THE HAMBURG KLIPPE RECONSIDERED

LUCIAN B. PLATT,* RICHARD B. LORING,** ATHANASIOS PAPASYROS,*** and GEORGE C. STEPHENS****

ABSTRACT. To explain Lower Ordovician grapolites in the Middle Ordovician Martinsburg Shale at Harrisburg and Hamburg, Pa., Stose proposed a large thrust sheet or klippe lying on the Martinsburg. Recent mapping in this area in the Great Valley suggests that the anomalously old grapolites are confined to blocks and slabs enveloped within normal Martinsburg graywacke and shale. Blocks of carbonate rock have also been identified as enclosed within the Martinsburg rather than being erosion remnants of large thrust sheets.

The area of the Hamburg klippe is, rather than one big plate, a jumble of smaller pieces that arrived in the area of deposition of the Martinsburg Shale during the Middle Ordovician, apparently by gravity sliding. That the blocks include carbonate rocks from the Great Valley sequence of Cambrian and Lower Ordovician limestone and dolomite shows that these were being deformed during the Middle Ordovician. Most of the blocks and slabs, including several that are kilometers long, are shaly rocks that probably came from Maryland, tens of kilometers away.

INTRODUCTION

For many years anomalously old grapolites have been recognized in the Martinsburg Shale in the Great Valley in Pennsylvania (fig. 1). Kinship with the Taconic thrust plate or klippe in New York has been recognized along with some relation to the Martic problem in southern Pennsylvania. About 30 years ago Marshall Kay (1941) explicitly noted that the presence of the anomalously old grapolites, Lower Ordovician in an upper Middle or Upper Ordovician unit, requires allochthonous rocks to be in the Martinsburg in the vicinity of Harrisburg and Hamburg. In addition to the old grapolites in this area, anomalous rock types were also recognized, mostly chert of various colors, some thinly-bedded, black or dark gray aphanitic limestone, and some red shale. Stose (1946) emphasized the similarity of these rocks with Taconic rocks in eastern New York and the similarity in the regional structural situation. To account for the anomalies, he proposed a Hamburg klippe, which is outlined in figure 1. About 1960 Carlyle Gray, then State Geologist of Pennsylvania, organized a mapping project in the Martinsburg Shale. In the summers of 1961, 1962, and 1963, Platt mapped the Martinsburg Shale around Harrisburg. Problems raised by that study (Carswell, Hollowell, and Platt, 1968) led to mapping by Papasyros immediately west of the Susquehanna and by Loring and Stephens north-east of Hamburg.

Many geologists other than the authors have contributed toward our new interpretation. Deserving of special thanks for their fossil identifications are W. B. N. Berry, Robert B. Neuman, and John Riva. The late James Dyson spent a long summer working toward an evaluation of the structure in the Martinsburg Shale west of the Susquehanna River; discussions with him pointed up several difficulties with earlier inter-

* Bryn Mawr College, Bryn Mawr, Pa. 19010
** 1030 Camino Miramonte #10, Tucson, Arizona 85716
*** 812 Lowander Lane, Silver Spring, Md.
**** Department of Geological Sciences, Lehigh University, Bethlehem, Pa. 18015
Fig. 1. Dashed line is Stose's Hamburg klippe. Crosses are 15-minute quadrangle corners. One thousand foot (300 m) contour line is shown to delineate the first ridge of younger sandstone on the north from the Great Valley of Ordovician Martinsburg Shale and older rocks on the south. Fossil localities are identified in table 1 by the numbers shown. A circle identifies a fossil locality in autochthonous rocks; an X identifies a fossil locality from within an allochthonous rock type; a dot is shown in doubtful cases.

In making helpful comments on the manuscript, we thank R. V. Amenta, W. A. Crawford, John Rodgers, and Edward H. Watson. In spite of their concern, perhaps some slips remain for later workers to discover.

The field work forming the basis for the interpretations offered here has been given financial support by the Pennsylvania Geological Survey, first under Carlyle Gray and then under A. A. Socolow, by the Society of the Sigma Xi, and by funds from The George Washington University and Bryn Mawr College. Mr. R. S. Graham drafted the figures.

REGIONAL RELATIONS

The Paleozoic rocks older than the Martinsburg Shale in the Great Valley of Pennsylvania are carbonate and sandstone. Recent reviews of these rocks may be found in Drake (1969), MacLachlan (1967), and Root (1968). Table 2 summarizes the general aspect of the section. For present purposes, the main point recorded in these articles and many others (Craig, 1949; Hobson, 1963; Neuman, 1951; Sando 1958; Swartz, 1948) is that Upper Cambrian and Lower and lower Middle Ordovician rocks are
dominantly carbonate with minor quartz sandstone. Little or no shale is present.

The next unit younger than the Martinsburg is sandstone and conglomerate which forms a prominent ridge all along the north side of the Great Valley in Pennsylvania. From the Susquehanna River west the rocks are the Bald Eagle and Juniata fluvial sandstones and conglomerates discussed by Yeakel (1962). Above the Juniata is the Tuscarora Sandstone or Quartzite, equivalent to the Clinch Sandstone farther southwest and equivalent, at least in part, to the Shawangunk Conglomerate in eastern Pennsylvania and southeastern New York. The Juniata and Bald Eagle were thought to disappear east of the Susquehanna River, though it was not clear whether they lens out by erosion prior to deposition of the Tuscarora-Shawangunk or whether they were never deposited in the eastern part of the state. Recent work (Epstein and Epstein, 1967; Smith, 1967) indicates that rocks equivalent in stratigraphic position continue eastward intermittently along the northern edge of the Great Valley into New Jersey, beneath the Tuscarora as far as the Hamburg quadrangle and in the lower part of the Shawangunk farther east.

The Martinsburg Shale has complicated relations with the units above and below it in the Great Valley of eastern Pennsylvania. On the south the older carbonates are thrust against the Martinsburg Shale. Where the depositional contact is preserved, the Martinsburg is gradational with the underlying argillaceous limestone of Trenton age, called the Chambersburg, et cetera. The literature contains some discussion of the contact between the Martinsburg and the overlying coarse clastic rocks. That the Martinsburg is unconformably overlain by these rocks will be discussed below.

At its type section in West Virginia the Martinsburg is a dark shale with increasing silt and sand content upward. It is said to be 400 m thick, but may be two or three times that, and in Pennsylvania estimates range up to 3 km or more (Drake and Epstein, 1967). A similar unit, or units, has been called Austin Glen Graywacke and Pawlet Formation (Berry, 1962) and Snake Hill Shale and Canajoharie Shale (Berry, 1963), et cetera, in eastern New York, where the thickness is also difficult to determine. McBride (1962) demonstrated a southeastern source for the graywacke of the Martinsburg Shale from West Virginia to New York.

Between the Susquehanna and the Lehigh Rivers, as Stose (1946) pointed out, the area of the Martinsburg in the Great Valley contains, apart from the normal gray shale, siltstone, and graywacke, several other rock types—red shale and mudstone, some thin stringers of chert of various colors, and a few bentonite layers. Also noted by various people (Miller, 1937; Moseley, 1952; Dyson, 1967) are thin beds of dark, aphanitic limestone interbedded with equally fine and black shale. One cluster of pillow basalts is recorded from the Bunker Hills, at the fork of Swatara Creek (Bricker, 1960). Such a collection of rock types is rare or unknown in the Martinsburg in Pennsylvania, except in this 150-km stretch, or in the Valley and Ridge province to the northwest, where the
equivalent unit is called the Reedsville Shale. To the southeast, shaly rocks of possibly the same age are metamorphosed, and no fossils have been found. As a matter of fact, diligent search by many failed to produce fossils from the aphanitic limestone within the Martinsburg in the Great Valley. Few fossils have been found in the area at all, probably because little detailed mapping has been done.

NEW DATA

Our mapping in the Great Valley is far from complete, but it has confirmed what was long suspected—that outcrops are poor and discontinuous. We have also confirmed the existence of the anomalous rock types that Stose enclosed in his Hamburg klippe. Newly discovered fossil localities and map relations within the Martinsburg belt, and on it, and by implication below it, lead to a revised interpretation of the geologic history of this part of Pennsylvnia. In the paragraphs below the data is taken up as follows: the Martinsburg itself, its contact with younger rocks, and its relation to older rocks.

Martinsburg Shale belt.—Table 1 attempts to bring together known fossil localities in the Martinsburg belt, including a few not previously published. The localities are shown on figure 1, and the rock type, age assignment, and reference are shown in the table. One of the localities (22) is from the previously unfossiliferous, thin-bedded, dark, aphanitic limestone and black shale; a tentative evaluation of the graptolites by John Riva suggests that they are Early Ordovician. The similarity of this rock type to the Schaghticoke Shale (Berry, 1962) and Poulney A (Theokritoff, 1964), of similar age though sparsely fossiliferous, prompts the hope that further search will produce a richer fauna to confirm Riva’s tentative age assignment. This lithologic type has been mapped discontinuously for 25 km west of Harrisburg (Dyson, 1967) and has been found as far east as the Schuylkill River.

A few other fossil localities are Middle Ordovician but apparently too old to be Martinsburg (23, 24). The shales bearing these fossils are of the same age as the carbonates that underlie the Martinsburg and that are exposed in the southern part of the Great Valley.

Where outcrops are best, individual beds of chert have been traced a few kilometers along strike. Three kilometers northeast of Spitzenberg a ridge topped by chert extends for 3 km along strike, but its eastern and western ends are abrupt. The western end of the hill is exposed in a pit for road metal and reveals a good deal of fine gray shale and siltstone and a small interval of conglomerate, with pebbles of chert, et cetera up to several centimeters in diameter imbedded in shale. In the northeastern part of the Harrisburg quadrangle a similar chert bed has produced pre-Martinsburg fossils; although this bed extends several kilometers, its eastern end, as shown by the topography, is also abrupt. In suburban Harrisburg, an exposure of chert makes a local topographic high, but it is limited to a few tens of meters of strike length. It ends in graywacke of more normal Martinsburg aspect. Numerous stripes of
The Hamburg klippe reconsidered

Table 1

Locality

1. Conglomerate containing *Leperditia*; middle Chazy age (Stose, 1946, p. 672).
2. Gray shale containing graptolites; Normanskill age (Stose, 1946, p. 674).
3. Conglomerate with *Pachydictya aff. acuta, Rhinidictya*, bifoliate bryozoa, orthoids; early Trenton age (Stose, 1946, p. 675).
4. Conglomerate same as 3; early Trenton age (Stose, 1946, p. 675).
5. Conglomerate same as 3; early Trenton age (Stose, 1946, p. 675).
6. Shochary sandstone, black slate, and calcareous shale containing brachiopods; middle Eden age, Pulaski age (Stose, 1946, p. 680; see also Bretsky, Flessa, and Bretsky, 1969).
7. Purple and green shale and sandstone (underneath is cement rock of the Jacksonburg); early Trenton age (Stose, 1946, p. 682-683).
10. Shaly arkosic sandstone containing graptolites; Normanskill age (Willard, 1943, p. 1099).
13. Shochary sandstone containing brachiopods; Pulaski age (Willard, 1941, p. 224).
15. Shale containing brachiopods; Pulaski age (Stose, 1930, p. 648).
16. Gray shale containing graptolites; locality ill-defined; Trenton age (Jonas and Stose, 1930, p. 40-42).
17. Calcareous sandstone; Trenton age (Stose, 1930, p. 655).
18. Sandstone and soft shale containing *Crypto lithus bellulus*; middle Eden age (Stose, 1930, p. 651).
22. Dolomitic shale associated with thin-bedded limestone and shale containing graptolites; Early Ordovician (Carswell, Hollowell, and Platt, 1968, p. 12).
23. Cherty shale containing graptolites; Middle Ordovician (Carswell, Hollowell, and Platt, 1968, p. 12).
24. Gray shale containing graptolites; Middle Ordovician, probably Berry's (1960) zone 11 or 12; new collection: eastern Harrisburg West 7½', quadrangle, northeast of road metal pit, 240 m northeast of railroad bridge over Pennsylvania Route 39.
25. Weathered silty graptolite shale; probably late Middle Ordovician; new collection: Harrisburg West 7½', quadrangle, north side of Pennsylvania Route 944, 1 km west of U.S. Route 11 and 15.
26. Shale and siltstone containing graptolites; probably late Middle Ordovician; new collection: southern New Ringgold 7½', quadrangle, north side of road 370 m west of Bolich Church intersection.
27. Shochary Ridge sandstone containing brachiopods; Trenton age; new collection: southern New Tripoli 7½', quadrangle, crest of hill 2.7 km N56E of BM 420 at Trelxler.
28. Cross-bedded, fine-grained, calcareous sandstone containing conodonts; Early Ordovician (J. B. Epstein, personal comm.).
29. Spitzenberg red, cross-bedded sandstone with limestone pebbles, containing brachiopods; probably early Late Ordovician; new collection: northwestern Kutztown 7½', quadrangle, southeast side of Spitzenberg Hill, large slump block of red, conglomeratic sandstone.
30. Stromatolitic, oolitic, gray dolomite, the Allentown Formation; Upper Cambrian by lithologic type; although no fossils other than stromatolites were found, the evidence cited is convincing (Aldrich, 1967).
31. Shale, possibly bentonitic, containing graptolites; Middle Ordovician (Aldrich, 1967).
32. Bentonitic gray shale containing graptolites; Middle Ordovician (Aldrich, 1967).
33. Interbedded graywacke and shale with graptolites; Middle Ordovician; new collection: eastern Harrisburg West 7½', quadrangle, small road metal pit 40 m west of locality 24.
red shale have been traced across plowed fields, and limy beds have been traced along little stream valleys and other, less-pronounced, strike depressions, by many geologists in several quadrangles. But nowhere has a sequence been established in these rocks by turning an anticline or syncline of several units on a map. Either the beds disappear along strike, or adjacent bands have unclear relations, or only one identifiable bed has been turned—not showing a sequence. Miller (1937, p. 99) noted this lack of persistence of units, and it has been the bane of all workers attempting to establish a coherent stratigraphy in the Martinsburg Shale belt.

In a few road cuts, individual blocks of these various rock types have been observed embedded in normal Martinsburg. The Fairview Member of the Martinsburg, named by Willard and Cleaves (1939) for a prominent small hill on the west side of the Susquehanna River opposite Harrisburg, is a coarse graywacke with grit-sized pieces of chert and limestone, et cetera. In Harrisburg, Reservoir Park is on a hill underlain by a similar conglomerate with pieces up to 3 cm in size. Elsewhere in the Harrisburg and Hamburg quadrangles, and in between, blocks up to a meter have been found; in a few places blocks several meters long can be reasonably inferred. It is now clear why earlier mappers could not bring order out of the chaos of stripes on their maps; the rocks are in part chaotic.

Approximately half the fossil collections indicate that the enclosing shale is late Middle or early Late Ordovician, consistent with the stratigraphic position of the Martinsburg Shale between the Middle Ordovician Chambersburg or Jacksonburg Limestone (table 2) and the Bald Eagle and Juniata coarse clastic rocks of Late Ordovician age. These collections are from exposures of gray, olive-weathering shale and silty shale and graywacke, in other words typical Martinsburg Shale. Several fossil collections are so small that a close definition of the age of the enclosing shale cannot be given, but a new collection of shells from the youngest part of the Martinsburg Shale in the Hamburg quadrangle (loc. 27), kindly identified by R. B. Neuman, is of Trenton, or late Middle Ordovician, age. Graptolites, kindly identified by W. B. N. Berry, from nearby and stratigraphically a little below (loc. 26) are also of this age, to the extent that correlations between the shelly and graptolite faunas can be made. The bulk of the Martinsburg Shale seems to be Trenton in age, based on the shelly fauna, and of zone 15 age from the graptolites (Berry, 1970). We know of no recent collections of fossils from it in this area which are clearly younger.

There has been considerable discussion of the line between Middle and Upper Ordovician in recent years (Schopf, 1966, p. 12-13; Sweet and Bergstrom, 1970). Whittington (1968) expresses his belief that trilobites from Swatara Gap, locality 8 in figure 1, include Cryptolithus bellulus which is apparently younger than Trenton, but he notes an inadequate suite of specimens for certainty. Bretsky, Flessa, and Bretsky (1969), in their study of Shochary Ridge (fig. 2), did not particularly concern them-
Table 2: Stratigraphic sequence beneath the Martinsburg Shale in the Great Valley

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<tr>
<th>Adapted from: Root, 1968, p. 5</th>
<th>MacLachlan, 1967, p. 11</th>
<th>Drake, 1969, p. 78</th>
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<td>St. Paul Group</td>
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<td>Beckmantown Group</td>
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<td>Pinesburg Station Dolomite</td>
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<td>Antictam Sandstone</td>
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<td>Hardyston Quartzite</td>
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selves with time-stratigraphic aspects even though their fauna is a veritable garden of Eden. Here we attempt a Middle view.

The upper contact of the Martinsburg.—The Hamburg quadrangle provides an excellent opportunity to observe the relations between the Martinsburg Shale and the overlying coarse clastic deposits. Not only is the Tuscarora folded back across strike to the north, but also two outliers of sandstone lie on the Martinsburg here (fig. 2). Sharps Mountain, close to the long ridge of sandstone called Blue Mountain, and Spitzenberg, 3 km to the east.

At Sharps Mountain, between Blue Mountain and Spitzenberg, the Tuscarora Quartzite is underlain conformably by approximately 80 m of reddish sandstone, and this is underlain by at least another 30 m of gray sandstone. The contact between the Martinsburg and this gray sandstone is not exposed, but mapping immediately to the east shows that the Martinsburg is not conformable beneath the Sharps Mountain sandstone.

At Spitzenberg the steeply-dipping Martinsburg is overlain unconformably by 35 m of flat-lying sandstone and conglomerate which has attracted the attention of geologists interested in the Great Valley for some years. There are approximately 15 m of greenish-gray sandstone on approximately 15 m of red sandstone with numerous limestone pebbles up to 7 cm in greatest diameter. The lowest 5 m of rock above the
Martinsburg is gray sandstone with limestone and chert pebbles. Two broken brachiopods were collected from the red middle unit. They were kindly identified by R. B. Neuman, U.S. Geological Survey, as \textit{Sowerbyella} sp. and \textit{Parastrophina} cf. \textit{P. hemipticata}, suggesting a late Middle or early Late Ordovician age. After the long dearth of fossils from the Spitzenberg rocks, these two brachiopods are an embarrassment, even if they are not riches, for the Martinsburg itself supposedly continues into the Upper Ordovician.

Several explanations might be suggested. (1) It has been inferred (Whitcomb, 1942) that the Spitzenberg is an erosion remnant of Triassic, and the red sandstone and siltstone do bear some resemblance to the Newark Series. However, this view is rejected because the red and gray sandstone on Sharps Mountain that is so similar to Spitzenberg rocks lies beneath the Silurian Tuscarora Quartzite. (2) The Spitzenberg might be an erosion remnant of a large thrust sheet; such are abundant in the vicinity (Drake, 1969). However, red and gray sandstones are not known to the south, so every other bit of the thrust sheet would have to have been eroded. Furthermore, the slide blocks in the Martinsburg are conformable within it whereas the Spitzenberg sandstones are unconformable on the Martinsburg but conformable beneath the Tuscarora at Sharps Mountain. (3) The most reasonable explanation seems to be that these red and gray conglomeratic rocks are the first overlapping sediment after deposition and deformation of the Martinsburg Shale. In other words, these are similar and more or less contemporary with the Bald Eagle and Juniata Formations. The Spitzenberg and Sharps Mountain sandstones have a composition closely similar to the Bald Eagle and Juniata, and cross bedding at the Spitzenberg indicates a southeastern source similar to that of the Juniata and Bald Eagle (Yeakel, 1962) as well as that of the Tuscarora and the Martinsburg (McBride, 1962). The only significant differences are the limestone pebbles and the brachiopods at the Spitzenberg.

If the brachiopods are pebbles brought from an area of active erosion, then the true age of the enclosing rocks is only known to be Late Ordovician. But what was the source area for the limestone pebbles and the brachiopods? If the brachiopods were eroded out of the Martinsburg Shale, where is the mud that would also have been eroded? It is not in the Oswego or Juniata. No other source rock from which fossils of this age could have been derived is known or seems reasonable. If the brachiopods do date the enclosing rocks, and this seems at least equally tenable on the available evidence, then the Martinsburg Shale is limited to the late Middle Ordovician in this area. It may be significant that all the Upper Ordovician fossils recorded in table 1 are brachiopods and trilobites; no Upper Ordovician graptolite localities are listed.

In any case, the unconformity at the top of the Martinsburg is clearly established, but it is not at the end of the Ordovician. The unconformity is more logically interpreted as between Middle and Upper Ordovician rocks or close to it. A recollection of the graptolite and shelly
faunas from the Martinsburg and a restudy of old collections thought to be Late Ordovician seems needed.

Relation of Martinsburg Shale to older rocks.—In 1987, Miller reported dozens of outcrops of limestone within the Martinsburg Shale belt, and, as he noted, bedding in the limestone is, in common cases, parallel to bedding in the Martinsburg. From this he concluded that much of the limestone is indigenous to the surrounding shale. Perhaps this fact was one of those that led Stose (1946) to the belief that the entire area of his Hamburg klippe was one allochthonous mass. Dyson (1967) found additional exposures of the aphanitic limestone several kilometers beyond Stose’s western boundary, and Aldrich has reconsidered the relations of a few of Miller’s localities east of the Lehigh River (loc. 30). Aldrich makes a convincing case (1967) that the localities he studied contain Cambrian dolomite as blocks surrounded by Martinsburg, although he did not recover fossils from the carbonate. At Stissing Mountain, in southern New York approximately 150 km northeast of Aldrich’s area, Mrs. Knopf (1962) showed that large blocks of the Cambrian and Ordovician carbonate sequence are tectonic fish swimming in Middle Ordovician shale. Mrs. Knopf worked with an established fossiliferous sequence, and Aldrich leans heavily on the lithologic similarity of his dolomite to exposures nearby in sequence. The geologic map of Pennsylvania (Gray and others, 1960) outlines several exposures of carbonate rock surrounded by Martinsburg and identifies a few as older than Martinsburg, notably two areas of Beekmantown in the southern part of the Hamburg quadrangle. Another block of Lower Ordovician limestone, indicated as no. 28 in figure 1, has been found just east of Lenhartsville faulted against red and green shales. A more perplexing area of carbonate outcrop in the Martinsburg Shale has been mapped near the fork in Swatara Creek by Bricker (1960) and others in connection with the Jonestown volcanics, but fossils have not been recorded from there. Thus within and upon the Martinsburg Shale lie older carbonate rocks derived from beneath or south of the area of the present Great Valley. This much seems well documented. But what does it have to do with our reconsideration of the Hamburg klippe?

INTERPRETATION

The key element in our synthesis is that large and small blocks of various rock types were incorporated in the Martinsburg at the time of its deposition, in the late Middle and possibly early Late Ordovician. The pieces range from granules though all intermediate sizes to slabs several kilometers in exposed strike length. A varied suite of rocks has been found, including red, green, and black chert, various carbonates, a hill of volcanics, and a rather banal olive to brown shale. Fossils show that the suite includes Lower and Middle Ordovician rocks, and lithologic similarities with the known sequence in the Reading Prong indicate that Cambrian rocks are also present among the blocks swimming in the
Martinsburg Shale. No doubt further detailed mapping will bring to light additional allochthonous rocks in the area of figure 1.

That the blocks slid by gravity rather than being pushed in the more conventional thrust plates is supported by several lines of evidence. The blocks are irregularly arranged and end abruptly. Individual blocks, both large and small, are surrounded by ordinary Martinsburg Shale. Although individual plates have been mapped for several kilometers along strike, their maximum thickness is rarely as much as a kilometer; most are less than a tenth as thick as they are wide. The pebbles of these various allochthonous rocks are in graywacke beds which are in a few places close to or interbedded with boulder conglomerates. The individual slabs are too weak to sustain being pushed. Many slabs are isolated within envelopes of ordinary Martinsburg; thus they cannot have formed a mechanical train pushing each other along even if each was strong enough to bear pushing. So many slabs have been mapped interleaved in the Martinsburg that each cannot reasonably be considered the erosion remnant of a separate big thrust sheet. Thus the blocks moved individually and by gravity at least the last few kilometers.

How many miles did the blocks move? The several blocks of Allen-town, Beekmantown, and Hershey-Myerstown carbonate rocks need not have come northward more than the few kilometers from their nearest outcrop to the south, along one of the numerous thrust faults which apparently formed during the Ordovician. In fact, the very presence of the blocks of these various samples of the Cambrian and Ordovician carbonate suite in the Martinsburg is, itself, evidence that the carbonate suite was deformed during deposition of the Martinsburg Shale. The carbonate suite is now exposed on the south side of the Martinsburg in a band 50 or 60 km wide, obscured by the Triassic in part and eroded away exposing the Precambrian in part. Regardless of the Triassic and the Precambrian interruptions, the Cambrian and Ordovician carbonates were surely deposited across the entire area of the present Great Valley and some kilometers to the south in the Piedmont. The deformation of the carbonates and the recognition that they are involved in extensive nappes (Gray, 1959; Drake, 1969) imply that the carbonate belt was originally wider than it is now. How much wider it may have been is not now determinable.

However wide the carbonate belt was, the suite of shaly rocks allochthonous to the Martinsburg—the chert, the ordinary-looking shale with zone 11 graptolites, the thin- and inter-bedded aphanitic limestone and shale with Schaghticoke affinities—must have come from still farther south, for the carbonates are not shaly and cannot have been the original home of these shales. The original area of deposition of the shale blocks now in the Martinsburg must have been southeast of the carbonates of the same age. Putting this another way, the fossils establish where the blocks belong in the geologic time scale, but the rock type excludes them from the local stratigraphic column shown in table 2.
A line of reasoning suggesting several tens of kilometers of movement relates to the Cocalico Shale, in the vicinity of locality 16 in figure 1, where the shale is apparently conformable on the carbonate sequence. Although some purple slate that might be allochthonous like the blocks in the Great Valley has been recorded in the Lancaster quadrangle, the great bulk of the shale seems entirely like the ordinary Martinsburg, and the fossils would appear to bear this out (Jonas and Stose, 1930), although recollection is desirable. If the Cocalico is autochthonous upon a carbonate sequence, then the allochthonous shale and chert blocks would have to have come from still farther south both because the Lower Ordovician shale cannot come out of the carbonate and because if the sea depositing the Cocalico and the Martinsburg was doing so, in other words was progressively covering the substrata, the substrata were not contemporaneously being eroded here. The shale blocks came from farther south.

A rather tenuous line of reasoning suggests that 100 km of movement is likely for the volcanics in the Bunker Hills near Jonestown. Along the state line between Pennsylvania and Maryland several serpentine bodies have produced a radiometric date of metamorphism of approximately 300 m.y. but a date of original formation near 460 m.y., which is perhaps Middle Ordovician (Lapham and Bassett, 1964). This is pertinent if the pillow basalts and chert at Bunker Hills are part of an ophiolite suite and the serpentine and gabbro at the state line is the rest. No fossils support this, and it is not at all clear that the Bunker Hills volcanics are rootless, let alone that they came from Maryland. However, they cause only a tiny deflection of the magnetic field, an order of magnitude less than nearby Triassic basalt (U.S. Geol. Survey, 1969), and the carbonate and sandstone clustered around them seem to be out of place. A further source might be the pillow basalts in Cecil County, Md. (Higgins, 1970).

Thus the shale blocks and slabs are truly far-traveled, for they show a facies contrast with rocks of their ages in their present vicinity (table 2). The blocks moved 70 km or more, from the vicinity of the Martic Front or from still farther south, where suitable source rocks are known. This is the essence of the point made by Kay (1941).

Finally, the shale blocks and slabs are both more and less extensive than the Hamburg klippe was thought to be, for they are exposed several kilometers west of the earlier outline of the klippe, and yet much, perhaps most, of the shale within the outline is autochthonous.

References
The Hamburg klippe reconsidered


Kay, G. M., 1941, Taconic allochthone and the Martic thrust: Science, new ser., v. 94, p. 73.


