to regional cleavage. In the Chester Valley, the mica is coarser grained and suggests that the rocks in the southern part of the northern Piedmont are at slightly higher metamorphic grade than the rocks farther north. The lower contact is gradational with th underlying Ledgers Dolomite (£lg); locally, a resistant sandy limestone and chert-rich andstone at the base makes a good marker horizon. The thickness north of Welsh Mountain is approximately 305 m (1,000 ft), whereas the unit thins to approximately 240 Ledger Dolomite (Middle Cambrian)—Coarse-grained, white to light- to medium-darkmassive, thick-bedded, finely laminated, pure, high-magnesian dolomite with some iliceous beds which weather to rust-stained, granular, cherty layers. In the Chester Vall the dolomite is interbedded with laminated limestone, weathers to a rough granular surface, and is finely speckled in places. The lower part of the unit is characterized alternating light and dark layering and porous, cherty layers. When the unit is high with the Elbrook Formation (€e) except where overlain by the Conestoga Limestone (O€c). Lower contact is gradational with the Kinzers Formation (€k) in the Chester Valley, and with the Vintage Dolomite (€v) north of the Honey Brook uplands. Thickness is proximately 300 m (1,000 ft) Kinzers Formation (Middle and Lower Cambrian)—The upper part consists of fine-to edium-grained, white to light- to medium- to bluish-gray, thin- and irregularly bedde

argillaceous limestone, nodular limestone, and marble lenses surrounded by argillaceous esidue left behind during pressure solution. Marble in some places is mottled ("leopar ock"). Lower part consists of medium-grained, white to light-gray, thin-bedded, impure dolomite that weathers to a buff-yellowish-brown and contains fragments of trilobites. In the Chester Valley, this part is represented by impure limestone that weathers to a shaly mica schist. The lower contact is gradational with the Vintage Dolomite (£v). The thickness north and west of the Barren Hills is 40 m (130 ft) and the thickness is less than 9 m (30 Vintage Dolomite (Lower Cambrian)—Upper part is fine- to medium-grained, mottledblue limestone, grading downward into medium-grained, dark-blue, knotty dolomite with blebs of coarse-grained dolomite, grading downward into medium-grained, gray, thickled, glistening dolomite. The lower part is fine-grained, cream-white, thin- to medium bedded, argillaceous to sandy dolomite with mica abundant on bedding planes. This is in gradational contact over 3 m (10 ft) with the underlying ferruginous and calcareous sandstone beds at the top of the underlying Antietam Quartzite (Cah). In the north, the thickness of the entire unit is approximately 180 m (600 ft), and in the Chester Valley, the unit is probably less than 60 m (200 ft). Reliable estimates of thickness for this lowest zoic carbonate are difficult to make due to poor exposure Elbrook Formation, Ledger Dolomite, Kinzers Formation, and Vintage Dolomi undivided (Cambrian)—Shown in cross section only. Includes units €e, €lg, €k, and

Antietam Quartzite and Harpers Phyllite, undivided (Lower Cambrian)-The Antietam s a fine-grained, light-gray, slabby, rusty, laminated quartzite which weathers to a dark brown manganese-stained soil. Contains Obellella in the rusty layers. It is in gradational contact with the underlying Harpers which is a fine- to medium-grained, greenish- to dark gray, sandy, argillaceous phyllite. Bedding in the Harpers is almost always impossible to lentify due to pervasive cleavage. In areas where it is possible to map both units the hickness of the Antietam ranges from 140 m (450 ft) in the north to less than 60 m (20 t) in the south. In the Chester Valley, the maximum thickness is 60 m (200 ft) in the east and the unit is absent in the west. The Harpers ranges from 240 m (800 ft) in the north to less than 150 m (500 ft) in the south Chickies Quartzite (Lower Cambrian)—Upper part consists of medium-grained, gray, massive, crossbedded, medium-bedded, finely laminated, vitreous quartzite with cle quartz grains and fine-grained, variously colored, thin-bedded, sericitic quartz schist. Lower part (commonly referred to as the Hellam Member) consists of a coarse-grained, gray,

ourmaline-bearing quartzite, arkosic-pebble conglomerate, and interbeds of black slat and biotite schist. This unit rests unconformably and abruptly upon a wide variety of Proterozoic gneisses. The thickness ranges from 400 m (1,300 ft) in the north to less than $130\,\mathrm{m}$ (430 ft) in the south. In the Chester Valley the unit is considerably more schistose Octoraro Phyllite* (Cambrian and Late Proterozoic)—Fine- to medium-grained greenish- to silvery-gray, dark-olive-green-weathering phyllite and phyllonite. In some places, abundant white-weathering albite and magnetite grains reach 1 cm (0.25 in) in ameter. Porphyroclasts of albite, magnetite, garnet, tourmaline, rutile, and ilmenite are found in a fine-grained chlorite-muscovite-ribbon quartz matrix. Along the northern edge of the outcrop belt where the Octoraro is thrust over the Conestoga (O c) it is finer grained contains ilmenite as the dominant oxide mineral (commonly sandwiched between large chlorites), and some very fine grained albite. To the south the albite crystals become large he dominant oxide mineral is magnetite, and the muscovite and chlorite become coarser grained. This suggests that the unit may have undergone a low to medium grad metamorphism, been phyllonitized, and then metamorphosed again at a lower grade. It similar history has been suggested for equivalent rocks along strike to the southwest in Maryland. The upper and lower contacts of this unit are marked by major thrust faults. the north, the Octoraro is thrust over and into the Conestoga along numerous splays of the Martic thrust fault. On the south side an important fault that marks the boundar between the northern and southern Piedmont brings a number of units structurally on to of the Octoraro. These include the Peach Bottom Slate (which crops out as a small fau sliver along the east branch of Octoraro Creek approximately 10 km (6 mi) south of th southwest corner of the Newark 1° x 2° quadrangle), the Peters Creek Schist (£Zpc), the numerous faults within the unit that make an estimate of thickness impossible. This unit resembles the Everett Formation in the high-Taconic slices of the Berkshires of New

Middle Proterozoic Basement Rocks of the Northern Piedmont hese poorly exposed rocks have undergone at least one Proterozoic metamorphism of amphibolite to granulite grade, and a Paleozoic metamorphism of chlorite grade. Metamorphosed igneous rocks are represented by anorthosites and charnockitic gneisses. Metamorphosed sedimentary rocks are represented by graphite-bearing gneisses, marbles, and perhaps some amphibolites. The long narrow belt of gneisses that lie north of the Huntingdon Valley fault and extend as far east as Trenton, N. J., is referred to here as the Trenton Prong. The Proterozoic rocks of the northern Piedmont have a close affinity to some the rocks of the Reading Prong and the Adirondack massifs.

Pickering Gneiss (Middle Proterozoic)—Medium- to very coarse grained, highly variable gneiss consisting of interlayered quartz-feldspar gneiss, quartz-schist, mica schist, homblende schist, and calcareous schist and is characterized by the presence of abundant graphite, calc-silicates, and pods of marble. Common accessory minerals are microcline, scapolite, diopside, and garnet. Rock is commonly deeply weathered and disaggregate Pyrrhotite and pyrite react to form limonite which occurs in such abundance that in pl it has been mined. Intruded by numerous pegmatite dikes ranging in width from 5 cm (2 in) to a meter (3 ft) that are composed primarily of microcline, quartz and abundant graphite. The calcareous schists can contain as much as 16 weight percent graphite, which easily mined due to the highly weathered nature of the rock; marble lenses are associated with the graphite-rich horizons. Although the marble can be found throughout the kering, it appears that most marble lenses occur near the contact between the Pic e granulite gneisses (Ygg). If the granulite gneisses are older and underlie the Pickering, as implied in the correlation chart, this would place most of the marble near the base of the Pickering. This unit, which is probably a metamorphosed sedime sequence, is metamorphosed to the granulite grade of metamorphism north of the Brandywine Manor thrust fault, and to the amphibolite facies south of the fault

Marble (Middle Proterozoic)—Discontinuous lenses of coarse-grained, white marble with ignificant accessory graphite occurring both as individual grains and as concentrated chlieren parallel to the regional schistosity. Occurs throughout the Pickering Gneis (Ypgn), but appears to be concentrated near the contact between the Pickering and the anulite gneisses (Ygg). If the Pickering is younger and sits on top of the granulite gneisses, en marble is concentrated in the lower part of the Pickering Amphibolite (Middle Proterozoic)—Medium- to coarse-grained, very dark gray to black, blende-plagioclase schist and gneiss that can contain as much as 5 percent persthene and accessory magnetite, epidote, zircon, pyrite and, in many cases, abunda sphene. Because of its wide-ranging association with the Pickering (Ypgn), amphiboli ligmatite (Ymg), leucocratic gneisses (Ylg), and marble (Ym), it is highly likely that thi unit has at least two different protoliths, one that is sedimentary and generally associate with calcareous schists and gneisses, and another that is igneous and associated with bo etaplutonic and metavolcanic rocks Amphibolitic migmatite and related hybrid rocks (Middle Proterozoic)-Schists ar gneisses ranging in composition from felsic to intermediate to mafic, but with the larges omponent being intermediate in composition. Contains a great variety of rock types ncluding medium- to very coarse grained, graphitic schists that are migmatized to varying degrees; lenses of fine- to coarse-grained marble; coarse- to extremely coarse gra nphibolites containing as much as 50 percent almandine; plagioclase amphibolites with a trace to 5 percent hypersthene, and medium-grained, biotite-blue quartz-oligoclase garnet-layered gneiss. Clearly some, but probably not all, of these rocks represent the and injected with a felsic magma. Makes up most of the Trenton Prong Leucocratic and intermediate felsic gneisses (Middle Proterozoic)-Fine- to medium grained, white to light- to medium-dark-gray, microcline-microperthite-quartz gneiss with minor hornblende, magnetite, and biotite intimately associated with biotite-oligoclasemicroperthite-quartz gneiss. This unit is interlayered with amphibolite at all scales. Found both north and south of the Brandywine Manor thrust fault at both amphibolite- and granulite-facies metamorphism. Probably a metamorphosed felsic volcanic or volcanic lastic rock. May be roughly equivalent in age with Pickering Gneiss (Ypgn) and younger than Honey Brook anorthosite (Yha) and related chamockitic granulite gneisses Honey Brook anorthosite (Middle Proterozoic)—A large, poorly exposed, elliptically zoned body of anorthosite ranging from anorthosite in the center through dioritic anorthosite, anorthositic diorite, and a layered diorite. The mafic component, primarily iornblende, biotite, and magnetite increases from 10 percent in the core to 60 percent in he rim. The entire body displays a hypidiomorphic texture and contains plagioclas hornblende, magnetite, apatite, and biotite. Although the Honey Brook anorthosite an the leucocratic and intermediate gneisses (YIg) are both light colored and, in some place similar in composition, the leucocratic and intermediate gneisses in contrast, have a texture that varies from granoblastic to lepidoblastic. Occurs entirely within the granulite facies of netamorphism. Locally intruded by coarse-grained, light-gray, microcline perthite-quartzlagioclase pegmatite with accessory hornblende, biotite, garnet, and magnetite. gioclase is myrmekitic Granulite gneisses (Middle Proterozoic)—Rocks of charnockitic characteristics sociated with and probably intruded by the Honey Brook anorthosite (Yha). Coarsegrained, leucocratic to slightly melanocratic, commonly layered, mesoperthite-plagioclas juartz-hornblende-biotite (potassium feldspar, clinopyroxene, hypersthene, garnet ar llimanite) Exposed north of the Brandowine Manor thrust fault, except for a small area centered 1 mile (1.6 km) west-northwest of Chester Springs, Penn., where it is expose in a small tectonic window completely surrounded by amphibolite grade rocks. The inferred fault framing this window is shown on cross section A–A' as the Brandywine

Paleozoic and Late Proterozoic Cover Rocks of the Southern Piedmont Most of these rocks are highly deformed mélanges containing exotic blocks of altered mafic and ultramafic rocks, which may, in some cases, represent dismembered ophiolites. These rocks probably range in age from late Proterozoic to earliest Paleozoic. They are definitely older that the regional schistosity, which is presumed to be of Taconic age everywhere. The Swarthmore Granodiorite probably an igneous rock associated with the Taconic metamorphic event and is included below for Swarthmore Granodiorite (Ordovician)—Microcline-oligoclase-quartz-biotite-musco vite gneiss with accessory epidote, sphene, and apatite. The contact between the Wissahickon Formation (€Zw) and the Swarthmore is characterized by a series of replacement textures such as myrmekite, perthite, anti perthite, corroded quartz, and the

formation of mica-quartz and epidote-quartz symplectites in contact with microcline and quartz. However, a thrust fault brings the Wissahickon south over the granodiorite further Wissahickon Formation* (Cambrian and Late Proterozoic)—Fine- to medium-grained medium- to dark-gray to black, brownish-gray to slightly rusty weathering, aluminous, pelitic schist, feldspathic metagraywacke with thin interbedded amphibolites, and lenses nd pods of altered ultramafic rocks. Rocks range in metamorphic grade from greenschi through upper amphibolite facies, including partial melting producing migmatites. Where the unit is exposed in thin fault slivers between the Cream Valley fault and the fault conta on the south side of the Octoraro Phyllite (€Zo), it is a highly crenulated, coarse-graine garnet-mica schist. Southeast toward the type sections along Wissahickon Creek in Philadelphia the metamorphic grade increases and the percentage of feldspathic netagraywacke increases. In south part of map area the unit becomes gneissic. Contact with the Swarthmore Granodiorite (Osg) within the map area is a thrust fault (probably a back-thrust) bringing the Wissahickon south over the granodiorite Peters Creek Schist (Cambrian and Late Proterozoic)-A flyschoid sequence of metagraywacke, metasemipelite and pelite rich in quartz and magnetite. The metagraywacke is fine to medium grained, light to medium gray, yellowish- to reddish own weathering, well-bedded with graded beds and parallel laminations recognizable aces. The metasemipelite is fine to medium grained, light to medium gray, reddish brown reddish brown weathering, quartz-rich phyllite, schist, and mica gneiss. Ba

weathering schist and gneiss. The metapelite is fine grained, lustrous, greenish gray to gray sedimentary facing indicators and sense of rotation of minor folds. it is possible that the entire outcrop belt of the Peters Creek on this map is upside down. Thickness estimate is impossible due to faulting and incomplete section. Contains tectonic slivers of altere ultramafic rocks, primarily serpentinite (€Zs) erpentinite (Cambrian and Late Proterozoic)—Tectonic lenses, pods, and slivers of serpentinite with abundant actinolite and chlorite. Highly sheared rocks that preserve few original igneous textures. These tectonic lenses are found within the Member C of the hattan Schist (CZmc) and the Wissahickon Formation (CZw), but are present in greater abundance east of Cameron's Line (the unnamed thrust fault that wraps around aten Island on the east side of the Newark 1° x 2° quadrangle) in the Hartland terro of Westchester County, N.Y. and western Connecticut. Although none of the rocks associated with the serpentinite bodies east of Cameron's Line are found within the may area, a very large serpentinite body underlies much of Staten Island. Many of these serpentinite bodies have probably been depositionally included in the surrounding sedimentary rocks after their tectonic inclusion along numerous shear planes and thru Amphibolite (Cambrian and Late Proterozoic)-Fine-to coarse-grained, "salt and pepper"-textured, hornblende-plagioclase-epidote rock with minor magnetite in discontinuous layers, lenses and pods commonly parallel to cleavage and, in some places, to bedding, contained within the Wissahickon Formation (CZW), Peters Creek Schist

EZpc), and Member C of the Manhattan Schist (EZmc). Protolith may be intrusive sill Member C of the Manhattan Schist of Hall (1976) (Cambrian to Late Proterozoic)fine- to medium-grained, medium-dark-gray to black, brown- to brownish-gray- and rusty-weathering feldspathic sillimanite-garnet-muscovite-biotite schist and layered gr with lesser siliceous schist, thin metaquartzite, metagraywacke, and amphibolite. Alwa well-foliated, with bedding difficult to recognize. In some places contains large sills amphibolite and lenses of serpentinite. Thickness perhaps as much as 1,600 m (5,200 ft), t estimates are difficult because of incomplete section due to faulting Middle Proterozoic Basement Rocks of the Southern Piedmont

All rocks in the West Chester Prong have been metamorphosed to granulite grade during th Proterozoic and to a high grade during the Taconic. The rocks described below display significan variation from west to east in the West Chester Prong, and are therefore subdivided into an eastern and western facies. Although most of the map area falls in the eastern end of the West Chester Prong, both facies are described. Immediately south of the mapped area these same rocks have been retrograded Aluminous quartzites (Middle Proterozoic)—These rocks are found only in the western nd of the West Chester Prong and only in one small pod at the south edge of this man They are coarse grained, primarily kyanite-quartz-garnet rocks with accessory phlogopite, plagioclase, orthoclase, fine perthite, and occasional rutile, graphite, zircon, and zinc-rich inel and staurolite. Kyanite can be as much as 40 percent of the rock and generally occu as aggregates. In some places, however, the rocks become garnet-guartz granulites with accessory zircon. Both the kyanite- or garnet-rich, quartzose rocks contain very little alkalies. They may either represent the restite left after partial melting of a quartz-rich sediment or may be metamorphosed clay deposits yroxene granulites (Middle Proterozoic)—In the eastern end of the West Chester ong, these hypersthene-salite-plagioclase granulites are medium grained, faintly foliate and have equigranular granoblastic textures and diorite to gabbro composition. Plagioclase is commonly antiperthitic, and very low in potassium. Accessories consist of magnetit nd(or) ilmenite, zircon, and apatite. In the western end of the West Chester Prong, these rocks differ by having no foliation and, in places, by containing hornblende in addition to the two pyroxenes. Also, there are 1-10 cm (0.5-4 in) lenses of coarse-grained pyroxenite

ntaining 90 percent hypersthene and 10 percent salite. The protoliths for these rocks are nost likely a series of mafic and ultramafic igneous rocks, perhaps olivine basalts or gabbros Quartzofeldspathic granulites (Middle Proterozoic)—In the eastern end of the West er Prong, these rocks are coarse grained, dark colored, quartz-potassium-feldsp garnet-biotite granulites with occasional clinopyroxene and hornblende, that are highly variable in mineralogy and composition. They contain a conspicuous lineation marked by streaks of mafic minerals. In the western end of the West Chester Prong, these granulit ontain much more quartz (as much as 50 percent), are finer grained, lighter in color, and have more abundant potassium feldspar in the form of coarse mesoperthite, which is present in roughly equal amounts to plagioclase. The second metamorphism produ arnet coronas between plagioclase and mafic minerals. To the south of the map area, lese rocks underwent extensive recrystallization at amphibolite grade. The protoliths for these rocks are most likely sedimentary, perhaps quartz-rich graywackes, with or without

1) The Brunswick Formation as originally defined by Kümmel (1897) is raised in rank to the Brunswick up and is revised to include the the Watchung Basalt of Darton (1890), which is herein abandone Olsen (1980a, b) divided these rocks into seven formations in New Jersey, which are, from youngest to oldest, the Boonton Formation, Hook Mountain Basalt, Towaco Formation, Preakness Basalt, Feltville nation, Orange Mountain Basalt, and Passaic Formation. The Orange Mountain Basalt through the nton Formation, as well as the Jacksonwald Basalt in Pennsylvania, are herein accepted for use by the U.S. Geological Survey. The Passaic Formation of Olsen (1980a) has enough textural differences between its type section in northeastern New Jersey and its outcrops in Pennsylvania that the sylvania Geological Survey has not accepted that name. Likewise, the use of the Passaic Formation in western New Jersey is open to question. Several varieties of conglomerates, whose stratigraphic positions are not entirely clear, are listed separately from the units of the Brunswick Group. The nwald Basalt near Reading, Penn., is probably the same flow as the Orange Mountain Basalt, ar he strata overlying the Jacksonwald (the upper part of the Brunswick Group) correlate with the Feltvil ormation of New Jersey. Figure 1 shows the regional stratigraphic relations for the Newark and ?) The name Wissahickon Formation herein applies only to those rocks included in the original definition e Wissahickon mica gneiss (Bascom and others, 1909). This includes the type section in the ladelphia area between Chestnut Hill and Manayunk, as well as the narrow, fault-bounded, slivers

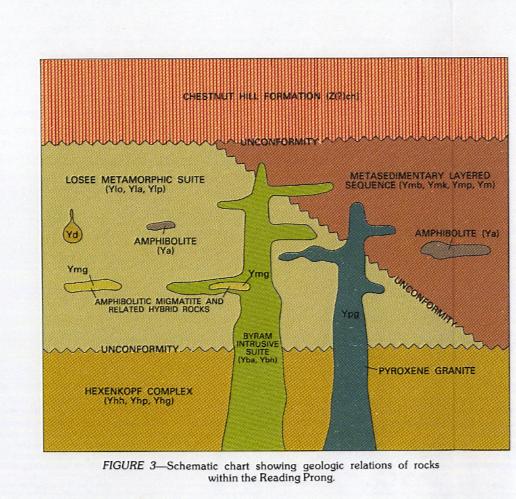
south of Berwyn and Devon, Penn. 3) The name Octoraro Schist of Bascom (1909) is herein reinstated for use by the U. S. Geological Survey and is changed to Octoraro Phyllite. The assignment of the Cambrian-Late Proterozoic age is based on regional correlations with similar rocks in the high-Taconic slices of the Berkshires of Massachusetts (e.g. the Everett Formation) and the fact that these rocks rest in structural (not depositional) contact on the underlying Conestoga Limestone of probable Ordovician-Cambrian age. These rocks are not part of the Wissahickon Formation as assumed by many workers.

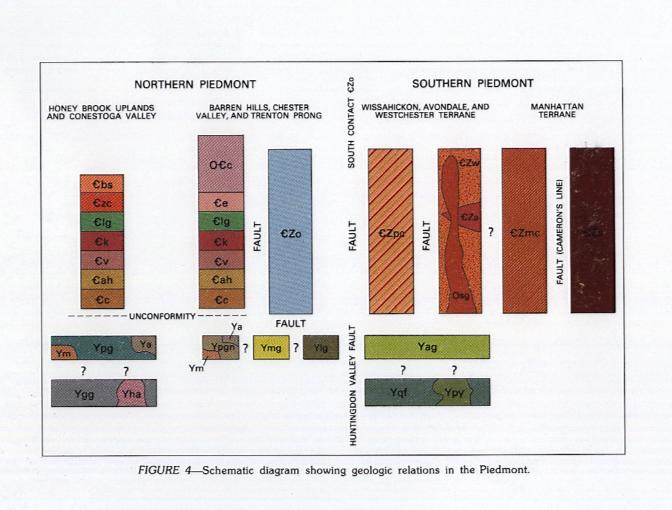
EXPLANATION OF MAP SYMBOLS

Thrust fault—Teeth on hanging wall. Dashed where inferred; dotted where concealed; queried where uncertain Anticline—Showing trace of axial surface

FIGURE 1—Correlation diagram for the Newark and Gettysburg Basins.

MARCELLUS SHALE ESOPUS FORMATION DISTANCE IN KILOMETERS DISTANCE IN MILES FIGURE 2—Stratigraphic section of Upper Silurian through lower Middle Devonian rocks in the Valley and Ridge Province showing formation groupings in the Newark 1° x 2° quadrangle.





Normal fault—U, upthrown side; D, downthrown side Syncline—Showing trace of axial surface FIGURE 5-Index map showing sources of data. Numbers refer to asterisked entries in reference list.