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TIOGA BENTONITE IN THE APPALACHIAN BASIN

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ABSTRACT

The Tioga Bentonite is an interval up to 258 ft (79 m) thick with several tuff layers. It is present throughout nearly all of the central and northern portion of the Appalachian basin, but is missing in the southern Appalachian basin because of the unconformity at the base of the Chattanooga Shale. In parts of the southern Ohio outcrop belt the Tioga Bentonite is uncomformably omitted by overstep of the Ohio Shale, as is true in the Kentucky outcrops on the west side of the Appalachian basin. The Tioga Bentonite also occurs in the Illinois basin, where it is called by the same name in southwestern Indiana, Illinois, and western Kentucky. In the Michigan basin the Kawkawlin Bentonite is probably the same bed as the Tioga Bentonite middle coarse zone of the Appalachian basin. The middle coarse zone of the Tioga characteristically consists of three tuff beds within an interval of 2 ft (0.6 m). The top of the Tioga middle coarse zone marks the top of the Onesquethaw Stage of the Devonian System throughout 102,000 sq mi (265,000 sq km) in the Appalachian basin.

The base of Devonian shales is diachronous in the Appalachian basin, occurring about 530 ft (160 m) below the Tioga middle coarse zone in northeastern Virginia, and about 45 ft (14 m) above the Tioga middle coarse zone in central Ohio.

This report lists well and outcrop data for 763 localities where the Tioga Bentonite has been identified in the Appalachian basin. A series of detailed stratigraphic cross sections of the Tioga ash beds shows the internal stratigraphy of the Tioga Bentonite and its relation to overlying and underlying strata. Details of the Tioga internal stratigraphy are portrayed of a series of maps. Grain size data for biotite, quartz, feldspar, zircon, and apatite are also portrayed on maps. All maps in this report are at a

scale of 1:1,000,000.

In a preliminary phase of this study, the Berea pluton near Fredericksburg, Virginia was considered the best fit for an intrustive equivalent of the volcanic root for the Tioga middle coarse zone, based on thickness and grain-size data of the middle coarse zone and a compatible mineralogy and age of the Berea pluton. It is now believed that the Virginia Blue Ridge and Piedmont were thrust westward many tens of miles by the Alleghany orogeny in Permian time and that the roots of the Tioga volcano be present only in the subsurface, piercing upward through the true basement and through the Cambrian and Ordovician strata beneath the overthrust crystalline rocks of the Piedmont near Fredericksburg, Virginia. The Tioga volcanic plume of the middle coarse zone was dispersed across the Appalachian, Michigan, and Illinois basins by winds of the Devonian southern trade wind belt, where the Tioga eruptive center was situated before North America drifted to its present location.

INTRODUCTION

The Tioga Bentonite is a volcanic ash layer which, by definition, marks the top of the Devonian Onesquethaw Stage throughout its occurrence and preservation in a continuous area of about 102,000 sq mi (265,000 sq km) of the eastern and northern part of the Appalachian basin. The same tuff layer is also recognized in the Illinois and Michigan basins by various authors. An earlier preliminary report on this contract (Dennison and Textoris, 1978) summarized conclusions, based principally on data from the Appalachian basin, that the principal source of the volcanic eruption was located in the Virginia Piedmont at about latitude 38.5 degrees, east of the limits of presently preserved Tioga strata in the Appalachian basin.

This final report on the contract includes many of the conclusions of the Dennison and Textoris (1978) paper, and also updates evolving thought on the Tioga Bentonite stratigraphic data base and its interpretation.

The principal function of this final report is to summarize for the first time the large data base on Tioga Bentonite stratigraphy, listing data and bibliographic sources for specific outcrops and wells, presenting detailed stratigraphic columns of Tioga Bentonite internal stratigraphy and the relationships of the Tioga to the immediately superadjacent and subadjacent stratigraphic units. Tioga thickness data and other stratigraphic information are summarized in 1:1,000,000-scale map form, as shown on Plates 6-11.

The same 1:1,000,000-scale base map is used to summarize the petrographic results on grain size of the tuff in the Tioga middle coarse zone, as obtained by Daniel A. Textoris in his studies of thin sections.

PREVIOUS WORK

The first identification in the literature of the bed now known as the Tioga Bentonite was by James Hall (1843, p. 163), who described a clay parting near the top of the Onondaga Limestone in Seneca County, New York. Fettke (1931, p. 8) recognized a biotite-rich layer near the base of the Devonian shales in the Tioga gas field, located in the county by that name in northern Pennsylvania; in 1949 he proposed the name Tioga Bentonite for this subsurface marker (Ebright, Fettke, and Ingham, 1949, p. 10). Oliver (1954, 1956) identified the Tioga Bentonite bed a few feet below the bottom of the Marcellus Shale in western New York, and he thought that eastward in New York the base of the Devonian shales drops lower in the section, so that the Tioga Bentonite occurs at the base of or perhaps within the lower few feet of Marcellus Shale in the Catskill region (see correlation charts by Rickard in 1964, 1975). Flowers (1952) first identified the Tioga in wells of West Virginia, and Fettke (1952) summarized the known occurrence of the Tioga in the subsurface of Pennsylvania. Weaver (1956) and Melhorn (1964) reported on the clay mineralogy of the Tioga.

Outcrop studies of the Tioga Bentonite in the Appalachian Valley and Ridge Province were initiated by Dennison in 1958, and later he carried this stratigraphic work into the subsurface. Dennison (1960, 1961) recognized the importance of the Tioga as a time surface, and he designated the Tioga Bentonite zone as the top of the Onesquethaw Stage of the Devonian System. Use of the Tioga tuff to mark the top of the Onesquethaw Stage has been followed by Rickard (1964, 1975) and by Oliver and others (1967, 1969).

Daniel A. Textoris joined Dennison in investigation of the Tioga in 1963, adding emphasis on petrology. These authors have published three short papers summarizing the Tioga stratigraphy and petrology (Dennison and Textoris, 1970,

1971, and 1978), as well as one important abstract on paleo-wind direction during deposition of the Tioga middle coarse zone (Dennison and Textoris, 1981).

Detailed studies of the Tioga revealed that there are several tuff layers, especially near the proposed volcanic source area, and an internal stratigraphy of the Tioga tuff beds has emerged. Near the middle of the Tioga tuffaceous interval, there occurs a bundle of three or four readily recognizable tuff beds within a span of usually 2 ft (0.6 m), the coarsest portion of the Tioga tuffaceous material. This is called the Tioga middle coarse zone, and it is apparently the portion of the Tioga which forms the principal marker horizon which can be traced farthest from the volcanic source. The top of the Tioga middle coarse zone is now designated as the precise top boundary of the Onesquethaw Stage (Dennison and Hasson, 1976).

The Tioga volcanic ash was blown beyond the limits of the Appalachian basin (Figure 1), so that the Tioga is now generally recognized in the deeper parts of the Illinois basin in Illinois, southern Indiana, and western Kentucky and in some Indiana outcrops and cores at the east edge of the Illinois Basin (Meents and Swan, 1965; Collinson and others, 1967; Droste and Vitaliano, 1973; Droste and Shaver, 1975a, 1975b). The Tioga is probably the same bentonite as the Michigan basin ash fall called the KawKawlin Bentonite by Baltrusiatis (1974, 1975), from occurrences near the top of the Lucas Formation within the Detroit River Group. Droste and Shaver (1975a, 1975b) and Doheney, Droste, and Shaver (1975) maintain that the bentonite of northern Indiana (Figure 1 of the present report) is within the Detroit River Formation and is equivalent to the Kawkawlin Bentonite of Baltrusaitis. Resolution of the literature controversy over the Tioga Bentonite(s) of the Midwest will ultimately depend on a more detailed understanding of the Tioga stratigraphic patterns in the Appalachian basin. Swan (Meents and Swan, 1965) thought he

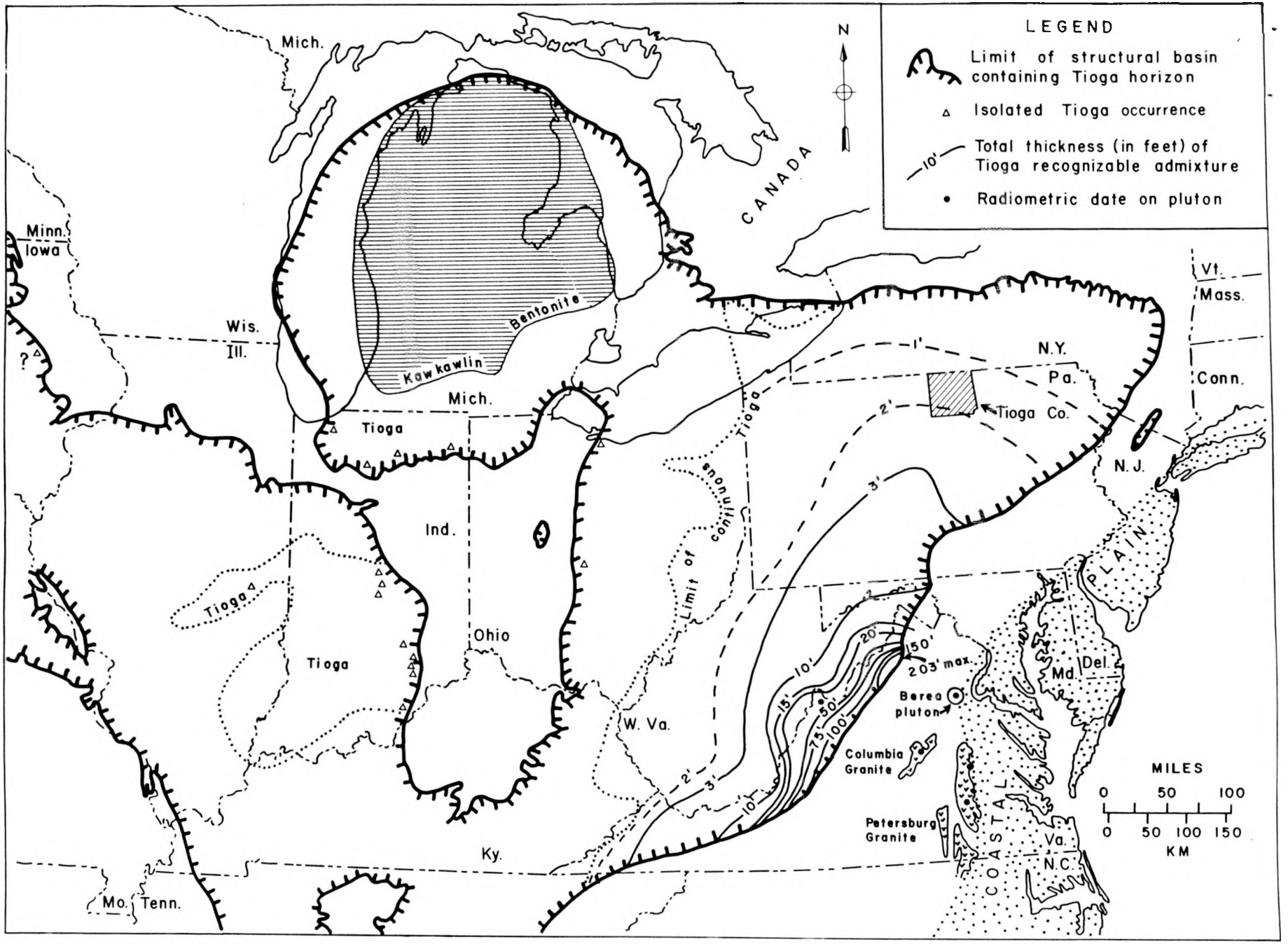

Figure 1. Distribution and thickness of Devonian Tioga tuffaceous beds in structural basins.

recognized the Tioga in one Iowa outcrop, which has never been verified by others.

Conkin and Conkin (1979) studied the Tioga Bentonite in New York, Ohio, and Indiana in considerable detail, and studied one outcrop in Pennsylvania and in Virginia. They used insoluble residues to detect trace amounts of tuff in carbonates, which Dennison was unable to do with field examination of outcrops. They also determined that some thin shale partings in the Onondaga, Columbus, and Jeffersonville Limestones are actually ash beds. Conkin and Conkin (1979) wanted to restrict the name Tioga Bentonite to those beds which Dennison calls the Tioga middle coarse zone (the group of three or four tuff beds generally within 2 ft (0.6 m) near the middle of the tuffaceous interval. Conkin and Conkin (1978) also proposed the name Onondaga Indian Nation Bentonite for the single coarse tuff bed about 10 ft (3 m) below the Tioga middle coarse zone, taking the name from the Onondaga Indian Nation near Nedrow, New York, and close to Syracuse. This type section is on land controlled by the Onondaga Indian Nation, and it is very difficult to obtain permission to study the type section. However, I am confident that the Onondaga Indian Nation Bentonite is the single bed of coarse tuff (fine sand- to silt-size) that I record on Plates 2, 3, 4, and 5 about 10 ft (3 m) below the Tioga Middle coarse zone. Conkin and Conkin (1979) also named two older betonites within the Morehouse Member of the Onondaga Limestone; these are the First Cheektowaga Bentonite (older) and the Second Cheektowaga Bentonite (younger) and taking their names from Cheektowaga near Buffalo, New York. The First Cheektowaga and Second Cheektowaga Bentonites are not as readily traceable as the Tioga middle coarse zone (Tioga Bentonite in the restricted sense of Conkin and Conkin, 1979) or the Onondaga Indian Nation Bentonites. The new bentonites named by Conkin and Conkin (1979) have not yet been formally accepted in the geologic literature, since their publication was in a

geologic field trip guidebook.

Roen and Hosterman (1982) proposed a formal change of stratigraphic name from Tioga Bentonite to Tioga Ash Bed because the Tioga is not rich in the mineral montmorillonite (or the more modern name smectite) which characterizes the swelling clays of true bentonites. They were especially critical of the Dennison and Textoris (1978) paper which called the Tioga a bentonite rather than a tuff. As a matter of clarifying the historical record, Dennison and Textoris used the name Tioga tuff in the original manuscript of the 1978 paper, but were forced editorially to change the published wording to Tioga Bentonite, because the U. S. Department of Energy insisted on using the exact stratigraphic nomenclature (Tioga Bentonite) that was then formally accepted by the U. S. Geological Survey.

Roen and Hosterman erred (1982) erred in applying the name Tioga Ash Bed rather than Tioga Ash Beds. There has been no doubt in the literature of the last 30 years that the Tioga is of volcanic origin. When Fettke originally named the Tioga Bentonite (Ebright, Fettke, and Ingham, 1949, p. 10), he made careful determination of the stratigraphic position in cable-tool well cuttings of the biotite-rich fragments, and he prepared thin thin sections of well cuttings for petrographic examination (which Textoris has borrowed from the Pennsylvania Geological Survey). Fettke used the then-in-vogue appellation Tioga Bentonite. The limits of stratigraphic resolution of cable-tool samples from nearly a mile down in Tioga County, Pennsylvania (the source of the name Tioga Bentonite) are probably no more precise than about 10 ft because of well cavings of the soft tuff bed or beds, so it was impossible as the Tioga was first named to do internal stratigraphy of the several tuff beds in the subsurface. What was known when the Tioga Bentonite was named by Fettke, is that the tuff or ash was present approximately at the Marcellus-Onondaga contact, and further detail was

impossible to recognize because of the lack of geophysical logs. Therefore, I suggest that the entire tuffaceous zone near the Onesquethaw-Cazenovia Stage boundary be designated as the Tioga Ash Beds (not Tioga Ash Bed). Tuff would be as good a lithologic formal name Ash.

STRATIGRAPHY

Some 126 Tioga outcrops are known in the Valley and Ridge Province from Virginia to Pennsylvania and along the north edge of the Appalachian basin in New York and Ontario. In addition the Tioga is recognized in at least 637 wells in the Appalachian basin, from sample descriptions or from a characteristic gamma ray peak on well logs.

The Tioga Bentonite on outcrop is characterized by brownish tuff layers up to a few inches (few centimeters) thick and by interlayers of grayish brown to brownish gray, thinly laminated, platy- to sheety-weathering, tuffaceous shales with a color contrasting with the medium dark gray to black of the enclosing Devonian shales. This brownish color persists into the subsurface accounting for the drillers term "brown break" recognized for over 30 years near the base of the Devonian shales. In the subsurface the tuff beds are identified in well cuttings by prominent biotite flakes with abundant pyrite. The Tioga cuttings have been reported generally at one position in any well, but multiple bentonites are sometimes noted. These could represent more than one ash layer, or they may represent well cavings from a single layer.

In outcrop, certain tuffaceous layers contain profuse Styliolina, Tentaculites, Leiorhynchus, and Ambocoelia, often with various bedding planes dominated by one particular genus, as if a spatfall was killed by ash from an eruption.

Figures 2A, 2B, and 2C are correlation charts of the Tioga Bentonite and

associated strata in different portions of the study area covered by this report.

The general stratigraphic occurrence of the Tioga Bentonite within the Devonian shales is diagrammed in Figure 3, where the letter "T" designates an identified Tioga occurrence at the base of the Millboro or Marcellus Shale. In this cross section, at the latitude of the south border of Pennsylvania, the Tioga tuffaceous interval coarsens eastward from about 2 ft (0.6 m) in the west to 8 ft (2.4 m) in the east. The Tioga middle coarse zone occurs precisely at the basal boundary of the black Devonian shales and separates the overlying black shales from the limy, underlying dark gray shales of the Needmore Shale or the limy cherty beds of the upper Huntersville Formation. Just to the left of the west end of the cross section of Figure 3, the base of the Devonian shales is even yuounger, and the Tioga occurs within limestone beneath the Devonian shales. In the Marble Cliffs quarry at Columbus, Ohio, an isolated Tioga outcrop has been identified at the Columbus-Delaware Limestone contact, so that in central Ohio the Tioga position at the base of the Delaware Limestone is some 45 ft (14m) below the base of the Devonian shales.

Dennison and Hasson (1979) published a stratigraphic diagram along the of Devonian shale facies along the Alleghany Front from Maryland to Highland County, Virginia. Their Allegheny Front stratigraphic panel is along structural strike and is nearly at right angles to the facies diagram of Figure 3.

In much of the eastern Appalachian basin the Tioga Bentonite is overlain by the Marcellus Shale. Farther west the Tioga is overlain by Millboro Shale, because the name Marcellus Shale disappears to the west where the last gray shale tongue of the Mahantango Formation changes facies westward to black shale (see Figure 3). Hasson and Dennison (1978a, 1978b) have mapped this

			Southwestern Virginia	Northeastern Virginia	Maryland	Central Pennsylvania	Southeastern Pennsylvania	Southwestern Pennsylvania	Northwestern Pennsylvania
DEVONIAN SYSTEM	Middle Devonian	Taghanic Stage	Chattanooga Shale	Harrell Shale / Tully Ls.	Tully Ls.	Tully Ls.	Tully Ls.	Tully Ls.	Tully Ls.
		Tioughnioga Stage	Millboro Shale	Harrell Shale	Harrell Shale	Harrell Shale	Harrell Shale	Millboro Shale	Millboro Shale
				Mahantango Fm.: Clearville Silt.	Mahantango Fm.: Clearville Silt.	Mahantango Fm.: Clearville Siltstone	Mahantango Fm.: Nis Hollow Siltstone		
				Chaneysville Siltstone	Chaneysville Siltstone	Chaneysville Siltstone	Centerfield Ls. Mbr.		
		Cazenovia Stage		Marcellus Shale / Purcell Mbr.	Marcellus Shale / Purcell Mbr.	Marcellus Shale / Purcell Mbr.	Marcellus Shale / Purcell Mbr.		
				********** calcitic shale and limestone member + + + + + + + + + + ########## oooooooooooo	********** calcitic shale and limestone member + + + + + + + + +	********** Selinsgrove Ls. + + + +	********** Buttermilk Falls Ls. + + + + + ### ? ##	********** Onondaga Ls.	********** Onondaga Ls. + + + + + +
				Needmore Shale	Needmore Shale	Needmore Shale			
				calcitic shale member	calcitic shale member	calcitic shale member	Palmerton Ss.	Huntersville Chert	Bois Blanc Ls.
					Beaver Dam Member (black shale)	Beaver Dam Mbr. (black shale)	Bowmanstown Chert	Beaver Dam Shale	Hiatus
	Lower Devonian	Onesquethaw Stage	Southwood Substage: Wildcat Valley Ss. (Onondaga Mbr.); Bobs Ridge Ss; Huntersville Chert; Needmore Shale						
			Sawkill Substage: Hiatus						

********** Tioga middle coarse zone
+ + + + + Onondaga Indian Nation tuff
########## Second Cheektowaga tuff
oooooooooo First Cheektowaga tuff

Range of Tioga ash beds

Figure 2A. Correlation chart of Tioga Bentonite and associated beds.

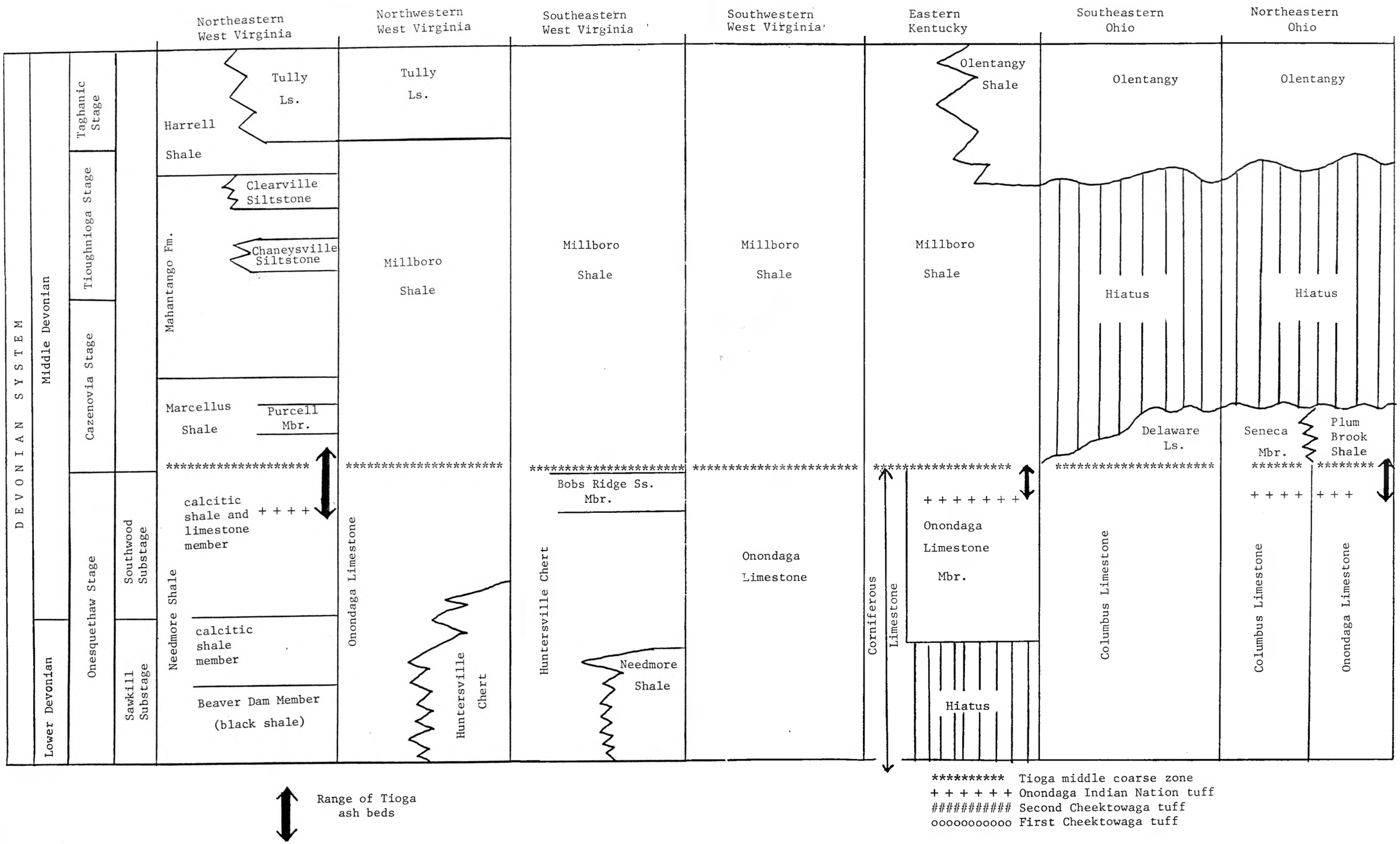

Figure 2B. Correlation chart of Tioga Bentonite and associated strata.

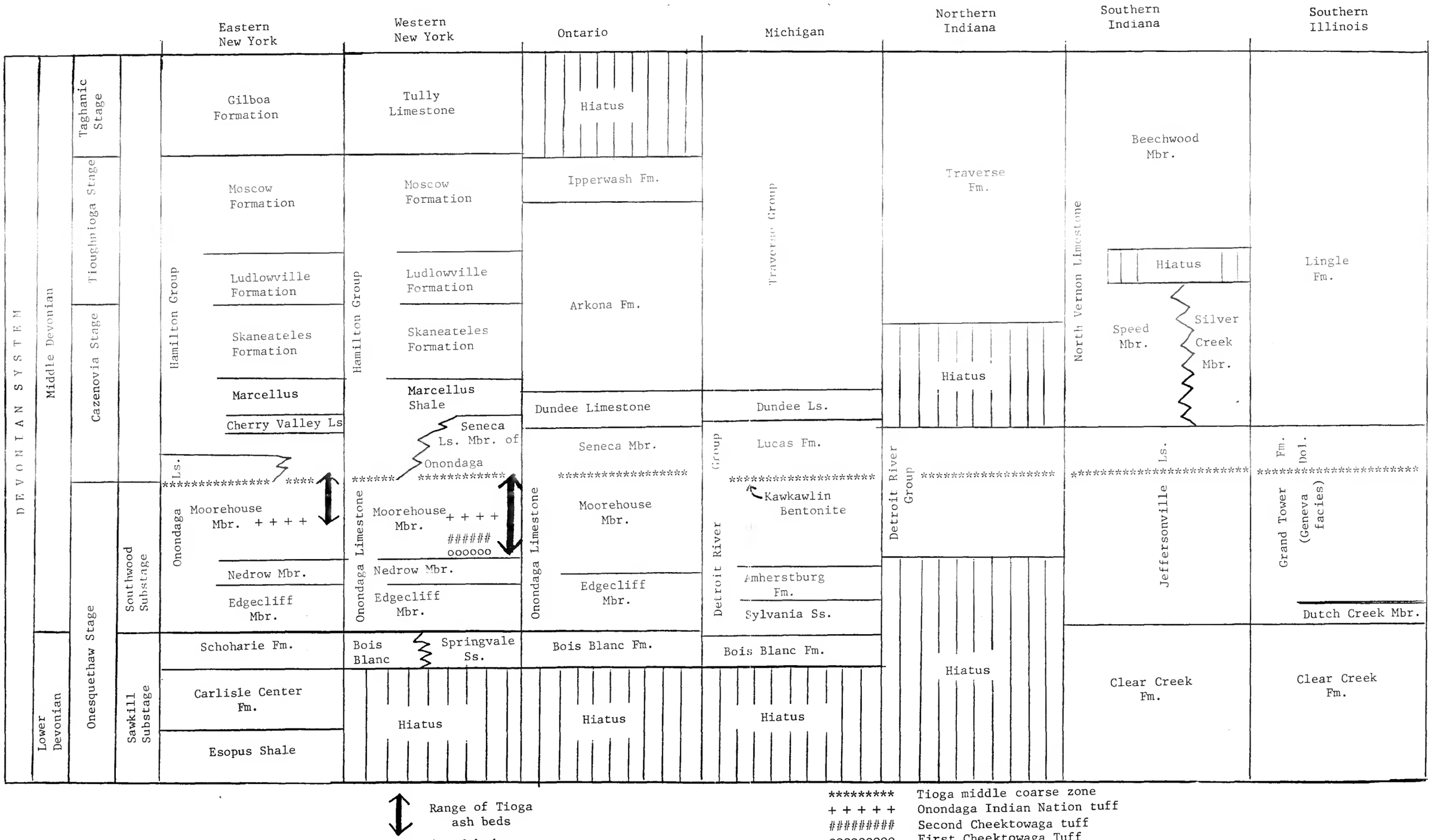

Figure 2C. Correlation chart of Tioga Bentonite and associated beds.

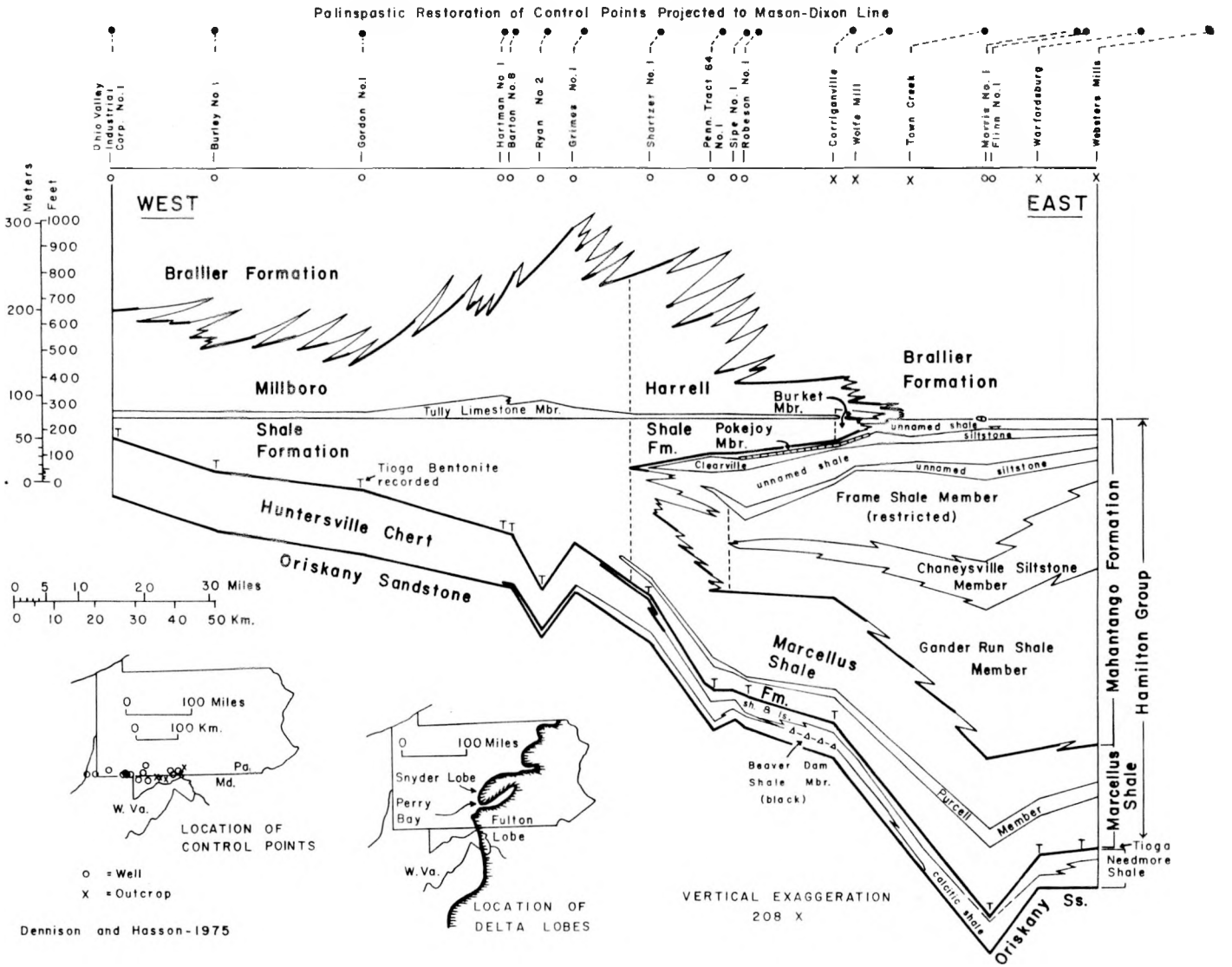

Figure 3. Facies and recommended nomenclature of Hamilton Group and associated strata along latitude 39° 43' N in stratigraphic cross section at the Mason and Dixon Line (after Dennison and Hasson, 1976).

facies change and nomenclature change, and their mapping serves as the basis for nomenclature used in the present report for the strata overlying the Tioga Bentonite (see Plate 9). Farther to the west and southwest the name of black shales directly above the Tioga Bentonite changes to Chattanooga Shale or Olentangy Shale, as all traces of siltstone disappear by westward facies change within the Devonian shales.

The bottom of the Devonian shales (Needmore Shale) extends below the Tioga in eastern areas, with the maximum stratigraphic distance occurring at Seven Fountains, Virginia (locality V-3), where the base of the Needmore Shale is about 530 ft (160 m) below the Tioga middle coarse zone. Using the middle coarse zone as a time surface, the base of the Devonian shale climbs about 575 stratigraphic ft (175 m) from east to west across the Appalachian basin.

The Tioga Bentonite is omitted by overstep of the Chattanooga Shale-Ohio Shale, where the unconformity increases westward onto the Nashville dome and Cincinnati arch. Figure 1 shows the west limit of continuous Tioga outcrops and wells on the west side of the Appalachian basin.

In the Ohio and Kentucky subsurface there is a fairly pronounced west limit to the occurrence of the Tioga Bentonite, either because of pre-Devonian shale erosion of the tuff bed, or because the tuffs were deposited in shallow water along the Cincinnati arch and were generally obliterated by wave reworking. Isolated Tioga occurrences have been reported at the top of the Columbus Limestone at Columbus and Sandusky, Ohio. The westward termination of continuous Tioga in Kentucky is based on westward abrupt loss of the characteristic strong gamma ray kick in well logs. The mapped termination suggests that renewed subsidence of the Rome trough permitted preservation of the Tioga beneath the Chattanooga-Ohio shale overstep several miles farther west in Kentucky within the Rome trough structural region.

There are several Tioga tuffaceous layers. The Tioga middle coarse zone is easily recognized as 3 or 4 distinct tuff beds all within an interval of generally 2 ft (0.6 m). The total thickness of the middle coarse zone, as well as the thickness and field observation of grain size of the individual tuffs within the middle coarse zone all increase toward the latitude of northern Massanutten Mountain (38.7 degrees) in the Valley and Ridge Province. The additional tuff layers also increase in number toward Massanutten Mountain, so that at Seven Fountains (locality V-3) there occurs a maximum of 44 silt- to sand-size tuff beds within the total Tioga interval. These extend both above and below the middle coarse zone. The middle coarse zone thins and finer-grained away from Massanutten Mountain. At the most northern outcrop in the Valley and Ridge Province (Milesburg, Pennsylvania; locality P-77) there is a single tuffaceous zone 0.3 ft (0.09 m) thick at the Marcellus-Selinsgrove contact, but within this lighter-colored tuffaceous zone there are three faintly-recognizable graded tuff beds; thus the middle coarse zone merges into a single lighter-colored clay parting far from the volcanic source. This is This is apparently the single Tioga tuff bed recognized in outcrops of New York (Oliver, 1954, 1956) and in the isolated outcrop within the Illinois basin (Figure 1).

About 10 feet (3 m) below the Tioga middle coarse zone in several outcrops in Pennsylvania there occurs another tuff layer, and this is probably the so-called "second Tioga" (probably the Onondaga Indian Nation tuff bed) which occurs in some wells in New York and adjacent Pennsylvania. Eastern New York and northeastern Pennsylvania are located farther from the apparent volcanic source, and only one Tioga bed (probably usually the Tioga middle coarse zone) extends to most wells located there and to outcrops in central New York The careful work of Conkin and Conkin (1979) indicates that with patient additional tuff beds can be found in the Onondaga and Columbus Limestones.

I am inclined to recognize the Onondaga Indian Nation Tuff (not Bentonite) as a widespread bed within the Tioga Ash Beds (although I have not been able to see its type locality in the Onondaga Indian Nation). I m confident in recognizing the Tioga middle coarse zone within the Tioga Ash Beds (or Tioga Tuff Beds).

On Plates 2, 3, 4, and 5 several other distinctive zones within the Tioga stratigraphy are also indicated, without attempting formal nomenclature. The First Cheektowaga Bentonite and the Second Cheektowaga Bentonite named by Conkin and Conkin (1979) probably both occur in some Valley and Ridge outcrops, but it is difficult to trace them precisely, because the tuff beds which are recognized above and below the positions of the Tioga middle coarse zone and the Onondaga Indian Nation tuff bed, become more numerous within the Tioga Ash Beds closer to the presumed volcanic source (probably hidden under the Piedmont crystalline overthrust near Fredericksburg, Virginia). The tuffs closer to the apparent volcanic source also extend a greater stratigraphic distance above and below the Tioga middle coarse zone and the Onondaga Indian Nation tuff bed closer to the volcanic source than away from the presumed volcanic source.

The Tioga tuffaceous interval is not vertically continuous tuff or tuffaceous brownish shale. There are also intervening layers with no recognizable tuffaceous admixture. It is possible to determine from outcrop and well sample descriptions the total recognizable thickness of strata with tuff admixture. This total thickness is isopached on the maps in Figure 1 and Plate 7, reaching a maximum of 203 ft (62 m) at Seven Fountains on Massanutten Mountain, Virginia (locality V-3). Plate 6 portrays the thickness of the Tioga interval, from oldest to youngest tuff, including tuffaceous beds and intervening beds with no recognizable tuff.

The Tioga middle coarse zone is an isochronous surface throughout its

occurrence in the Appalachian basin. It was apparently deposited on the sea floor below wave base, since the internal stratigraphy of the middle coarse zone is always recognizable. The strata which enclose the middle coarse zone are a complex group of facies. At various places the middle coarse zone rests on Onondaga Limestone, Buttermilk Falls Limestone, Selinsgrove Limestone, Needmore Shale, Huntersville Chert, and Colmunbus Limestone. Oliver (1956) believed that the lowest Marcellus probably dropped beneath the Tioga in eastern New York, but Dennison has observed the Tioga somewhat below the precise Onondaga-Marcellus boundary in well records just west of the Catskill escarpment outcrop belt. Thus the Tioga tuffs along the Hudson Valley outcrop belt is probably within the upper Onondaga Limestone, rather than within the lower Marcellus Shale.

The Tioga middle coarse zone nearly everywhere in the Appalachian basin is overlain directly by black shale of the Marcellus, Millboro, or Ohio Shale Formations (with nomenclature usage determined by presence or absence of certain siltstone units hundreds of feet higher in the stratigraphic section), but in the northwest the middle coarse zone is overlain by limestone (in western New York by the Seneca Member of the Onondaga Limestone or by the Delaware Limestone in much of Ohio).

The geologic moment of the Tioga middle coarse zone volcanism was also the time of an abrupt sea-level rise (or dropping of the sea floor) throughout the Appalachian basin (Dennison and Head, 1975). More precisely, the deepening of the sea is recoprded in strata about a foot beneath the Tioga middle coarse zone, as aerobic shales change abruptly upward into anaerobic shales (Newton, 1979). Throughout most of the basin, where the middle coarse zone is preserved, there is an abrupt transition at the volcanic event to a black shale environment (Marcellus or Millboro) directly overlying Onesquethaw Stage chert or limestone or limestone and shale. It is difficult to know for

certain whether this change in sedimentation was a result of sea-level rise or if the sudden incursion of euxinic shale resulted from tectonic downsinking of the basin accompanied by a sudden uplift of the terriginous source area as the Acadian orogeny was intensified at the moment of Tioga volcanism. Evidence at several localities favors actual water depth increase at the time of the middle coarse zone eruptions, and the distribution of these localities around the basin margin suggest a real rise in sea level. In southeastern West Virginia and part of southwestern Virginia the shallow marine Bobs Ridge Sandstone is directly overlain by the Tioga followed by black Millboro Shale. At Seven Fountains, in the Massanutten Mountain area of Virginia (locality V-3), the Tioga rests on probable moderate water-depth sandy siltstone of the upper Needmore Formation, and the Tioga zone is directly overlain by fissile, very dark gray shale of the Marcellus Formation. At Bowmanstown, Pennsylvania shallow marine sandy limestones and sandstones of the Buttermilk Falls Formation (Epstein, Sevon, and Glaeser, 1974) contain the lowest tuff layers of the Tioga; these are followed by the middle coarse zone of the main Tioga eruption and are immediately overlain by fissile black shales of the Marcellus. In central and eastern outcrops and in the subsurface of New York, the upper Onondaga Limestone was probably deposited slightly below wave base, but immediately after the Tioga ash fall an upward change to very fine muds of the basal Marcellus Shale probably indicates an increase of water depth (Lawrence Rickard, personal communicationm, 1975). All of these localities with local evidence of water depth increase combine to show a regional consistency probably implying a true sea-level rise throughout the Appalachian basin.

PETROLOGY

Nearly 300 samples of the Tioga tuff and associated rocks have been studied in detail by Daniel A. Textoris. This mineralogic and grain size information reveals the character and location of the Tioga eruptions.

Besides the samples from the Appalachian basin, we studied some samples from outcrops and wells from southeastern Michigan, northeastern and southwestern Indiana, and east-central Illinois, all of which are probably Tioga Bentonite. These areas enter into our analysis of the winds affecting the volcanic ash plume.

The Tioga tuff ranges (in its original rock state) from coarse crystal tuffs rich in biotite and feldspars to tuffaceous shales. A large variety of diagenetic processes has altered these tuffs to rock types such as bleached biotite-rich mudstone or shale. The most widely distributed beds of the middle coarse zone range from coarse biotite-feldspar crystal tuffs near the postulated source volcano to vitric-crystal tuffs to fine vitric tuffs and finally tuffaceous shales farthest away in New York, and biotite-bearing or tuffaceous dolostones, shales, and siltstones in Ohio.

Perhaps the most unique character of the Tioga tuff, both megascopically and microscopically is the presence of euhedral to subhedral crystals of bleached biotite. In the Tioga middle coarse zone, the biotite may constitute up to 80 percent of the tuff. It lies with crystal plates parallel to bedding, is often graded, and occurs densely packed or scattered throughout the rock. Diameter to thickness ratios vary from 4:1 near the source to 12:1 in more distant areas. A distribution of biotite size is give in Plate 12, and a pattern fining away from the probable source in northern Virginia is

evident. Similar distribution maps for quartz (Plate 13), feldspar (Plate 14), zircon (Plate 15) and apatite (plate 16) emphasize this pattern, with coarsest crystals in northern Virginia corresponding to the thickest accumulation of tuffaceous beds (Plate 7). The iron leached from the biotite to produce the bleached appearance has been used to supply iron for the authigenic pyrite and limonite stain which pervades most samples. Some muscovite has been identified in X-ray, also, but has not been isolated petrographically.

SOURCE VOLCANO

The location of the source volcano for the Tioga ash beds was known to be in the latitude of central Virginia since the first stratigraphic studies by Dennison (1960, 1961). Determining the source more precisely has been difficult, but a continuing array of data helps specify it. Dennison (1960, 1961) first speculated the volcanic center was east of Lexington or Staunton, Virginia. An investigation of possible feeder dikes near Monterey, Virginia produced negative results, since the ages of those dikes unexpectedly turned out to be Eocene (Fullagar and Bottino, 1969). This then led Dennison and Textoris (1970, 1971) to suggest the Columbia Granite granodiorite pluton pluton in Fluvanna County, Virginia. Hoqwevewr, the Columbia Granite turned out to be about 595 million years old (Fullagar, 1971), compared with an expected 370 million years required for the Tioga part of the geologic time scale.

With the discovery of the Seven Fountains it was (locality V-3) readily apparent that northern Massanutten Mountain is the exposure located closest to the volcanic center. This led to a consideration of the Berea Pluton as the most likely source of the ash beds. That pluton has the right composition, and Plavides (1976) reported an age of 341-367 million years. Considering

that a large pluton 6 miles across would take millions of years to cool. Dennison and Textoris (1978) speculated that the Berea pluton near Fredericksburg, Virginia is the best choice for an intrusive equivalent of the volcanic source. However, Plavides and others (1979) reinterpreted the age of the Berea Pluton (which they remaned the Falls Run Granite Gneiss) as 385-415 million years old, which is probably too old for the Tioga intrusive equivalent.

Since the initiation of this contract, advances in Appalachian structural geology force a reconsideration of the Berea Pluton as a possible source magma of the Tioga volcanics. The COCORP line across the Great Smoky Mountains led (Cook and others, 1981; Cook and others, 1983) to propose that the Blue Ridge-Great Smoky Mountain masses and the western Piedmont have been thrust at least 70 miles to the west over underlying, relatively flat Paleozoic strata. Farther north, near Charlottesville, Virginia, Harris, De Witt, and Bayer (1982) published on a similar seismic traverse and concluded that the Blue Ridge and Piedmont had similarly been thrust tens of miles or possibly over a hundred miles across underlying Paleozoic strata.

The Paleozoic strata beneath the Blue Ridge overthrust are relatively flat and possibly do not contain beds as young as Devonian. The Piedmont rocks are all allochthonous, so the Berea Pluton with appropriate mineralogy for the Tioga tuffs was much farther to the east of present Fredericksburg during Devonian time, and is an ulikely candidate for the pluton equivalent to the Tioga ash beds. The older date obtained by Plavides and others (1979) also rules against the Berea Pluton.

The isopleths of various Tioga aspects portrayed in Plates 2-16 suggest that the Seven Fountains locality (locality V-3) is the Tioga data point closest to the source volcano. Palinspastic reconstruction of that site would put the Tioga volcano well to the east of the present Blue Ridge, because

present structural interpretations of the North Mountain fault based on seismic lines indicate that the Massanutten syncline was displaced tens of miles northwestward by the Alleghany orogeny.

It now seems that the best place for finding roots of the Tioga volcano would be near present Fredericksburg, Virginia, hidden beneath the Blue Ridge overthrust, probably as feeder dikes cutting Cambrian-Ordovician strata. The Devonian rocks older than and contemporaneous with the Tioga eruptions probably either were displaced and sheared from the feeder dikes by the Alleghany orogeny or perhaps the topography of the Tioga volcanic complex was uplifted and eroded away later in the Paleozoic rather than be preserved in the Paleozoic strata beneath the crystalline overthrust of the Blue Ridge and Piedmont.

If the overthrust emplacement theory is correct for the Blue Ridge-Piedmont rocks, then further search for an outcropping of the Tioga volcanic center is futile, either in the Piedmont outcrops or in the Piedmont shallowly buried beneath the Coastal Plain.

One other new geochemical development supports the concept that the Tioga volcanic vent(s) erupted magma from one magma chamber. Smith and Way (1983) and Way and Smith (1985) studied the major and minor oxide distribution in the ash beds at Selinsgrove Junction, Pennsylvania, and concluded that all of the ashes were part of a single magmatic differentiation.

Based on the thickness of the stratigraphic interval containing the Tioga tuff beds and the relative rates of sedimentation in that part of the geologic column, I estimate that the time span of all of the Tioga eruptions was on the order of 100,000 to 1,000,000 years. Because limestone beds locally occur between ash beds in the Tioga middle coarse zone, each of those three or four major eruptions were probably sepatated by many years, perhaps thousands.

Dennison and Textoris (1980) analyzed the shape of the volcanic ash plume

of the Tioga middle coarse zone (Plates 8 ,12, 13, 14, 15, and 16) and concluded that the Tioga middle coarse zone tuffs were distributed by the southern trade wind belts. This is consistent with current paleomagnetic xinterpretations which place Virginia in the southern hemisphere trade wind latitudes during the Devonian.

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APPENDIX

DATA BASE FOR TIOGA BENTONITE

Each of the 763 Tioga Bentonite localities used for this study are described briefly in the Appendix and are plotted on Plate 1. If the Tioga Bentonite has been reported previously at that location, references are listed. Additional sources of subsurface information were unpublished sample descriptions by individuals listed with specific data points. Particular acknowledgement for large quantities of Tioga stratigraphic information is noted for the copyrighted Geologs prepared by The Geological Sample Log Company of Pittsburgh, Pennsylvania. The cooperation of Glascow Rector of that company is especially appreciated.

Descriptions of outcrop data are all from the personal observations of John M. Dennison, except for some notations for New York and Ohio as indicated in the details of this Appendix.

Certainly additional Tioga outcrops and occurrences in wells are known to others, but this is a systematic inventory of data which has come to Dennison's attention over nearly a quarter-century. Dennison searched the entire length of all the outcrop belts from New York to Tennessee to locate this stratigraphic control.

Localities where wells and outcrops were examined without finding the Tioga Bentonite are not listed in this Appendix or portrayed on Plate 1. The distribution of Tioga localities on Plate 1 is an adequate statistical sample to define the general preservational limits of the Tioga Bentonite in the Appalachian basin and the nature of the Tioga stratigraphic relationships. Localities from the Illinois and Michigan basins identify the thin sections studied for petrographic data.

The detailed stratigraphic information on the Tioga tuff beds portrayed in Plates 2, 3, 4, and 5 were all obtained personally by Dennison as outcrops came

available, often as a result of brief exposure during construction. This modest number of really good exposures provides a basis for tracing the detailed internal stratigraphy of the Tioga ash beds. In nearly every case, the detailed exposure was described only once, and now that the pattern of internal stratigraphy is outlined, almost certainly more marker beds could be traced from outcrop to outcrop as a result of revisiting the field localities. Over a period of many years, this detailed stratigraphic data base was condensed into a format suitable for Plates 2, 3, 4, and 5. These diagrams constitute the detailed data base for internal stratigraphy of the Tioga Ash Beds, and should be combined with the field descriptions of outcrop locations as documented in this Appendix.

ILLINOIS

Douglas County

ILL-1. Tuscola Stone Company quarry 2 miles southeast of Tuscola. Located in Sec. 1, T. 15 N, R. 8 E. Tioga Bentonite was reported first in this quarry by Hubert Bristol of the Illinois Geological Survey. The quarry face was measured by J. Rogers for the Illinois Geological Survey in May 1971. Dennison sampled the Tioga Bentonite in the quarry on August 7, 1973. Tioga Bentonite occurs within the Grand Tower Formation dolomite. Top of Tioga bed occurs 27 ft 7 in below top of Grand Tower Formation. Tioga Bentonite bed in this quarry is 2 to 8 inches thick and light gray in color. The geology of the area is described by Bristol and Prescot (1968), who also mention the Tioga in two nearby wells. Their published report was issured before the Tuscola Stone Company quarry was opened, so it does not mention the Tioga exposure in the quarry. Meents and Swan (1965) also mention the Tioga Bentonite in nearby wells.

INDIANA

Gibson County

IND-1. Indiana Geological Survey Sample 668.LB1.19 sample to thin section loaned to Textoris. Tioga Bentonite is 26 ft below top of Jeffersonville Limestone according to Droste and Shaver (1975, Fig. 10).

Boone County

IND-2. Indiana Geological Survey file core 100. Sample of Tioga Bentonite for thin section loaned to Textoris. Tioga is 535 ft below surface. Tioga Bentonite occurs 18 ft below top of Jeffersonville Limestone according to Droste and Shaver (1975, Fig. 10).

Allen County

IND-3. Indiana Geological Survey file core 250. Sample of Tioga Bentonite for thin section loaned to Textoris. Tioga is 321.5 ft below surface. Tioga Bentonite occurs 27 ft below top of Detroit River Formation according to Droste and Shaver (1975, Fig. 10).

Steuben County

IND-4. Indiana Geological Survey core H-A-7. Located in Sec. 27, T. 36 N, R. 12 E. Tioga Bentonite occurs 37 ft below top of Detroit River Formation according to Droste and Shaver (1975, Fig. 10). Tioga in core is also referenced by Orr (1971, p. 97).

KENTUCKY

Boyd County

K-1. Inland Gas Company tract. Inland Gas Company well 534. Carter Coordinates 1-W-82. 1700 ft from SL, 2100 ft from WL. Gamma ray log records top of Onondaga at 2306 ft. Two strong gamma ray kicks at 2281 and 2297 are probably Tioga Bentonite. Tioga is at base of Devonian shales, resting on Onondaga Member of Corniferous Limestone.

K-2. Samuel McKland et al well. Inland Gas Company. Permit 2086. Carter Coordinates 25-W-83. 1790 ft from SL, 1700 ft from EL. Gamma ray log records top of Onondaga at 2674 ft. Two strong gamma ray peaks at 2655 and 2660 ft are confidently Tioga, but moderate peak at 2635 ft is probably not Tioga Bentonite. Tioga is at base of Devonian shales, resting on Onondaga Member of Corniferous Limestone.

Lawrence County

K-3. V. E. Ball No. 1 well. Mt. Carmel Drilling Company. Carter Coordinates 1-R-81. 2850 ft from SL, 2150 ft from WL. Drillers log records top of Onondaga at 2668 ft. Very strong gamma ray kick at 2665 ft and moderate kick at 2662 ft are probably both Tioga Bentonite. Tioga is at base of Devonian shales, and rests on Onondaga Member of Corniferous Limestone.

Martin County

K-4. Jasper James et al well. United Fuel Gas Company. Carter Coordinates 19-Q-84. 8500 ft from SL, 6400 ft from EL. Sample description by G. R. Thomas places top of Corniferous at 2808 ft, with pyritic shale directly overlying limestone and chert. Gamma ray has strong Tioga kick at 2800 ft, which is directly on top of Corniferous. A rather strong kick at 2750 ft may also be Tioga tuff, but it is probably too high in the well to be the Tioga.

K-5. U. S. Signal well. Elkhorn City Coal Corp. Carter Coordinates 7-P-82. 900 ft from SL, 1600 ft from WL. Geolog records top of Onondaga at 2350 ft and wireline log records top of Onondaga at 2348 ft. Gamma ray log records a Tioga kick off scale at 2340 ft in basal 10 ft of Devonian shale.

K-6. H. F. Strong well. Kentucky-West Virginia Gas Company well 6787. Carter Coordinates 19-P-81. 1400 ft from SL, 1600 ft from WL. Permit 10921. Drillers log records top of Corniferous at 2132 ft. Gamma ray log has two strong Tioga kicks at 2116 and 2126 ft. Tioga is at base of Devonian shales, and rests on Onondaga Member of Corniferous Limestone.

K-7. Jesse Hall well. Kentucky-West Virginia Gas Company well 6831. Carter Coordinates 1-O-80. 50 ft from SL, 850 ft from WL. Permit 12246. Drillers log shows top of Corniferous at 1992 ft. Gamma ray log has two strong Tioga kicks at 1770 and 1778 ft and top of Corniferous is at 1788 ft. Tioga is at base of Devonian shales, and rests on Onondaga Member of Corniferous Limestone.

Magoffin County

K-8. Kentucky-West Virginia Gas Company (Levi Allen, Jr.) well. San Juan Oil Company. Carter Coordinates 13-O-79. 750 ft from SL, 520 ft from EL. Huntersville is 11 ft thick with top at 1786 ft. Gamma ray log has strong Tioga peaks at 1774 and 1783 ft, with top of Huntersville (Onondaga) at 1788 ft. Tioga is at base of Devonian shales, and rests on Onondaga Member of Corniferous Limestone.

Pike County

K-9. Jake Smith et al No. 1 well. Columbian Fuel Corporation well GW-832. Carter Coordinates 10-M-86. 2300 ft from NL, 1400 ft from WL. 0.6 mile W of 82° 20', 1.6 miles S of 37° 05'. Flowers (1952) reported Tioga Bentonite in cable tool samples. Martens (1945, p. 745) described samples from this well, but mentioned nothing which is readily identifiable as Tioga. Freeman (1951, well 1280) described samples from this well but did not describe Tioga. Identification of Tioga by Flowers is reliable. Tioga is at base of Devonian shales, resting on Onondaga Member of Corniferous Limestone.

Floyd County

K-10. J. W. Webb well. Kentucky-West Virginia Gas Company well 1277. Carter Coordinates 22-M-81. 200 ft from SL, 1050 ft from WL. Permit 14518. Drillers log records top of Corniferous at 2548 ft. Gamma ray log records one very strong Tioga kick at 2535 ft and top of Corniferous at 2539 ft. Tioga is at base of Devonian shales, resting on Onondaga Member of Corniferous Limestone.

MARYLAND

Allegany County

M-1. William B. Yowell N-1098. Consolidated Gas Supply Corp. Artemas 7 1/2 Minute Quadrangle. 1,350 ft S of 39° 42' 30"; 11,100 ft W of 78° 27' 30". Tioga Bentonite peak present on gamma ray. Top of Needmore 4982 ft.

M-2. Flintstone exposure. Flintstone 7 1/2 Minute Quadrangle. Lat. 39° 41' 53" N, Long. 78° 33' 34" W. Along U. S. Route 40 0.7 mile east of the village of Flintstone at east base of Warrior Ridge and at west edge of small village of Gilpin. Detailed section of Tioga Bentonite in cuts along north edge of highway was measured June 27, 1966. Exposure is probably now covered with grass planted along highway.

M-3. Oldtown exposure. Oldtown 7 1/2 Minute Quadrangle. Lat. 39° 32' 00" N, Long. 78° 35' 03" W. In cuts along Western Maryland Railroad opposite cemetery and 1.8 airline miles southeast of Oldtown. Outcrop is 300 feet east of "Oldtown" sign at east end of railroad yard. Detailed section of Tioga Bentonite measured July 2, 1965.

M-4. Spring Gap exposure. Patterson Creek 7 1/2 Minute Quadrangle. Lat. 39° 33' 40" N, Long. 78° 42' 31" W. Along Western Maryland Railroad 0.4 mile east of village of Spring Gap. Detailed section of Tioga Bentonite measured June 30, 1965.

M-5. Pittsburgh Plate Glass Company No. 7 well. Pittsburgh Plate Glass Company and Joyce Pipeline Company. Frostburg Quadrangle F. 25,900 ft S of 39° 40'; 3,200 ft W of 78° 45'. Data on file at Maryland Geologic Survey. Tioga Bentonite at depth 2075-2086 feet.

M-7. Centenary Church exposure. Evitts Creek 7 1/2 Minute Quadrangle. Lat. 39° 43' 12" N, Long. 78° 42' 16" W. Along U. S. Route 220 0.2 mile south of Pennsylvania-Maryland border and 0.2 mile southeast of Centenary Church. Weathered Tioga Bentonite middle coarse zone sand-size mica occurs in cuts on west side of road about 400 feet north of historical marker labeled "Washington's Road."

M-8. Corriganville exposure. Cumberland 7 1/2 Minute Quadrangle. Lat. 39° 40' 42" N, Long. 78° 48' 15" W. At crossing of county road over Western Maryland Railroad 1.3 miles southwest of Corriganville. Brownish, tuffaceous shale of Tioga Bentonite exposed at top of Needmore Shale, about 100 feet east of railroad crossing.

M-9. Pinto exposure. Cresaptown 7 1/2 Minute Quadrangle. Lat. 39° 34' 58" N, Long. 78° 50' 45" W. Along U. S. Route 220 0.4 mile northeast of junction of old road to village of Pinto. Tioga Bentonite middle coarse zone occurs at top of Needmore Shale.

M-10. Twenty-first Bridge exposure. Keyser 7 1/2 Minute Quadrangle. Lat. 39° 27' 10" N, Long. 78° 57' 40" W. Along cuts of Baltimore and Ohio Railroad 0.1 mile north of Twenty-first Bridge across North Branch of Potomac River. Deeply weathered Tioga Bentonite middle coarse zone mica flakes in railroad cut over 65 years old. Tioga occurs at Need-

more-Marcellus contact.

Garrett County

M-11. Robesin No. 1 well. Superior Oil Company. Permit 7,613. Lat. 39° 38' 10" N, Long. 79° 03' 01" W. Tioga Bentonite recorded as "brown break" in Onondaga at depth 4,890 ft; Tioga may be 30 ft below top of Onondaga, or this may represent cavings of Tioga after limestone was penetrated. Sample description in Amsden and others (1954, well F-66, plate III).

M-12. Katherine Shartzer (Humbertson) No. 1 well. New Penn Development Company and others. Accident Quadrangle EC. 2.18 miles S of 39° 40'; 3.97 miles W of 79° 15'. Tioga Bentonite brown, silty, micaceous shale recorded at Marcellus-Onondaga contact in sample interval 7,890-7,899 by Martens (1945, p. 757). Tioga recorded by Flowers (1952) and by Amsden and others (1954, well F-12, plate III).

M-13. Shaw No. 2 well. New York State Natural Gas well N-277. 5,900 ft S of 39° 25'; 9,525 ft W of 79° 20'. Tioga Bentonite at depth 3,770 ft in Geolog sample description, at Marcellus-Onondaga contact. Amsden and others (1954, well F-78, plate III).

M-14. Baker No. 1 well. Snee and Eberly. Permit 6,951. Lat. 39° 23' 35" N; Long. 79° 23' 02" W. Tioga Bentonite "brown break" recorded at depth 3,190 ft at Marcellus-Onondaga contact. Data from Amsden and others (1954, well F-18, plate III).

M-15. Norris K. Welch No. 1 well. Columbian Carbon GW-1502. Permit 6,272. Lat. 39° 23' 07" N; Long. 79° 23' 28" W. Tioga Bentonite recorded by Flowers (1952) and location is plotted by Amsden and others (1954, well F-16, plate I).

MICHIGAN

Inoia County

MICH-1. Core drilled by Dow Chemical Company in T. 7 N, R. 8 W, with sample provided to Textoris by E. J. Baltrusaitis. In the Michigan basin this bentonite is called the Kawkawlin Bentonite (Baltrusaitis, 1974), rather than Tioga Bentonite. The Kawkawlin Bentonite occurs within the Lucas Formation of the Detroit River Group. Comparison of the stratigraphic relations of the Kawkawlin-Tioga relationship prompted vigorous discussion of the Baltrusaitis (1974) article by Droste and Shaver (1975) and a reply by Baltrusaitis (1975).

NEW YORK

Greene County

N-1. Borden No. 1 well. Gas, Oil, and Land Leasing Corp. Catskill Quadrangle, A. 19,600 ft S 42°15'; 6,000 ft W 73°55'. Permit 4750. Geolog records top of Onondaga at 420 ft and Tioga Bentonite at 510 ft. Cherry Valley Limestone not noted. Recorded top of Onondaga is possibly calcareous zone of Cherry Valley horizon, or the recorded Tioga Bentonite may be actually cavings. Another possibility is a post-Tioga lime mound and the recorded Tioga is actually the lower coarser mica bed.

N-2. Catskill outcrop. Located 2.7 airline miles couthwest of Catskill in Kaaterskill Creek where N. Y. Route 23A crosses it. Cementon 7.5 min. Quadrangle. 42°12'1" N; 73°55'41" W. Oliver (1956, p. 1465) quotes Chadwick (1927, p. 160; 1944, p. 103) as interpreting a distinct erosion surface at Marcellus-Onondaga contact. Cooper (1930, p. 123) believed the erosional break to be minor. If Tioga is at recorded position in well of locality N-1, then the scouring surface is at top of Seneca Limestone. Oliver (1956, p. 1464) interprets uppermost Onondaga fauna as Moorehouse Member.

N-3. Maurice Gans No. 1 well. United Carbon. Durham Quadrangle, D. 100 ft N 42°20'; 6,000 ft E 74°15'. Permit 3904. Geolog records top of Onondaga Limestone at 3726 ft and Tioga Bentonite at 3738 ft. Cherry Valley Limestone not noted on Geolog.

Albany County

N-4. Clarksville outcrop. Clarksville 7.5 min. Quadrangle. Location is approximately 42°34' N; 73°58' W. Oliver (1956, p. 1465) quotes Goldring (1943, p. 243) about exposure of Onondaga-Marcellus contact in bed on Onesquethaw Creek (near Clarksville, either south branch or north branch of stream). She reported a 3 foot transition zone from Onondaga Limestone to block shale; Oliver interprets Tioga Bentonite to be within the black shale, but did not actually locate it.

N-5. Thompsons Lake outcrop. In small stream behind the old hotel at Thompsons Lake. Altamont, N. Y. 7.5 min. Quadrangle. 42°38'35" N; 74°2'46" W. Oliver (1956, p. 1464-1465) states that upper 1 foot of Onondaga (Moorehouse Member) is overlain by 3 or 4 feet of black shale with a few thin grayish black limestone beds. The unfossiliferous upper limestones are related to Union Springs Member of Marcellus Shale. Tioga not seen; it may be within black shale or it may be missing by erosion on Albany arch.

Ulster County

N-6. I. Schaller Fee No. 1 well. Gas, Oil, and Land Leasing Corp. Kaaterskill Quadrangle, F. 19,700 ft S of 42°10'; 8,500 ft W of 74°0'. Permit 4202. Geolog records probable Cherry Valley Limestone streak at 2350 ft, top of Onondaga Limestone at 2400 ft, and Tioga Bentonite at 2417 ft.

N-7. I. A. Herdman well. Dome Oil and Gas. Phoenicia Quadrangle "E". Permit 3199. Geolog records Cherry Valley Limestone at 4964-4965 ft, top of Onondaga Limestone at 5192 ft, and Tioga Bentonite at 5210 ft.

Delaware County

N-8. H. A. and M. W. Campbell well. Gulf Oil Corp. Andes Quadrangle, A. 24,550 ft S of 42°15'; 1,390 ft W of 77°55'. Permit 4214. Geolog records Cherry Valley Limestone at 5072-5120 ft and top of Onondaga Limestone at 5170 ft. Gamma ray curve records top of Onondaga Limestone at 5125 ft and Tioga Bentonite appears to be at 5135 ft.

N-9. Lanzilotta well. Gulf Oil Corp. Hobart Quadrangle, H. 21,771 ft S of 42°20'; 12,000 ft W of 74°35'. Gamma ray curve records Tioga Bentonite at 4225 ft.

N-10. M. Hazlett No. 1 well. E. S. Warner et al. Oneonta Quadrangle, F. 3,300 ft N of 42°20'; 400 ft E of 75°5'. Geolog records top of Onondaga Limestone at 3640 ft, and Tioga Bentonite at 3690 ft. Gamma ray curve records Cherry Valley Limestone at 3477-3483 ft and Onondaga Limestone at 3638-3735 ft. The Tioga Bentonite noted in Geolog is apparently the lower Tioga zone.

N-11. Caroline E. Leslie well. Gulf Oil Corp. Oneonta Quadrangle, F. 9900 ft S of 42°25'; 12,200 ft W of 75°0'. Permit 4455. Geolog records two Tioga Bentonite zones at 3320 and 3380 ft. Gamma ray curve records Cherry Valley Limestone at 3260-3275 ft, Seneca Limestone at 3310-3330 ft, upper Tioga at 3330, lower Tioga at 3390, and base of Onondaga Limestone at 3495 ft.

Schoharie County

N-12. Lawyersville outcrop. In road cut and ditch on west side of N. Y. Route 145, 1.15 miles north of Lawyersville. Richmondville, N. Y. 7.5 min. Quadrangle. 42°43'9" N; 74°30'12" W. Oliver (1956, p. 1464) records uppermost Moorehouse overlain by black shale; Tioga Bentonite was not seen, but Oliver presumed it within Marcellus Shale. Another possibility is that Tioga is missing by erosion on Albany arch.

Otsego County

N-13. Cherry Valley East outcrop. Easternmost of two new road cuts along U. S. Route 20 located 2 miles northeast of Cherry Valley. Sprout Brook, N. Y. 7.5 min. Quadrangle. Lat. approximately 42°49'; Long. approximately 74°42'30". Union Springs Black Shale Member of Marcellus Shale overlies 6 feet of Seneca Limestone Member, 3-8 inches of Tioga Bentonite, and Moorehouse Member of Onondaga Limestone. Oliver (1956, p. 1466). Welden (1966, p. 25) indicates about 4 inches of Tioga Bentonite.

N-14. Cherry Valley south outcrop and core. Located 1 mile south of Cherry Valley. East Springfield, N. Y. 7.5 min. Quadrangle. Lat. approximately 42°47'; Long. approximately 74°45'30". A composite section of outcrops and a core taken in 1952 by the State College of Ceramics reveals the following succession from top downward: Cherry Valley Lime-

stone, 27-30 ft of Union Springs Shale Member of Marcellus Formation, 6 ft of Seneca Limestone, 3 inches of Tioga Bentonite, and Moorehouse Member of Onondaga Limestone. Oliver (1954, p. 630, 647); Oliver (1956, p. 1466).

N-15. Paul B. Lum et al. well. New York State Natural Gas Co. Richmondville Quadrangle, D. Permit 4055. Gamma ray curve records Cherry Valley Limestone at 1670-1680 ft, Tioga maximum at 1715 ft and top of good Onondaga at 1722 ft. There is no Seneca Limestone, and it appears that the 7 ft below Tioga Bentonite are shaly limestone.

N-16. Edwin F. Baum well. New York State Natural Gas Co. well 866. Cooperstown Quadrangle, H. 12,500 ft S of 42°35'; 13,750 ft W of 74°50'. Permit 4245. Geolog records Cherry Valley Limestone at 2080 ft and Tioga Bentonite at 2130 ft. Gamma ray curve records Cherry Valley Limestone at 2095-2110, Marcellus Shale all the way down to Tioga Bentonite at 2130, and top of Onondaga Limestone at 2130 ft.

N-17. Walter Elliott No. 1 well. Joyce Pipeline Co. Hartwick Quadrangle, D. 22,600 ft S of 42°40'; 20,000 ft W of 75°10'. Permit 4050. Geolog records Cherry Valley Limestone at 2204 ft and top of Onondaga Limestone at 2056 ft. Gamma ray curve records Cherry Valley Limestone at 2035-2045 ft, with Tioga Bentonite peak at 2057 ft and top of good Onondaga Limestone at 2060 ft. Seneca Limestone is absent.

Oneida County

N-18. Homer A. Keith No. 1 well. New York State Natural Gas Co. Sangerfield Quadrangle D. 17,700 ft N of 42°55'; 2600 ft W of 75°25'. Permit 3928. Tioga Bentonite at 505 ft depth.

Madison County

N-19. Stockbridge Falls outcrop. Roadcut by Oneida Creek above Stockbridge Falls. Munnsville, N. Y. 7.5 min. Quadrangle. 42°57'9" N; 75°36'17" W. Oliver (1963, p. 21) states that weathered recess marks Tioga position; Dennison has visited this outcrop and this interpretation seems correct. Oliver (1956, p. 1465) records 27 ft of Union Springs Member of black shale of Marcellus Formation overlying 10 ft of Seneca Limestone Member, 4 inches of Tioga Bentonite, and Moorehouse Member of Onondaga Limestone. Welden (1966, p. 25) mentions this locality.

N-20. S. H. Seeley No. 1 well. New York State Natural Gas Co. Morrisville Quadrangle H. 3000 ft S of 42°50'; 20,500 ft W of 75°35'. Permit 4045. Geolog records top of Seneca Limestone at 1236 ft and Tioga Bentonite at 1261 ft.

N-21. Donald L. Branagan No. 1 well. New York State Natural Gas Co. Morrisville Quadrangle H. 10,400 ft S of 42°50' N; 18,000 ft W of 75°35' W. Permit 3970. Geolog records top of Seneca Limestone at 1265 ft and Tioga Bentonite at 1280 ft.

N-22. J. Danisevich No. 1 well. New York State Natural Gas Co. Sangerfield Quadrangle H. 13,500 ft N of 42°50'; 7950 ft W of 75°22'30". Tioga recorded on gamma ray log. Geolog records top of Seneca Limestone at 1070 ft and Tioga at 1100 ft.

Chenango County

N-23. Wilbur H. Decker No. 1 well. Geneganslet Oil and Gas. Greene Quadrangle F. 6300 ft S of 42°25'; 5400 ft W of 75°45'. Permit 4475. Geolog records top of Seneca Limestone at 3034 ft and Tioga Bentonite at 3050 ft.

N-24. Wilbur H. Decker No. 5 well. Geneganslet Oil and Gas. Greene Quadrangle F. 9450 ft S of 42°25'; 6200 ft W of 75°45'. Permit 5344. Geolog records top of Seneca Limestone at 3430 ft and Tioga Bentonite at 3447 ft.

Onondaga County

N-25. Jamesville outcrop. Penetentiary Quarry located 0.7 mile southeast of Jamesville N. Y. Jamesville, N. Y. 7.5 min. Quadrangle. 42°58' 59" N; 76°3'51" W. Oliver (1963, p. 20) records Tioga Bentonite here, and Dennison visited exposure in 1963 and 1974. Seneca Limestone present above Tioga Bentonite. Welden (1966, p. 25) described this locality.

N-26. G. G. Frost, Jr. No. 1 well. Reliance Oil Corp. Skaneateles Quadrangle. 29,000 ft S of 43°0'; 10,750 ft W of 76°15'. Permit 4902. Gamma ray curve records top of Seneca Limestone at 626 ft and lower Tioga Bentonite at 642 ft.

Cortland County

N-27. T. H. McCloy well. New York State Natural Gas Corp. Moravia Quadrangle F. 11,800 ft N of 42°35'; 3,000 ft W of 76°15'. Geolog records top of poorly developed Onondaga at 2085 ft (shaly Seneca Limestone Member) and Tioga Bentonite at 2100 ft at top of solid limestone of Onondaga.

N-28. K. and O.Clough No. 1 well. Delta Drilling Co. Cortland Quadrangle I. 23,500 ft S of 42°35' N; 250 ft W of 76°0'. Permit 4714. Geolog records Tioga Bentonite and top of Onondaga Limestone at 2660 ft.

N-29. Woodward No. 1 well. Penn-York Natural Gas. Harford Quadrangle A. 1800 ft N of 42°25'; 10,600 ft W of 76°10'. Geolog records two Tioga Bentonites at 2480 and 2490 ft with Marcellus-Onondaga contact at 2490 ft. Upper Tioga is probably middle coarse zone.

N-30. P. Overbaugh No. 1 well. C. Fralich-Suburban Propane Gas Co. Harford Quadrangle A. 2000 ft S of 42°25'; 9400 ft W of 76°10'. Geolog records Tioga Bentonite at 2528 ft and Marcellus-Onondaga contact (top of Seneca Limestone) at 2506 ft.

Broome County

N-31. Lester W. and Nellie A. Richards No. 1 well. Fenix and Scisson, Inc. Greene Quadrangle G. 3600 ft S of 42°20'; 8430 ft W of 75°55'. Gamma ray curve shows top of Onondaga at 3100 ft. Geolog records top of Onondaga at 3110 ft and two Tioga Bentonites at 3110 and 3125 ft.

N-32. R. G. Hotchkiss No. 1 well. Lamphere et al. Appalachian Quadrangle F. 100 ft S of 42°10'; 2000 ft E of 76°5'. Geolog records Tioga at 2725 ft just above top of Onondaga Limestone at 2732 ft. Within accuracy of these data consider the Tioga to occur at Marcellus-Onondaga contact.

Tioga County

N-33. K. Pompelli No. 1 well. Susquehanna Natural Gas. Owego Quadrangle F. 200 ft N of 42°5'; 5900 ft W of 76°15'. Geolog records Tioga Bentonite at 3905 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

Tompkins County

N-34. Jean H. Smiley No. 1 well. New York State Natural Gas. Ithaca Quadrangle F. 18,500 ft N of line; 15,000 ft E of line. Permit 4007. Geolog records Tioga Bentonite at 2347 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-35. Fee Richardson well No. 1. New York State Natural Gas well N914. Ithaca Quadrangle F. 11,900 ft S of 42°25'; 11,200 ft W of 76°30'. Permit 4467. Tioga Bentonite recorded at 2283 ft on Geolog, and is also present on gamma ray curve.

N-36. G. H. Grund No. 1 well. New York State Natural Gas. Ithaca Quadrangle B. 21,050 ft N of line; 2,500 ft E of line. Permit 4130. Geolog records Tioga Bentonite at 2500 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-37. Joe Farkas No. 1 well. Reserve Oil Company. Genoa Quadrangle. 2.04 miles N of 42°30'; 0.29 mile W of 76°30'. Sample description by Fettke (1961, p. 552) records Tioga Bentonite at 1434-1436 ft, with Tioga occurring beneath 13 ft of Seneca Limestone and resting on Onondaga Limestone.

N-38. J. W. Agard well. Great Lakes Gas Corp. Genoa Quadrangle H. 22,900 ft S of 42°35' N; 3,600 ft W of 76°35'. Permit 5017. Geolog records Tioga at 1495 ft. Tioga occurs 5 ft below top of solid limestone of Onondaga and 17 ft below top of shaly portion of Onondaga. Consider Seneca Limestone 17 ft thick. Tioga Bentonite rests on Onondaga Limestone.

Cayuga County

N-39. Union Springs outcrop. Exposed in abandoned quarry alongside N. Y. Route 90 about a mile south of Union Springs. Union Springs 7.5 min. Quadrangle. Approximate Lat. 42°49'36"; approximate Long. 76°41'36". Exposures of Tioga Bentonite near Union Springs were described by Lincoln (1895, p. 91), Oliver (1954, p. 629, 631, 647), and Oliver (1956, p. 1465). Dennison visited this locality with Douglas Brew in 1962. Tioga Bentonite is 6 inches thick and occurs beneath 24.9 ft of Seneca Limestone and overlies Moorehouse Member of Onondaga Limestone. Welden (1966, p. 26) described this locality as Old Woods Quarry.

Seneca County

N-40. Fayette outcrop. Old Wolf quarry operated by Warren Brothers. 0. mile north of Yellow Tavern Road; quarry is located 3 miles north of Fayette and 2 miles west of Canoga. Romulus 7.5 min. Quadrangle. 42°51'19" N; 76°47'6" W. Tioga Bentonite samples collected by L. V. Rickard were used for petrographic study. Luther (1909, p. 14). Welden (1966, p. 26) described Tioga Bentonite as about 6 inches thick.

N-41. Waterloo area exposures. Located in Geneva North 7.5 min. Quadrangle at approximately 42°54' N; 76°52' W. Exposures in the Waterloo area are the first published mention (Hall, 1843, p. 163) of the stratum later identified as the Tioga Bentonite. This same clay bed was also mentioned in the Waterloo area by Delafield (1850, p. 448), Luther (1909, p. 14), and Oliver (1954, p. 629). Hall described the clay bed as 4 inches thick. Luther (1909, p. 14).

Schuyler County

N-42. Robert Morris No. 1 well. Felmont Oil Corp. Ithaca Quadrangle D. 1,200 ft S of 42°25'; 14,900 ft W of 76°40'. Geolog records Tioga Bentonite at 2681 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-43. L. Webb No. 1 well. Tri-State. Watkins Quadrangle D. 21,100 ft S of 42°25'; 20,700 ft W of 76°55'. Geolog records Tioga Bentonite at 2825 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-44. New York State Lands No. 2 well. Felmont and Donovan. Hammondsport Quadrangle I. 10,100 ft N of 42°15'; 6,300 ft W of 77°0'. Geolog records bentonite at 3350, 3423, and 3430 ft and Onondaga-Marcellus contact at 3423 ft. Bentonite at 3350 is probably not really Tioga Bentonite. The two layers of bentonite at 3423 and 3430 are probably the Tioga middle coarse zone and the lower single Tioga coarse bed, respectively.

N-45. E. Hines No. 1 well. Dearth-Vendergrift. Watkins Quadrangle I. 6,800 ft S of 42°20'; 17,100 ft W of 76°45'. Geolog records Tioga Bentonite at 2389 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

Chemung County

N-46. Chester DeMunn est. No. 1 well. Trans-Eastern Petroleum, Inc. Watkins Quadrangle G. 22,500 ft S of 42°20'; 850 ft W of 76°55'. Permit 3933. Geolog records Tioga Bentonite at 3052 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-47. Willis No. 1 well. Peterman et al. Elmira Quadrangle B. 9,700 ft S of 42°15' N; 19,200 ft W of 76°50'. Geolog records Tioga Bentonite at 3065 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-48. S. Boor No. 1 well. Rio Oil Company. Watkins Quadrangle I. 29,600 ft S of 42°20'; 8,000 ft W of 76°45'. Permit 4863. Geolog records Tioga Bentonite at 3187 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-49. Wheaton No. 1 well. National Exploration Development. Waverly Quadrangle A. 300 ft N of 42°10'; 5,000 ft W of 76°40'. Geolog records Tioga Bentonite at 3701 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-50. Edward C. Kesselring No. 1 well. New York State Natural Gas Corp. Waverly Quadrangle C. 2.22 miles N of 42°10'; 1.89 miles W of 76°30'. Well samples described by Fettke (1961, p. 571). Tioga Bentonite occurs at 2784-2785 ft. Tioga underlies Marcellus Shale and rests on grayish-black, calcareous shale at depth 2985-2991 ft, limestone at 2991-3005 ft, shale and limestone at 3005-3016, and main interval of Onondaga Limestone at 3016-3034 ft. Interpret Tioga Bentonite to overlie Needmore Shale tongue. Geolog also considers Tioga to occur about 5 ft above base of Devonian shale.

N-51. English well. New York State Natural Gas. Waverly Quadrangle C. 16,250 ft N of line; 11,500 ft E of line. Geolog records Tioga at 3157 ft, occurring at top of pure limestones of Onondaga and at base of Devonian shale.

N-52. Ben Barcus No. 1 well. Updegraff. Elmira Quadrangle F. 26,500 ft S of 42°10'; 10,650 ft W of 76°45'. Geolog records Tioga Bentonite at 2620 ft, and top of Onondaga Limestone at 2635 ft. It seems that Tioga underlies Marcellus Shale and overlies 15 ft of Needmore Shale tongue.

N-53. Berthod No. 1 well. Elmira Natural Gas. Elmira Quadrangle E. 6.8 miles N of 42°0'; 6.4 miles E of 77°0'. Geolog records Tioga Bentonite at 3270 ft and top of Onondaga Limestone at 3275 ft. It seems that Tioga underlies Marcellus Shale and overlies 5 ft of Needmore Shale tongue.

N-54. William T. Richards No. 1 well. Rio Oil Co. Elmira Quadrangle G. 22,400 ft S of 42°5'; 8,250 ft W of 76°55'. Permit 4923. Geolog records Tioga Bentonite at 4058 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

Steuben County

N-55. L. Lilley No. 1 well. Empire Keystone. Corning Quadrangle E. 4,100 ft W of line; 4,250 ft N of line. Geolog records Tioga Bentonite at 3787 ft, occurring beneath 3 ft of Seneca Limestone and overlying Onondaga Limestone.

N-56. T. Cole No. 1 well. New York State Natural Gas. Corning Quadrangle F. 10,150 ft S of line; 750 ft E of line. Geolog records Tioga Bentonite at 4005 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-57. Robert Dann No. 1 well. Joyce Pipeline Company. Corning Quadrangle E. 8,050 ft S of 42°10'; 15,600 ft W of 77°5'. Permit 4574. Geolog records Tioga Bentonite at 3356 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-58. Ellen Collins No. 1 well. Godfrey L. Cabot, Inc. Corning Quadrangle A. 0.97 mile N of 42°10'; 1.38 mile W of 77°10'. Samples described by Fettke (1961, p. 512). One ft of Tioga Bentonite occurs beneath 3 ft of Seneca Limestone and overlies Onondaga Limestone.

N-59 Roy W. Herrington No. 1 well. New Penn Development Corp, et al. Woodhull Quadrangle H. 1.03 mile S of 42°5'; 0.33 mile E of 77°5'. Samples described by Fettke (1961, p. 493). Tioga Bentonite occurs at 3935-3938 ft. Tioga underlies 24 ft of Seneca Limestone and shale. Tioga overlies Onondaga Limestone. This may be merger of Seneca and Cherry Valley Limestones, or it may result from a reef in the Seneca Limestone.

N-60. J. McKeon well. Sylvania Natural Gas Corp. Greenwood Quadrangle H. 2,000 ft S of 42°5'; 17,900 ft W of 77°35'. Geolog records Tioga Bentonite at 4795 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-61. Joe White No. 1 well. Allegheny Producing Corp. Greenwood Quadrangle E. 4,950 ft N of 42°5'; 4,700 ft W of 77°35'. Geolog records Tioga Bentonite at 4900 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-62 J. H. McCormick No. 1 well. Rex Natural Gas. Greenwood Quadrangle E. 1.19 mile N of 42°5'; 1.7 mile E of 77°40'. Geolog records Tioga Bentonite at 4913 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-63. A. Rogers No. 1 well. Empire. Greenwood Quadrangle D. 16,600 ft S of 42°10'; 15,900 ft W of 77°40'. Geolog records Tioga Bentonite at 4790 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-64. New York State No. 1 well. Empire Gas and Fuel Co. Greenwood Quadrangle D. 3,625 ft S of 42°10'; 1,250 ft W of 77°40'. Geolog records Tioga Bentonite at 4680 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-65. H. Warriner No. 1 well. Appalachian Development Co. Greenwood Quadrangle A. 28,200 ft S of 42°15'; 2,900 ft W of 77°40'. Geolog records Tioga Bentonite at 4494 ft. Geolog interprets top of Onondaga at 4510 ft, but Dennison thinks formation boundary on lithologic log is better placed at 4495 ft, so that Tioga underlies Marcellus Shale and overlies Onondaga Limestone.

N-66. Warriner No. 1 well. Wittmer Oil and Gas. Greenwood Quadrangle A. 2,950 ft S of line; 3,700 ft E of line. Geolog records Tioga Bentonite at 4512 ft, occurring at base of Marcellus Shale and top of Onondaga Limestone.

N-67. Belmont Quadrangle No. 1 well. Felmont and Donovan. Greenwood Quadrangle A. 13,100 ft S of 42°15'; 3,600 ft W of 77°40'. Permit 3864. Geolog records Tioga Bentonite at 4675 ft, occurring at base of Marcellus Shale and overlying Onondaga Limestone.

N-68. W. Broughton No. 1 well. Witmer Oil and Gas. Greenwood Quadrangle C. 24,200 ft S of 42°15'; 14,500 ft W of 77°30'. Geolog records Tioga Bentonite at 3960 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-69. Andrew Taft No. 1 well. Belmont Quadrangle Drilling Company. Woodhull Quadrangle, D. 2,700 ft S of 42°10'; 3,000 ft W of 77°25'. Tioga Bentonite recorded on Geolog at 4165 ft.

N-70. S. A. House well. New York State Natural Gas. Woodhull Quadrangle D. 13,000 ft S of 42°10'; 6,400 ft E of 77°30'. Geolog records Tioga Bentonite at 4532 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-71. Ayres A. Stevens No. 1 well. Leiderbach-French. Elmira Quadrangle A. 13,250 ft S of 42°15'; 9,100 ft E of 77°0'. Permit 3932. Geolog records Tioga Bentonite at 3300 ft, occurring at base of Marcellus Shale, and apparently overlying 4 ft of Needmore Shale above Onondaga Limestone.

N-72. Pooley No. 1 well. Peterman et al. Corning Quadrangle A. 7,500 ft N of line; 10,300 ft E of line. Geolog records Tioga Bentonite at 2872 ft and top of Onondaga at 2910 ft. This would make a thickness of 38 ft for Needmore Shale, which is far too great for regional pattern; there is apparently some Needmore Shale present, however. Interpret Tioga Bentonite to underlie Marcellus Shale and overlie Needmore Shale.

N-73. Gilbert D. Scudder well. R. W. Harding et al. Corning Quadrangle. 5,200 ft S of 42°15'; 15,100 ft W of 77°10'. Geolog records Tioga Bentonite at 3310 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-74. New York State and others No. 1 well. Felmont et al. Hammondsport Quadrangle I. 8,400 ft N of 42°15'; 6,450 ft W of 77°0'. Geolog records Tioga Bentonite at 3510 ft, occurring beneath Marcellus Shale and apparently overlying 8 ft of Needmore Shale which rests on Onondaga Limestone.

N-75. State of New York No. 3 well. Donovan, Inc. Hammondsport Quadrangle I. 21,300 ft S of 42°20'; 16,500 ft W of 77°0'. Geolog records Tioga Bentonite at 3276 ft, occurring at base of Marcellus Shale and overlying Onondaga Limestone.

N-76. New York State (A. Carthley) well. New York State Natural Gas well N-115. Hammondsport Quadrangle H. 16,400 ft S of 42°20'; 6,100 ft W of 77°5'. Geolog records Tioga Bentonite at 3247 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-77. C. Whitcomb No. 1 well. Donovan et al. Hammondsport Quadrangle G. 7,000 ft S of 42°20'; 18,000 ft W of 77°10'. Geolog records Tioga Bentonite at 3108 ft, occurring beneath Marcellus Shale and overlying 8 ft of Needmore Shale which rests on Onondaga Limestone.

N-78. Blair No. 1 well. Anchor Petroleum. Bath Quadrangle I. 9,400 ft S of 42°20'; 1,800 ft W of 77°15'. Geolog records Tioga Bentonite at 2615 ft, which occurs beneath Marcellus Shale and overlies Onondaga Limestone.

N-79. S. Hemphill No. 1 well. New Penn Development Corp. Hornell Quadrangle G. 16,250 ft S of 42°20'; 9,300 ft W of 77°40'. Geolog records Tioga Bentonite at 3948 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-80. J. Freeborn No. 1 well. Penn York and Empire. Hornell Quadrangle E. 200 ft N of 42°20'; 300 ft W of 77°35'. Geolog records Tioga Bentonite at 3615 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-81. Albert F. Doster No. 1 well. Lee Minter et al. Hornell Quadrangle E. 29,250 ft S of 42°25'; 10,200 ft W of 77°35'. Permit 4433. Geolog records Tioga Bentonite at 3377 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-82. J. Magin No. 1 well. Eastern States Gas. Hornell Quadrangle B. 2.71 miles S of 42°30'; 1.0 mile W of 77°35'. Geolog records Tioga Bentonite at 3342 ft, underlying 9 ft of Seneca Limestone and overlying Onondaga Limestone.

N-83. Anthony Smolos No. 1 well. Great Lakes Gas Corp. et al. Hammondsport Quadrangle A. 9,300 ft S of 42°30'; 7,800 ft W of 77°10'. Permit 5063. Geolog records Tioga Bentonite at 2236 ft, occurring beneath 14 ft of Seneca Limestone and overlying Onondaga Limestone.

Yates County

N-84. Weldy No. 1 well. Interstate Natural Gas. Hammondsport Quadrangle B. 1,900 ft S of 42°30'; 700 ft W of 77°5'. Geolog records Tioga Bentonite at 2044 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-85. W. Stouterburg No. 1 well. Pentaga Oil and Gas. Penn Yan Quadrangle I. 3,300 ft S of 42°35'; 21,100 ft W of 77°0'. Geolog records Tioga Bentonite occurring at 1330 ft at top of main mass of Onondaga Limestone. Interpret Tioga to underlie the Marcellus Shale and overlie Onondaga Limestone.

N-86. Greger Borglum No. 1 well. Consolidated Gas Supply. Penn Yan Quadrangle C. 24,100 ft S of 42°55'; 5,900 ft W of 77°0'. Permit 4796. Geolog records Tioga Bentonite at 1115 ft, occurring beneath 13 ft of Seneca Limestone and overlying Onondaga Limestone.

gestive of a mica schist or a decomposing volcanic tufa. Oliver (1954, p. 629, 637) identified this clay parting as the Tioga Bentonite.

N-96. G. F. Nivers No. 1 well. United Producing Company. Honeoye Quadrangle H. 25,100 ft S of 42°50'; 20,500 ft W of 77°35'. Permit 4053. Geolog records Tioga Bentonite at 1380 ft, occurring beneath 35 ft of Seneca Limestone and overlying Onondaga Limestone.

N-97. A. R. Christiano No. 1 well. W. C. Partee. Caledonia Quadrangle H. 2,150 ft S of 42°50'; 13,000 ft W of 77°50'. Permit 4217. Geolog records Tioga Bentonite at 528 ft, occurring beneath 23 ft of Seneca Limestone and overlying Onondaga Limestone.

Genesee County

N-98. G. Niediek No. 1 well. H. D. Weaver. Caledonia Quadrangle A. 1,580 ft S of 42°57'30"; 1,740 ft W of 77°57'30". Geolog records Tioga at 245 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-99. Quarries at LeRoy. LeRoy 7.5 minute Quadrangle. Lat. 42°58'20"; Long. 77°57'30". Oliver (1966, p. 41 and fig. 3) describes Seneca Limestone as 30 ft thick at LeRoy. Tioga Bentonite presumably occurs at base of Seneca Limestone, but Oliver indicates he did not see Tioga there; he did see Tioga at nearby Stafford.

N-100. Lehigh Salt and Mining Company shaft one mile south of LeRoy. Location is shown on Diagram 3 in N. Y. State Museum Annual Report 47 (1894). Luther (1894, p. 240) states that "the layer (which later work showed to be the Tioga Bentonite) appeared also in the Greigsville shaft and the Lehigh shaft, amintaining its thickness and presenting no apparent difference in character (from the Livonian shaft)." Stafford 7.5 min. Quadrangle. 42°58'9" N; 78°0'32" W. Tioga Bentonite at this site mentioned by Oliver (1954, p. 629).

N-101. Stafford exposure. Quarry 0.9 mile west of Stafford. Stafford 7.5 min. Quadrangle. Lat. 42°58'43"; Long. 78°5'32". Oliver (1966, p. 41, fig. 3) states that Tioga Bentonite was found at base of Seneca Limestone and overlying Moorehouse Limestone Member of Onondaga Limestone.

Wyoming County

N-102. Harriett Schueltze No. 1 well. Great Lakes Exploration Company. Attica Quadrangle F. 29,300 ft S of 42°55'; 22,200 ft W of 78°55'. Geolog records Tioga Bentonite at 1055 ft at top of Onondaga Limestone and occurring beneath Marcellus Shale.

N-103. Wellman No. 1 well. Transamerican Petroleum Corp. Middleburg Township. Well 30 of Wallace and others (1977). Gamma ray curve records two Tioga Bentonite peaks at 1240 ft and 1248 ft (stronger). Tioga Bentonite probably underlies about 15 ft of Seneca Limestone, according to gamma ray curve, and Tioga overlies Onondaga Limestone.

Ontario County

N-87. Merle Hale No. 1 well. George Drury. Naples Quadrangle A. 4,300 ft N of 42°40'; 7,100 ft W of 77°25'. Permit 3866. Geolog records Tioga Bentonite at 1970 ft, occurring beneath 5 ft of Seneca Limestone and overlying Onondaga Limestone.

N-88. Outhouse No. 1 well. Eason Oil Co. Canandaigua Quadrangle F. 7,000 ft S of 42°55'; 15,800 ft W of 77°15'. Geolog records Tioga Bentonite at 347 ft, occurring beneath 42 ft of Seneca Limestone and overlying Onondaga Limestone. The Seneca Limestone thickness is so great here that it probably represents a merger of the Cherry Valley and Seneca Limestones.

N-89. Neenan No. 1 well. Eason Oil Co. Canandaigua Quadrangle D. 4,000 ft S of 42°55'; 5,200 ft W of 77°25'. Permit 4402. Geolog records Tioga Bentonite at 219 ft, occurring beneath 19 ft of Seneca Limestone and overlying Onondaga Limestone.

N-90. Clifford Murphy No. 1 well. Alleghany Producing Co. Canandaigua Quadrangle D. 10,150 ft S of 42°55'; 2,900 ft W of 77°25'. Permit 4159. Geolog records Tioga Bentonite at 717 ft, occurring beneath 10 ft of Seneca Limestone and overlying Onondaga Limestone.

N-91. Max Gonenhauser No. 1 well. Eason Oil Co. Canandaigua Quadrangle D. 10,600 ft S of 42°55'; 17,100 ft W of 77°25'. Geolog records Tioga Bentonite at 505 ft, occurring beneath 12 ft of Seneca Limestone and overlying Onondaga Limestone.

Livingston County

N-92. Mulligan No. 1 well. Eason Oil Co. Honeoye Quadrangle A. 23,000 ft N of line, 12,450 ft E of line. Permit 4451. Geolog records Tioga Bentonite at 55 ft, occurring beneath 23 ft of Seneca Limestone and overlying Onondaga Limestone.

N-93. Alex Marshall No. 1 well. C. Kissinger et al. Honeoye Quadrangle D. 15,800 ft S of 42°55'; 10,600 ft W of 77°40'. Permit 4056. Geolog records Tioga Bentonite at 469 ft, occurring beneath 19 ft of Seneca Limestone and overlying Onondaga Limestone.

N-94. Greigsville Salt and Mining Company shaft at Greigsville. This presently abandoned salt shaft is shown on the leicester, N. Y. 7.5 min. Quadrangle at 42°50'10" N, 77°54'13" W. Luther (1894, p. 240) records clay parting later recognized to be Tioga Bentonite in this salt shaft. Location of salt shaft relative to other salt shafts is shown on Diagram 3 of New York State Museum Annual Report 47. Oliver (1954, p. 629) mentions Tioga Bentonite in this salt shaft.

N-95. Livonia Salt and Mining Company shaft about 2 miles south of Livonia. This shaft is no longer in operation, but is located at approximately 42°47'30" N, 77°40'30" W. Location of this salt shaft relative to other salt shafts is shown in Diagram 3 of New York State Museum Annual Report 47. Luther (1894, p. 240) records a 4-inch clay parting at depth 888 ft, occurring beneath 22 ft of Seneca Limestone. He described this parting as glistening brownish gray color with appearance strongly sug-

N-104. Bell No. 2 well. W. C. Partee. Caledonia Quadrangle G. 11,700 ft S of 42°50'; 330 ft E of 78°0'. Permit 4349. Geolog records Tioga Bentonite at depth 1070 ft, occurring beneath apparently 10 ft of Seneca Limestone and overlying Onondaga Limestone. There are no samples described above 1060 ft at apparent top of Seneca Limestone.

N-105. Willard Bell No. 1 well. W. C. Partee. Caledonia Quadrangle G. Permit 4343. 11,250 ft S of 42°50'; 17,400 ft W of 77°55' W. Geolog records Tioga Bentonite at depth 920 ft, occurring beneath 17 ft of Seneca Limestone and overlying Onondaga Limestone.

N-106. S. B. Cornwell No. 1 well. New York State Natural Gas. Caledonia Quadrangle G. 13,600 ft S of 42°50' N; 12,000 ft W of 77°55'. Permit 4008. Geolog records Tioga Bentonite at depth 915 ft, occurring beneath 10 ft of Seneca Limestone and overlying Onondaga Limestone.

N-107. No. 13 Fee. Morton Salt Company. Portage Quadrangle F. 4,000 ft S of 42°40' N; 8,750 ft W of 78°5' W. Geolog records Tioga Bentonite at 1700 ft, occurring beneath 17 ft of Seneca Limestone and overlying Onondaga Limestone.

N-108. D. Veith No. 1 well. New York State Natural Gas Co. Portage Quadrangle D. 17,600 ft S of 42°40' N; 21,800 ft W of 78°0'. Permit 4092. Tioga Bentonite occurs at depth 2040 ft, underlying Seneca Limestone.

N-109. Wesley Johns No. 1 well. Great Lakes Exploration. Portage Quadrangle E. 13,350 ft S of 42°40'; 18,900 ft W of 78°5'. Permit 4385. Geolog records Tioga Bentonite at depth 2066 ft, occurring beneath 11 ft of Seneca Limestone and overlying Onondaga Limestone.

N-110. H. Lockwood No. 1 well. Farmers Oil. Portage Quadrangle I. 4,700 ft S of 42°35'; 1,200 ft E of 78°5'. Geolog records Tioga Bentonite at depth 2200 ft, occurring beneath 18 ft of Seneca Limestone and overlying Onondaga Limestone.

Alleghany County

N-111. T. McElroy well. Butera Oil Company. Portage Quadrangle G. 5,500 ft E of 78°15' W; 400 ft N of 42°30'. Geolog records Tioga Bentonite at 2912 ft, occurring beneath 23 ft of Seneca Limestone and overlying Onondaga Limestone.

N-112. M. Conners well. Filmore and Belmont. Angelica Quadrangle B. 11,100 ft S of 42°30'; 19,250 ft W of 78°5'. Geolog records two Tioga Bentonite zones at depths 2460 and 2490 ft.

N-113. G. M. Cook No. 2 well. Parsons Bros. Angelica Quadrangle A. 17,000 ft S of 42°30'; 2,050 ft W of 78°10'. Permit 3956. Geolog records Tioga Bentonite at 2712 ft, occurring beneath Seneca Limestone and overlying Onondaga Limestone. Gamma ray curve also records Tioga Bentonite.

N-114. Lynn Chase No. 1 well. Parsons. Angelica Quadrangle A. 3,400 ft N of 42°25'; 3,500 ft W of 78°10'. Geolog records Tioga Bentonite at 2592 ft, occurring beneath 28 ft of Seneca Limestone and overlying Onondaga Limestone.

N-115. Atherton Est. No. 1 well. Parsons. Angelica Quadrangle F. 10,400 ft S of 42°25'; 13,300 ft W of 78°0'. Geolog records Tioga Bentonite at 3100 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-116. Shay No. 1 well. Great Lakes Exploration Company. Canaseraga Quadrangle F. 7,100 ft S of 42°25'; 21,250 ft W of 77°45'. Geolog records Tioga Bentonite at 3275 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-117. Fleming well. John Shaw et al. Canaseraga Quadrangle D. 1,900 ft N of 42°20'; 9,500 ft E of 78°0'. Tioga Bentonite recorded at 3945 and 3960 ft depth, with base of Marcellus Shale and top of Onondaga Limestone at 3945 ft depth.

N-118. Charles W. Lytle well. Great Lakes Gas Corp. Canaseraga Quadrangle D. 12,800 ft S of 42°20'; 10,950 ft W of 77°55'. Permit 4925. Tioga Bentonite recorded at 3397 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-119. C. Duffy well. Donahue et al. Canaseraga Quadrangle G. 10,800 ft S of 42°20'; 600 ft E of 78°0'. Geolog records two horizons of Tioga Bentonite at depth 3320 and 3337 ft, with base of Marcellus Shale and top of Onondaga Limestone at 3320 ft depth.

N-120. J. Herdman well. Heiser et al. Angelica Quadrangle I. 12,700 ft N of 42°15'; 2,000 ft W of 78°0'. Geolog records Tioga Bentonite at two horizons, occurring at depths 3783 and 3797 ft. Top of Onondaga Limestone and base of Marcellus Shale is at 3783 ft depth.

N-121. Hillabush No. 1 well. Bentley et al. Angelica Quadrangle H. 15,400 ft S of 42°20'; 21,300 ft W of 78°5'. Permit 3995. Geolog records Tioga Bentonite at 3361 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-122. L. F. Eberl No. 1 well. Bentley and Gregg. Franklinville Quadrangle I. 20,400 ft S of 42°20'; 10,200 ft W of 78°15'. Geolog records two horizons of Tioga Bentonite, at depths 3705 and 3720 ft. Top of Onondaga Limestone occurs at 3726 ft depth, so there appears to be 21 ft of Needmore Shale beneath Tioga. This amount of Needmore Shale seems unusually great for this location. Tioga Bentonite underlies Marcellus Shale.

N-123. Earl Angell No. 1 well. Pennzoil Company. Wellsville Quadrangle B. 19,750 ft S of 42°15'; 20,900 ft W of 77°50'. Geolog records Tioga Bentonite at depth 4115 ft and top of Onondaga Limestone at 4120 ft. The Tioga underlies Marcellus Shale and appears to overlie 5 ft of Needmore Shale.

N-124. K. S. Black estate No. 1 well. Penn Natural Gas et al. Wellsville Quadrangle A. 27,500 ft S of 42°15'; 7,500 ft W of 77°55'. Permit 5060. Geolog records Tioga Bentonite at 4030 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-125. Vincent Middaugh, Jr. No. 1 well. Amity Gas Corp. Belmont Quadrangle C. 27,100 ft S of 42°15'; 14,600 ft W of 78°2'30". Geolog records Tioga Bentonite at 4356 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-126. A. King No. 1 well. Ravening et al. Wellsville Quadrangle D. 11,600 ft S of 42°10'; 7,800 ft E of 78°0'. Geolog records Tioga Bentonite at 3951 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-127. C. Clark Estate well. Empire Gas and Fuel. Wellsville Quadrangle F. 18,500 ft S of 42°10' N; 11,850 ft W of 77°45'. Geolog records Tioga Bentonite at 4820 ft depth, occurring beneath Marcellus Shale and above Onondaga Limestone.

N-128. S. Crandall No. 1 well. Empire Gas and Fuel. Wellsville Quadrangle F. 23,800 ft S of 42°10'; 5,000 ft W of 77°45'. Geolog records Tioga Bentonite at 4865 ft depth and records top of Onondaga Limestone at 4879 ft, in which case the Tioga Bentonite occurs beneath Marcellus Shale and overlies 14 ft of Needmore Shale.

N-129. M. Bassett No. 1 well. Empire Gas and Fuel. Wellsville Quadrangle I. 1,550 ft S of 42°5'; 8,700 ft W of 77°45'. Geolog records Tioga Bentonite at 4878 ft depth and top of Onondaga Limestone at 4899 ft. This would mean that Tioga Bentonite occurs beneath Marcellus Shale and overlies 21 feet of Needmore Shale.

N-130. F. Wilson No. 1 well. Empire Gas and Fuel. Wellsville Quadrangle H. 11,750 ft S of 42°5'; 2,050 ft W of 77°50'. Geolog records Tioga Bentonite at 4865 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-131. C. Graves No. 1 well. Empire Gas and Fuel. Wellsville Quadrangle H. 13,700 ft S of 42°5'; 150 ft W of 77°50'. Geolog records Tioga Bentonite at 5149 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-132. Fred Hillglass No. 1 well. Belmont Quadrangle Drilling Company. Wellsville Quadrangle H. 15,000 ft S of 42°5'; 7,700 ft W of 77°50'. Geolog records Tioga Bentonite at 4775 ft and top of Onondaga Limestone at 4780 ft. Tioga Bentonite occurs beneath Marcellus Shale and apparently overlies 5 ft of Needmore Shale.

N-133. M. Costello well. Empire Gas and Fuel. Wellsville Quadrangle G. 23,500 ft S of 42°5' N; 8,700 ft W of 77°55'. Geolog records Tioga Bentonite at 4702 ft depth, occurring 5 ft above top of Onondaga Limestone. Tioga Bentonite occurs beneath Marcellus Shale and apparently overlies 7 ft of Needmore Shale.

N-134. Dean Estate well. Empire Fuel and Gas. Wellsville Quadrangle G. 27,800 ft S of 42°5' N; 11,500 ft W of 77°55'. Geolog records two horizons of Tioga Bentonite at 4585 and 4605 ft depth.

N-135. Homestead Oil Co. Flanagan et al. Belmont Quadrangle H. 8,650 ft S of 42°5'; 8,100 ft W of 78°5'. Permit 4865. Geolog records Tioga Bentonite at 4823 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-136. J. N. Gadsby No. 1 well. Allegany Gas. Belmont Quadrangle H. 2,100 ft N of 42°0'; 5,300 ft E of 78°10'. Geolog records Tioga Bentonite at depth 4872 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-137. Clair No. 1 well. Quaker State Oil Refining Corp. Belmont Quadrangle I. 1,150 ft S of 42°5'; 14,575 ft W of 78°0'. Permit 5510. Geolog records Tioga Bentonite at 4600 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-138. F. Chadwick No. 1 well. B. Q. D. and W. E. Sawyer. Belmont Quadrangle D. 25,950 ft S of 42°10'; 1,650 ft W of 78°10'. Geolog records Tioga Bentonite at 4347 ft depth, occurring beneath Marcellus Shale and overlying 5 ft of apparent Needmore Shale.

N-139. H. Ames No. 1 well. Bradley Producing Co. Belmont Quadrangle D. 17,200 ft S of 42°10'; 1,900 ft W of 78°10'. Permit 4654. Geolog records Tioga Bentonite at 4611 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-140. Arthur Burdick well. Joyce Pipeline Company. Canaseraga Quadrangle I. 27,300 ft N of 42°20'; 1,500 ft W of 77°45'. Geolog records Tioga Bentonite at depth 3800 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

Cattaraugus County

N-141. W. Torrey well. Parsons. Olean Quadrangle H. 9,900 ft S of 42°5'; 1,900 ft W of 78°20'. Geolog records Tioga Bentonite at 3833 ft, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-142. Messer Oil No. 1 well. Comaco Oils, Inc. Olean Quadrangle G. 28,800 ft S of 42°5'; 4,000 ft W of 78°25'. Geolog records Tioga Bentonite at 4728 ft, occurring beneath 33 ft of Seneca Limestone and overlying Onondaga Limestone.

N-143. No. 72 Fee Kinley Oil Company. Parsons Brothers. Salamanca Quadrangle I. 27,400 ft N of 42°5'; 3,200 ft W of 78°0'. Permit 4169. Geolog records Tioga Bentonite at 4878 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-144. A. Walker No. 2 well. G. Kroh et al. Salamanca Quadrangle G. 26,000 ft S of 42°5'; 350 ft W of 78°40'. Geolog records Tioga Bentonite at 3938 ft, occurring beneath 43 ft of Seneca Limestone and overlying Onondaga Limestone.

N-145. E. Keery No. 1 well. Flanigan et al. Salamanca Quadrangle G. 7,700 ft N of 42°0'; 7,100 ft E of 78°45'. Geolog records Tioga Bentonite at 4192 ft depth, occurring beneath 32 ft of Seneca Limestone and overlying Onondaga Limestone.

N-146. J. B. Veach No. 1 well. Felmont Oil Corp. Randolph Quadrangle H. 2,450 ft N of 42°0'; 7,800 ft E of 78°55'. Geolog records Tioga Bentonite at 4150 ft depth, occurring beneath 24 ft of Seneca Limestone and overlying Onondaga Limestone.

N-147. Seneca Nations of Indians No. 3 well. Devonian Gas and Oil. Randolph Quadrangle G. 21,700 ft S of 42°5'; 9,500 ft W of 78°55'. Permit 4088. Geolog records Tioga Bentonite at depth 3328 ft, occurring beneath 28 ft of Seneca Limestone and overlying Onondaga Limestone.

N-148. E. Goodrich No. 1 well. Felmont Oil Corp. Randolph Quadrangle I. 8,200 ft S of 42°5'; 7,500 ft W of 78°45'. Geolog records Tioga Bentonite at 4,070 ft, occurring beneath 43 ft of Seneca Limestone and overlying Onondaga Limestone.

N-149. DeWolfe and McDowell No. 1 well. Dellwood Oil. Salamanca Quadrangle D. 4,100 ft S of 42°5'; 4,400 ft W of 78°40'. Geolog records Tioga Bentonite at 4333 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-150. Goldsboro-Matson No. 1 well. Pennzoil No. 102. Salamanca Quadrangle H. 9,200 ft S of 42°5'; 10,600 ft W of 78°35'. Permit 4554. Geolog records Tioga Bentonite at 4037 ft depth, occurring beneath 54 ft of Seneca Limestone and overlying Onondaga Limestone.

N-151. Seneca Nation No. 1 well. New York State Natural Gas. Salamanca Quadrangle D. 8,400 ft N of 42°5'; 300 ft W of 78°40'. Geolog records Tioga Bentonite at 3422 ft depth, occurring beneath 28 ft of Seneca Limestone and overlying Onondaga Limestone.

N-152. Seneca Nation No. 2 well. Felmont Oil Corp. Salamanca Quadrangle F. 20,500 ft S of 42°10'; 15,350 ft W of 78°35'. Geolog records Tioga Bentonite at 3662 ft depth, occurring beneath 37 ft of Seneca Limestone and overlying Onondaga Limestone.

N-153. Hosea B. Ackerly No. 1 well. Comaco Oils, Inc. Salamanca Quadrangle F. 15,200 ft S of 42°10'; 1,500 ft W of 78°35'. Permit 5106. Geolog records Tioga Bentonite at 3815 ft depth, occurring beneath 57 ft of Seneca Limestone and overlying Onondaga Limestone.

N-154. Andrews No. 1 well. J. F. Flanigan. Salamanca Quadrangle F. 11,150 ft S of 42°10'; 4,300 ft E of 78°35'. Geolog records Tioga Bentonite at 3745 ft depth, occurring beneath 75 ft of Seneca Limestone and overlying Onondaga Limestone.

N-155. E. W. Potter No. 1 well. J. F. Flanigan. Salamanca Quadrangle F. 12,000 ft S of 42°10'; 5,600 ft W of 78°30'. Permit 4373. Geolog records Tioga Bentonite at 3933 ft depth, occurring beneath 40 ft of Seneca Limestone and overlying Onondaga Limestone.

N-156. Frederick M. Russell No. 1 well. J. F. Flanigan. Olean Quadrangle D. 9,300 ft S of 42°10'; 17,150 ft W of 78°25'. Geolog records Tioga Bentonite at 3659 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-157. H. A. Crosby No. 1 well. Thropp Oil and Gas Corp. Olean Quadrangle B. 25,250 ft S of 42°15'; 18,250 ft W of 78°20'. Permit 4574. Geolog records Tioga Bentonite at 3728 ft depth, occurring beneath Marcellus Shale and apparently overlying 5 ft of Needmore Shale.

N-158. M. F. Brown No. 1 well. Felmont Oil Corp. Olean Quadrangle B. 6,050 ft N of 42°10'; 2,000 ft W of 78°20'. Geolog records Tioga Bentonite at 4000 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-159. Smith-Tucker No. 1 well. Bozard Hill Oil and Gas. Olean Quadrangle A. 10,700 ft S of 42°15'; 8,550 ft E of 78°30'. Geolog records Tioga Bentonite at 3640 ft depth, occurring beneath Marcellus Shale and overlying Onondaga Limestone.

N-160. O. E. Osgood No. 1 well. Minter. Olean Quadrangle B. 8,550 ft S of 42°15'; 9,100 ft W of 78°20'. Geolog records Tioga Bentonite at 3952 ft depth, occurring beneath Marcellus Shale and overlying apparently 5 ft of Needmore Shale.

N-161. Utter No. 1 well. Swan. Olean Quadrangle C. 12,550 ft S of 42°15'; 21,800 ft W of 78°15'. Geolog records streaks of Tioga Bentonite at 3428, 3438, and 3448 ft. Geolog records top of Onondaga Limestone at 3395 ft, so middle coarse zone of Tioga apparently occurs beneath 33 ft of Seneca Limestone and overlies Onondaga Limestone. Perhaps some of these Tioga Bentonite streaks are cavings in well.

N-162. Pettingill No. 1 well. Sunburst Oil and Gas. Olean Quadrangle B. 4,200 ft S of 42°15'; 6,200 ft E of 78°25'. Geolog records Tioga Bentonite at 3540 ft depth, occurring beneath 34 ft of Seneca Limestone and overlying Onondaga Limestone.

N-163. E. Laubacker No. 1 well. Bentley. Olean Quadrangle B. 3,100 ft S of 42°15'; 6,400 ft W of 78°20'. Geolog records Tioga Bentonite at 3752 ft depth, occurring beneath 26 ft of Seneca Limestone and overlying Onondaga Limestone.

N-164. Pratt No. 1 well. Iroquois Gas Corp. Cattaraugus Quadrangle B. 24,400 ft S of 42°30'; 9,300 ft W of 78°50'. Permit 5313. Geolog records Tioga Bentonite at 2290 ft depth, occurring beneath 32 ft of Seneca Limestone and overlying Onondaga Limestone.

N-165. Thomasett well. Iroquois Gas Corp. Perrysburg Township. Well 27 of Wallace and others (1977). Gamma ray log of Tioga Bentonite interval shows one thick peak with two small peaks on it at 1928 and 1931 (stronger) ft. Tioga Bentonite occurs at base of Devonian shales and overlies Onondaga Limestone. There is no clear gamma ray evidence of Seneca Limestone above the Tioga Bentonite.

Erie County

N-166. Edwin P. Heary No. 1 well. Consolidated Gas Corp. Concord Town. Well 29 of Wallace and others (1977). Strong gamma ray peak extends off record at position of Tioga Bentonite at 1830 ft depth. There appears to be about 15 ft of Seneca Limestone above Tioga Bentonite in this well, and Tioga overlies Onondaga Limestone.

N-167. No. 4 Fee well. J. F. Schoellkopf. Eden Quadrangle A. 14,550 ft S of 42°45'; 9,000 ft W of 78°55'. Geolog records Tioga Bentonite at 390 ft depth.

N-168. Fee No. 3 well. Graoc Dairy. Springville Quadrangle B. 1,150 ft S of 42°45'; 6,000 ft W of 78°35'. Geolog records Tioga Bentonite at 730 ft depth, with no clear description of samples above that depth. Top of Onondaga is reported at 710 ft, so Tioga Bentonite is apparently overlain by 20 ft of Seneca Limestone, and Tioga overlies Onondaga Limestone.

N-169. Leroy Cornwell No. 1 well. Reserve Gas Company. Depew Quadrangle C. 29,200 ft S of 43°0'; 1,050 ft W of 78°30'. Geolog records Tioga Bentonite at 195 ft depth, occurring beneath 11 ft of Seneca Limestone and overlying Onondaga Limestone.

N-170. Bellevue quarry exposure. Bellevue quarry operated by Federal Crushed Stone Company 0.3 mile northwest of community of Bellevue. Located along north side of Como Park Blvd. 2.1 miles west of its intersection with N. Y. Route 78 and U. S. Route 20 in south edge of Depew. Lancaster 7.5 minute Quadrangle. 42°53'45"; Long. 78°44'15". Oliver (1966, p. 41) records presence of Tioga Bentonite in this quarry, without specifying its thickness. Only about 8 ft of lower Seneca Member is exposed in this quarry (Oliver, 1966, Fig. 3). Thickness of Seneca Limestone in Buffalo area is 40 ft or more (Oliver, 1966, p. 41), and Bellevue quarry is in edge of Buffalo metropolitan region.

Chautauqua County

N-171. Shadle No. 1 well. Humble Oil Company. Cherry Creek Quadrangle E. 3,000 ft N of 42°20'; 9,000 ft E of 79°10'. Permit 4154. Geolog records Tioga Bentonite at 2355 ft depth, occurring beneath 20 ft of Seneca Limestone and overlying Onondaga Limestone. Gamma ray curve shows Tioga Bentonite 21 ft below top of Seneca Limestone.

N-172. Houck No. 4 well. Meridian Exploration Corp. Arkwright Township. Well 26 of Wallace and others (1977). Gamma ray curve shows two Tioga Bentonite peaks at 1705 ft and 1715 ft (strongest), with Tioga Bentonite occurring beneath Devonian shale and at top of Onondaga Limestone.

N-173. Lyle H. Bennett No. 1 well. Flint Oil and Gas Company. Pomfret Township. Well 24 of Wallace and others (1977). Gamma ray curve shows two Tioga Bentonite peaks at 1195 ft (strongest) and 1205 ft with Tioga occurring beneath Devonian shale and overlying Onondaga Limestone.

N-174. E. Kister No. 1 well. Lapage Corp. Westfield Quadrangle F. 5,800 ft N of 42°20'; 16,400 ft W of 79°30'. Geolog records Tioga Bentonite at 1155 ft depth, occurring beneath 31 ft of Seneca Limestone and overlying Onondaga Limestone.

N-175. Sharon Marsh No. 1 well. Hart, Jeutler, and Yeager. Jamestown Quadrangle F. 9,800 ft N of 42°5'; 6,300 ft E of 79°5'. Geolog records Tioga Bentonite at 2955 ft depth, occurring beneath Marcellus Shale and apparently overlying 5 ft of Needmore Shale.

N-176. A. Donelson No. 1 well. T. M. Pettigrew et al. Chautauqua Quadrangle I. 8,350 ft N of 42°0'; 1,300 ft W of 79°15'. Geolog records Tioga Bentonite at depth 3175 ft, occurring beneath 12 ft of Seneca Limestone and overlying Onondaga Limestone.

N-177. Kyle Morse No. 1 well. Universal Delta Drilling Company. 1.05 miles S of 42°5'; 0.06 mile E of 79°25'. Sample description by Fettke (1961, p. 612-613). Marcellus Shale overlies a 10 ft sample (depth 2904-2914 ft) containing limestone and Tioga Bentonite. Seneca Limestone is probably present, based on regional distribution patterns, but its precise thickness in the well is up to 10 ft.

N-178. H. J. Stetson No. 1 well. Texaco I, Inc. Clymer Quadrangle D. 2,400 ft S of 42°10'; 3,300 ft W of 79°40'. Geolog records Tioga Bentonite at 2408 ft depth, occurring beneath 10 ft of Seneca Limestone and overlying Onondaga Limestone.

N-179. H. Carnahan No. 1 well. Apache Corp. - Hica Corp. Mina Township. 1,200 ft S of 42°10'; 7,525 ft W of 79°42'30". Well 23 of Wallace and others (1977). Gamma ray curve shows single peak of Tioga Bentonite at 2350 ft, with Tioga occurring beneath Devonian shales and overlying Onondaga Limestone.

OHIO

Ashtabula County

0-1. Matulus No. 1 well. Felmont (Sun) No. 1-117. Lot 15, Pierpont Township. Well 13 of Heyman (1977). Gamma ray curve records Tioga Bentonite peaks at 2038, 2042, and 2050 ft (all of equal strength). Tioga Bentonite is directly under Plum Brook Shale and rests on Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-2. French and Papp No. 1 well. Russell McConnell. Lot 38, Andover Township. 800 ft south of line, 960 ft east of line. Well 11 of Heyman (1977). Gamma ray curve records Tioga Bentonite peaks at 2447 and 2450 (strongest) ft, with Tioga Bentonite underlying 9 ft of Seneca Limestone and overlying Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone. Geolog records Tioga Bentonite at 2440 ft, overlain by 10 ft of Seneca Limestone.

0-3. Mueller No. 1 well. Devonian and Benedum-Trees. Lot 2, Dorset Township. Well 12 of Heyman (1977). Gamma ray curve records Tioga Bentonite peaks at 2249, 2255, and 2259 (strongest) ft, with Tioga Bentonite directly under Plum Brook Shale and resting on Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-4. Raymond and Vera Kaderly No. 1 well. (Russell McConnell, Inc.) Texaco, Inc. New Lyme Township. Permit No. 214. Well 18 of Wallace and others (1977). Gamma ray curve records Tioga Bentonite peaks at 2202 and 2206 ft and a fainter peak at 2187 ft. Tioga Bentonite is between Devonian shale (Marcellus Shale) and Onondaga Limestone.

0-5. Clarin Clark "D" No. 1 well. Northern Natural Gas Producing Co. Windsor Township. Permit No. 103. Well 17 of Wallace and others (1977). Gamma ray curve records Tioga Bentonite peaks at 2185-2196 ft. Tioga Bentonite is between Devonian Shale (Marcellus Shale) and Onondaga Limestone.

0-6. Burkholder No. 1-H well. Horizon Oil Co. Lot 35, Harperfield Township. Data from Heyman (1977, p. 7). Tioga Bentonite peak on gamma ray curve picked by Heyman at 23 ft below base of Devonian Shale. Tioga occurs within Delaware Limestone of Heyman (1977), which is equivalent to upper portion of Onondaga Limestone.

Lake County

0-7. Diamond Alkali Company core hole no. 202. Lot 18, Tract 4, Perry Township. Data from Heyman (1977, p. 6-8). W. A. Oliver, Jr. picked these stratigraphic positions in the core: top of Delaware Limestone at 1239 ft, possible Tioga Bentonite at 1300 ft, and top of Columbus Limestone at 1361 ft. Heyman (1977) records the positions on the gamma ray curve as 1243, 1302, and 1365 ft, respectively. If the Tioga Bentonite is correctly identified, the Delaware Limestone (= Seneca Limestone?) is 62 ft thick, and the Tioga rests on Columbus Limestone (= Onondaga Limestone).

Geauga County

0-8. R. and E. Timmons No. 1 well. (East Ohio Gas Co.) Quaker State Oil and Refining Corp. Section 3, Auburn Township. Permit No. 26. Well 16 of Wallace and others (1977). Gamma ray curve records Tioga Bentonite peaks at depths 2183 and 2193 ft. Tioga Bentonite occurs between Devonian Shale (Marcellus Shale) and Columbus Limestone.

Trumbull County

0-9. Runkle No. A-2 well. Northern Natural Gas. Lot 77, Gustavus Township. Well 10 of Heyman (1977). Gamma ray curve records strong Tioga Bentonite single peak at 2645 ft. Tioga Bentonite underlies 12 ft of Seneca Limestone and overlies Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-10. Frondlich No. 1-A well. Northern Natural Gas. Lot 148, Bloomfield Township. Well 9 of Heyman (1977). Gamma ray curve records single strong Tioga Bentonite peak at 2290 ft, with Tioga overlain by Plum Brook Shale and underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

Portage County

0-11. C. and S. Wheaton no. 1-2324 well. The East Ohio Gas Co. Lot 59, Windham Township. Well 8 of Heyman (1977). Gamma ray curve records single strong Tioga Bentonite peak at 2381 ft, with Tioga overlain by Plum Brook Shale and underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-12. Hauck No. 1 well. Cayman. Lot 28, Paris Township. Well 7 of Heyman (1977). Gamma ray curve records single strong Tioga Bentonite peak at 2852 ft. Tioga is overlain by 5 ft of Seneca Limestone and is underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper portion of Onondaga Limestone.

0-13. Kratz A and C Comm. No. 1 well. East Ohio Gas Co. well No. 2255. Edinburg Township. Geolog records probable metabentonite (Tioga) at 2706 ft, overlain by Devonian shale and underlain by Onondaga limestone with top at 2708 ft.

Medina County

0-14. Gilbert E. Fuller No. 2 well. Natol Corp. Brunswick Township. Permit No. 1312. Well 15 of Wallace and others (1977). Gamma ray curve records single Tioga Bentonite peak at 1838 ft at top of Columbus Limestone and base of Devonian shale.

0-15. M. E. Warner No. 1 well. The Ohio Fuel Gas Co. well No. 10,111. Lot 42, Grainger Township. Geolog records trace of Tioga Metabentonite at 1960 ft, with Tioga overlain by 25 ft of Seneca Limestone and underlain by Onondaga Limestone.

Mahoning County

0-16. Fields No. 1 well. Magnolia. Lot 19, Tract 2, Berlin Township. Geolog records Tioga Metabentonite at 2971 ft, overlain by 33 ft of Seneca Limestone and underlain by Onondaga Limestone.

0-17. Brenner No. 1 well. El Paso Products Co. Section 4, Smith Township. Permit 123. Gamma ray curve records Tioga Bentonite peaks at 2866 and 2874 ft.

0-18. Russ Miller No. 1 well. Atlas Exploration Co. Section 4, Smith Township. Well 6 of Heyman (1977). Gamma ray curve records a single Tioga Bentonite peak at 2850 ft, overlain by 6 ft of Seneca Limestone and underlain by Delaware Limestone of Heyman (1977), which is equivalent of upper Onondaga Limestone.

Columbiana County

0-19. Elden E. Denny No. 1 (2468) well. The East Ohio Gas Co. Section 12, Knox Township. Permit 592. Well 5 of Heyman (1977). There is a strong gamma ray Tioga Bentonite peak at 3250 ft, with a weak Tioga peak at 3245 ft. Tioga Bentonite is overlain by 8 ft of Seneca Limestone and is underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-20. Halverstadt No. 1 well. Manufacturers Heat and Light Co. Section 36, Salem Township. Well 43 of Heyman (1977). Gamma ray curve records single strong Tioga Bentonite peak at 3850 ft. Tioga Bentonite is overlain by Plum Brook Shale and is underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-21. Tritter No. 1 well. Tri-State. Section 8, Center Township. Gamma ray curve records Tioga Bentonite peaks at 3824 and 3830 ft.

0-22. Sell unit No. 1 well. Tri-State. Section 7, Center Township. Gamma ray curve records Tioga Bentonite peaks at 3850 and 3856 ft.

0-23. Burrows Comm. No. 1 well. East Ohio Gas Co. well No. 2419. Section 34, Hanover Township. Gamma ray curve records Tioga Bentonite peaks at 3685 and 3690 ft.

0-24. Gruber No. 1 well. Quaker State. Section 22, Hanover Township. Permit 593. Gamma ray curve records Tioga Bentonite peaks at 3775 and 3780 ft.

0-25. John and Bertha Batzli No. 1 well. Atlas Exploration Company. Section 10, Hanover Township. Well 4 of Heyman (1977). Gamma ray curve records single strong Tioga Bentonite peak at 3638 ft. Tioga Bentonite is overlain by 3 ft of Seneca Limestone and is underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone.

0-26. J. and V. Gilson unit No. 1 well. John T. Galey. Section 15, Madison Township. Well 2 of Heyman (1977). Gamma ray curve records Tioga Bentonite peaks at 4185 (stronger) and 4192 ft. Tioga Bentonite is overlain by 11 ft of Seneca Limestone and is underlain by Delaware Limestone of Heyman (1977), which is equivalent to upper Onondaga Limestone. Top 30 feet of Delaware Limestone seems to be beveled, when compared to Burrows well (data point 0-23).

0-27. W. Strudthoff No. 1 well. Natural Gas Company of West Virginia. Southeast corner of Section 31, Madison Township. Well is mentioned by Martens (1939, p. 46), Dennison (1960, data point 01), and Dennison (1961, data point 01). Martens describes 4180-4182 ft depth as shale, black, with some brown and gray, hughly calcareous. Interpret as 2 ft zone with Tioga Bentonite between Devonian shales and Onondaga Limestone or Huntersville Chert.

0-28. D. Desellum No. 1 well. Natural Gas Company of West Virginia. Section 26, Wayne Township. Geolog records Tioga Bentonite at 4183 ft. Tioga Bentonite is overlain by 8 ft of Seneca Limestone and is underlain by Onondaga Limestone.

Holmes County

0-29. F. H. Oates No. 1 well. Ohio Oil Company. Northwest quarter of Section 25 of Millerburg Quadrangle. Well is mentioned by Martens (1945, p. 793), Dennison (1960, data point 033), Dennison (1961, data point 033). Textoris examined samples of Tioga Bentonite from interval 2111-2119 ft. Tioga Bentonite occurs between Devonian shales and Columbus Limestone (equivalent to Onondaga Limestone). Interpret as outlier of Tioga Bentonite preservation in this well.

Knox County

0-30. Cunningham or Palis Verdes No. 1 well. David Kantway. Section 9, Pike Township. Geolog records Tioga Metabentonite at 1657 ft. Tioga apparently occurs at basal contact of Devonian shales and overlies Columbus Limestone (equivalent to Onondaga Limestone). Interpret as outlier of Tioga Bentonite preservation in this well.

Harrison County

0-31. George D. Miller No. 1 well. Columbian Carbon Company. Section 23, German Township. Well mentioned by Martens (1945, p. 791), Flowers (1952), Dennison (1960, data point 09), and Dennison (1961, data point 09). Tioga Bentonite occurs in sample descriptions at contact between Devonian shale and Onondaga Limestone.

0-32. J. L. Cramblett No. 1 well. East Ohio Oil and Gas Company. Section 22, Stock Township. Geolog records Tioga Bentonite at 3938 ft, at contact between Devonian shale and Onondaga Limestone.

0-33. D. K. West No. 1 well. Brendol Producing Company. Section 20, Stock Township. Geolog records Tioga Bentonite at 3942 ft. Tioga Bentonite occurs beneath 17 ft of Seneca Limestone, and Tioga rests on Onondaga Limestone.

0-34. H. W. Blackwell No. 1 well. Ohio Oil Company. Section 2, Washington Township. Geolog records Tioga Bentonite at 4237 ft. Tioga Bentonite occurs beneath 4 ft of Seneca Limestone, and Tioga rests on Onondaga Limestone.

O-35. W. Phillips No. 1 well. East Ohio Gas Company. Washington Township. Geolog records Tioga Bentonite at 3980 ft. Tioga Bentonite occurs beneath 22 ft of Seneca Limestone, and Tioga rests on Onondaga Limestone.

Tuscarawas County

O-36. J. P. Porcher No. 1 well. Benedum-Trees. Section 11, Warwick Township. Geolog records Tioga Bentonite at 3212 ft. Tioga Bentonite occurs at base of Devonian shale and rests on Onondaga Limestone.

Gurnsey County

O-37. Charles Fieldson No. 1 well. Black River Petroleum. Section 19, Wheeling Township. Geolog records Tioga Bentonite at 3479 ft. A small amount of Seneca Limestone occurs between base of Devonian shale and Tioga Bentonite. Tioga Bentonite rests on Onondaga Limestone.

O-38. Marshall No. 1 well. Lake Shore Pipeline. Section 15, Adams Township. Geolog records Tioga Bentonite at 3198 ft. Tioga Bentonite is overlain by 31 ft of Seneca Limestone on Geolog, and Tioga is underlain by Onondaga Limestone. Well is also mentioned by Martens (1945, p. 785), Dennison (data point 072), and Dennison (1961, data point 072).

Belmont County

O-39. E. A. Mobley No. 1 well. Natural Gas Company of West Virginia. Section 19, Smith Township. Tioga Bentonite in well is mentioned by Martens (1945, p. 776), Flowers (1952), Dennison (1960, data point 089), and Dennison (1961, data point 089). Tioga Bentonite occurs in sample at 5451-5454 ft. Devonian shale rests directly on Tioga Bentonite, and Tioga overlies Onondaga Limestone.

Monroe County

O-40. Louise Kerr No. 1 well. South Penn Oil Company. Section 6, Center Township. Martens (1945, p. 804) described samples, but did not note Tioga Bentonite. Well is mentioned by Dennison (1960, data point 091) and Dennison (1961, data point 091). Textoris examined Tioga Bentonite in samples from interval 5300-5322 ft. Devonian shale rests on Tioga Bentonite, which rests on Onondaga Limestone.

Noble County

O-41. Robert Ullman No. 1 well. Amerada Petroleum Corp. Section 31, Elk Township. Geolog records Tioga Bentonite at 4802 ft. Devonian shale rests on Tioga Bentonite, and Tioga overlies Onondaga Limestone.

Morgan County

O-42. Alice Hill No. 1 well. Texaco, Inc.- Section 33, Manchester Township. Geolog records Tioga Bentonite at 3730 ft. Devonian shale rests on Tioga Bentonite, and Tioga overlies Onondaga Limestone.

Washington County

O-43. Harvey Scott No. 1 well. Section 20, Liberty Township. Devonian shale rests on Tioga Bentonite, and Tioga rests on Onondaga Limestone. Textoris studied samples of Tioga Bentonite from this well. Tioga Bentonite described by Shearrow (1957, p. 40) but not named at depth 4912-4925 as fairly porous brown shale with traces of pyrite.

O-44. Rosanna Hill No. 1 well. Sinclair-Prarie Oil Company. Section 25, Lawrence Township. Tioga Bentonite in this well mentioned by Martens (1945, p. 826), Flowers (1952), Dennison (1960, data point 0105), and Dennison (1961, data point 0105). Geolog records Tioga Bentonite at 4936 ft. Devonian Shale rests on Tioga Bentonite, and Tioga overlies Onondaga Limestone.

O-45. D. and F. Hall No. 1 well. East Ohio Gas Co. Section 17, Marietta Township. Geolog records Tioga Bentonite at 4708 ft. Tioga Bentonite is overlain by 10 ft of Seneca Limestone, and Tioga overlies Onondaga Limestone.

O-46. Virginia Troot Gustke et al. well. Columbian Carbon GW523. Section 14, Warren Township. Geolog records Tioga Bentonite at 4320 ft. Tioga Bentonite underlies 18 ft of Seneca Limestone, and Tioga overlies Onondaga Limestone.

Meigs County

O-47. W. T. Longworth No. 1 well. Sinclair-Prarie Oil Company. Section 22, Olive Township. Geolog records Tioga Metabentonite at 3981 ft. Tioga Bentonite underlies 18 ft of Seneca Limestone, and Tioga overlies Onondaga Limestone.

Franklin County

O-48. Marble Cliff Quarries Company quarry outcrop. Located in Frnaklin Township along Trabue Road just west of U. S. Route 33. Lat. 39°59'18"; Long. 83°4'33". In this quarry 13 ft of Delaware Limestone overlies the Columbus Limestone. The Tioga Bentonite occurs at the Columbus-Delaware contact. Textoris verified presence of Tioga Bentonite at this horizon from samples furnished by Arie Janssens. Description of this exposure is given by Janssens (1969, p. 1-5 through 1-7 and p. 1-19 through 1-20). Conkin and Conkin (1975) identify probable Tioga Bentonite in their "bone bed 8" located 1.0-1.7 ft above their choice for the Columbus-Delaware contact in the Marble Cliffs quarry.

Erie County

O-49. Venice, Ohio quarry exposure, 2.0 miles south of Venice, Ohio, 3 miles southwest of Sandusky. This is the abandoned quarry which shows as a lake with elevation 613 ft on the Castalia 7.5 minute quadrangle. Lat. 41°24'54"; Long. 82°46'8". Tioga Bentonite was identified here by W. A. Oliver, Jr. (Oliver and others, 1967, p. 1019). Janssens (1969, p. 1-19) records the Tioga Bentonite as 1.5 inches thick at this locality.

ONTARIO

Data from four localities were supplied by Bruce V. Sanford of the Geological Survey (letter of July 22, 1966 to John M. Dennison). E. J. Baltrusaitis, an oil and gas consultant in Calgary, supplied Tioga Bentonite samples from three wells. Baltrusaitis (1974) is the geologist who named the Kawkawlin Bentonite in the Lucas Formation in the Detroit River Group in the Michigan basin (see Plate 1 of the present report), which he thinks of probably equivalent to the Tioga Bentonite of Ontario. For stratigraphic mapping purposes, New York terminology is used in this adjacent part of Canada.

Norfolk County

ONT-1. Gridland No. 1 well. Union No. 39. South Walsingham Township, Lot 20, Concession 1. Tioga Bentonite occurs in petrographic samples supplied by Baltrusaitis. from depth 340-357 ft., occurring 29-46 ft beneath top of Dundee Limestone (29-46 ft beneath base of Devonian shales). Expressed in New York terminology, the Tioga Bentonite occurs beneath 29-46 ft of Seneca Limestone Member and overlies Moorehouse Member of Onondaga Limestone.

ONT-2. Lot 13, Concession 1. South Walsingham Township. Sanford records presence of Tioga Bentonite in a limestone sequence which he correlates with the Seneca-Moorehouse strata of New York.

ONT-3. Lot 15, Concession 1. South Walsingham Township. Sanford records presence of Tioga Bentonite in a limestone sequence which he correlates with the Seneca-Moorehouse strata of New York.

ONT-4. Lot 10, Concession 9. North Walsingham Township. Sanford records presence of Tioga Bentonite in a limestone sequence which he correlates with the Seneca-Moorehouse strata of New York.

ONT-5. Wingrove No. 2 well. Union No. 36, Lot 22, Concession 9. North Walsingham Township. Tioga Bentonite is present in petrographic samples supplied by Baltrusaitis.

ONT-6. Fassell No. 2. Union No. 40. Lot 14, Concession 11. North Walsingham Township. Tioga Bentonite is present in samples supplied by Baltrusaitis.

Oxford County

ONT-7. Lot 22, Concession 11. South Norwich Township. Sanford records presence of Tioga Bentonite in a 7 ft interval within a limestone which he correlates with the Seneca-Moorehouse strata of New York.

PENNSYLVANIA

Pike County

P-1. W. Hess No. 1 well. Transcontinental Production Company. 11,250 ft N of 41°25'; 2,000 ft W of 74°55'. Geolog does not record Tioga Bentonite in sample descriptions. Marcellus Shale overlies Onondaga Limestone at 6425 ft depth; this would be expected position of Tioga Bentonite. Glaeser (1974, p. 81) records Tioga Bentonite at depths 6466-6468 and 6505-6510 ft. If these are true, then the interval between the two bentonites is about 41 ft. The top bentonite should be the Tioga middle coarse zone, which lies beneath 41 ft of shaly Seneca Limestone and overlies about 134 ft of more pure Onondaga Limestone.

Wayne County

P-2. Clarence Price No. 1 well. Transcontinental Production Company. Damascus Quadrangle C. 4,800 ft N of 41° 20'; 2,400 ft E of 75° 05'. Glaeser (1974, p. 82) records Tioga Bentonite at 7478-7482 ft depth.

Monroe County

P-3. East Stroudsburg exposure. Located along the Delaware, Lackawanna, and western railroad, 0.5 mile south of the station in East Stroudsburg. 5,000 ft S of 41° 00'; 5,800 ft W of 75° 10'. Inners (1975, p. 531) described 1 ft of tuffaceous siltstone 30.5-31.5 ft below top of Onondaga Limestone. Based on thickness and regional subsurface relations to the northeast, this tuffaceous bed is almost certainly the Tioga Bentonite middle coarse zone, although Inners did not recognize it as Tioga. If this identification of the Tioga Bentonite is correct, the Tioga occurs 30.5 ft beneath the base of the Devonian shales, and the Tioga is overlain by Seneca equivalents of the Onondaga Limestone, and underlain by the equivalents of the Onondaga Limestone. However, the official nomenclature used by the Pennsylvania Geological Survey for these limestone outcrops in Monroe, Pike, Carbon, Schuylkill, and Lebanon Counties is Buttermilk Falls Limestone (Willard, 1939, p. 144-145), most recently used in a publication of that Survey by Epstein, Sevon, and Glaeser (1974).

Carbon County

P-4. Bowmanstown exposure. Located 0.5 mile west of Bowmanstown along the Northwest Extension of Pennsylvania Turnpike about 500 ft south of overpass bridge of Route 895 in the community of West Bowmans. 40° 47' 42" N; 75° 40' 23" W. Dennison measured a detailed section of Tioga Bentonite in June, 1966 and July 1968. Measured section by Sevon in Epstein, Sevon, and Glaeser (1974, p. 403-404). Tioga Bentonite occurs directly beneath Marcellus Shale and overlies Buttermilk Falls Limestone. Tioga in this section was measured by Inners (1975, p. 541-542).

P-5. Graver Estate No. 1 well. Phillips Petroleum. Mauch Chunk Quadrangle well E-2. Gamma ray curve records high peaks in interval 3220-3260 ft. Some may be highly organic zones, but some are certainly Tioga Bentonite peaks. Other notes in file put top of Onondaga Limestone at 3268 ft. Within limits of measurement, Tioga Bentonite occurs directly beneath Marcellus Shale and

overlies Onondaga Limestone (= Buttermilk Falls Limestone of adjacent outcrops.

Luzerne County

P-6. Nellie J. Harrison No. 1 well. John T. Galey et al. Tioga Bentonite in sample descriptions by Fettke (?) on file at Pittsburgh office of Pennsylvania Geological Survey. Onondaga Limestone at 4255-4382 ft. Tioga Bentonite at 4274-4309 ft. Top of Needmore or Esopus-Schoharie 4382 ft. Top of Oriskany at 4719 ft.

Lackawanna County

P-7. Lawrence Richards No. 1 well. Transcontinetal Production Company. 2,050 ft S of 41° 25'; 8,850 ft W of 75° 47' 30". Pittston 15-minute Quadrangle F. Ransom 7.5 minute Quadrangle. Tioga Bentonite not recorded on Geolog. Sample description by Kehn, Glick, and Culbertson (1966, p. 76) records top of Onondaga Limestone at 7410 ft depth, Tioga Bentonite at 7464 ft,7512-7517, and 7521-7525 ft, top of Esopus Shale at 7725 ft, and top of Oriskany Group (Shriver Chert) at 8912 ft. Tioga Bentonite is noted in this well by Glaeser (1974, p. 74) and by Inners (1975, p. 265). The upper 40 ft of Onondaga Limestone is shaly. The bentonite at 7464 ft is interpreted as Tioga middle coarse zone occurring 54 ft below top of Onondaga, and the lower single bentonite zone with cavings occurs in interval 7512-7525 ft. The interval between the Tioga middle coarse zone and the lower single coarse zone (Onondaga Indian Nation Bentonite ?) is about 48 ft.

Wyoming County

P-8. John Sheehan No. 1 well. John H. Rebold. 1.70 mile S of 41° 35'; 0.12 mile E of 76°05'. Meshoppen Quadrangle E. Geolog records Onondaga-Marcellus contact at 7946 ft depth, and Tioga Bentonite at 7957 ft. Glaeser (1974, p. 86) records Tioga Bentonite at 7955-7970 ft.

Susquehanna County

P-9. Kelly-Hendrickson 1-A well. Kewanee Gas Well Supply Company. LeRaysville Quadrangle C-3. Bentonite recorded at 5540-5541, 5541-5557, and especially at 5555-5557 in sample descriptions. Top of Onodaga is at 5544 ft, and top of Schoharie is at 5578 ft. Tioga Bentonite occurs beneath Marcellus Shale and overlies Onondaga Limestone.

P-10. W. Wesley Pace No. 1 well. Shell Oil Company. 20,250 ft S of 41°50'; 8,000 ft W of 75°40'. Geolog records Tioga Bentonite at 6848 ft depth at contact between Marcellus Shale and Onondaga Limestone.

Bradford County

P-11. Ralph Kissell well. Shell Oil Company. 18,550 S of 41° 45'; 2,400 ft W of 76° 20'. Monroeton Quadrangle B. Geolog records Tioga Bentonite at 6848 ft depth at contact between Marcellus Shale and Onondaga Limestone.

TENNESSEE

Hawkins County

T-1. Little War Gap section. Kyles Ford 7 1/2 Minute Quadrangle. Lat. 36° 30' 16" N, Long. 83° 00' 59" W. Cuts along Tennessee Route 70 at lower switchback on south side of Clinch Mountain. This section was measured by John M. Dennison and the megainvertebrate fossils were identified by Arthur J. Boucot (Dennison and Boucot, 1974, p. 98-99). Dennison thought that units 51-67 of that published section were Tioga Bentonite, ranging through perhaps as much as 27 feet of the lowest strata of the Chattanooga Shale. Anita Harris (personal communication, 1977) has sampled conodonts from the black shale between bentonites in interval of units 59-67 of that published section; she considers the conodonts in that span as definitely Upper Devonian, and units 59, 61, 65, and 67 as the Center Hill bentonite first reported by Hass (1948) in central Tennessee Chattanooga outcrops and named by Conant and Swanson (1961). Units 51 and 52 totaling 1.4 feet thickness at the base of the Chattanooga Shale may indeed be leached Tioga Bentonite with an Onesquethaw fauna. Certainly bed 50 resembles the Bobs Ridge Sandstone Member of the Huntersville Formation, which directly underlies the Tioga Bentonite in parts of Virginia and West Virginia. If both of these paleontologic age determinations are correct, somewhere within the 10 feet span of units 53-57 of the published section there is probably a regional unconformity which omits much of the lower portion of the Upper Devonian strata which are present in the northern part of the Appalachian basin. Such an unconformity has been traced regionally across the subsurface from New York to Pennsylvania, Ohio, and Kentucky (Wallace, Roen, and deWitt, 1977).

VIRGINIA

Frederick County

V-1. Gainesboro exposure. Gore 7 1/2 Minute Quadrangle. Lat. 39° 17' 05" N; Long. 78° 15' 44" W. Along U. S. Route 522 0.7 mile northwest of Gainesboro. Brownish shale of Tioga Bentonite occurs at top of exposure of Needmore Shale and beneath Marcellus Shale.

V-2. Hayfield section. Hayfield 7 1/2 Minute Quadrangle. Lat. 39° 13' 15" N; Long. 78° 16' 30" W. Along U. S. Route 50 300 feet southeast of its intersection with Virginia Route 600 at Hayfield. Detailed section of Tioga Bentonite measured in 1966. Tioga middle coarse zone occurs at contact between Needmore and Marcellus Shales.

Shenandoah County

V-3. Seven Fountains section. Rileyville 7 1/2 Minute Quadrangle. Lat. 38° 50' 48" N; Long. 78° 23' 48" W. Along Virginia Route 758 0.98 airline miles N 82° E of the crossroads at Detrick, 1.0 airline miles S 10° E from the village of Seven Fountains, and 0.3 mile northeast from old spa of Seven Fountains in Massanutten Mountain synclinorium. Detailed section of Tioga Bentonite measured . Tioga middle coarse zone occurs at contact between Needmore and Marcellus Shale. Tioga middle coarse zone occurs approximately 530 feet above base of Needmore Shale.

V-4. Camp Roosevelt exposure. Hamburg 7 1/2 Minute Quadrangle. Lat. 38° 44' 34" N; Long. 78° 30' 38" W. Along Virginia Route 675 1.0 mile northeast of Camp Roosevelt Recreation Area and on opposite side of Route 675 from a Lutheran church camp. Tioga weathered sandy mica, brownish shale, and Tioga fossils occur at Needmore-Marcellus contact.

Rockingham County

V-5. T. S. Lantz No. 1 well. James Gas. Bergton 7 1/2 Minute Quadrangle. Lat. 38° 47' 48" N; 78° 57' 33" W. Tioga Bentonite recorded by Flowers (1952, p. 2037).

V-6. Casper Dove No. 1 well. James Gas. Bergton 7 1/2 Minute Quadrangle. Lat. 38° 46' 36" N; Long. 78° 57' 37" W. Tioga Bentonite recorded by Flowers (1952, p. 2037). Sample description by Dennison (1960, p. 119-121) records Tioga Bentonite at 2,485-2,490 ft depth, occurring at contact between Marcellus and Needmore Shales.

V-7. R. J. Whetzel No. 1 well. Shell Oil Company et al. Bergton 7 1/2 Minute Quadrangle. 25,000 ft S of 38° 50'; 11,000 ft W of 78° 55'. Geolog records Tioga Bentonite at depth 3,110 ft at approximate contact between Marcellus and Needmore Shales.

Augusta County

V-8. Stribling Springs exposure. Stokesville 7 1/2 Minute Quadrangle. Lat. 38° 18' 23" N; Long. 79° 10' 30" W. Along Virginia Route 728 at a distance of 0.1 mile east of the intersection of Routes 728 and 730 at Stribling Springs. Tioga Bentonite is poorly exposed at contact between Marcellus and Needmore Shales, and consists of brownish and brownish black shale with fossils characteristic of Tioga.

V-9. Augusta Springs exposure. Augusta Springs 7 1/2 Minute Quadrangle. Lat. 38° 06' 16" N; Long. 79° 18' 30" W. Very weathered Tioga Bentonite is exposed in cut along Chesapeake and Ohio Railroad 0.5 mile northeast of the village of Augusta Springs.

V-10. Craigsville exposure. Augusta Springs 7 1/2 Minute Quadrangle. Lat. 38° 04' 57" N; Long. 79° 21' 53" W. In shale quarry 0.7 mile northeast of abandoned cement plant and 0.1 mile south of Virginia Route 42 0.5 mile east of Craigsville. Tioga Bentonite middle coarse zone occurs on both limbs of syncline exposed on hill top on west side of shale quarry. Tioga occurs beneath Marcellus Shale and above Needmore Shale.

Highland County

V-11. Bullpasture Mountain exposure. McDowell 7 1/2 Minute Quadrangle. Lat. 38° 19' 30" N; Long. 79° 26' 38" W. Along U. S. Route 250 on southeast slope of Bullpasture Mountain and 1.7 airline miles west of the village of Headwaters. Tioga Bentonite occurs in section measured by Dennison (1960, p. 129-131). Tioga is deeply weathered and occurs at contact between Needmore and Millboro Shales.

V-12. Monterey A exposure. Monterey 7 1/2 Minute Quadrangle. Lat. 38° 25' 54" N; Long. 79° 33' 04" W. In fields 400 feet east of U. S. Route 220 2.1 miles northeast of Monterey. Tioga Bentonite occurs at contact between Needmore and Marcellus Shale. Tioga is intruded by andesite sill of Eocene age. Diagram of exposure is published in Johnson, Milton, and Dennison (1971, p. 51).

V-13. Monterey B exposure. Monterey 7 1/2 Minute Quadrangle. Lat. 38° 25' 42" N; Long. 79° 33' 20" W. Tioga Bentonite mica sandstone tuff occurs in float on hillside at cemetery 1.7 miles northeast of Monterey and 0.2 mile southeast of U. S. Route 220.

V-14. Monterey C exposure. Monterey 7 1/2 Minute Quadrangle. Lat. 38° 25' 33" N; Long. 79° 33' 24" W. Brownish shale of Tioga Bentonite is exposed in float and deeply weathered outcrops along hillside adjacent to old logging road at a point 1.5 miles northeast of Monterey and 0.5 mile southeast of U. S. Route 220. A volcanic breccia zone is intruded into Tioga strata; volcanics are apparently a part of the Eocene intrusions in the Monterey area.

V-15. Monterey D exposure. Monterey 7 1/2 Minute Quadrangle. Lat. 38° 24' 50" N; Long. 79° 34' 41" W. At concrete retaining wall along driveway leading to house from U. S. Route 220 at a point 0.2 mile northeast of

intersection of U. S. Routes 220 and 250 in the village of Monterey. Tioga Bentonite brownish shale was exposed in excavation for this retaining wall when it was constructed about 1971.

V-16. Monterey E exposure. Monterey 7 1/2 Minute Quadrangle. Lat. 38° 23' 46" N; Long. 79° 35' 20" W. Tioga Bentonite weathered brownish shale is exposed on hillside 0.2 mile east of stockyard building 1.3 miles southwest of Monterey on east side of U. S. Route 220. Tioga occurs at contact of Needmore and Millboro Shales.

V-17. Back Creek exposure. Hightown 7 1/2 Minute Quadrangle. Lat. 38° 27' 09" N; Long. 79° 38' 50" W. In bed of farm access road 400 feet north of U. S. Route 250 at a point 0.3 mile northeast of bridge of U. S. Route 250 across Back Creek. Deeply weathered brownish shale of Tioga Bentonite occurs at contact between Needmore and Millboro Shales.

V-18. Straight Fork exposure. Snowy Mountain 7 1/2 Minute Quadrangle. Lat. 38° 30' 04" N; Long. 79° 36' 20" W. Along Virginia Route 642 between crest of Lantz Mountain and Straight Fork. Deeply weathered brownish shale of Tioga Bentonite occurs at contact between Needmore and Millboro Shales.

Bath County

V-19. Williamsville section. Williamsville 7 1/2 Minute Quadrangle. Lat. 38° 10' 23" N; Long. 79° 35' 17" W. Detailed section of Tioga Bentonite measured 2.0 miles southwest of Williamsville in cuts along west side of county road. Tioga occurs at contact of Needmore and Millboro Shales. Diagram of exposure is published in Johnson, Milton, and Dennison (1971, p. 47).

V-20. J. L. Lawrence No. 1 well. Pennzoil United. Williamsville Quadrangle. 5,100 ft S of 38° 05'; 1,100 ft W of 79° 35'. Geolog records Tioga Bentonite at depth 108 ft at contact between Millboro and Needmore Shales.

V-21. McClung exposure. Bath Alum 7 1/2 Minute Quadrangle. Lat. 38° 02' 45" N; Long. 79° 41' 20" W. 0.6 mile southeast of the village of McClung in road bank at junction of Virginia Routes 39 and 625 0.25 mile west of bridge of Route 39 across Thompson Creek. Deeply weathered exposure of Tioga Bentonite exposed at contact of Millboro and Needmore Shales.

V-22. Bacova Junction exposure. Mountain Grove 7 1/2 Minute Quadrangle. Lat. 38° 00' 32" N; Long. 79° 53' 03" W. Along Virginia Route 607 0.4 airline miles west of Bacova Junction. Deeply weathered brownish shale and Tioga Bentonite fossils occur at contact between Needmore and Marcellus Shales.

V-23. Millboro Springs section. Green Valley 7 1/2 Minute Quadrangle. Lat. 38° 00' 28" N; Long. 79° 37' 03" W. Section of weathered Tioga Bentonite was measured along logging trail extending northwest from Virginia Route 633 0.7 mile northeast along Route 633 from its intersection with Virginia Route 642 at Millboro Springs. Tioga occurs at contact between Millboro and Needmore Shales.

Rockbridge County

V-24. Panther Gap exposure. Green Valley 7 1/2 Minute Quadrangle. Lat. 38° 00' 05" N; Long. 78° 31' 58" W. Along Chesapeake and Ohio Railroad tracks at southeast entrance to Panther Gap and 0.2 mile southeast of Bath-Rockbridge County boundary. Tioga Bentonite mica siltstone float is exposed in rather weathered section measured here. Tioga occurs at contact between Needmore and Millboro Shales.

V-25. Bells Valley exposure. Craigsville 7 1/2 Minute Quadrangle. Lat. 38° 01' 11" N; Long. 79° 25' 33" W. Along county road 1.5 miles east of village of Bells Valley on hill just east of Wilson Bridge. Deeply weathered Tioga Bentonite brownish shale occurs at contact between Needmore and Millboro Shales.

V-26. North Mountain section. Millboro 7 1/2 Minute Quadrangle. Lat. 37° 53' 17" N; Long. 79° 35' 34" W. In access cuts (under construction) on southwest side of Interstate 64 at interchange 1.0 mile southwest of crest of North Mountain. Detailed section of Tioga Bentonite middle coarse zone measured June 1, 1977. Tioga occurs at contact between Needmore and Marcellus Shales.

Alleghany County

V-27. Greenwood section. Falling Spring 7 1/2 Minute Quadrangle. Lat. 37° 55' 42" N; Long. 79° 58' 44" W. Located 1.9 miles southwest of Greenwood on northwest slope of Morris Hill along road which connects Greenwood and Callaghan. Detailed section of Tioga Bentonite. Tioga occurs at contact between Needmore and Millboro Shales.

V-28. Callaghan exposure. Callaghan 7 1/2 Minute Quadrangle. Lat. 37° 47' 46" N; Long. 80° 03' 03" W. Located 1.5 miles southeast of the village of Callaghan in a shale quarry along Virginia Route 600 200 feet south of bridge of Interstate 64 over Route 600. Very weathered exposure of drag-folded, brownish gray shale with fossils characteristic of Tioga Bentonite.

V-29. Covington South exposure. Covington 7 1/2 Minute Quadrangle. Lat. 37° 46' 25" N; Long. 79° 59' 38" W. On south edge of Covington at interchange of Interstate 64 and Virginia Route 154. Tioga Bentonite mica siltstone tuff was exposed on July 12, 1968 while Interstate was under construction, but Tioga is now covered with grass. Tioga occurs at contact between Needmore and Millboro Shales.

V-30. Covington East exposure. Covington 7 1/2 Minute Quadrangle. Lat. 37° 46' 38" N; Long. 79° 58' 16" W. In east edge of Covington along U. S. Route 60 0.3 mile northwest of Holiday Inn and Interstate 64 exit to Mallow Shopping Center. Deeply weathered Tioga Bentonite brownish shale is 9 ft thick and occurs at contact between Needmore and Millboro Shales. Needmore Shale is 30.4 ft thick.

V-31. Clifton Forge South exposure. Clifton Forge 7 1/2 Minute Quadrangle. Lat. 37° 48' 45" N; Long. 79° 48' 45" W. In cuts along north edge of Chesapeake and Ohio Railroad tracks 0.75 mile east of railroad station at Clifton Forge. Weathered Tioga mica sandstone tuff occurs at contact between Needmore and Millboro Shales. Needmore Shale is about 70 ft thick.

V-32. Clifton Forge North exposure. Clifton Forge 7 1/2 Minute Quadrangle. Lat. 37° 48' 57" N; Long. 79° 48' 54" W. In east edge of Clifton Forge in excavations along U. S. Route 60 near city cemetery and beside auto dealership on north side of highway. Tioga Bentonite mica sandstone tuff is exposed in excavation; samples were used for petrographic studies.

Botetourt County

V-33. Gala exposure. Eagle Rock 7 1/2 Minute Quadrangle. Lat. 37° 42' 29" N; Long. 79° 49' 22" W. Located 1.5 miles northwest of village of Gala along Virginia Route 622 at southwest end of Big Hill. Tioga Bentonite sand-size tuff occurs at contact between Needmore and Millboro Shales. Section measured December 14, 1968.

V-34. Hollins exposure. Roanoke 7 1/2 Minute Quadrangle. Lat. 37° 22' 10" N; Long. 79° 57' 33" W. Located 2.7 miles northwest of Hollins and 1.3 miles northwest of Hollins College along reservoir shoreline at west end of concrete dam of Roanoke Reservoir. Detailed section of Tioga Bentonite measured December 14, 1978. Tioga middle coarse zone overlies 194 ft of Needmore Shale.

Roanoke County

V-35. Catawba Mountain (Mason Cove) exposures. One exposure is weathered Tioga Bentonite mica sandstone tuff exposed along dirt road connecting two farm ponds, at a location 0.1 mile north of intersection of Virginia Routes 311 and 912. This exposure is in Salem 7 1/2 Minute Quadrangle at Lat. 37° 22' 14" N; Long. 80° 03' 17" W. Another exposure is along Virginia Route 311 about 0.3 mile southeast of a dirt road extending up the side of a hill on the southwest side of Route 311; this exposure of Tioga brownish shale and middle coarse zone mica sandstone tuff is approximately at Lat. 37° 22' 03" N; Long. 80° 03' 38" W. The Tioga there occurs at the contact between the Needmore and Millboro Shales, with the middle coarse zone occurring estimated 70 feet above the base of the Needmore Shale.

Montgomery County

V-36. Ironto exposure. Ironto 7 1/2 Minute Quadrangle. Lat. 37° 12' 59" N; Long. 80° 17' 15" W. Located 0.5 mile west southwest of village of Ironto. Along Virginia Route 603 0.1 mile west of Midway Baptist Church and 1.6 miles east of intersection of Virginia Routes 603 and 637. Also exposed on north bank of small stream just south of Midway Church. Weathered Tioga Bentonite mica sandstone tuff occurs at contact of Needmore and Millboro Shales.

V-37. Fagg exposure. Ironto 7 1/2 Minute Quadrangle. Lat. 37° 12' 12" N; Long. 80° 18' 21" W. Located 1.1 miles northeast of village of Fagg along Virginia Route 603 0.25 mile west of intersection of Virginia Routes 603 and 637. Tioga Bentonite mica sandstone tuff and associated brownish shales with abundant small fossils showing pronounced lineation.

V-38. Radford East section. Blacksburg 7 1/2 Minute Quadrangle. Lat. 38° 07' 48" N; Long. 80° 29' 30" W. About 4 miles east of Radford on north side of U. S. Route 11 at intersection of U. S. Route 11 and Virginia Route 604 and 800 ft east of intersection of Virginia Route 738 and U. S. Route 11. Detailed section of Tioga Bentonite measured August 28, 1966. Tioga Bentonite middle coarse zone occurs 44 feet above base of Needmore Shale and immediately beneath Millboro Shale.

V-39. Radford South exposure. Radford South 7 1/2 Minute Quadrangle. Lat. 37° 06' 58" N; Long. 80° 32' 17" W. Along connecting route between Interstate 81 and the town of Radford, 0.5 miles north of intersection of these two roads. Tioga Bentonite mica sandstone exposed on road bank at contact between Needmore and Millboro Shales. (Final location of this connecting road is about 200 feet north of where it is shown as a proposed road on the Radford South Quadrangle.)

Giles County

V-40. Kire East exposure. Interior 7 1/2 Minute Quadrangle. Lat. 37° 26' 31" N; Long. 80° 30' 07" W. In road cuts along Virginia Route 635 0.4 mile southwest of West Virginia-Virginia boundary on the same road and 1.0 airline miles east of the village of Kire. Tioga Bentonite brownish shale at least 6 feet thick directly overlies Bobs Ridge Sandstone Member of Huntersville Formation and underlies Millboro Shale. Tioga occurs here in section measured by Dennison (1960, p. 159-160).

V-41. Kire West exposure. Interior 7 1/2 Minute Quadrangle. Lat. 37° 26' 26" N; Long. 80° 30' 47" W. In road cuts along Virginia Route 635 1.0 mile southwest of West Virginia-Virginia boundary on the same road and 0.4 mile east of the village of Kire. Tioga Bentonite dusky brown to brownish gray shale directly overlies Bobs Ridge Sandstone Member of Huntersville Formation and underlies Millboro Shale. Tioga occurs here in section measured by Dennison (1960, p. 160-161).

V-42. Narrows exposure. Narrows 7 1/2 Minute Quadrangle. Lat. 37° 20' 48" N; Long. 80° 46' 59" W. Exposed in new road cuts along U. S. Route 460 1.7 road miles east of the overpass bridge of Virginia Route 61 leading to the main part of the town of Narrows. Deeply weathered Tioga Bentonite brownish shale directly above Bobs Ridge Sandstone Member of Huntersville Chert has caused landslides along dip slope on north side of Route 460. In this tightly folded syncline the Tioga Bentonite is overlain by Marcellus Shale.

Pulaski County

V-43. Poplar Hill exposure. Staffordsville 7 1/2 Minute Quadrangle. Lat. 37° 11' 27" N; Long. 80° 44' 40" W. In shale quarry on north side of Virginia Route 601 0.8 mile southwest of intersection of Routes 601 and 100; shale quarry is 1.9 miles southwest of village of Poplar Hill. Tioga brownish shale with coquina of tiny fossils is exposed at Needmore-Millboro contact. There are at least 27 feet of Needmore Shale beneath Tioga Bentonite. Generalized section was described by Dennison (1960, p. 163-167).

Wythe County

V-44. Wytheville section. Wytheville 7 1/2 Minute Quadrangle. Lat. 36° 59' 34" N; Long. 81° 04' 42" W. Three miles north of Wytheville along Virginia Route 603 in gap of Cove Creek between Cove Mountain and Queens Knob. Located in high cuts for Route 603 beside Interstate 77. Detailed section of Tioga Bentonite measured October 19, 1969. Tioga directly overlies Bobs Ridge Sandstone Member of Huntersville Formation and underlies Millboro Shale.

V-45. Walker Mountain Tunnel section. Bland 7 1/2 Minute Quadrangle. Lat. 37° 02' 00" N; Long. 81° 07' 25" W. At southeast entrance to tunnel on Interstate 77. During construction of tunnel, a detailed section of the Tioga Bentonite was measured on April 1, 1968 and July 29, 1968. This exact locality is now buried beneath concrete retaining wall. During construction of the tunnel adit, there was a slide failure of the Millboro Shale down the weathered bedding surface of the Tioga Bentonite middle coarse zone laying bare bedrock of the Needmore Shale and the underlying Huntersville Formation. This delayed tunnel construction by about three weeks. The weathered Tioga middle coarse zone was a slippery, yellowish gray clay near the surface, which passed down dip deeper in the excavation to a weathered mica sandstone tuff. About 2 feet of Needmore Shale separates Tioga middle coarse zone from the underlying Bobs Ridge Sandstone Member of the Huntersville Formation. Further information on engineering problems connected with the tunnel is contained in the thesis by Markham (1970).

V-46. Walker Mountain section. Big Bend 7 1/2 Minute Quadrangle. Lat. 37° 01' 28" W; Long. 81° 11' 38" W. Along U. S. Routes near south base of Walker Mountain. Top of section is at Dry Gulch Junction scenic railroad station. Section of somewhat weathered Tioga Bentonite measured in detail April 20, 1968 and July 29, 1968. Tioga Bentonite middle coarse zone underlies Millboro Shale and overlies 2.8 feet of Needmore Shale, which in turn overlies Bobs Ridge Sandstone Member of Huntersville Formation.

Bland County

V-47 Holly Brook exposure. Mechanicsburg 7 1/2 Minute Quadrangle. Lat. 37° 11' 14" N; Long. 80° 57' 26" W. In excavation behind a gasoline station on east side of Nobusiness Creek and north of Virginia Route 606 in village of Hollybrook. Weathered, brownish, drag-folded Tioga Bentonite shale at least 1.6 ft thick occurs above 3.0 ft of Needmore Shale, which

overlies Bobs Ridge Sandstone Member of Huntersville Formation. Generalized measured section is described by Dennison (1960, p. 175-177).

V-48. East River Mountain Tunnel exposure. Princeton 7 1/2 Minute Quadrangle. Lat. 37° 15' 58" N; Long. 81° 07' 19" W. At east portal of East River Mountain Tunnel on Interstate 77. Exposures visible on September 26, 1969 during tunnel construction reveal deeply weathered Tioga Bentonite brownish shale with light colored clay streaks corresponding to deeply weathered Tioga middle coarse zone. Entrance to this tunnel is stratigraphically lower than southeast entrance of Walker Mountain Tunnel on Interstate 77, so the Tioga Bentonite caused no engineering problems during construction of East River Mountain Tunnel.

Tazawell County

V-49. Bluefield South section. Bastain 7 1/2 Minute Quadrangle. Lat. 37° 14' 51" N; Long. 81° 14' 42" W. In south edge of Bluefield, Virginia on east side of ball park and 50 ft southwest of Virginia-West Virginia border. Tioga Bentonite middle coarse zone occurs stratigraphically beneath Millboro Shale and stratigraphically overlies 2.0 ft of Needmore Shale which was deposited above 59 ft of Huntersville Chert. Section is structurally overturned. Detailed section of Tioga Bentonite was measured April 24, 1966.

V-50. Bluefield Southwest exposure. Cove Creek 7 1/2 Minute Quadrangle. Lat. 37° 14' 30" N; Long. 81° 15' 38" W. In south edge of Bluefield, Virginia 1.0 mile southwest of ball park and 0.6 mile east northeast of Graham High School along east side of Virginia Route 102. Deeply weathered Tioga Bentonite brownish shale observed as interbeds about 6 feet above base of Millboro Shale. This is stratigraphically above position of Tioga middle coarse zone, which is concealed because of extreme weathering.

V-51. Asberrys East exposure. Tazewell South 7 1/2 Minute Quadrangle. Lat. 37° 00' 01" N; Long. 81° 31' 55" W. Located 0.8 mile northeast of Wesley Chapel in the village of Asberrys, with exposure of brownish shale of weathered Tioga Bentonite at contact between Millboro Shale and Huntersville Chert. A generalized measured section at this locality is given by Dennison (1960, p. 191-192).

V-52. Asberrys West section. Tazewell South 7 1/2 Minute Quadrangle. Lat. 37° 00' 23" N; Long. 81° 33' 38" N. Located 0.8 mile southwest of Wesley Chapel in the village of Asberrys along bank of Virginia Route 601 1.6 miles southwest of the intersection of that road with Virginia Route 16 at southeast base of Clinch Mountain. Detailed section of Tioga Bentonite measured April 24, 1966. Tioga middle coarse zone underlies Millboro Shale and overlies 5 feet of Onondaga Limestone which overlies Huntersville Chert.

Smyth County

V-53. Marion exposure. Chatam Hill 7.5 Minute Quadrangle. Lat. 36° 53' 22" N; 81° 32' 00" W. Located 5 miles north of Marion along Virginia Route 16 on southeast slope of Walker Mountain at position of BM elevation 2378. Weathered exposure of Tioga Bentonite underlies Millboro Shale and overlies 12 ft of Needmore Shale, which overlies 3 ft of Bobs Ridge Sandstone Member of Huntersville Chert.

Washington County

V-54. Hayters Gap section. Hayters Gap 7 1/2 Minute Quadrangle. Lat. 36° 51' 56" N; Long. 81° 55' 54" W. Located 2.1 airline miles north of the village of Hayters Gap 100 feet south of bridge of Virginia Route 80 across Price Creek. Detailed section of Tioga Bentonite measured March 17, 1966. Tioga underlies Millboro Shale and overlies 13 ft of Onondaga Limestone, which in turn overlies Huntersville Chert.

V-55. Holston exposure. Brumley 7 1/2 Minute Quadrangle. Lat. 36° 47' 27" N; Long. 82° 04' 50" W. Located 1.0 mile north of the village of Holston and 0.4 mile east of Little Moccasin Gap in the first valley and 0.4 mile east of the intersection of Virginia Route 619 and U. S. Route 19-Alternate Route 18 at a site 0.1 mile north of Route 619. Tioga brownish weathering shale and coquina fossil zone occurs at contact of Millboro Shale and Onondaga Limestone 65 ft thick.

Scott County

V-56. Pattonsville exposure. Duffield 7 1/2 Minute Quadrangle. Lat. 36° 40' 59" N; Long. 82° 51' 38" W. Located 1.1 airline miles southwest of village of Pattonsville along Virginia Route 753 at Powers Ford. Tioga Bentonite mica siltstone occurs about 10 feet above base of Chattanooga Shale. The Chattanooga directly overlies the Wildcat Valley Sandstone here. A pre-Chattanooga unconformity may omit the middle coarse zone of the Tioga. The mica siltstone 10 ft above the base of the Chattanooga is probably a thin Tioga siltstone tuff bed younger than the middle coarse zone horizon, or possibly even a totally different bentonite. There is a possibility that the mica siltstone tuff 10 ft above the base of the Chattanooga is actually the Center Hill bentonite named by Conant and Swanson (1961) in central Tennessee, and that the Tioga Bentonite is totally absent here. Detailed paleontologic sampling for conodonts is needed to establish the age of this bentonite occurrence. Harris and Miller (1958) report 3 inches of bentonite about 100 ft above the base of the black shale on the Red Hill anticline near Pattonsville, and report a conodont age of early and middle Late Devonian for the enclosing black shale; thus the bentonite they report seems to be the age of the Center Hill rather than Tioga.

V-57. Duffield exposure. Big Stone Gap 7 1/2 Minute Quadrangle. Lat. 36° 45' 10" N; Long. 82° 48' 08" W. Located 2.6 miles northeast of Duffield and 1.1 mile southeast of Scott-Lee County boundary. About 2.5 feet of brownish shale at base of Chattanooga Shale is probably Tioga Bentonite. Tioga overlies Wildcat Valley Formation cherty limestone (Onondaga Limestone of Dennison 1960, p. 219-220, and Dennison 1961).

Wise County

V-58. Big Stone Gap East exposure. Norton 7 1/2 Minute Quadrangle. Lat. 36° 53' 05" N; Long. 82° 42' 27" W. Along bank of Virginia Route 610 at Legion Memorial Methodist Church, located 2.3 miles east of Big Stone Gap. Brownish shale which is almost certainly Tioga Bentonite directly overlies sandy chert which has weathered from Onondaga portion of Wildcat Valley Sandstone.

V-59. Little Stone Gap exposure. Norton 7 1/2 Minute Quadrangle. Lat. 36° 53' 29" N; Long. 82° 40' 43" W. Located 1.9 miles southwest of village of Little Stone Gap along Virginia Route 610 at Buffalo Gap. Conspicuous brownish black shale at base of Chattanooga Shale is almost certainly Tioga Bentonite tuffaceous shale. Apparent Tioga directly overlies Wildcat Valley Sandstone (probably the Onondaga portion of the Wildcat Valley).

V-60. Big Stone Gap West exposure. Big Stone Gap 7 1/2 Minute Quadrangle. Lat. 36° 50' 28" N; Long. 82° 48' 55" W. Located 2.8 miles southwest of downtown Big Stone Gap along U. S. Route 58 Alternate at a site 0.5 mile northeast of Wise-Lee County boundary. Dennison (1960, p. 223-224) measured a section here which included 1.3 feet of grayish brown to dark grayish brown shale with fauna characteristic of Tioga Bentonite stratigraphically underlying about 6 ft of exposed black Chattanooga Shale and stratigraphically overlying 5.3 ft of Onondaga Limestone (portion of Wildcat Valley Formation), which in turn stratigraphically overlies Helderberg portion of Wildcat Valley Formation. Section here is on the structurally overturned northwest limb of the Powell Valley anticline. Miller (1965) interprets this structural setting quite differently. Miller maps the Chattanooga Shale and Wildcat Valley Sandstone as being in fault contact at this locality, with that fault being a sliver rising from the Pine Mountain thrust fault which he interprets as being no more than a few hundred feet beneath the ground surface here.

WEST VIRGINIA

Berkeley County

W-1. Allensville section. Hedgesville 7 1/2 Minute Quadrangle. Lat. 39° 34' 43" N, Long. 77° 58' 58" W. Along Baltimore and Ohio Railroad in cut through North Mountain 0.7 mile southeast of the village of Allensville. Exposure is overturned and about 1000 feet from North Mountain fault, so exposure is cut by several small faults. Detailed measured section of upper part of Tioga Bentonite zone. Middle coarse zone of Tioga underlies 0.45 ft bed of limestone, and then Marcellus Shale, so the Tioga is considered to underlie stratigraphically the Marcellus Shale and overlie the calcitic shale and limestone facies of the Needmore Shale. Alternately, one could consider the Tioga middle coarse zone to lie beneath 0.4 ft of Seneca Limestone.

W-2. Tomahawk section. Big Pool 7 1/2 Minute Quadrangle. Lat. 39° 30' 22" N, Long. 78° 03' 39" W. Along an abandoned road cut 1.6 miles south southwest of the village of Tomahawk, 0.15 mile west of a large meander loop of Back Creek and beside unnamed tributary of Back Creek 150 feet east of county road bridge across that tributary. Detailed measured section of Tioga Bentonite. Tioga middle coarse zone directly underlies Marcellus Shale and overlies Needmore Shale.

Morgan County

W-3. Hancock exposure. Hancock 7 1/2 Minute Quadrangle. Lat. 39° 41' 27" N, Long. 78° 11' 17" W. Along Baltimore and Ohio Railroad at north end of Warm Spring Ridge at railroad yards identified as Hancock and directly south of Potomac River from Hancock, Maryland. Located 0.1 mile west of highway bridge of U. S. Route 522 across railroad and river. Tioga Bentonite quite weathered, but brownish shale and some silty micaceous shale was observed. Needmore Shale is in fault contact with Oriskany Sandstone, with at least 60 feet of displacement on nearly vertical fault, and probably 80 to 100 feet of fault displacement.

W-4. Berkeley Springs exposure. Hancock 7 1/2 Minute Quadrangle. Lat. 39° 40' 11" N, Long. 78° 12' 01" W. Three miles northeast of town of Berkeley Springs and 1.7 miles south southwest of south end of bridge of U. S. Route 522 over Potomac River, in quarries of Pennsylvania Glass Sand Corporation along west side of Route 522. Tioga Bentonite sandy mica is present, but difficult to locate because the Tioga middle coarse zone forms a decollement with pronounced movement along the contact between the Needmore Shale and Marcellus Shale.

W-5. E. P. Nixon well M-1. Joyce Pipeline Corporation. Paw Paw 7 1/2 Minute Quadrangle. 29,500 ft S of 39° 40'; 4,900 ft W of 78° 25'. Tioga Bentonite peak on gamma ray log at depth 4,580 ft.

Hampshire County

W-6. Duckworth No. 1 well. Shell Oil Company. 21,000 ft S of 39° 30'; 17,500 ft W of 78° 35'. Permit Hampshire--12. Geolog records Tioga Bentonite at 20-30 ft depth.

W-7. W. W. McBride No. 1 well. M. E. Anderson. 1.2 miles S of 39° 20'; 2.92 miles W of 78° 35'. Permit Hampshire-3. Sample study by R. R. Flowers on file with West Virginia Geological and Economic Survey records Tioga Bentonite at 5475-5479 ft depth.

W-8. Eldon Hott No. 16 well. Hampshire Gas Company. Wardensville A Quadrangle. 1.97 miles S of 39° 15'; 2.76 miles W of 78° 40'. Permit Hampshire-23. Geolog records Tioga Bentonite at 6,999 feet depth, at Needmore-Marcellus contact.

W-9. Herbert W. and Phyllis T. White No. 20 well. Hampshire Gas Company. 39° 14' 10" N; 78° 44' 40" W. Permit Hampshire-27. Drilling report on file with West Virginia Geological and Economic Survey records Tioga Bentonite.

W-10. Mechanicsburg exposure. Romney 7 1/2 Minute Quadrangle. Lat. 39° 19' 45" N, Long. 78° 47' 36" W. Along U. S. Route 50 0.9 airline mile southeast of the village of Mechanicsburg and 2 airline miles southwest of Romney. Tioga Bentonite mica siltstones are exposed on both limbs of a small syncline 0.2 mile northeast of east entrance of Mechanicsburg Gap of Mill Creek through Mill Creek Mountain.

W-11. Romney exposure. Romney 7 1/2 Minute Quadrangle. 39° 20' 10" N, 78° 47' 11" W. Along U. S. Route 50 1.6 miles southwest of Romney and 0.1 mile west of crossing of Route 50 over Baltimore and Ohio Railroad. Tioga Bentonite occurs in deeply weathered exposure.

Mineral County

W-12. Fort Ashby exposure. Cresaptown 7 1/2 Minute Quadrangle. Lat. 39° 30' 55" N, Long. 78° 45' 15" W. Along banks of county road leading northeast from the village of Fort Ashby, at a distance of 1.1 miles northeast from the main crossroads intersection in that village. Tioga Bentonite brownish gray shale and mica siltstone are present, but exposure is too poor to permit measurement of section.

W-13. Burlington exposure. Burlington 7 1/2 Minute Quadrangle. Lat. 39° 19' 46" N, Long. 78° 53' 24" W. Along U. S. Route 50 1.9 miles east of village of Burlington, at east end of roadside park. This locality is where Dennison first identified the Tioga Bentonite in outcrop in the Valley and Ridge Province in June, 1968. A generalized section of Tioga Bentonite relations here is given by Dennison (1960, p. 237-239). The exposure is too poor to permit a detailed measured section of the Tioga. The Tioga Bentonite middle coarse zone occurs at the Marcellus-Needmore contact.

W-14. Hess No. 1 well. Federal Oil and Gas. Keyser 15 Minute Quadrangle. 17,000 ft S of 39° 25'; 14,940 ft W of 78° 50'. Permit Mineral-1. Geolog records Tioga Bentonite at 1,205 ft depth at contact between Marcellus and Needmore Shales.

W-15. Antioch exposure. Antioch 7 1/2 Minute Quadrangle. Lat. 39° 17' 31" N, Long. 79° 02' 59" W. Along county route which follows east base of Knobly Mountain, 3.3 road miles southwest of intersection at Antioch

and 1.2 airline miles northeast along strike of outcrop belt from Mineral-Grant County border. Tioga Bentonite mica sandstone is exposed, but section is inadequate to measure in detail.

W-16. Ridgeville exposure. Burlington 7 1/2 Minute Quadrangle. Lat. 39° 21' 18" N, Long. 78° 59' 50" W. Along U. S. Route 50 0.5 mile north northwest of the village of Ridgeville. Tioga Bentonite brownish shale and sandy mica present, but too poorly exposed to measure a detailed section. A generalized section of Tioga Bentonite here is given by Dennison (1960, p. 241-243). Tioga middle coarse zone occurs at contact of Marcellus and Needmore Shales.

W-17. Keyser section. Keyser 7 1/2 Minute Quadrangle. Lat. 39° 26' 53" N, Long. 78° 57' 14" W. Along county road at south end of Forge Hill 1.2 miles east northeast of Keyser. Detailed measured section of Tioga Bentonite.

W-18. F. B. Davis No. 1 well. Pittsburgh Plate Glass. Elk Garden 15 Minute Quadrangle. 23,700 ft S of 39° 30'; 6,200 ft W of 79° 00'. Permit Mineral-2. Tioga Bentonite occurs at 8,580 ft depth at contact of Marcellus and Needmore Shales.

W-19. Claysville exposure. Antioch 7 1/2 Minute Quadrangle. Lat. 39° 20' 01" N, Long. 79° 04' 32" W. Along small unnamed tributary creek off New Creek near a large barn, at a site 0.8 mile southwest of the intersection of W. Va. Route 93 and U. S. Route 50 0.8 mile southwest of the village of Claysville. About 2 feet of brownish shale of Tioga tuffaceous shale is exposed at Needmore-Marcellus contact, with some mica flakes in the shale.

Grant County

W-20. Kittlelich Ridge North outcrop. Antioch 7 1/2 Minute Quadrangle. Lat. 39° 17' 47" N, Long. 79° 06' 28" W. At north end of Kittlelick Ridge at proposed site of flood control reservoir 0.2 mile southwest of boundary between Mineral and Grant Counties. Tioga Bentonite brownish shale and mica siltstone at contact of Needmore and Marcellus Shales.

W-21. Keyser Reservoir locality. Mount Storm 7 1/2 Minute Quadrangle. Lat. 39° 16' 13" N, Long. 79° 07' 54" W. Tioga Bentonite middle coarse zone mica sandstone occurs in cores taken in preparation for construction of earth dam. The reservoir leaked along the porous Tioga horizon, requiring special grouting to stop the leak. The geology of this reservoir site is described by Dennison, Travis, and Ferguson (1966).

W-22. Hopeville Gap North exposure. Hopeville 7 1/2 Minute Quadrangle. Lat. 38° 59' 57" N, Long. 79° 16' 10" W. Along Jordan Run Road 0.7 mile north of Hopeville Gap, at sharp bend of road 0.2 mile east of bridge across Big Run. Tioga Bentonite micaceous and brownish shale are exposed at contact between Needmore and Marcellus Shales. Local residents have known about this unusual rock since about 1910: they call it a streak of "silver ore," apparently in reference to the shiny mica.

W-23. Hopeville Gap South exposure. Hopeville 7 1/2 Minute Quadrangle. Lat. 38° 57' 27" N, Long. 79° 16' 43" W. Located 0.7 mile southwest of Hopeville Gap, along Jordan Run Road at its intersection with Dolly Sods Road, in bank of east-west segment of road. Poor exposure of Tioga Bentonite at top of Needmore Shale.

W-24. Hopeville section. Hopeville 7 1/2 Minute Quadrangle. Lat. 38° 57' 25" N, Long. 79° 17' 10" W. Along West Virginia Routes 28-4 0.8 mile southwest of village of Hopeville and 0.15 mile northeast of bridge across Moyer Run. Detailed section of Tioga Bentonite measured July 18, 1964. Tioga occurs at contact between Needmore and Marcellus Shales in a section measured by Dennison (1960, p. 247-248).

W-25. Whip Gap section. Antioch 7 1/2 Minute Quadrangle. Lat. 39° 16' 11" N, Long. 79° 03' 55" W. In shale quarry beside county road at southeast entrance to Whip Gap. Detailed section of Tioga Bentonite measured July 19, 1966. Tioga occurs at contact between Needmore and Marcellus Shales in a section measured by Dennison (1960, p. 244-245).

W-26. Masonville exposure. Petersburg East 7 1/2 Minute Quadrangle. Lat. 38° 54' 44" N, Long. 79° 05' 19" W. Along county road 0.6 airline miles south southwest from village of Masonville. Tioga Bentonite occurs at contact of Needmore and Marcellus Shales in a section measured by Dennison (1960, p. 251-252).

Hardy County

W-27. Thomas Williams No. 1 well. Baker and Harshberger. Moorefield 15 Minute Quadrangle. Lat. 39° 10' 58" N, Long. 78° 56' 31" W. Permit Hardy-1. Tioga Bentonite at 478-487 ft depth in sample study by Dennison (1960, p. 254-256) at contact between Marcellus and Needmore Shales.

W-28. Old Fields exposure. Old Fields 7 1/2 Minute Quadrangle. 39° 08' 20" N, 78° 57' 35" W. Located 0.5 mile northwest of village of Old Fields along county road leading from Old Fields toward Patterson Creek Mountain. Weathered exposure of Tioga Bentonite at contact between Needmore and Marcellus Shales.

W-29. Moorefield exposure. Moorefield 7 1/2 Minute Quadrangle. Lat. 39° 01' 42" N, Long. 78° 57' 13" W. At northeast end of Elkhorn Mountain where Moorefield River (also known as South Fork of South Branch of Potomac River) flows past the end of the mountain 2.5 miles southeast of town of Moorefield. Deeply weathered Tioga Bentonite consists of grayish brown, platy shale at contact between Needmore and Marcellus Shales.

W-30. Brake exposure. Petersburg East 7 1/2 Minute Quadrangle. Lat. 38° 53' 00" N, Long. 79° 02' 33" W. Located 0.5 mile southwest of village of Brake along road beside South Fork of South Branch of Potomac River at a point 1.1 mile southwest from the road leading up Dumpling Run.

W-31. Ella and Henry Davidson well. United Fuel Gas Company No. 8,011. 1.98 miles S of 39° 10'; 1.88 miles W of 78° 45'. Tioga Bentonite

recorded at 6,755 to 6,767 ft depth in sample study by Dennison (1960, p. 261-263). Tioga occurs at contact between Marcellus and Needmore Shales.

W-32. W. S. Parks et al. No. 1 well. United Fuel Gas Company No. 9,410. 2.92 miles S of 39° 10'; 3.30 miles W of 78° 45'. Permit Hardy-20. Geolog records Tioga Bentonite at 7,230 ft depth at contact between Marcellus and Needmore Shales.

W-33. K. Funkhouser well. United Fuel Gas Company No. 9,373. 2.13 mile S of 39° 05'; 3.27 mile W of 78° 45'. Permit Hardy-17. Geolog records Tioga Bentonite at 6,478 ft depth, at contact of Marcellus and Needmore Shales.

W-34. Anna Baughman No. 1 well. United Fuel Gas Company No. 9,058. 26,000 ft S of 39° 05'; 13,600 ft W of 78° 45'. Geolog records Tioga Bentonite at 6,625 ft depth.

W-35. Wardensville section. Baker 7 1/2 Minute Quadrangle. 39° 04' 40" N, 78° 37' 38" W. Along cuts of West Virginia Route 55 on southeast slope of Sandy Ridge 1.7 miles west of Wardensville. Detailed measured section of Tioga Bentonite measured in 1964.

W-36. Trout Run North section. Baker 7 1/2 Minute Quadrangle. Lat. 38° 04' 00" N, Long. 78° 37' 45" W. In shale quarry beside Trout Run 1.7 airline miles southwest of Wardensville. Detailed section of Tioga Bentonite measured in July 1966.

W-37. Trout Run South exposure. Baker 7 1/2 Minute Quadrangle. Lat. 39° 03' 54" N, Long. 78° 37' 51" N. Along bank of Trout Run at a point 1.0 airline miles southwest of intersection of Trout Run Road and West Virginia Route 55 in west edge of Wardensville. Tioga Bentonite is very deeply weathered brownish gray shale in high stream bank beside Trout Run.

W-38. Sinks of Lost River exposure. Baker 7 1/2 Minute Quadrangle. Lat. 39° 03' 53" N, Long. 78° 39' 43" W. Located 4.0 airline miles west of Wardensville in a shale quarry beside West Virginia Route 55 0.5 mile west of Sinks of Lost River (where Lost River disappears underground). Exposure of Tioga Bentonite is too distorted tectonically and too weathered to permit measuring a detailed section.

Pendleton County

W-39. Upper Tract exposure. Upper Tract 7 1/2 Minute Quadrangle. Lat. 38° 48' 42" N, Long. 79° 16' 32" W. Along county road 0.4 mile north of bridge of U. S. Route 220 across South Branch of Potomac River one mile north of village of Upper Tract. Section of upper part of Needmore Shale and lower portion of zone with Tioga tuffaceous admixture is exposed in road bank. The zone with Tioga tuffaceous admixture is 12 feet thick, with a covered interval at top of exposure. There are Needmore Formation limestone interbeds present in the lower 7 feet of the interval with Tioga tuffaceous shale.

W-40. Franklin exposure. Sugar Grove 7 1/2 Minute Quadrangle. Lat. 38° 37' 15" N, Long. 79° 20' 40" N. In road cut and shale quarry along U. S. Route 220 2.5 miles south-southwest of Franklin. Micaceous tuff of Tioga Bentonite occurs at Needmore-Millboro contact, and brownish coloration of tuffaceous shale occurs above and below the micaceous tuff beds.

W-41. Mouth of Seneca North exposure. Upper Tract 7 1/2 Minute Quadrangle. Lat. 38° 50' 14" N, Long. 79° 22' 28" W. On north side of dirt road 0.1 mile west of West Virginia Routes 4 and 28 in north edge of village of Mouth of Seneca and 0.3 mile southwest of Seneca Rocks School. Tioga extends through 5.5 feet of poorly exposed section, with grayish brown, platy shale and some middle coarse zone micaceous sandstone tuff. Tioga occurs at contact between Needmore and Marcellus Shales.

W-42. Mouth of Seneca South outcrop. Onego 7 1/2 Minute Quadrangle. Lat. 38° 49' 47" N, Long. 79° 22' 44" W. In natural exposure on north side of highway W. Va. Route 28 - U. S. Route 33 0.4 mile south of main highway intersection in village of Mouth of Seneca. Tioga Bentonite occurs at contact between Needmore and Marcellus Shales.

W-43. Ketterman Knob exposure. Onego 7 1/2 Minute Quadrangle. Lat. 38° 46' 15" N, Long. 79° 25' 05" W. In shale quarry on northeast side of highway W. Va. Route 28 - U. S. Route 33 at a point 1.0 mile southeast of summit of Ketterman Knob. Tioga Bentonite occurs at contact between Needmore and Marcellus Shales.

W-44. Riverton outcrop. Circleville 7 1/2 Minute Quadrangle. Lat. 38° 44' 34" N, Long. 79° 26' 08" W. Along valley of Dice Run (formerly called Pound Mill Run) in southwest edge of village of Riverton. 3.2 feet of grayish brown, thinly laminated, tuffaceous shale of Tioga Bentonite occurs at contact of Needmore and Millboro Shales.

W-45. Judy Gap section. Circleville 7 1/2 Minute Quadrangle. Lat. 38° 42' 19" N, Long. 78° 28' 11" W. In natural cliffs along North Fork of South Branch of Potomac River at a point 0.25 mile southwest of junction of W. Va. Route 28 and U. S. Route 33 at the village of Judy Gap. Tioga Bentonite occurs at contact between Needmore and Marcellus Shales. Detailed section measured July 15, 1965.

W-46. U. S. Dept of Interior well. Hope Natural Gas Company well 10,093. Spruce Knob 15 Minute Quadrangle - NC. 4.32 miles S of 38° 45'; 0.48 mile W of 79° 35'. Permit Pendleton-5. Drilling report records "brown break" at Tioga Bentonite at 7,080 ft depth.

W-47. United States of America well B-1. Columbian Carbon GW-1203. Spruce Knob 15 Minute Quadrangle - C. 1.47 miles S of 38° 40'; 2.3 miles W of 79° 35'. Dennison (1960, p. 277-279) gives sample description with Tioga Bentonite at 6,085 to 6,098 ft depth.

Pocahontas County

W-48. United States of America well F-1. Columbian Carbon GW-1223. Spruce Knob 15 Minute Quadrangle - SC. 0.51 mile S of 38° 35'; 4.22 mile W

of 79° 35'. Permit Pocahontas-5. Sample study by Dennison (1960, p. 279-281) records Tioga Bentonite at 5,455 to 5,475 ft depth, occurring at contact between Needmore and Millboro Shales. Needmore Shale is 119 ft thick, and includes some silicified shale and small amounts of chert.

W-49. United States of America well L-1. Columbian Carbon GW-1329. Spruce Knob 15 Minute Quadrangle EC. 2.35 miles S of 38° 35'; 0.98 mile W of 79° 40'. Permit Pocahontas-18. Geolog records Tioga Bentonite at 5,228 and 5,318 ft depth. Middle coarse zone of Tioga middle coarse zone is probably at 5,318 ft depth, in which case the Needmore Shale is 137 ft thick. The lower Needmore contains some cherty interbeds. Tioga zone recorded at 5,228 ft depth is probably lower Millboro involved in drag folds, rather than a Tioga tuff layer 90 ft above middle coarse zone of Tioga.

W-50. United States of America well M-1. Columbian Carbon GW-1335. Spruce Knob 15 Minute Quadrangle-C. 3.64 miles S of 38° 35'; 1.81 miles W of 79° 40'. Permit Pocahontas-19. Geolog records Tioga Bentonite at 4,345 ft depth, overlying 173 ft of Needmore Shale and underlying Millboro Shale. The interval 18 to 100 ft above base of Needmore Shale contains considerable chert.

W-51. United States of America well J-1. Columbian Carbon GW-1296. Durbin 15 Minute Quadrangle-EC. 2.5 miles S of 38° 40'; 2.5 miles W of 79° 45'. Sample study by Dennison (1960, p. 281-283) records Tioga Bentonite at 5,780 to 5,806 ft depth. Tioga underlies Millboro Shale and overlies 74 ft of Huntersville Chert, which in turn overlies 74 ft of Needmore Shale, the top 20 ft of which is calcitic shale and cherty.

W-52. Greenbank Southeast exposure. Greenbank 7 1/2 Minute Quadrangle. Lat. 38° 24' 58" N, Long. 79° 49' 35" W. Abandoned chert quarry beside road 0.3 mile south southeast of Greenbank. Tioga Bentonite occurs at contact of Millboro Shale and Huntersville Chert in section described by Dennison (1960, p. 283-284).

W-53. Greenbank Southwest exposure. Greenbank 7 1/2 Minute Quadrangle. Lat. 38° 24' 14" N, Long. 79° 51' 18" W. Tioga Bentonite exposed along county road 1.2 airline miles southwest of Greenbank.

W-54. Frost section. Cass 15 Minute Quadrangle. Lat. 38° 16' 55" N, Long. 79° 53' 40" W. Along county road 0.9 mile northwest of village of Frost and 0.05 mile west of old Cove Hill School (now a house), along a county road 0.6 mile northwest of its intersection with West Virginia Route 28 0.5 mile north of Frost. Detailed section of Tioga Bentonite measured August 1966. Tioga underlies Millboro Shale and overlies 11 ft of Needmore Shale, which in turn overlies 92 feet of Huntersville Formation. Basal 45 ft of Huntersville is siliceous shale to chert. Tioga tuffaceous influence ranges through 97 feet of strata.

W-55. Thorny Creek School outcrop. Cass 15 Minute Quadrangle. Lat. 38° 16' 50" N, Long. 79° 55' 50" W. Chert quarry beside a county road 0.7 mile south of Thorny Creek School (abandoned). Tioga Bentonite grayish brown, thinly laminated shale ranges through 40 feet of strata in section measured by Dennison (1960, p. 286-288). Tioga underlies Millboro Shale and

rests on Bobs Ridge Sandstone Member of Huntersville Chert.

W-56. Bethel School outcrop. Cass 15 Minute Quadrangle. Lat 38° 15' 11" N, Long. 79°57' 30" W. Chert quarry 0.4 mile southwest of Bethel School at a point 5.5 miles northeast of Huntersville and 1.2 miles southwest of Dilleys Mill. Dennison (1960, p. 288) records Tioga Bentonite in interval 40 feet thick resting on Bobs Ridge Sandstone Member of Huntersville Chert and underlying Millboro Shale.

W-57. Huntersville outcrop. Marlinton 15 Minute Quadrangle. Lat. 38° 11' 30" N, Long. 80° 0' 40" W. Abandoned chert quarry on Barlow farm 0.5 mile northeast of Huntersville. This is type section of Huntersville Chert. Dennison (1960, p. 289-290) records about 20 feet of Tioga Bentonite resting on Bobs Ridge Sandstone Member of Huntersville Chert and underlying Millboro Shale.

Randolph County

W-58. A. W. Ewing No. 1 well. Hope Natural Gas Company well 10,296. Permit Randolph-111. 3.19 mile S of 38° 40'; 3.88 mile W of 80°5'. Geolog records Tioga Bentonite at 7,868 ft and top of Onondaga Group at 7,868 ft.

W-59. Elva Simmons No. 1 well. Cumberland and Allegheny Gas Company well 303. Permit Randolph-2. Flowers (1952, p. 2037) records Tioga Bentonite present. Dennison (1961, p. 326) cites Flowers (1952, p. 3037).

W-60. United States of America G-2 well. Columbian Carbon GW-1263. Permit Randolph-3. Sample study by Dennison (1960, p. 326-328). Tioga Bentonite at base of Devonian black shale at depth 4225-4230 ft, directly overlying calcitic shale and limestone facies of Needmore Shale. Dennison (1961, locality W 191).

W-61. United States of America No. 1 well. Columbian Carbon GW-1202. Permit Randolph-57. 1.17 mile W of 79° 40'; 2.98 mile S of 38°50'. Sample description on file with West Virginia Geological Survey records Tioga Bentonite at 4634-4653 ft.

W-62. J. R. Tingle No. 1 well. Ben Franklin Oil and Gas Corporation. Permit Randolph-82. Driller log records "brown break" (= Tioga Bentonite) at base of Devonian black shale at 5880-5884 feet, resting on 16 feet of lime (= calcitic shale and limestone member of Needmore Shale). Dennison (1960, p. 328); Dennison (1961, well W 193).

W-63. J. W. Isner well. South Penn Oil Company. Permit Randolph-3. Flowers (1951, p. 2037) records Tioga Bentonite present.

W-64. Endress Hartman No. 1 well. Potter Development Company. Permit Randolph-1. Flowers (1952, p. 2037) records Tioga Bentonite present.

Tucker County

W-65. Jason Harmon No. 1 well. Cumberland and Allegheny Gas Company well A-425. Permit Tucker 4. Flowers (1952, p. 2037) records Tioga Bentonite present.

W-66. Kuykendall and others No. 1 well. Ohio Oil Company. Permit Tucker-2. Flowers (1952, p. 2037) records Tioga Bentonite present.

W-67. West Virginia Power and Transmission Company No. 1 well. Ohio Oil Company. Permit Tucker-1. 0.25 mile S of 39° 25' N; 3.52 mile W of 79°20' W. Martens (1945, p. 566) records brown shale (= Tioga Bentonite) at base of Devonian black shale in interval 7873-7880 ft directly overlying Huntersville Chert.

W-68. West Virginia Power and Transmission Company No. 1 well. Cumberland and Allegheny Gas Company well A-418. Permit Tucker-3. Flowers (1952, p. 2037) records Tioga Bentonite present.

W-69. Tucker County Court No. 1 well. Natural Resources Corporation. Permit Tucker-8. Flowers (1952, p. 2037) records Tioga Bentonite present; cited by Dennison (1960, p. 329; 1961, locality W 196).

W-70. United States of America C-1 well. Columbian Carbon Company GW-1215. Permit Tucker-13. 5.63 miles S of 39° 15'; 2.88 miles W of 79° 35'. Geolog records Tioga Bentonite at base of Devonian black shale at 3348 ft with Onondaga Group at 3348-3540 ft. Flowers (1952, p. 2037) records Tioga Bentonite present; cited by Dennison (1960, p. 329; 1961, locality W 196).

W-71. William Blair No. 1 well. Eberly and Snee. Permit Tucker-10. Sample study by Dennison (1960, p. 329) records Tioga Bentonite at base of Devonian black shale at 4500-4508 ft, resting on calcitic shale and limestone facies of Needmore Shale. Dennison (1961, locality W 197).

Preston County

W-72. United States of America N-1 well. Columbian Carbon GW-1374. Permit Preston-99. 17,600 ft W of 79° 30'; 24,000 ft S of 39° 20'. Geolog records Tioga at base of Devonian black shale at 4264 ft resting on Onondaga Limestone.

W-73. W. G. Beatty No. 1 well. Cumberland and Allegheny Gas Company well 495. Permit Preston-49. 1.42 miles S of 39° 25'; 0.55 mile W of 79° 35'. Sample study by Cardea (1959, p. 194-195) records Tioga Bentonite at base of Devonian black shales resting on 21 ft of Onondaga Limestone interbedded with dark gray to black shale.

W-74. Margaret C. Kraus well. Hope Natural Gas Company well 9636. Permit Preston-20. 0.6 mile S of 39° 25' N; 4.4 miles W of 79° 30' W. Flowers (1952, p. 2037) records Tioga Bentonite in sample description at depth 5070-5104 ft.

W-75. J. Paul Martin No. 1 well. Hope Natural Gas Company well 9208. Permit Preston-7. 5.32 miles S of 39° 30'; 3.93 miles W of 79° 30'. Flowers (1952, p. 2037) records Tioga Bentonite at base of Devonian black shale in sample description at depth 5176-5208 ft. Cardea (1959, p. 99) quotes sample description by Flowers in which Tioga overlies 21 ft of Onondaga Limestone interbedded with shale.

W-76. V. S. Cuppitt No. 1 well. Snee and Eberly. Permit Preston-6. 0.6 mile N of 39° 25'; 3.65 mile W of 79° 30'. Geolog records Tioga Bentonite at base of Devonian black shale at 5448 ft resting on Onondaga Limestone. Cardea (1959, p. 96) quotes sample description by R. E. Bayles which records Tioga resting on 25 ft of Onondaga Limestone interbedded with shale.

W-77. James F. and Harrison Sisler well No. 3. William E. Snee. Permit Preston-4. 4.83 miles S of 39° 30'; 3.4 miles W of 79° 30'. Cardea (1959, p. 87) quotes sample description by R. E. Bayles which records Tioga at base of Devonian black shale resting on 28 ft of Onondaga Limestone interbedded with shale.

W-78. P. S. Pyles well. Hope Natural Gas Company well 9315. Permit Preston-9. 3.63 miles S of 39° 30'; 3.35 miles W of 79° 30'. Sample description by R. R. Flowers records Tioga Bentonite at base of Devonian black shale in interval 5643-5707 ft. Cardea (1959, p. 106) quotes sample description by R. E. Bayles with Tioga overlying 36 ft of Onondaga Limestone interbedded with shale.

Monongalia County

W-79. H. C. Greer and others well. Hope Natural Gas Company well 8526. Permit Monongalia-201. Martens (1945, p. 454) notes biotite in samples at 7346-7352 ft at Tioga position at base of Devonian black shales. Flowers (1952, p. 2037) records presence of Tioga Bentonite. Cited by Dennison (1960, p. 331; 1961, locality W-200).

W-80. A. F. Born A-1 well. Phillips Petroleum Company. Permit Monongalia-274. 17,950 ft S of 39° 35'; 9,550 ft W of 79° 50'. Geolog records Tioga Bentonite at base of Devonian black shales at 7466 ft, resting on Onondaga Limestone.

W-81. C. J. May A-1 well. Phillips Petroleum Company. Permit Monongalia-307. 7,150 ft S of 39° 35'; 11,000 ft W of 79° 50'. Geolog records Tioga Bentonite at base of Devonian black shale in interval 7640-7645 ft., resting on 11 ft of Onondaga Limestone which overlies Huntersville Formation.

W-82. Rosa B. Wolfe No. 1 well. Hope Natural Gas Company well 9745. 0.28 mile S of 39° 35'; 1.4 miles W of 79° 50'. Sample study by R. R. Flowers records Tioga Bentonite at 7278 ft at base of Devonian black shale; cited by Dennison (1960, p. 331; 1961, locality W 199). Tioga rests on 17 ft of strata with slightly more calcareous shale than limestone, so it probably rests on Needmore Shale rather than on Onondaga Limestone.

Marion County

W-83. R. R. Finch No. 1 well. Phillips Petroleum Company. Permit Marion-224. Geolog records Tioga Bentonite.

Wetzel County

W-84. Charles R. and Goldie Stoneking No. 1 well. Truman Smith. Permit Wetzel-410. 2.9 miles S of 39° 40'; 3.7 miles W of 80° 25'. Sample study by Dennison (1960, p. 332) records Tioga Bentonite at 7341-7346 ft at base of Devonian black shale and resting on 8 ft of calcitic shale and limestone overlying 17 ft of Huntersville Chert, 9 ft of Onondaga Limestone, and 200 ft of Huntersville Chert. Cited by Dennison (1961, locality W 201).

Marshall County

W-85. John Burley and others No. 1 well. Occidental Petroleum. Permit Marshall-539. Geolog records Tioga Bentonite.

W-86. Ohio Valley Industrial Corporation No. 1 well. Solvey Process Division, Allied Chemical and Dye. Permit Marshall-221. 0.9 mile S of 39° 25'; 2.8 miles W of 80° 45'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by R. R. Flowers recorded Tioga Bentonite at base of Devonian black shales in a 16 ft sample interval containing limestone (Onondaga Limestone) which in turn rests on chert and limestone in nearly equal proportions (Huntersville Chert). Cited by Dennison (1960, p. 334; 1961, locality W 203).

W-87. S. Minesinger well. Humble Oil. Permit Hancock-80. Geolog records Tioga Bentonite.

Doddridge County

W-88. Lewis Maxwell No. 11-F well. Columbian Carbon Company well GW-43. Permit Doddridge-71. 4.1 miles S of 39° 20'; 0.6 mile W of 80° 45'. Flowers (1952, p. 2037) records Tioga Bentonite. Dennison (1960, p. 325; 1961, locality W 184) quotes Flowers' report of Tioga at base of Devonian black shale and notes that Tioga position is underlain by 12 ft of Onondaga cherty limestone.

Lewis County

W-89. James B. Lovitt No. 2 well. Hope Natural Gas Company well 8610. Permit Lewis-57. 0.17 mile S of 39° 05'; 0.4 mile W of 80° 30'. Flowers (1952, p. 2037) records Tioga Bentonite. Dennison (1960, p. 325; 1961, locality W 185) uses unpublished sample study by R. R. Flowers which notes Tioga Bentonite at base of Devonian black shale and overlying 28 ft of Onondaga Limestone.

Harrison County

W-90. C. S. Gribble No. 8517 well. Hope Natural Gas Company. Permit Harrison-79. Martens (1945, p. 264-278); Flowers (1952, p. 2037); Dennison (1961, locality W 187). Interval at 7065-7070 ft contains brown micaceous siltstone (= Tioga Bentonite) in limestone with much gray to black shale. Tioga is interpreted to occur about 5 feet below base of Devonian black shales in Onondaga Limestone. Located 0.58 mile S of 39° 10'; 4.28 miles W of 80° 20'.

Braxton County

W-91. Ed. L. Boggs well. Hope Natural Gas Company well 8989. Permit Braxton-226. 4.52 miles S of 38° 45'; 4.36 miles W of 80° 45'. Unpublished sample study by R. R. Flowers records Tioga at 6094-6191 ft at base of Devonian black shale and overlying 17 ft of Onondaga Limestone. This sample study was used by Dennison (1960, p. 322; 1961, locality W 157).

Clay County

W-92. Jesse Chapman No. 1 well. Pittsburgh and West Virginia Gas Company. Permit Clay-122. 3.08 miles S of 38° 40'; 4.52 miles W of 80° 55'. Flowers (1952, p. 2037) records Tioga Bentonite; cited by Dennison (1960, p. 322; 1961, locality W 155).

Webster County

W-93. West Virginia and Pittsburgh Railroad Company No. 1 well. Hope Natural Gas Company well 9227. Permit Webster-2. 0.22 mile S of 38° 20'; 1.94 miles W of 80° 25'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by R. R. Flowers. Unpublished sample study by Dennison records Tioga Bentonite biotite at contact of Devonian black shales (Millboro Formation) with underlying 20 feet of Onondaga Limestone. Cited by Dennison (1960, p. 323; 1961, locality W 160).

Nicholas County

W-94. Scott Morris well. Hope Natural Gas Company well 9725. Permit Nicholas-129. 0.8 mile S of 38° 20'; 2.61 miles W of 80° 45'. Drilling report records "brown break" (= Tioga Bentonite) at 6778 ft. Dennison (1960, p. 318; 1961, locality W 110).

Fayette County

W-95. Foulke Meadow River Lands. Shell Oil Company. Permit Fayette-123. 20,200 ft S of 38° 10'; 4,150 ft W of 80° 55'. Geolog records Tioga at 6830 ft overlying Onondaga Limestone and underlying Devonian black shale.

W-96. Franklin Real Estate Company No. 1 well. Columbian Carbon well GW 796. 3.6 miles S of 38° 05'; 3.75 miles W of 80° 55'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by Dennison records 75 feet of cherty Onondaga Limestone beneath Tioga Bentonite, which occurs at contact between Millboro Shale and Onondaga Limestone.

Greenbrier County

W-97. M. J. Alderman No. 1 well. United Fuel Gas Company well 8240. Callaghan Quadrangle-NC. 2.6 miles S of 38° 00'; 2.75 miles W of 80° 05'. Permit Greenbrier-7. Tioga Bentonite at 1,005-1,010 ft depth in sample study by Dennison (1960, p. 294-295). Tioga underlies Millboro Shale and overlies 18 ft of Needmore Shale, which in turn overlies 28 ft of Huntersville Chert with some Needmore Shale intertongues 11 to 28 ft above base of Huntersville.

W-98. Camp Wood exposure. Callaghan 15 Minute Quadrangle. Lat. 37° 55' 40" N; Long. 80° 13' 35" W. Along county road 0.5 mile north of Camp Wood, on west flank of Browns Mountain anticline. Poorly exposed brownish gray shale float with some micaceous shale occurs beneath Millboro Shale and on top of Huntersville Chert Formation.

W-99. White Sulphur Springs section. White Sulphur Springs 7.5 Minute Quadrangle. Lat. 37° 49' 00"; Long. 80° 16' 32 "W. Along W. Va. Route 92 at point 1.2 miles northeast of intersection of W. Va. Route 92 and U. S. Route 60 in White Sulphur Springs. Detailed section of Tioga Bentonite measured by Dennison April 2, 1968. Tioga occurs at contact between Huntersville Chert beds (Bobs Ridge Sandstone Member) and Millboro Shale.

W-100. A. G. Davis No. 1 well. Humble Oil and Gas Company. Clintonville Quadrangle-SE. 3,600 ft N of 37° 45'; 6,400 ft W of 80° 30'. Permit Greenbier-14. Geolog records Tioga Bentonite at 6,592 ft depth.

W-101. Walter E. Hedrick No. 1 well. Columbian Carbon Company GW-1193. Clintonville Quadrangle-EC. 5.3 miles S of 37° 55'; 3.0 miles W of 80° 30'. Permit Greenbier-6. Sample study by Dennison (1960, p. 300-301) records trace of Tioga micaceous dark gray shale at 6,895 ft depth. Tioga is at Millboro Shale-Huntersville Chert boundary.

W-102. G. R. Dean No. 1 well. The Texas Company. White Sulphur Springs 15 Minute Quadrangle-NW. 3.99 miles S of 38° 00. 4.12 miles W of 80° 25'. Permit Greenbrier-2R. Tioga Bentonite recorded by Flowers (1952, p. 2037). Sample study by Dennison (1960, p. 298-300) records Tioga Bentonite at 6,427-6,430 ft depth. Tioga underlies Millboro Shale and overlies 10 ft of Needmore Shale mixed with chert and limestone, and then overlies 98 ft of bedded chert. Geolog records Tioga at 6,425 ft depth.

W-103. G. L. Walton No. 1 well. Union Oil of California. Lobelia Quadrangle-SC. 11,350 ft S of 38° 05'; 15,100 ft W of 80° 20'. Permit Greenbrier-17. Geolog records Tioga Bentonite at 6,855 ft depth, occurring beneath Millboro Shale and overlying Huntersville Formation, the top 5 feet of which is cherty limestone rather than bedded chert.

Monroe County

W-104. Brick Church section. Linside 7.5 Minute Quadrangle. Lat. 37° 25' 07" N; Long. 80° 42' 13" W. Along county road 1.1 airline miles southeast of Brick Church, along hillside overlooking a fish hatchery. Detailed Tioga Bentonite section measured August 27, 1966. Tioga underlies Millboro Shale and overlies Bobs Ridge Sandstone Member of Huntersville Formation.

W-105. Margaret J. Twohig No. 1 well. G. L. Cabot well 1239. Alderson Quadrangle-C. 2.58 miles S of 37° 40'; 2.3 miles W of 80° 45'. Permit Monroe-1. Tioga Bentonite recorded by Flowers (1952, p. 2037). Sample study by Dennison (1960, p. 309-311) records Tioga Bentonite at 6,422-6,434 ft depth. Tioga underlies Millboro Shale and overlies Huntersville Chert.

Mercer County

W-106. A. W. Hicks No. 1 well. United Fuel Gas Company well 6478. Permit Mercer-1. 0.4 mile S of 37° 20'; 3.24 miles W of 81° 10'. Flowers (1952, p. 2037) records Tioga Bentonite. Sample study by Dennison (1960, p. 312-313) records Tioga Bentonite at depth 8014-8020 ft directly under Devonian black shale and overlying 18 ft of cherty and shaly Onondaga Limestone. Dennison (1961, locality, W 85).

McDowell County

W-107. New River and Pocahontas Coal Company No. 1 well. United Fuel Gas Company well 6219. Permit McDowell-31. 5.55 miles S of 37° 20'; 1.5 miles W of 81° 35'. Flowers (1952, p. 2037) recorded Tioga Bentonite; cited by Dennison (1960, p. 315; 1961, locality W 89).

W-108. John Gilbert and others Trustees No. 2 well. G. L. Cabot well 1069. Permit McDowell-25. 0.42 mile S of 37° 30'; 2.05 miles W of 81° 35'. Sample study by Dennison (1960, p. 314-315) records Tioga Bentonite at depth 6175-6177 ft, beneath Devonian black shale and overlying 5 ft of cherty interbedded shale and limestone (assigned to Onondaga Limestone).

Wyoming County

W-109. Western Pocahontas Land Company No. 2 well. Owens, Libby-Owens well 745. Permit Wyoming-126. 0.39 mile S of 37° 40'; 0.82 miles W of 81° 25'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by Dennison records Tioga Bentonite at base of Devonian black shales and overlying calcitic and shaly Huntersville Chert. Cited by Dennison (1960, p. 313; 1961, locality W 86).

Summers County

W-110. J. Sanford Lilly No. 1 well. United Fuel Gas Company well 6788. Permit Summers-3. 0.1 mile S of 37° 55'; 0.28 mile W of 81° 00'. Sample study by Dennison is noted by Dennison (1960, p. 311; 1961, locality 80.: Tioga Bentonite mica occurs at 7874-7877 ft, just beneath Devonian black shale and overlying 13 ft of Onondaga Limestone. Unpublished sample study by Wallace McCord.

W-111. Elizabeth Ball No. 1 well. Anchor Petroleum Company. Permit Summers-5. 21,300 ft S of 37° 45'; 2,600 ft W of 81° 55'. Geolog records Tioga Bentonite just beneath Devonian black shale and overlying 22 ft of Onondaga Limestone.

W-112. Walter M. Elswick No. 1 well. G. L. Cabot well 1226. Permit Summers-1. 0.2 mile S of 37° 40'; 4.63 miles W of 80°45'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by Dennison has Tioga mica at 6640-6641 ft directly beneath Devonian black shale and overlying 6 ft (or 16 ft including missing samples) of shaly Onondaga Limestone. Cited by Dennison (1960, p. 311; 1961, locality W 79).

W-113. M. Gwinn No. 1 well. Anchor Gas Company. Permit Summers-6. 30,450 ft

S of 37° 45'; 11,650 ft W of 80° 40'. Tioga Bentonite recorded on Geolog.

Raleigh County

W-114. C. E. Gwinn No. 1 well. G. L. Cabot well 1115. Permit Raleigh-36. 3.27 miles S of 37° 30'; 4.62 miles W of 80° 50'. Flowers (1952, p. 3037) recorded Tioga Bentonite; cited by Dennison (1960, p. 311; 1961, locality W 81). Tioga seems to occur at contact between Devonian black shale and Huntersville Chert.

W-115. Russell and Doloff,Trustees No. 1 well. G. L. Cabot well 1236. Permit Raleigh-83. 5.07 miles S of 37° 5o'; 2.72 miles W of 81° 00'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by Dennison records Tioga just beneath Devonian black shale and overlying 11 ft of shaly Onondaga Limestone; cited by Dennison (1960, p. 312; 1961, locality W 82).

Logan County

W-116. Island Creek Coal Company No. 3 well. Columbian Carbon Company well 903. Permit Logan-155. Flowers (1952, p. 2037) reports Tioga Bentonite.

Wayne County

W-117. F. D. Caldwell and others No. 42 well. United Fuel Gas Company well 6181. Permit Wayne-465. 1.76 miles S of 37° 55'; 3.41 miles W of 82° 20'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by Flowers records 48 ft of Onondaga Limestone beneath Devonian black shales. Probably the Tioga reported in published information occurs at basal contact of Devonian shales. Dennison (1960, p. 315; 1961, locality W 92).

W-118. Wilson Coal and Land Company No. 27 well. Owens, Libby-Owens well 584. Permit Wayne-220. 1.78 miles S of 38° 00'; 1.21 miles W of 82° 20'. Flowers (1952, p. 2037) records Tioga Bentonite. Martens (1945, p. 596) did not describe Tioga, but it presumably occurs at the base of Devonian black shale and overlies 13-28 ft of Onondaga Limestone (thickness depending on interpretation of 15 ft interval with no samples between sampled Onondaga Limestone and Huntersville Chert). Cited by Dennison (1960, p. 315; 1961, locality W 93).

W-119. Hoard-Baldwin No. 21 well. Owens, Libby-Owens well 572. Permit Wayne-194. Flowers (1952, p. 2037) records Tioga Bentonite.

W-120. J. D. Baker No. 1 well. Owens, Libby-Owens well 593. Permit Wayne-229. 5.3 miles S of 38° 20'; 0.7 mile W of 80° 25'. Flowers (1952, p. 2037) reports Tioga Bentonite. Geolog records Tioga at 3157 ft.

Lincoln County

W-121. Koontz Realty No. 1 well. Owens, Libby-Owens well 692. Permit Lincoln-552. Flowers (1952, p. 2037) records Tioga Bentonite.

W-122. Lincoln Mineral No. 4 well. Harvard Gas. Permit Lincoln-157. 2.19 miles S of 38° 15';3.87 miles W of 81° 45'. Unpublished sample study by R. R. FLowers records very rare Tioga mica at 4340-4350 ft interval, occurring beneath Devonian black shale and overlying 12 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 316; 1961, locality W 97).

Boone County

W-123. Julian Hill No. 1 well. Hope Natural Gas Company well 7812. Permit Boone-4-4. 2.82 miles S of 38° 05'; 1.99 miles W of 81° 55'. Martens (1945, p. 94) records Tioga biotite at 4232-4241 ft occurring beneath Devonian black shale and overlying cherty Onondaga Limestone. Flowers (1952, p. 2037) reported Tioga Bentonite. These are cited by Dennison (1960, p. 316; 1961, locality W 99).

W-124. Little Coal and Land Company No. 27 well. Owens, Libby-Owens Gas Department well 666. Permit Boone-598. 0.7 mile S of 38° 05'; 4.15 miles W of 81° 50'. Unpublished sample study by R. R. Flowers records Tioga mica at 4630-4632 ft, occurring beneath Devonian black shales and overlying 21 ft of Onondaga shaly and cherty limestone. This sample study was cited by Dennison (1960, p. 316; 1961, locality W 100).

W-125. C. A. Croft and others No. 7 well. Rich Fork Gas Company. Permit Boone-29-D. 3.0 miles S of 38° 10'; 1.3 miles W of 81° 55'. Martens (1945, p. 82) records biotite-rich siltstone beneath Devonian black shales and at top of 25 ft of very cherty Onondaga Limestone. Cited by Dennison (1960, p. 316; 1961, locality W 101).

W-126. Allen and Pryor No. 1 well. Owens, Libby-Owens well 675. Permit Boone-612-R. 3.75 miles S of 38° 10'; 4.47 miles W of 81° 45'. Unpublished sample study by R. R. Flowers records Tioga Bentonite in interval 4176-4180 ft, occurring beneath Devonian black shales and overlying very cherty Onondaga Limestone. Cited by Dennison (1960, p. 316; 1961, locality W 102).

W-127. Allen and Pryor No. 4 well. Owens, Libby-Owens well 701. Permit Boone-685. 4.03 miles S of 38° 10'; 1.53 miles W of 81° 45'. Unpublished sample study by R. R. Flowers records Tioga biotite in interval 4381-4383 ft, at base of Devonian black shale and overlying 5 ft of Onondaga cherty limestone. Cited by Dennison (1960, p. 316; 1961, locality W 103).

W-128. Peytona Coal Land well No. 32. Owens, Libby-Owens well 475. Permit Boone-372. 0.14 mile W of 81° 40'; 4.91 miles S of 38° 10'. Geolog records Tioga Bentonite at 5095 ft.

W-129. R. H. Wood and others No. 4 well. Columbian Carbon well GW-285. Permit Boone 410-D. 3.6 miles S of 38° 10'; 3.0 miles W of 81° 35'. Martens (1945, p. 91) records Tioga biotite in interval 5317-5319 ft, occurring beneath Devonian black shales and overlying 6 ft of cherty Onondaga Limetone. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 316-317; 1961, locality W 104).

W-130. Bull Creek Coal and Land Company well No. 24. Owens, Libby-Owens well 720. Permit Boone-410. 4.03 miles S of 38° 10'; 4.53 miles W of 81° 35'. Flowers (1952, p. 2037) records Tioga Bentonite. Tioga mica shale is recorded in unpublished sample study by R. R. Flowers at 4583-4592 ft, occurring beneath Devonian black shale and overlying 30 ft of Onondaga Limestone. Cited by Dennison (1960, p. 317; 1961, locality W 105).

W-131. Brown and Cochran No. 5 well. Owens, Libby-Owens well 312. Permit Boone-720. 3.81 miles S of 38° 55'; 3.87 miles W of 81° 40'. Unpublished sample description by R. R. Flowers records Tioga mica in interval 4134-4138 ft, occurring beneath Devonian black shale and overlying shaly and calcitic Huntersville Chert. Cited by Dennison (1960, p. 317; 1961, locality W 106).

Kanawha County

W-132. Black Band Coal and Coke Company well. United Fuel Gas Company well 4067. No permit number (drilled before drilling permits were required). 0.91 mile S of 38° 15'; 3.94 miles W of 81°35'. Martens (1939, p.201) records biotite at 4530 ft, at base of Devonian black shale and overlying calcitic Huntersville Chert. Cited by Dennison (1960, p. 319; 1961, locality W 114).

W-133. Black Band Coal and Coke Company No. 10 well. United Fuel Gas Company well 5252. Permit Kanawha-1018. 5.2 miles S of 38° 20'; 2.85 miles W of 81° 35'. Unpublished sample study by R. R. FLowers records Tioga Bentonite at 4367 ft at base of Devonian black shale and overlying at least 18 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 319; 1961, locality W 115).

W-134. Black Band Coal and Coke Company No. 11 well. United Fuel Gas Company well 5330. Permit Kanawha-1069. 4.14 miles S of 38° 20'; 1.87 miles W of 81° 35'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 319; 1961, locality W 116).

W-135. Campbell Creek Coal Company No. 4 well. Columbian Carbon well GW-436. Permit Kanawha-662. 2.24 miles S of 38° 20'; 0.98 mile W of 81° 35'. Martens (1945, p. 341) records much biotite at 4723 ft at base of Devonian black shale and overlying 41 ft of chert and cherty limestone assigned to Huntersville Formation upper portion. Cited by Dennison (1960, p. 319; 1961, locality W 117).

W-136. R. E. Eskins No. 1 well. Owens, Libby-Owens Gas Department. Permit Kanawha-1176. 1.01 miles S of 38° 15'; 1.91 miles W of 81° 35'. Unpublished sample study by R. R. Flowers records Tioga Bentonite at 4690 ft, occurring at base of Devonian black shale and overlying 10 ft of cherty Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 316; 1961, locality W 112).

W-137. Great Kanawha Petroleum, Coal, and Lumber Company No. 20 well. Owens, Libby-Owens Gas Department well 769. Permit Kanawha-1401. 3.5 miles S of 38° 15'; 3.11 miles W of 81° 35'. Unpublished sample study by R. R. Flowers records Tioga mica at 9638 ft, occurring at base of Devonian black shale and overlying 2 ft of Onondaga Limestone. Cited

by Dennison (1960, p. 318; 1961, locality W 113).

W-138. Numa Block coal Coal Company No. 9 well. Glen Dearth. Permit Kanawha-1254. 1.62 miles S of 38° 25'; 2.30 miles W of 81° 25'. Unpublished sample study by R. R. Flowers records Tioga Bentonite at 4863-4866 ft at base of Devonian black shales and overlying 34 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 319; 1961, locality W 116).

W-139. A. D. Huntington No. 52 well. G. L. Cabot. Permit Kanawha-158. 0.92 mile S of 38° 15'; 1.78 miles W of 80° 15'. Geolog records Tioga Bentonite at 6089 ft.

W-140. United Fuel Gas Company No. 3 well. United Fuel Gas Company well 5592. Permit Kanawha-1187. 1..5 miles S of 38° 25'; 0.95 mile W of 81° 25'. Unpublished sample study records Tioga at 5260 ft at base of Devonian black shales and overlying 32 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 319; 1961, locality W 121).

W-141. Siler Coal Land No. 4 well. Owens, Libby-Owens well 485. Permit Kanawha-397. 2.3 miles W of 81° 45'; 2.8 miles S of 38° 15' N. Geolog records Tioga Bentonite at 4730 ft.

W-142. Garnet Wiseman and others No. 1 well. Owens, Libby-Owens Gas Department well 551. Permit Kanawha-575. 5.78 miles S of 38° 25'; 0.07 mile W of 81° 50'. Martens (1945, p. 373) records Tioga biotite at base of Devonian black shale and overlying 69 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 319; 1961, locality W 119).

W-143. M. C. Wingfield No. 1 well. Benedum Trees. Permit Kanawha-155. 1.12 miles S of 38° 25'; 2.52 miles W of 81° 30'. Geolog records Tioga Bentonite at 4660 ft.

W-144. W. L. Burdette No. 1 well. Columbian Carbon Company well GW 339. Permit Kanawha-190. 2.55 miles S of 38° 30'; 2.5 miles W of 81° 30'. Martens (1939, p. 197) records biotite at base of Devonian black shale and overlying 6 ft of cherty Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. These are cited by Dennison (1960, p. 319; 1961, locality W 124).

W-145. D. A. Griffith No. 1 well. W. O. Ziebold and others. Permit Kanawha-179. 3.8 miles S of 38° 15'; 3.7 miles W of 81° 30'. Martens (1939, p. 180) records much biotite at 4751-4759 ft at base of Devonian black shale and overlying 106 ft of calcareous Huntersville Chert. Flowers (1952, p. 2037) records Tioga Bentonite. These are cited by Dennison (1960, p. 319; 1961, locality W 125). Geolog records Tioga at 4738 and 4750 ft.

W-146. Sarah Ann Null No. 1 well. G. L. Cabot, Inc. Permit Kanawha-340. 1.32 miles S of 38° 30'; 0.65 mile W of 81° 40'. Martens (1939, p. 179) records biotite-rich siltstone in interval 4789-4813 ft at base of Devonian black shale and overlying 24 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 319; 1961, locality W 123).

W-147. J. M. Null and others No. 1 well. G. L. Cabot, Inc. Permit Kanawha-921.

0.28 mile S of 38° 30'; 2.30 miles W of 81° 40'. Flowers (1952, p. 2037). Cited by Dennison (1960, p. 319; 1961, locality W 122).

Putnam County

W-148. W. J. Rodgers Company. United Fuel Gas Company. Permit Putnam "C". 0.65 mile E of 81°55'; 3.8 miles N of 38° 20'. Geolog records Tioga Bentonite at 4387 ft at base of Devonian black shale and overlying 61 ft of cherty Onondaga Limestone.

W-149. East End Land Company No. 1 well. Teavee Oil and Gas. Permit Putnam-40. 2.48 miles S of 38° 30'; 2.41 miles W of 82° 00'. Martens (1939, p. 162) records biotite-rich siltstone at 4010 ft at base of Devonian black shale and overlying 32 ft of highly calcareous chert of Huntersville Formation. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 320; 1961, locality W 130). Geolog records Tioga Bentonite at 4008 ft.

W-150. Hatfield Campbell Creek Coal. G. L. Cabot well 1041. Permit Putnam-174. 4.57 miles S of 38° 35'; 3.26 miles W of 81° 45'. Geolog records bentonite at 4435 ft, with Onondaga Limestone at 4422-4500 ft. Tioga Bentonite is apparently 13 ft below top of Onondaga Limestone, which implies 13 ft of Seneca Member.

W-151. Mabel E. Smith No. 1 well. Spartan Gas Company. Permit Putnam-550. 4.52 miles S of 38° 45'; 0.43 mile W of 81° 55'. R. R. Flowers in unpublished sample study records Tioga in interval 4458-4493 ft.

Mason County

W-152. Daniel Matheny No. 1 well. G. L. Cabot, Inc. Permit Mason-29. 4.57 miles S of 38° 50'; 3.29 miles W of 81° 50'. Martens (1945, p. 435) records much biotite at approximately 4179 ft at base of Devonian black shale and top of 88 ft of Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. These are cited by Dennison (1960, p. 320; 1961, locality W 135).

W-153. Goldia Ankrum No. 1 well. Columbian Carbon well 993. Permit Mason-38. Flowers (1952, p. 2037) records Tioga Bentonite).

Jackson County

W-154. Andrew L. Click No. 1 well. The Heck Oil Company. Permit Jackson-10. 2.7 miles E of 81° 55'; 1.8 miles N of 38° 50'. Martens (1939, p. 125) records brown micaceous rock (Tioga) at contact of Huntersville Chert and overlying shale.

W-155. Luella Harrison well. Hope Natural Gas Company well 9333. Permit Jackson-657. 3.8 miles S of 38° 55'; 0.2 mile W of 81° 50'. Flowers (1952, p. 2037) records Tioga Bentonite (notes Tioga brownish shale at about 4219 ft). Cited by Dennison (1960, p. 320; 1961, locality W 136).

W-156. W. J. Brown No. 1 well. Joe Rubin. Permit Jackson-37. 1.01 mile W of 81° 45'; 3.48 miles S of 39° 00'. Martens (1939, p. 139) records

biotite in Onondaga Limestone at depth 4160-4165 ft, with 3 ft of cherty Onondaga Limestone (Seneca Member) above Tioga Bentonite. Cited by Dennison (1960, p. 321; 1961, locality W 137).

W-157. D. P. Curray well. J. Rubin, N. P. Johnson, and others. Permit Jackson-43. Martens (1939, p. 138) records siltstone with biotite at depth 4605-4608 ft, located 7 ft below top of Onondaga Limestone and resting on 99 ft of Onondaga Limestone. Cited by Dennison (1960, p. 321 ;1961,locality W 142. Located 2.22 miles S of 39° 00'; 3.6 miles W of 81° 35'.

W-158. S. R. Kessell No. 1 well. H. L. Starr. Permit Jackson-672. 1.3 miles S of 39° 00'; 0.03 mile W of 81° 40'. Unpublished sample description by R. R. Flowers records Tioga micaceous siltstone at 4628 ft at contact between Devonian black shales and 118 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 321; 1961, locality W 140).

W-159. F. F. Starcher and others No. 1 well. Columbian Carbon well 446. Permit Jackson-101. 3.8 miles S of 38° 55'; 2.6 miles W of 81° 35'. Martens (1945, p. 304) records siltstone with biotite at base of Devonian black shale and overlying 118 ft of cherty Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. These are cited by Dennison (1960, p. 321; 1961, locality W 144).

W-160. J. F. Parsons No. 1 well. Columbia Carbon well 429. Permit Jackson-47. 0.29 mile S of 38° 50'; 4.02 miles W of 81° 35'. Flowers (1952,p.2037) records Tioga Bentonite. Cited by Dennison (1960, p. 321; 1961, locality W 145). Geolog records Tioga at 4955 ft.

W-161. W. T. Chancey No. 1 well. New Penn Development Corperation. Permit Jackson-31. 1.80 mile S of 38° 40'; 4.43 miles W of 81° 45'. Martens (1939, p. 130) records Tioga Bentonite in interval 4743-4750 ft at base of Devonian shale and at top of 97 ft of mostly cherty Onondaga Limestone. Cited by Dennison (1960, p. 321; 1961, locality W 146).

W-162. Nellie Sayre King No. 1 well. South Penn Oil Company. Permit Jackson-615. 2.0 miles S of 38° 50'; 2.58 miles W of 81° 45'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 321; 1961, locality W 138).

W-163. G. W. Lathey No. 1 well. Columbian Carbon well 423. Permit Jackson-42. 0.9 mile S of 38° 45'; 1.1 miles W of 81° 45'. Martens (1945, p. 310) records thin streak of siltstone containing much biotite at 4822 ft,at base of Devonian black shales and overlying 87 ft of cherty Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 321; 1961, locality W 139).

W-164. Putnam County No. 3 well. Columbian Carbon Company well 443. Permit Jackson-58. 5.07 miles S of 38° 40'; 3.5 miles W of 81° 35'. Martens (1945, p. 319) records biotite-rich siltstone at 5071 ft at contact of Devonian black shales with underlying 100 ft of cherty Onondaga Limestone. Flowers (1952, p. 2037) records Tioga Bentonite. These are cited by Dennison (1960, p. 322; 1961, locality W 149).

Roane County

W-165. J. W. Heinzman well. United Fuel Gas Company well 4053. Permit Roane-19. 3.42 miles S of 38° 50'; 0.34 mile W of 81° 30'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 322; locality W 152).

Wirt County

W-166. G. W. Roberts No. 1 well. Belco. Permit Wirt-531. 16,650 ft S of 39° 00'; 11,600 ft W of 81° 15'. Geolog records Tioga Bentonite at 5702 ft, occurring at base of Devonian black shales and resting on 206 ft of Onondaga Limestone.

W-167. L. R. and J. A. Roberts well. Glen W. Roberts well 500. Permit Wirt-68. 0.34 mile S of 39° 00'; 3.17 miles W of 81° 15'. Martens (1939, p. 101) records much biotite at 4651 ft at base of Devonian black shales and overlying 20 ft of cherty Onondaga Limestone, which rests on 228 ft of mostly chert (Huntersville Chert). Cited by Dennison (1960, p. 323; 1961, locality W 165).

W-168. W. C. Patterson No. 1 well. Carnegie Gas Company. Permit Wirt-91. 4.11 miles S of 39° 05'; 2.91 miles W of 81° 15'. Flowers (1952, p. 2037) recorded Tioga Bentonite. Cited by Dennison (1960, p. 323; 1961, locality W 166).

W-169. Cora L. Brown and others well. United Fuel Gas Company well 6812. Permit Wirt-296. 5.61 miles S of 39° 10'; 3.6 miles W of 81° 15'. Unpublished sample study by R. R. Flowers records Tioga Bentonite in upper part of interval 4832-4845 ft, just beneath Devonian black shales and at top of 79 ft of cherty Onondaga Limestone which overlies 141 ft of Huntersville Chert. Cited by Dennison (1960, p. 323; locality W 167).

Ritchie County

W-170. Jessie Powell well. Hope Natural Gas Company well 9300. Permit Ritchie-1256. 0.78 mile S of 39° 15'; 0.45 mile W of 81° 15'. Flowers (1952, p. 2037) records Tioga Bentonite. Unpublished sample study by R. R. Flowers records Tioga mica at 5460-5463 ft at base of Devonian black shale and overlying 14 ft of cherty Onondaga Limestone. Cited by Dennison (1960, p. 325; 1961, locality W 179).

W-171. L. J.Rinehart No. 1 well. Benedum-Trees. Permit Ritchie-941. 4.51 miles S of 39° 20'; 1.20 miles W of 81° 10'. Geolog records Tioga Bentonite at 5647 ft, beneath Devonian black shales and overlying Onondaga Limestone.

Wood County

W-172. Leslie Thompson No. 1 well. Columbian Carbon well 1069. Permit Wood-252. 2.8 miles S of 39° 05'; 0.03 mile W of 81° 35'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 324; 1961, locality W 169).

W-173. J. S. Goudy No. 1 well. United Fuel well 5264. Permit Wood-137.

2.8 miles S of 39° 10'; 4.48 miles W of 81° 25'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 321; 1961, locality W 172). Geolog records Tioga Bentonite at depth 5165 ft at base of Devonian black shale and overlying 25 ft of Onondaga Limestone which rests on Huntersville Chert.

W-174. F. W. Hart No. 1 well. United Fuel Gas Company well 5263. Permit Wood-136. 0.57 mile S of 39° 10'; 0.07 mile W of 81° 30'. Location listed by Dennison (1960, p. 324; 1961, locality W 167), without record of Tioga Bentonite. However, Geolog records Tioga Bentonite at 4704 ft, occurring at base of Devonian black shales and resting on 35 ft of Onondaga Limestone.

W-175. B. H. Tennant No. 1 well. West Virginia Gas Corporation. Permit Wood-180. 4.06 miles S of 39° 15'; 2.72 miles W of 81° 40'. Geolog records Tioga Bentonite at 4123 ft.

W-176. Power Oil Company (The Sandhill Deep Well). Hope Natural Gas Company well 9634. Permit Wood-351. 5.48 miles S of 39° 20'; 1.15 miles W of 81° 15'. Woodward (1959, p. 18) records fine, dense, argillaceous limestone with metabentonite at 4012-4022 ft, concluding that there is up to 10 ft of limestone equivalent to Delaware Limestone (or Seneca Member of Onondaga Limestone) between base of Devonian black shales and the Tioga Bentonite. The Tioga rests on cherty Onondaga Limestone. Cited by Dennison (1960, p. 324; 1961, locality W 168).

W-177. H. A. Cline and others well. G. L. Cabot well 1141. Permit Wood-169. 5.8 miles S of 39° 25'; 3.36 miles W of 81° 25'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, 324; 1961, locality W 176).

W-178. W. H. Orem No. 1 well. New Penn Development Company. Permit Wood-172. Martens (1939, p. 95) records Tioga Bentonite in interval 4217-4221 ft underlying 7 ft of Onondaga Limestone (Seneca Member) and overlying 77 ft of cherty Onondaga Limestone. Located 0.02 mile S of 39° 05'; 2.75 miles W of 81° 4o'. Cited by Dennison (1960, p. 324; 1961, locality W 171).

Pleasants County

W-179. Ella Hammat and others No. 1 well. Columbian Carbon Company well GW-416. Permit Pleasants-124. 3.43 miles S of 39° 25'; 1.11 miles W of 81° 55'. Flowers (1952, p. 2037) records Tioga Bentonite. Cited by Dennison (1960, p. 324; 1961, locality W 177).

February 2, 1988

Mary

'Tioga Bentonite in the Appalachian Basin', John Dennison, University of North Carolina

I talked with John Dennison about the maps. He was most happy to hear from someone at DOE finally. The map size was required by the DOE contract, and he was unable to change the requirement when he learned about it. The size created a lot of problems for him and the University. (I'm using 'map' to refer to all the oversize plates.)

The reoport could be distributed without the maps although its usefulness will be less. Much of the text refers to the maps.

He has no extra copies and is not aware of any aperture cards.

He thinks the plates could be reshot at the following reductions without significant loss of clarity:

Plates 6 - 16: 1/3 of present size (Plate 11 could be 1/4)

Plates 1 and 5: 1/2 of present size (Plate 5 could be 1/3)

Plates 2-4 are foldouts in the text.

** I gave him the report number (DOE/ET/12139--T2) for use in referencing the report. Told him we would provide him with availability information when we have it. (Phone number: 919/966-4516 If he is out, message can be left with secretary, but make sure she has the correct information.) **

Nancy