New Jersey Geological and Water Survey
Bulletin 78

Subdivision of the Jutland Sequence into Formations and Members

by

Richard F. Dalton, Donald H. Monteverde, David C. Parris,
Stanley C. Finney and Frank J. Markewicz

New Jersey Department of Environmental Protection

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Cover photo: View across the Clinton Block Quarry in opposite direction of figure 5. *Photo from D.C. Parris*

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Frank “Mark” Markewicz is listed as an author of this bulletin. He did extensive work on the Jutland sequence rocks of New Jersey in the late 1950’s and 1960’s. State Geologist Meredith Johnson and Frank Markewicz completed the original geologic mapping of the proposed Spruce Run Reservoir in 1957 and the map is included in Division of Water Policy and Supply (1958). The Jutland sequence rocks, at the time mapped as Martinsburg Formation, underlie the western part of the reservoir. When the boring program, for the reservoir, began in late 1958 Mark was onsite much of the time logging the boreholes. Between logging of the individual coreholes he began detailed geologic mapping of the reservoir area. Eventually, in 1961, the mapping was expanded to include the entire High Bridge quadrangle.

The detailed mapping for Spruce Run area of the High Bridge quadrangle indicated several marker horizons in the varicolored shales, siltstones, sandstones and limestones of the Jutland sequence that allowed him to develop a stratigraphic section. Because these rocks were very similar to the Hamburg klippe sequence of eastern Pennsylvania, he spent many weekends examining those rocks. As mapping progressed in the Jutland rocks he found many new outcrops containing fossils, including graptolites and conodonts. Mark was the first person to recognize conodonts in these rocks only using a hand lens, and he was a coauthor of a paper on the conodonts from both the Clinton and Peapack-Gladstone areas of New Jersey (Ethington and others, 1958).

Many of the outcrops Markewicz found and described are now under the reservoir and are inaccessible today. Much of Mark’s stratigraphic sections and unit descriptions of the Jutland Member of the Martinsburg Formation from the 1967 unpublished draft Bulletin “Geology of the High Bridge Quadrangle” have been updated and form the foundation of this current report using his field notes and maps along with current remapping of the High Bridge quadrangle (Monteverde and others, 2015).

Frank Markewicz retired from the New Jersey Geological Survey as Acting State Geologist in 1983 and passed away on November 25, 1999.

Acknowledgements

The authors would like to thank Drs. G. Robert Ganis and Charles E. Mitchell for reviewing the manuscript of the Subdivision of the Jutland Sequence into Formations and Members. Both provided many excellent comments that made the report much better. A special thanks the Dr. Mitchell for updating some of the graptolite names. A special thanks goes to Dr. John E. Repetiski for all the conodont identifications he did in New Jersey in these rocks.

Subdivision of the Jutland Sequence into Formations and Members

Abstract

A sequence of varicolored shale, siltstone, sandstone, and conglomerate, commonly called the Jutland rocks, occur at various locations along the southeastern edge of the New Jersey Highlands and Piedmont Provinces. It had been mapped as the Ordovician-aged Martinsburg Formation and shown on the Geologic Map of New Jersey, (Atlas Sheet 40) by Lewis and Kümmel, 1910-1912. These rocks, in the Piedmont Province, are in some areas directly overlain by younger Triassic and Jurassic rocks of the Newark Basin. Ever since the rocks were first described there has been controversy over their age and origin due to slightly older graptolites being found in the Jutland railroad cut than the graptolite fauna in the dark gray and black shales and slates of the Martinsburg at Branchville in northwestern New Jersey. The varicolored shales in the Jutland to Clinton area are the largest exposed area of these rocks in the state, but similar rocks are found in eastern Pennsylvania near Hamburg.

The New Jersey Geological Survey began a more detailed mapping program in the 1950's as a result of a proposed reservoir system on the Raritan River in the Clinton area. After Meredith Johnson (State Geologist) and Frank Markewicz completed preliminary mapping in 1957, Markewicz began a more detailed mapping of the reservoir area during the planning and construction of the reservoir. The mapping was eventually expanded to the entire High Bridge Quadrangle (unpublished 1967). Markewicz was able to develop a stratigraphic section of the questionable-aged shale, sandstone and limestones of the Jutland area, and correlated them to the Hamburg rocks of Pennsylvania. During the mapping he found additional fossil localities in the varicolored rocks containing graptolites and conodonts. At that time the usefulness of conodonts was just beginning to be understood.

The New Jersey State Museum began studies of fossils from both the Martinsburg Formation of northwestern New Jersey and the older "Martinsburg rocks" otherwise termed the Jutland rocks of central New Jersey in the mid 1980's. Additional conodont information was gathered during the completion of the 1:100,000 scale geologic map of New Jersey by the New Jersey Geological Survey in cooperation with the U.S. Geological Survey. This and more recent fossil data indicates the varicolored rocks in the Jutland to Clinton area range in age from early Late Ordovician to possibly Late Cambrian and hence are older than the Martinsburg Formation of northwestern New Jersey, as noted by Bayley and others (1914) and Lewis and Kümmel (1915).

Using the fossil data, detailed mapping and unit descriptions combined with the State Museum's additional graptolite collections from the typical Martinsburg elsewhere, the shales in the Musconetcong Valley and the rocks of the Jutland area allow those varicolored rocks of questionable origin to be subdivided into two new formations and two members.

Introduction

This report describes the new formation and member breakdown of the Jutland sequence that was used on the Bedrock Geologic Map of the High Bridge Quadrangle, Hunterdon and Warren Counties, New Jersey by Monteverde and others, 2015. The Jutland rocks contain graptolite and conodont faunas that assisted in this subdivision. Graptolites found in the early 1900's showed that the rocks in the Jutland area were slightly older in age besides being different in color and lithology from the Ordovician dark gray to black shales and slates of Sussex and Warren counties. During the 1950's the age difference became more significant with the discovery of additional graptolite sites along with the identification of conodonts in these rocks. Although there are some brief discussions of the Hamburg sequence of Pennsylvania and mention of the Deepkill and Normanskill of New York they are only to fit the Jutland rocks into the regional framework. This report also provides all the current biostratigraphic

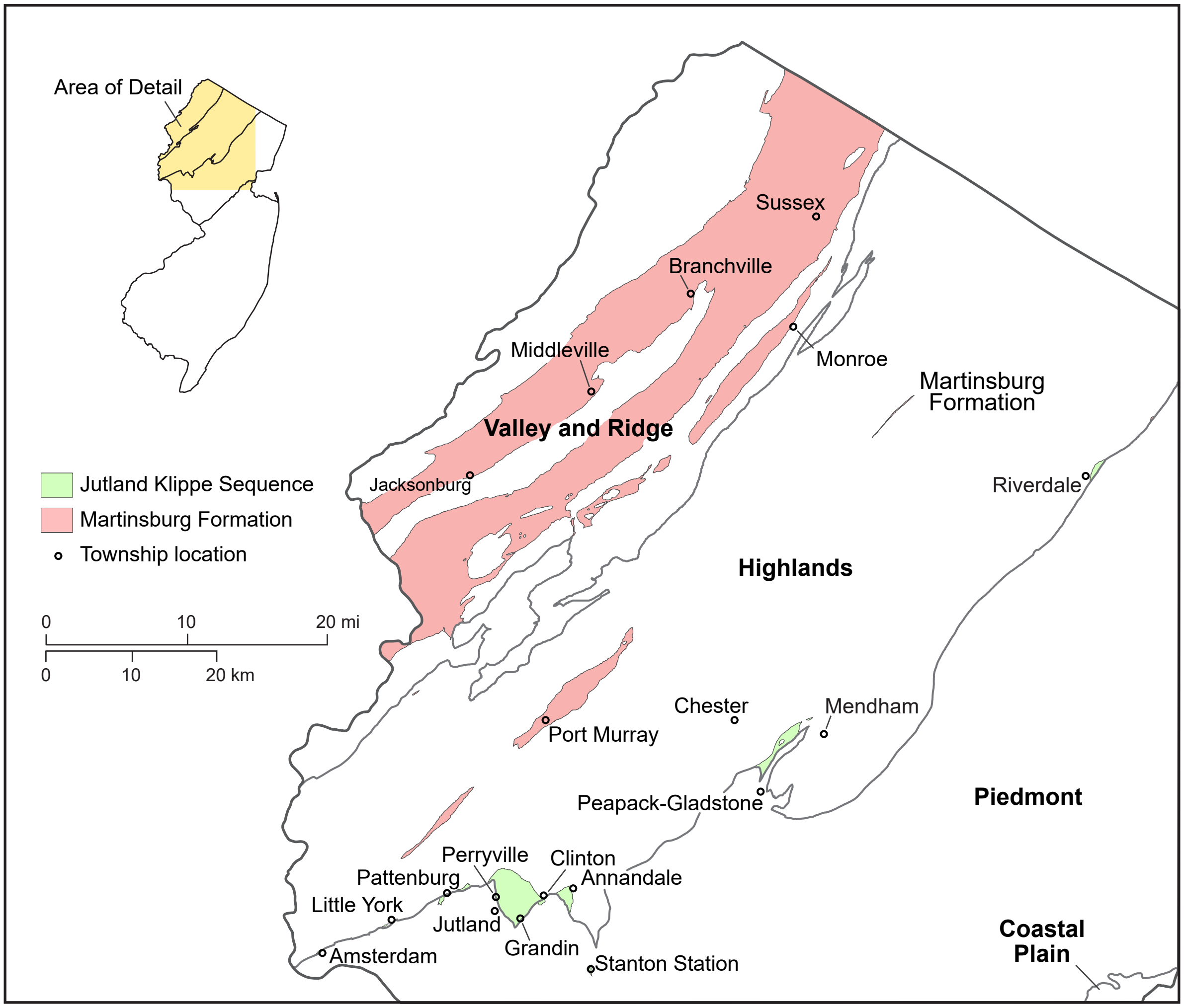


Figure 1. Map of the northern half of New Jersey showing locations of the Jutland klippe rocks, outcrop areas of the Martinsburg Formation and physiographic provinces.

information on the Jutland sequence.

A sequence of varicolored shale, siltstone, sandstone, conglomerate and limestone occurs at various locations along the southeastern boundary of the New Jersey Highlands within the Piedmont Province. These Upper Cambrian to Upper Ordovician-aged rocks, known as the Jutland sequence, crop out in small areas at Riverdale, Passaic County; Mendham, Morris County; Annandale, Pattenburg, Little York, Amsterdam, and Stanton Station, Hunterdon County; with the largest area from Clinton to Jutland in Hunterdon County (fig. 1). They are locally overlain by Mesozoic rocks of the Newark Basin. The Geologic Map of New Jersey (Lewis and Kümmel, 1910-1912) identified these rocks as Martinsburg Shale although it was recognized that the rocks were older than the Martinsburg (Lewis and Kümmel, 1915, p. 48). Based on graptolites, Kümmel (1940, p. 73) further categorized the highly folded and faulted rocks in Jutland and other areas along the southeast edge of the Highlands as Chazyan (Darriwilian to lower Sandbian) in age. Kümmel explained that although labeled as Martinsburg Shale on the Geologic Map of New Jersey, they are older than the black slates of the Martinsburg Formation in the Kittatinny Valley.

The New Jersey Geological Survey (NJGS) began mapping these rocks in 1957 as a result of a proposal to build a reservoir in the Clinton area. Investigations for the Spruce Run and

Round Valley Reservoir system started in the late 1950's pursuant New Jersey Public Law 1957, Chapter 217, authorizing an investigation of surface water resources of the Raritan River Basin (Shanklin, 1958). After preliminary mapping of the Spruce Run Reservoir area, a more detailed mapping program continued during the engineering, design and construction of the reservoir. Examination of investigatory drill core and later excavations for the reservoir construction resulted in discovery of numerous fossiliferous exposures of varicolored shale and siltstone. The mapping project was expanded in 1961 to include the entire High Bridge 7 ½ minute quadrangle. A draft report of the quadrangle was completed by Frank Markewicz in 1967.

Since the completion of Markewicz's original work on the "Martinsburg Formation" of the Jutland area, many studies have been done on similar aged rocks in eastern Pennsylvania (Hamburg klippe, aka Taconic allochthons) some of which will be discussed later. However, very little was done in New Jersey until the mid-1980's when the New Jersey State Museum began a study of fossils from both the Martinsburg Formation of northwestern New Jersey and the older "Martinsburg rocks" of central New Jersey. Additionally, new information was gathered during the completion of the 1:100,000 scale geologic map of New Jersey by the New Jersey Geological Survey in cooperation with the U.S. Geological Survey which began in 1984.

This report is based on detailed mapping of the Jutland area rocks and unit descriptions from the unpublished Geology of the High Bridge Quadrangle (Markewicz, 1967), and the reexamination of many of Markewicz's original fossil collections and more recent fossil data to confirm age assignments. Additional information gathered during the statewide 1:100,000 scale Cooperative Geologic Mapping Program (COGEOMAP), Drake and others (1996), and the STATEMAP-funded 1:24,000 scale geologic map of the High Bridge quadrangle (Monteverde and others, 2015) also contributed to this report.

Markewicz (1967) considered the varicolored rocks in the Jutland area to be a nearshore facies of the Martinsburg Formation, a view favored by a number of early workers (e.g. Willard, 1943). These varicolored rocks of questionable origin were able to be subdivided into two new formations and two members, all older than the Martinsburg Formation, by using fossils collected by Markewicz and his detailed unit descriptions, along with the New Jersey State Museum's graptolite collections from typical Martinsburg in Sussex and Warren Counties, the shales in the Musconetcong Valley and the rocks of the Jutland area (Parris and Cruikshank, 1986, 1992). Numerous conodont identifications by John Repetski, U.S. Geological Survey (Karklins and Repetski, 1989; Harris and others, 1995), during the COGEOMAP and STATEMAP mapping programs, further support the new subdivision.

Based on geologic mapping and biostratigraphic data from the 1950's to the present rocks previously mapped as Martinsburg (Lewis and Kümmel, 1910-1912) and as the Jutland klippe sequence (Drake and others, 1996) in the Clinton and Peapack-Gladstone areas, herein known as the Jutland sequence, can be subdivided into the Spruce Run Formation (Upper Cambrian to Lower Ordovician) with two members: the Mulhockaway Creek Member (Upper Cambrian to Lower Ordovician) and Van Syckel Member (Upper Cambrian) and the Hensfoot Formation (Lower to Upper Ordovician). The other areas of the Jutland sequence along the southeast edge of the Highlands, at Amsterdam, Little York, Pattenburg, and Riverdale have not yet been mapped in sufficient detail since they are small and highly deformed.

Previous Work and Correlation

Cook (1868, p. 135) assigned Ordovician shales, slates, and sandstones of northern and central New Jersey to the Hudson River Slate. The Martinsburg Shale was first named by Geiger and Keith (1891) for the thick section of shaly Ordovician rocks at Martinsburg, West Virginia. Weller (1903, p. 51-53) described two Hudson River slate faunas from Sussex and Branchville Boroughs, Sussex County, and an older graptolite fauna from the Lehigh Valley railroad (now Norfolk Southern Lehigh Line) cut at Jutland, Hunterdon County. Spencer and others (1908, p. 11) correlated the "Hudson River slate" with the type Martinsburg section at Martinsburg, West Virginia and adopted the Martinsburg name for the New Jersey rocks. Bayley and others (1914, p. 12) indicated the graptolites collected by Weller (1903) at Jutland, were a characteristic Normanskill fauna and "… considered by Ruedemann to be of Chazy age." Ruedemann (1947, p. 87) stated that the Branchville faunule, due to poor preservation and an incomplete knowledge of the Trenton shales at the time was considered to be a Normanskill faunule, but it was more likely a Canajoharie fauna (fig. 2A). He continued that Normanskill did occur in New Jersey as indicated by the Jutland faunule.

The uppermost part of the Martinsburg Formation in northwestern New Jersey is considered Eden (lower Katian) in age, based on a shelly fauna found just below the contact between the Martinsburg and the overlying Shawangunk near the Sussex and Warren County boundary (Willard, 1949). Twenhofel and others (1954) indicated the Martinsburg Shale ranges from Trenton to Eden in age; Kay (in Twenhofel and others, 1954, p. 276) further stated the rocks referred to as Martinsburg Shale, on column 20 (of chart 2), were those stratigraphically succeeding the Jacksonburg Limestone and not the older rocks of the Hamburg klippe sensu Stose (1946).

The age and origin of the "Martinsburg" rocks in the Clinton area has been in dispute for some time with the problem becoming more complex as additional work was done. Graptolites from the Lehigh Valley Railroad cut at Jutland were identified by Weller and substantiated by Ruedemann to be Normanskill (Weller, 1903, p. 52). In a letter to Dr. Kümmel, New Jersey State Geologist, dated April 6, 1931 [New Jersey Geological and Water Survey (NJGWS), Permanent Notes], Dr. Ruedemann stated, "It is therefore our opinion that this particular shale in the Jutland cuts of the Lehigh Valley railroad is not Martinsburg shale, but Normanskill shale, probably brought up by folding or faulting." Graptolites indicative of the older Deepkill shale were identified in eastern Pennsylvania (Stose, 1930, pgs. 640, 641) and the Clinton area (Dodge, 1952).

Stose (1946) described varicolored (red, green, buff and gray) shales mapped as Martinsburg in eastern Pennsylvania and in "detached" areas of New Jersey and tentatively correlated these shales with the Taconic section of eastern New York (p. 695). He suggested (p. 692) these rocks were the remnants of a thrust sheet from the southeast that rested on typical Martinsburg Shale and older limestones; and concluded that the argillaceous rocks of the Taconic sequence must have been deposited far to the southeast and contemporaneously with the lower Paleozoic argillaceous and carbonate rocks of the Great Valley (p. 692). Stose did not assign the varicolored Ordovician shales in the Musconetcong Valley, at Port Murray, to his Taconic sequence because of the underlying Jacksonburg Limestone he stated on page 689:

> In New Jersey, 2 areas of Ordovician shale within the Jersey Highlands are enclosed in a syncline along the Musconetcong River. The shale in these areas is gray, argillaceous, and is underlain by Jacksonburg limestone. It is, therefore, Martinsburg and not part of the Taconic sequence.

Most early workers used the absence or presence of the Jacksonburg Limestone or a similar age limestone to separate the Taconic sequence from the true Martinsburg Formation.

On pages 689 and 690, Stose (1946) discussed three areas of Ordovician shale south of the New Jersey Highlands: north of Peapack-Gladstone, south of Annandale, and northeast of Jutland (fig. 1). He concluded that the rocks were likely part of his Taconic sequence based on the more representative Normanskill fauna at Jutland rather than the sparse fauna found at Branchville, New Jersey and the fact that he did not observe the Jacksonburg Limestone at the lower contact in the Jutland area when he was in the field with Henry B. Kümmel.

Although Stose (1946) did not observe the Jacksonburg Limestone in the Clinton-Jutland area, it was shown on both the Raritan Folio (Bayley and others, 1914) and Geologic Map of New Jersey (Lewis and Kümmel, 1910-1912). Based on mapping begun during the drilling program for the Spruce Run Reservoir (Markewicz, 1967) showed the Epler (Beekmantown), Jacksonburg, and "Martinsburg" (Jutland sequence) which appeared to be in normal stratigraphic relationship, although the contacts were sheared and faulted. Cross sections and boring records for the Spruce Run Reservoir [on file at New Jersey Geological and Water Survey (NJGWS)] indicate the contact in this area between the Jutland sequence and the underlying Jacksonburg and Beekmantown carbonates is a moderate southwesterly dipping thrust fault.

Kümmel (1940, p. 72), wrote, "Certain shale beds near Clinton in Hunterdon County may represent a part of the time interval between the Beekmantown and the Jacksonburg limestones …." Then he further stated, on page 73:

> The second great submergence of Ordovician time began for New Jersey with the creation of a narrow strait across the state and southeast of the present Highlands belt … in this body of water were deposited beds of silty to sandy clay, which now form a bed of greatly folded yellow and black shale which is best exposed west of Clinton. A few species of fossils (graptolites) have been found near Jutland in exposures along the Lehigh Valley Railroad which connect the beds with the Normanskill shale of New York and fix their age as Chazyan. On the geologic map of New Jersey they are all labeled Martinsburg shale, but later evidence indicates that they are older than the black slates of Kittatinny Valley.

Willard (1943, p. 1082) cited a letter from Meredith E. Johnson to B. Willard, February 1, 1941 where Johnson indicated the "Clinton area Martinsburg" was underlain by Jacksonburg Limestone, therefore, these shales are comparable to those of the Great Valley, and on page 1101 in his discussion of Martinsburg in Pennsylvania he stated:

> Much of the lower Martinsburg from the Susquehanna Valley into New Jersey appears from its graptolites to be of Normanskill age except for the Deepkill forms, yet the underlying limestones, where in unbroken sequence are generally younger. When we include the Deepkill fauna, the situation grows more paradoxical. What explanation seems reasonable? It might be supposed that the Deepkill shale was faulted up among the younger beds, but no structural evidence was seen. Even if movement had taken place from whence could such beds be faulted? No Deepkill shale, nor for that matter an appreciable amount of any shale older than the Trenton crops out in the Ordovician of the Susquehanna Valley. Peculiar circumstances about which we are ignorant seem to have permitted a few Deepkill graptolites to survive into post-Trenton time.

Stose (1946, pgs. 668 to 670) discussed the interpretation of Willard and suggested the shales with the Deepkill fauna on the Susquehanna

River could not have been deposited there in place but were deposited far to the southeast and thrust into their current position.

Deepkill graptolites were first documented in New Jersey by Dodge (1952, p. 3) where he states, “discovery of Deepkill faunas in the presupposed Martinsburg formation has led this author to redefine part of the shales west of Clinton as equivalent to the Deepkill shales of New York stratigraphic section.” Dodge, page 11, stated:

> In the area of Clinton there is no evidence that the Deepkill-Normanskill sequence rests on rocks of younger age than Kittatinny. The field evidence seems to indicate normal clastic deposition and no Jacksonburg limestone was discovered beneath the shales at Clinton containing Normanskill graptolites. The point being, that if the Jacksonburg is present in the area it seems probable that it is above the shales containing the Normanskill graptolites, not below it.

Dodge collected graptolites from four localities which he used to subdivide, on his map, the “Martinsburg shale” west of Clinton into three basic types:

1. A reddish gray shale unit with inter-bedded limestone.
2. Olive drab and gray shale with inter-bedded sandstone. Some beds contain Normanskill graptolites.
3. Multicolored shales, red predominant. Two Deepkill graptolite zones.

During the mapping for the Spruce Run Reservoir and the High Bridge quadrangle, Markewicz collected numerous graptolites from several other localities. Professor Helgi Johnson (Rutgers University) examined a suite of these graptolites from the Jutland and indicated a lower middle Chazy (currently Darriwilian to lower Sandbian) age with some forms ranging higher into the Normanskill (oral communication to Markewicz, 1966).

Perissoratis (1974), and Perissoratis and others (1979) collected graptolites from additional localities in the Clinton area. They use the name Jutland sequence and divided the rocks into two units, Unit A and Unit B, although unit names were flipped from one report to the other with Perissoratis and others (1979) having Unit A as the older unit. These authors placed the base of the upper unit (B) at the boundary between Berry’s (1960, 1968) graptolite Zones 8 (*Isograptus*) and 9 (*Paraglossograptus etheridgei*) in both reports (fig. 2 A). The authors did not recollect the four Deepkill localities of Dodge, (1952), Weller’s original locale, or the Twichell locale discussed in Ruedemann’s April 6, 1931 letter to Kümmel. Perissoratis (1974), and Perissoratis and others (1979) cited these faunules and used the information to define their units. Perissoratis and others (1979, p. 172 and on their cross sections, p. 173) indicated that the Jutland rocks were overturned whereas other authors have indicated that the Jutland shales were generally right side up (Dodge, 1952; Markewicz, 1967; Drake and others, 1996; Parris and others, 1998; Monteverde and others, 2015).

Parris and Cruishank (1986) collected a graptolite fauna from Unit B of Perissoratis and others (1979) that correlated to the *Nemagraptus gracilis* Zone [Zone 11 of Berry (1960)]. Parris and others (1998) described a faunal succession from Zone 8 through Zone 11 collected in a nearly continuous exposure at the Clinton Block quarry. They believed they had found, recollected and confirmed the Deepkill determination of the Hedgehaven Farm site of Dodge (1952). Subramanian and Parris (2016) have reinterpreted the Hedgehaven Farm graptolites (collected in 1994) of Parris and others (1998) and suggested these graptolites originated from a locality different than that described by Dodge (1952) and represented a younger faunal zone equivalent to the upper Deepkill of Berry (1962). The fauna was

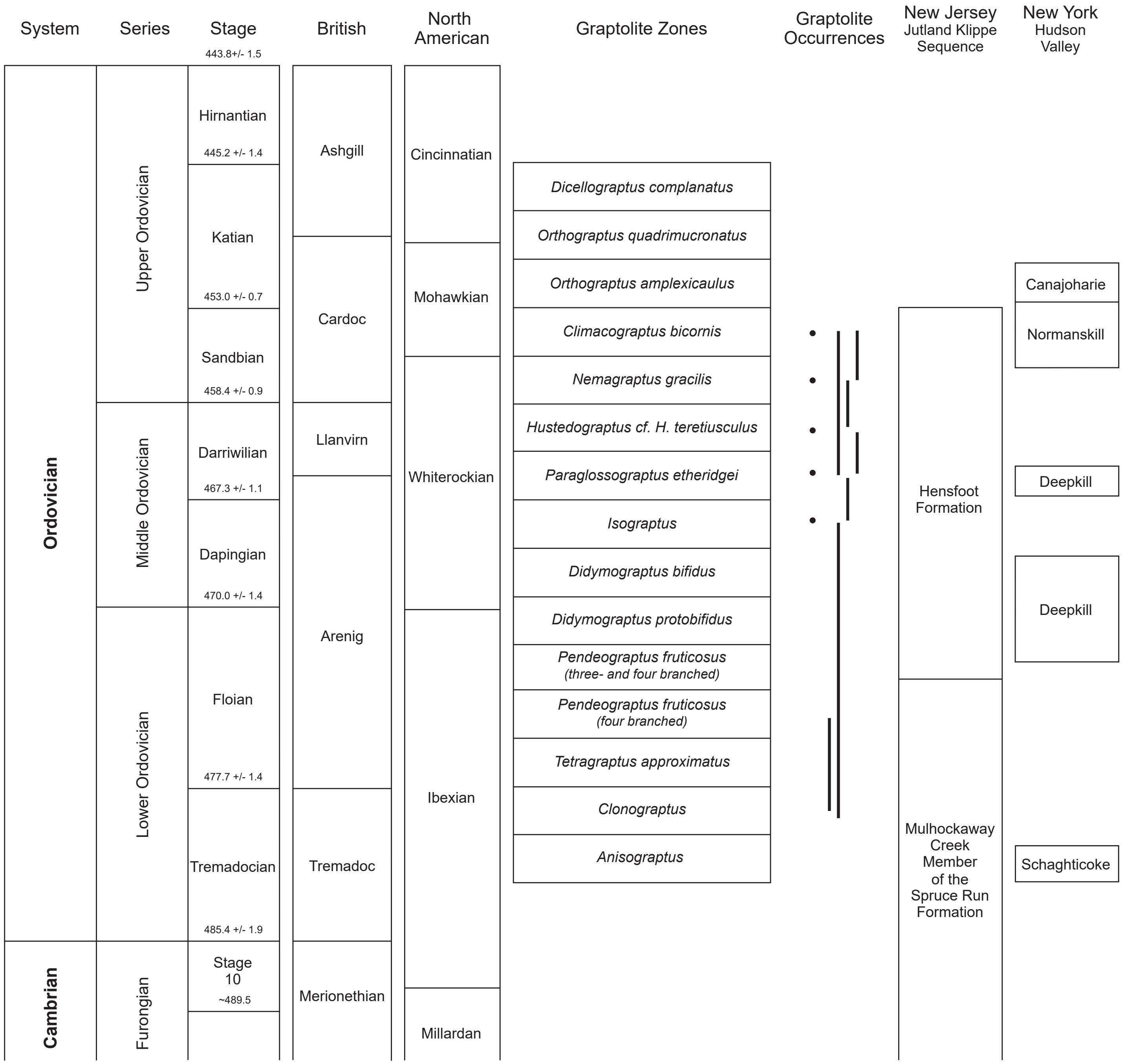
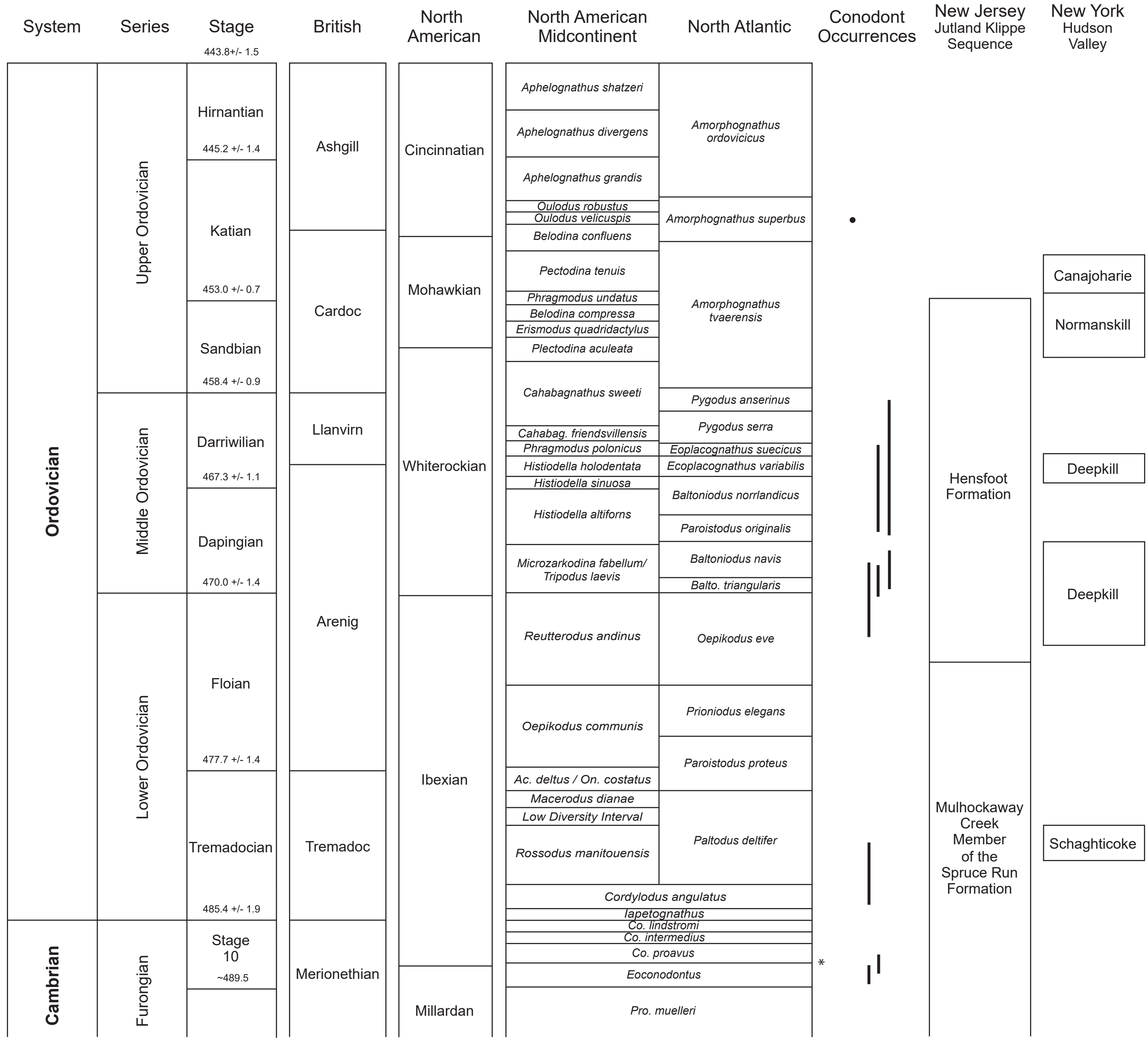


Figure 2A. The Jutland klippe sequence rocks, column 8, are compared to similar age rocks of the Hudson Valley, New York, the current global series and stages of the Ordovician (modified from Ross and others, 1982; Bergström and others, 2009; and Berry, 1962). The graptolite zones are based on Berry's zones for the Appalachian Belt. Berry (1960), Finney (1986), Harris and others (1995), Gradstein and others (2012), and Taylor and others (2012) were also used in the construction of this chart. The numerical ages (Ma) for the Global Stages are from Cohen and others (2013, updated 2020/03).

The New Jersey column shows the part of the Jutland klippe sequence that has age control by either graptolite or conodant data. The lower part of the Mulhockaway Creek and the entire Van Syckel Members has not yielded identifiable fossils to date and are not shown here.

Each dot, in the "Graptolite Occurrences" column, indicates a fauna identified to a single zone and the solid line indicates zonal range of the sample. Each dot or range may represent one or more samples falling in the same zone or zones. For example, four graptolite localities were identified down to *Nemagraptus gracilis* Zone (see Table A1).



*Cambrian-Ordovician boundary as shown in Harris and others (1995).

Figure 2B. The Jutland klippe sequence rocks, column 8, are compared to similar age rocks of the Hudson Valley, New York, the current global series and stages of the Ordovician (modified from Ross and others, 1982; Bergström and others, 2009; and Berry, 1962). The conodontzones are for the North Atlantic and North American Midcontinent Realms. Berry (1960), Finney (1986), Harris and others (1995), Gradstein and others (2012), and Taylor and others (2012) were also used in the construction of this chart. The numerical ages (Ma) for the Global Stages are from Cohen and others (2013, updated 2020/03).

The New Jersey column shows the part of the Jutland klippe sequence that has age control by either graptolite or conodant data. The lower part of the Mulhockaway Creek and the entire Van Syckel Members has not yielded identifiable fossils to date and are not shown here.

Each dot, in the “Conodont Occurrences” column, indicates a fauna identified to a single zone and the solid line indicates zonal range of the sample. Each dot or range may represent one or more samples falling in the same zone or zones (see Table A2).

completely different and not as well preserved as the early Deepkill fauna of Dodge (1952). To date, the exact location of the original Dodge beds remains a mystery.

Some of the graptolite specimens collected by Markewicz in the late 1950's and early 1960's were examined by H. Johnson in 1966. In 1991 the entire Markewicz collection was sent to Dr. Stanley Finney for identification, and in a letter to Richard Dalton dated October 16, 1991, he confirmed H. Johnson's identifications and indicated the collections could range as old as *T. fruticosus* (now *Pendeograptus fruticosus*) but were definitely from the *Isograptus* to *C. bicornis* zones (fig. 2 A).

Drake and others (1996) described the Jutland klippe sequence as interbedded varicolored shale and sandstone with lesser amounts of limestone, dolomite and conglomerate, and accepted the subdivision of the rocks into Unit A and Unit B of Perissoratis and others (1979) with the contact placed between the graptolite faunas *Isograptus caduceus* and *Paraglossograptus etheridgei* of Berry (1968), the base of Berry's Zone 9, as did Perissoratis and others, (1979). Unit A consists of an interbedded red, green and tan shale, sandstone, and dark-gray limestone which grades downward through an interbedded sequence of red, green and brown shale, and brown sandstone to quartz pebble conglomerate. Toward the base of the unit the shale and siltstone become dark gray with some minor limestone beds.

Drake and others stated the graptolites in Unit A ranged from the *Anisograptus* to *Isograptus caduceus* Zones of Berry (1968) and conodonts ranged from the *Cordylodus proavus* to *Paroistodus proteus* faunas of the North Atlantic Realm (fig. 2B). The problem with this graptolite zone range is there are no published records of graptolites in the Jutland region from the *Anisograptus* zone (Zone 1) of Berry (see table A1). As indicated earlier, Perissoratis (1974) did not collect from any of the oldest graptolite localities but used Dodge's (1952) identifications. Perissoratis (1974) and Perissoratis and others (1979) suggested the oldest graptolites, localities 1 and 2 (Dodge, 1952, localities 1 and 4), were from Berry Zones 2 to 4, not Zone 1 (*Anisograptus* Zone).

Unit B was described as a heterogeneous sequence of interbedded red, green, tan and gray shale; interlaminated shale and dolomite; greywacke, siltstone, sandstone, quartzite and interbedded limestone; and red and green shale. The graptolite fauna of Unit B ranged from the *Paraglossograptus etheridgei* Zone to the *Climacograptus bicornis* Zone of Berry (1968). They further indicated the unit contained conodonts ranging from the *Prioniodus triangularis* to *Pygodus anserinus* faunas of the North Atlantic Realm.

Subdivision of the Jutland Sequence

Recent mapping (fig. 3) by Monteverde and others (2015) allowed the rocks previously shown on Drake and others (1996) as the Jutland klippe sequence, Unit A and Unit B to be subdivided into the Spruce Run Formation (Upper Cambrian to Lower Ordovician) and the Hensfoot Formation (Lower Ordovician to Upper Ordovician) . The contact between these two new formations does not follow the arbitrary boundary of the base of Berry's Zone 9 as used by Perissoratis and others (1979) and Drake and others (1996), but rather a mappable lithologic boundary. The Spruce Run Formation is further subdivided into the Van Syckel and the Mulhockaway Creek Members.

The authors are also changing the name of the Jutland klippe sequence to Jutland sequence since the use of "klippe" in the name implies an origin that has not been determined by current knowledge of these rocks.

Spruce Run Formation (Upper Cambrian to Lower Ordovician)

The Spruce Run Formation consists of a thin-bedded medium- to dark-gray shale and siltstone with some local thin-bedded limestone

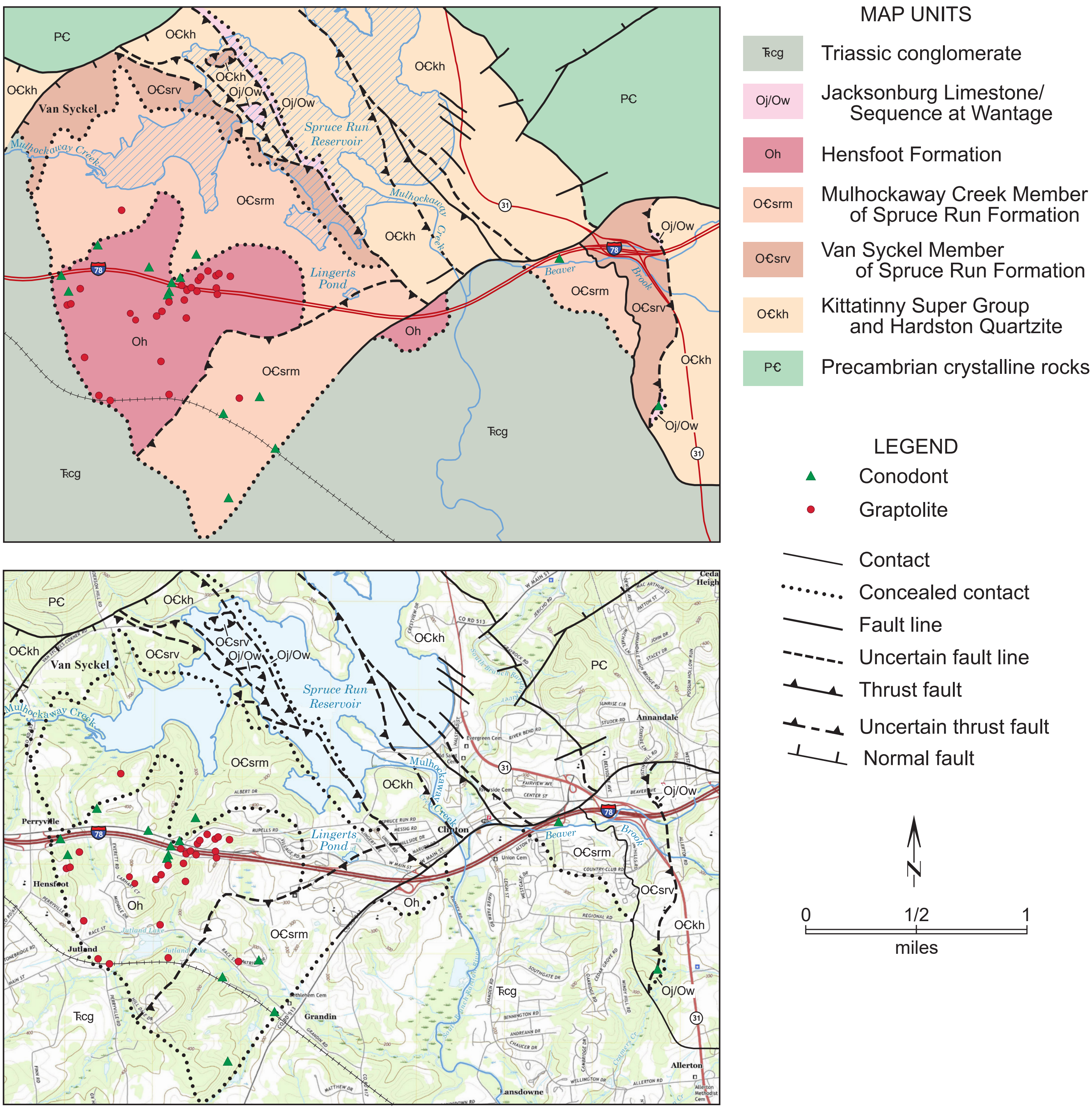


Figure 3. Geologic map of the Clinton-Jutland area showing the Jutland klippe sequence with the formation and members. Locations of conodont (triangle) and graptolite (dot) are shown and coordinates are provided in Tables A2 and A3. Map is based on Herman and others (1992) and Monteverde and others (2015).

that grades upward into a fine- to coarse-grained sandstone and quartz-pebble conglomerate. The upper part is an interbedded red, tan, brown, and green shale, siltstone, and sandstone with some massive- to thin-bedded, fine grained limestone near the top of the formation. The estimated thickness of the Spruce Run Formation is about 1,700 feet based on cross sections (Monteverde and others, 2015) with the lower contact being a fault. The Spruce Run is divided into the Van Syckel and Mulhockaway Creek Members.

Van Syckel Member of the Spruce Run Formation (Upper Cambrian)

The Van Syckel Member is a thin-bedded, medium- to dark-gray shale and siltstone with local thin-bedded, dark-gray, fine-grained to aphanitic limestone. It grades upward to a medium-gray to brown, fine- to coarse-grained sandstone and quartz-pebble conglomerate, poorly- to moderately-sorted. The lower contact with the underlying Cambrian and Ordovician carbonate rocks of the Kittatinny Supergroup and Jacksonburg Formation is a fault contact based on nine borings drilled for the Spruce Run Reservoir in the 1950's (N. J. Geological and Water Survey files). Thickness is estimated as 800 feet, based on cross section construction (Monteverde and others 2015).

The member is best exposed in the Beaver Brook area just south of the junction of Routes 78 and 31 where the color, texture, sedimentary features, and in part, the pencil-like fracture pattern is more similar to the Martinsburg Formation of Sussex County than any other location. This may be why these rocks were originally called Martinsburg. The lower part of the unit generally consists of gray to black shales, siltstones and very fine sandstones with convolutions, cross bedding and other small-scale turbidity current and soft sedimentary deformation structures. Poorly visible to micro-scale crossbedding, scour and fill, compaction and other turbidite features present in the dark siltstone bands are characteristic of deeper water deposition in contrast to the shallower water multi-colored shale, siltstone and limestone stratigraphically above the lower, dark sections. Limited bleaching occurs in basal beds, whereas rocks higher in the section are strongly bleached. During subsurface exploration work for the Spruce Run Reservoir project, several core holes located in the lower part of the unit passed through more than 150 feet of dark shales and siltstones before encountering the Jacksonburg Limestone (files of NJGWS). Based on the drilling and mapping at the Spruce Run Reservoir, the thickness of the lower dark shale and siltstone sequence can be as much as 500 feet.

Shoaling of the water above the basal dark shale and siltstone unit initiated the deposition of the varicolored shales, siltstones, sandstones, conglomerates and limestones. Progressing upward, the unit is marked by a sequence of mixed gray and black shales and siltstones with alternating red, olive, green, tan, brown, yellow, and buff shales, siltstones, and fine sandstones (locally calcareous). Thin chert seams are interbedded with the yellow and buff shales, calcareous sandstones, and siltstones. The red beds may indicate an intermediate depositional cycle induced by an influx of lateritic material derived from a regolithic provenance possibly underlain by weathered carbonates. This interbedded sequence ranges from about 150 to 200 feet in thickness.

The top of the member is marked by thick sandstone and graywacke pebble conglomerate beds. There are, however, scattered, thin, fine- to medium-grained sandstone beds present throughout the entire Jutland sequence. Within the graywacke sandstone-conglomerate sequence, pebbles can range over one inch in diameter. Local facies contain flat pebbles mixed with rounded siliceous rock fragments, dolomite and quartz pebbles. One of the best exposures of the thick sandstone and conglomerate beds is about 4,000 feet east of Van Syckel and just north of a farm pond.

This area previously mapped as Hardyston Quartzite (Lewis and Kümmel 1910-1912) is underlain by medium- to very-coarse-grained sandstone and graywacke pebble conglomerate. An abrupt north-south linear ridge between the farm road and the pond is formed by coarse- to very-coarse-grained glauconitic, locally pebbly, quartzitic sandstone. The glauconite-bearing rock is composed chiefly of rounded quartz grains with interstitial light green, flat to ovoid pellets and amoeboid-like glauconite masses that encase some quartz grains. Glauconite was identified by both thin section and X-ray diffraction (NJGWS Permanent Notes). It is tough, blocky, and breaks both around and through the quartz grains. A hydrous iron film derived from glauconite decomposition coats much of the quartz. Although the top and bottom of the sandstone beds are not exposed, they are estimated to be at least 35 to 45 feet thick at this location. The thickness is variable and can be up to 60 feet.

Approximately 1,500 feet west of the farm pond there are several low quartzitic sandstone and heterogeneous conglomerate and chip conglomerate outcrops containing ovoid to flat pebbles measuring up to one inch in long dimension. In some graywacke conglomerate facies the interstices between mineral and rock grains are filled with fine grained, feldspar rich, Precambrian rock detritus. The clasts are composed typically of quartz and lesser amounts of leached dolomite, sandstone, quartzite, shale chips, minor chert, weathered Precambrian pebbles and mineral fragments. A few flakes of graphite were noted in several samples. Many small cavities previously occupied by carbonate pebbles are now lined with small, well formed, quartz crystals that are coated with iron or manganese oxide.

No fossils of any type have been noted in the sandstone-conglomerate facies, but several poorly preserved brachiopods and crinoid-like columnals and a few carbonaceous films were found in the lower dark beds exposed on Route 31. No conodonts have been found in this member but based on conodont data from the overlying Mulhockaway Creek Member this unit is Cambrian in age.

Mulhockaway Creek Member of the Spruce Run Formation (Upper Cambrian to Lower Ordovician)

The Mulhockaway Creek Member consists of thinly interbedded red, green, and ocher shale and siltstone grading upward to interbedded red, tan and green, thin bedded shale with lesser fine-grained sandstone and, locally, interbeds of dark-gray, fine-grained to aphanitic, thin- to medium-bedded limestone. The limestone can be crossbedded, contain floating frosted quartz sand grains or edgewise conglomerate. The lower contact is placed at the top of a medium-gray to brown, fine- to coarse-grained sandstone and quartz-pebble conglomerate of the underlying Van Syckel Member. Conodonts found in the limestones in the middle and upper part of the member range from late Cambrian to early Ordovician (*Cordylodus angulatus* or *Rossodus manitouesis* Zone) Harris and others (1995). On page 7, they indicate the conodont faunas of the Jutland rocks are representative of the North Atlantic Realm or pandemic species but use the North American Midcontinent Realm zone names which causes some confusion. The oldest faunas contain the conodonts *Eoconodontus notchpeakensis* and the proconodont *Phakelodus*. Fossil assemblage suggests an age of late Cambrian (Millardan, Furongian) to early Ordovician (middle Ibexian, early Floian) for the Molhockaway Creek. The first identifiable graptolites occur several hundred feet below the top of the member at Dodge's localities 1 and 4, and range in age from *Clonograptus* to *Pendeograptus frutiosus* (four branched) zones, (zones 2-4) of Berry (1960, 1968) according to Perissoratis and others (1979). The thickness is estimated at 900 feet, based on cross section construction and field observations. Best exposures are along banks of Spruce Run Reservoir during periods of low water.

The lower 400 to 500 feet consists of an interbedded sequence of red, green, yellow, and tan shales, silty shale and siltstone with minor sandstone and thin chert layers. The chert is extremely fractured and weathered, and fresh surfaces cannot be obtained. Some of the siltstone beds are calcareous, and near the top of this section a few black shale layers can be found below a thick limestone unit.

Limestone and dolomite layers can be found throughout the entire Jutland sequence, but the thickest and most consistent carbonate unit is found just above the middle of the Mulhockaway Creek Member. It is 80 feet or more in thickness. The top and bottom are mostly covered and considering the vertical and lateral variability the total thickness could easily exceed 100 feet. The limestone consists of three distinct subfacies: a fine grained, lenticular limestone with intercalated varicolored, highly siliceous shale (upper unit); an intraformational edgewise chip conglomerate and breccia consisting of limestone clasts (middle unit); and a massive bedded, sandy to oolitic limestone (lower unit). A sample from this thick limestone unit yielded a conodont age of latest Cambrian (Harris and others (1995).

Figure 4. Upper part of the thick limestone sequence just above the middle of the Mulhockaway Creek Member of the Spruce Run Formation. Location is on the Beaver Brook Golf Course (Figure 24 from Markewicz, 1967).

The upper subfacies of the limestone unit is aphanitic to medium grained, locally coarsely crystalline, light gray weathering, ribbony to platy to massive, dark gray, and in beds one-half to six inches thick with massive beds ranging up to three feet in thickness. The fine-grained rock ranges from a calcisiltite to calcilutite. In the ribbony beds, individual beds are separated by shale or highly siliceous varicolored shale ranging from paper thin to several inches thick. Some individual limestone lenses and plates are wrapped by shale and are less than three inches long in any direction. The base of some limestone beds contains a thin chip conglomerate consisting of fragments torn from the bed below. Beds are locally cross-bedded and some thin beds have "floating" frosted quartz grains. Occasional irregular patches of purple fluorite can be present in the upper part of the section. Although the top and bottom are covered, the total estimated thickness is 40 to 60 feet.

The middle subfacies is a sequence of beds containing intraformational, edgewise chip conglomerate and breccia containing chips and irregular fragments (up to a foot long) of fine-grained limestone and oolitic quartzose calcarenite in a quartz-carbonate matrix. This ruditic material is derived (torn) from underlying carbonate beds. There can be some minor shaly interbeds. No complete sections are exposed but the brecciated unit is estimated to be 10 to 15 feet thick.

The lower subfacies is a thin to moderately thick-bedded oolitic quartzose calcarenite containing fine to coarse, well rounded, frosted quartz "floating" in carbonate matrix consisting of crystalline calcite. Up to 40% quartz can be present. Well-formed oolites usually of the concentric and radial type range from small to large. The rock weathers to a rusty-brown, very porous and permeable sandstone. At some locations carbonate is replaced by hydrous iron cement. The top and bottom are covered, the thickness is estimated to be up to 30 feet.

One of the better exposures of the limestone is approximately seven-tenths of a mile southeast of Clinton on the south side of Beaver Brook. There the upper unit is a fine grained, lenticular limestone with intercalated varicolored highly siliceous shale (fig. 4). Near the base (east end) of this section, a few feet of the middle "breccia" unit is exposed. This location was mapped as "Kittatinny Limestone" on older geologic maps. Five hundred feet southeast of Lingerts Pond, an interbedded platy limestone and shale section represents part of the upper limestone unit. A minor amount of fluorite is present in the limestone float at this location. The upper unit is exposed in a small abandoned limestone quarry at the base of a steep hill approximately 2,000 feet north-northwest of a water tower on U.S. Route 78 (mile post 14.8).

Above the limestone unit, the rock consists of thin-bedded, tan to brown, locally red, siliceous sandstone beds and tough, thin-bedded quartzite, some leached, brown calcareous siltstone and some dark-blue-gray, massive limestone beds. The sequence becomes more shaly and varicolored toward the top and can be as much as 300 feet thick. Dodge's Hedgehaven Farm graptolite site (locality 1) is in one of the thicker limestone beds in this upper sequence, several hundred feet below the top of the member. The graptolites from this locality indicates age of upper Tremadocian to lower Floian. Conodont data from beds a couple hundred feet lower than locality 2 (same graptolite zones as locality 1) are late Cambrian (Millardan).

Hensfoot Formation (Lower to Upper Ordovician)

The Hensfoot Formation is a heterogeneous sequence of interbedded red and green, thin bedded shale, interlaminated dolomite and shale, thinly interbedded, fine-grained graywacke siltstone to medium-grained sandstone and shale; yellow, red, green, tan and gray shale; and light-gray to pale pinkish-gray quartzite. Lower contact is placed within a red shale bed approximately 50 to 100 feet above a prominent limestone sequence. The oldest identified graptolites are from the Isograptus Zone (Zone 8) of Berry (1968) with the youngest being from the Climacograptus bicornus Zone (Zone 12) of Berry (1968) according to Parris and others (1998). Carbonate and pelitic rocks locally contain conodonts of Baltoniodus triangularis to Pygodus anserinus faunas of North Atlantic Realm (Ethington and others, 1958; Karklins and Repetski, 1989; Repetski, oral communication, 1992) and sparse brachiopod fragments. Based on graptolites the unit is upper Dapingian to Sandbian. Thickness, due to structural complexity, is difficult to determine but could be as much as 1,500 to 1,700 ft. Best exposures are along train tracks between Jutland and Grandin on the Pittstown quadrangle and in old quarries on the south side of Rt. 78 about a mile east of Perryville.

The lower 500 to 700 feet consists of varicolored shales, siltstones, minor chert, thin limy beds, and red and green clay shales to silty shales. Red beds vary from bright, thin splitting, homogenous clay shale to uneven fracturing, dull red, heterogeneous silty shale. Conodonts and small, thin shelled (phosphatic-linguloid) brachiopods are typically present in the bright, smooth, fissile, red shales, whereas they occur only sporadically in silty shale. No graptolite

Figure 5. Meta bentonite bed in the upper part of the Hensfoot Formation. Location is the Clinton Block quarry. The bed sampled is the lowest thick light-colored bed in middle of quarry face (see arrow). *Photo from D.C. Parris.*

fragments have been noted in any of the red beds or green shales. The best-preserved graptolites have been found in thin-bedded brown shale and in thin-bedded tan to brown calcareous silty shale to siltstone layers throughout the member.

Some red beds are spotted with small, rust colored cavities while others contain leached glauberite casts. Red beds are typically homogenous in contrast to the multi-colored shales which are usually interbedded with siltstones, limy beds, chert and fine sandstone. No chert is known within any red beds. Much of the greenish shale is very finely micaceous. The lower part, just above the contact with the underlying Spruce Run Formation consists of a sequence of thin-bedded tan, brown, locally red, siliceous beds, and light gray, thin bedded quartzite and leached brown sandstone.

The upper 800 to 1,000 feet of the Hensfoot consists of a varicolored red, green, tan, yellow, brown and dark gray sequence of shales, laminated shales and siltstones with minor fine-grained calcareous sandstones and siliceous limestones along with some thin calcirudite and manganese bearing limestone beds. The calcareous beds range from less than one inch to more than ten feet thick and are scattered. Many individual beds are encrusted with a thin, porous, manganiferous rind. Some units consist of thin bedded, calcareous, argillitic rock with numerous shaly partings. A two-foot calcirudite bed about 1,200 feet southwest of the NJ Department of Corrections water tower contained numerous dark chert granules and black fossil shell remains in addition to frosted quartz grains. Except for fragmentary shell remains and conodonts, no other distinct fossils have been found in the carbonate beds of the Hensfoot Formation. Occasional fragmentary graptolitic remains occur in thin shaly partings separating limy siltstone beds in the upper part of the formation.

A metabentonite bed up to four feet thick was described by Dodge (1952) and confirmed by differential thermal analyses and x-ray diffraction that indicated an interlayered illite and montmorillonite structure. Survey staff visited the site shortly after it was found and collected samples to run some swelling tests on the material (NJGWS Permanent Notes). The bed is in the upper part of the formation, but due to structural complications in the exposure the exact stratigraphic location within the Hensfoot could not be determined. The original exposure has been destroyed by the construction of Route 78, but currently (2017) there is a new exposure of this bed or a similar bed in the Clinton Block quarry just south of Rt. 78 (fig. 5). Graptolites collected from siltstone layers within the bentonite are indicative of the Hustedograptus cf. H. teretiusculus Zone (Zone 10 of Berry, 1960) according to Parris and others (1998).

Fossils of the Jutland Sequence

The most prolific faunas found in the Jutland sequence in the Clinton area are graptolites and conodonts. Figure 3 shows geology along with the location of all the graptolite and conodont localities. Table A1 provides location information of all the graptolite localities in the Jutland sequence of New Jersey along with the zone identifications, and who identified the fauna or the report where it is described. Table A2 provides the location information for the conodont sites along with who identified the fauna or the report where it is described and the zone or age. Table A3 is an updated listing of all the graptolite species found in the Jutland sequence and the source of the identification. Table A4 provides a listing of all the graptolite species found at each site in the Jutland sequence, the source of the identification, the graptolite zone, and any other pertinent information. Appendix B contains table B, a listing of all the graptolite species identified by various workers and has been compiled from the various reports and other identification sources. This listing was updated during the review of this current report by Dr. Mitchell and is “Table A3” of the report. Appendix B also has seven figures of graptolites found by Dodge (1952) and Markewicz (1967).

Less common fossils include diminutive (linguloid) brachiopods in bright red shales of the Hensfoot Formation and some poorly preserved brachiopods and crinoid-like columnals in the lower dark shaly and silty beds near the base of the Spruce Run Formation. Fragmentary, black and amber colored phosphatic shells and/or plate-like fossil material occur in several upper calcirudite beds of the Hensfoot Formation.

Conodonts occur in red, light purple, yellow and tan shales, and are most abundant in bright red homogenously textured shale where they occur as white to light amber colored microfossils. Some thin, black, silty shale laminae and very thin, porous, tan to light brown shale layers at the top or bottom of distinct lithic units contain numerous conodonts and conodont fragments. In some red shale beds the specimens have dissolved, leaving perfect fossil molds. Conodonts have also been recovered from limestone beds throughout the entire Jutland sequence. Conodonts and whole specimen graptolites generally are not found in direct association. However, poorly preserved conodonts are frequently found with fragmentary graptolitic remains in leached tan to buff shales on the south side of Route 78 just west of the water tower. It is not known if the conodonts were carried in from a deeper offshore environment along with fragmentary graptolites or if, more likely, broken graptolites floated into the conodont environment.

Diminutive (1.5 mm to 5 mm), white to amber, poorly preserved, thin shelled phosphatic brachiopods are restricted to the bright red, conodont-bearing shale. Usually a single valve is present, but occasionally specimens with both valves have been found. Robert B. Neuman, U.S. Geological Survey at the National Museum (written communication, 1964) identified them as a long ranging linguloid type brachiopod. Some thin, silty, semi-bleached laminae in red shale yield imprints of the small linguloid brachiopod in addition to much larger, tan and cream colored, phosphatic shell fragments of an unidentified brachiopod. To date, no complete specimen of this larger form has been found.

Possible fragmentary graptolite remains are present in many of the varicolored units above the basal dark beds of the Van Syckel Member. No graptolites, whole or fragmentary, have ever been found in red or greenish shale. In some yellow, bleached shales, there are abundant fine fragmentary carbon streaks possibly of graptolitic origin.

Brachiopods and conodonts were found by Markewicz in the late 1950's in Jutland sequence rocks near Chester, New Jersey. The conodonts, from both Clinton and Peapack-Gladstone (near Chester) were suggestive only of Middle Ordovician age (Ethington and others, 1958). The brachiopods from the Peapack-Gladstone valley were tentatively identified as being of the Plectorthid, Dalmanellid, Rafinesquinoid, and Sowerbyella types indicating a late Middle or early Late Ordovician Age (Minard, 1959, p. 81-82). In addition, a few graptolites, ostracodes, a bryozoan, crinoid-like columnals, and part of a trilobite were found in the Peapack-Gladstone area. The graptolite samples collected by Markewicz were identified by Finney in 1991 as indicative of Isograptus to Climacograptus bicornis zones (letter to Richard Dalton dated October 16, 1991). Additionally, a conodont sample (Harris and others, 1995) was determined to be late Early or early Middle Ordovician (Oe. evae to Ba. navis zones). Based on the limited fossil data the upper part of the Jutland sequence in the Peapack-Gladstone valley is similar in age to the upper part of the sequence in the Clinton area. No detailed mapping of the Jutland rocks has been done in the Peapack-Gladstone valley since Minard (1959), who estimated the rocks were about 1,700 feet thick. Even though the lithologies of the rocks in the Clinton-Jutland area are very different from the Martinsburg Formation of northwestern New Jersey, it was the presence of graptolites that eventually allowed the Jutland rocks to be differentiated from the Martinsburg. The fact that both the Jutland sequence and the

Martinsburg of northwestern New Jersey were "apparently" in similar stratigraphic succession with the underlying Cambrian-Ordovician limestones and dolomites led some geologists, such as Willard, to believe the rocks of the Jutland area were a nearshore facies of the deeper water Martinsburg Formation.

The first graptolites from the Jutland sequence were found in the first Lehigh Valley railroad cut (now Norfolk Southern, Lehigh Line) immediately east of Jutland and identified by Weller (1903, p. 53) as a Normanskill graptolite fauna. The specimens identified were:

Climacograptus phyllophorus (Gurley)
Dicranograptus ramosus (Hall)
Coenograptus gracilis (Hall)
Reteograptus geinitzianus (Hall)

Additional graptolites were found in 1914 by M. W. Twitchell in the second railroad cut east of Jutland, and Ruedmann identified the following species in an April 6, 1931 letter to H. B. Kümmel:

Climacograptus scharenbergi (Lapworth)
Dicellograptus smithi (Ruedemann)
Dicellograptus cf. divaricatus (Hall)
Diplogaptus. angustifolius (Hall)

He indicates "It is our opinion that this particular shale in the cuts of the Lehigh Valley railroad is not Martinsburg shale, but Normanskill shale probably brought up by folding or faulting."

H. Dodge (1952) collected and described an older graptolite fauna at four different sites near Jutland that included:

Dictyonema amplum (Ruedemann)
Dodge site 1
Dictyonema murrayi (Hall)
Dodge site 1
Callograptus salteri (Hall) var. *jerseyensis* n. var. Dodge site 1
Goniograptus thureaui (McCoy) var *postremus* (Ruedemann) Dodge site 1
Bryograptus lapworthi (Ruedemann)
Dodge sites 1, 2
B. pusillus Ruedemann Dodge site 1
Tetragraptus clarkei (Ruedemann)
Dodge sites 1, 2
Tetragraptus quadribrachiatus (Hall)
Dodge site 1
Didymograptus bifidus (Hall)
Dodge site 1
Didymograptus extensus (Hall)
Dodge site 1
Didymograptus nicholosoni (Lapworth)
Dodge site 3
Cryptograptus antennarius (Hall)
Dodge sites 3, 4,
Glossograptus hystrix (Ruedemann)
Dodge site 3
Clonograptus flexilis (Hall)?
Dodge site 4

Based on the above fauna, Dodge redefined part of the shales west of Clinton as early Deepkill (his localities 1 and 4) and late Deepkill (his localities 2 and 3) equivalents.

Markewicz submitted a preliminary graptolite collection (from several sites) to Helgi Johnson (Rutgers University) who indicated a Chazyan equivalent within the Normanskill (H. Johnson, oral communication, 1966). The fauna consisted of:

Callograptus salteri
Tetragraptus quadribrachiatus (Hall)

Didymograptus sp.

Dicranograptus sp.

Climacograptus bicornis (Hall)

Climacograptus sp.

Diplograptus sp.

Glossograptus sp.

Isograptus sp.

Perissoratis (1974), and Perissoratis and others (1979) described graptolites from 16 sites in the Clinton area but did not collect from five of those localities. Four of the five were Dodge's original "Deepkill" localities and the other was the Weller locality. Dodge and Neuman, in 1964, recollected the Dodge 1 (Hedgehaven Farm) locality and the Twitchell locality, and Berry identified the graptolites (Neuman and Dodge, 1964, p. A83; Perissoratis, 1974, p. 18 and p. 28).

The additional graptolite localities described in Perissoratis (1974), and Perissoratis and others (1979) confirmed the earlier works of Weller, Ruedemann and Dodge that the rocks in the Jutland area are older than typical Martinsburg Shale. A problem with the geologic mapping and stratigraphic interpretations of Perissoratis (1974), and Perissoratis and others (1979) was that they made the assumption that the oldest graptolite zone was at or near the very bottom of the section and the youngest zone was at or near the very top of the section. They then fit all the various lithologies between those two graptolite zones rather than developing a stratigraphic sequence based on mappable units and then fitting the graptolite locations into the section based on their lithologies and stratigraphic position. Perissoratis (1974, p. 32) estimated the thickness of the upper unit to be about 1,300 feet and lower unit at 600+ feet. Drake and others (1996), using the Perissoratis and others (1979) biostratigraphic interpretations supplemented with conodont data, estimated a thickness of 1,500 to 1,800 feet for the upper unit and an unknown thickness for the lower unit.

Additional graptolite sites were found and described by Parris and Cruikshank (1986), and Parris and others (1998), and several original sites were resampled. A nearly continuous exposure at the Clinton Block quarry with four individual graptolite horizons was described by Parris and others (1998). The succession of graptolite zones indicated that the rocks of the Jutland sequence are right-side up, at least in the quarry area. Three of the horizons (localities 19, 20 and 21) were collected by the authors and the fourth (locality 22), a few hundred yards north-northeast, was collected by Markewicz in the late 1950's and 1960's. The faunas present went from *Isograptus* Zone (Zone 8) to *Nemagraptus gracilis* Zone (Zone 11). Appendix A of Parris and others (1998) continues the locality numbering of Perissoratis and others (1979) and included all the previously published graptolite sites in the Jutland rocks. Table A4 (this report) describes all the graptolite faunas from the Jutland sequence including those in Appendix A of (Parris and others, 1998), the Markewicz graptolite localities (identified by Finney), and a new collection from Hedgehaven Farm (Subramanian and Parris, 2016).

The graptolite collections made by Markewicz from the late 1950's through the late 1960's were identified by Finney in 1991. Most of his localities are from the Jutland-Clinton area with three being from outside of that area; one from the Peapack-Gladstone valley and two from the Musconetcong Valley near Port Murray. Drake and others (1996) mapped the clastic rocks in the Peapack-Gladstone area as Jutland klippe sequence units A and B and the rocks in the Port Murray area as the Bushkill Member of the Martinsburg Formation. Graptolites (identified by Finney) from all the localities of the Jutland sequence near Clinton as well as Peapack-Gladstone indicate an age range from the *Isograptus* to *C. bicornis* zones. The graptolites from the two sites near Port Murray were badly cleaved and the age determination was extremely uncertain. An extensive collection of graptolites and a shelly fauna was made at the Port Murray location and described in Parris and others (1993). They determined that the graptolite fauna was from the *Orthograptus amplexicaulus* Zone (Zone 13), which fits with the rocks at Port Murray being from the lower part of the Bushkill Member of the Martinsburg Formation as mapped.

As indicated earlier detailed mapping done by Markewicz identified several distinctive marker horizons that could be traced throughout the entire Jutland sequence. These marker horizons allowed the various graptolite localities to be placed in correct stratigraphic context. Based on current mapping by Monteverde and others (2015), the oldest identifiable graptolites (Dodge's Hedgehaven Farm site) occur about 1,500 feet above the base of the Jutland sequence near the top of the Mulhockaway Creek Member of the Spruce Run Formation. Conodont samples collected by Monteverde from several limestone beds a hundred or more feet stratigraphically below the lowest graptolite collections were of latest Cambrian to earliest Ordovician age with one identified as latest Cambrian by Harris and others (1995). All the published conodont data from the rocks of the Jutland sequence can be found in table A2.

Correlation of Jutland Sequence and relation to the Hamburg Klippe

The stratigraphic position in New Jersey of the "Normanskill" and "Deepkill" graptolite-bearing units relative to the underlying Jacksonburg Limestone posed a complex problem considering that Jacksonburg was significantly younger than the "Normanskill-Deepkill" beds. Some geologists, such as Stose (1946), explained this by complex long-distance thrusting from the southeast. Additional explanations involved the mechanics of large allochthonous masses sliding by gravity into the Martinsburg basin (see Lash, 1985, 1987; Ganis and Wise, 2008, Wise and Ganis, 2009; Codegone and others, 2012; and Jacobi and Mitchell, 2018, among others). With a number of similar detached areas in Pennsylvania, New Jersey and eastern New York it is difficult to conceive how the gravity slide mechanism would position the masses with such unique stratigraphic regularity that the allochthonous sequences are emplaced mainly on the Middle and Lower Ordovician shelf carbonates. The field evidence indicates that the Jacksonburg type rocks of the High Bridge quadrangle are Jacksonburg equivalents relative to age, position, and lithology. However, the conodont fauna is mainly a North Atlantic Realm, whereas the Jacksonburg Formation in the Highlands, and in the Valley and Ridge Physiographic Provinces of New Jersey contains a Midcontinent Realm fauna (Barnett, 1965 and Harris and others, 1995, p. 6). Yet, the underlying Beekmantown carbonate rocks in the Jutland-Clinton area, the Highlands and in the Valley and Ridge all contain a Midcontinent Realm fauna.

Nowhere in New Jersey have rocks of the Jutland sequence been documented as overlying or in contact with the Martinsburg Formation. At Amsterdam, Little York, Pattenburg, Jutland-Clinton, Annandale, and Peapack-Gladstone, the Jutland rocks are in contact with either the Cambrian-Ordovician carbonates of the Kittatinny Supergroup or Jacksonburg Limestone. At Little York, in one area they are also in fault contact with crystalline rocks. In the Riverdale area, Volkert (2011) shows the Jutland sequence only in fault contact with crystalline rocks of the Highlands in the footwall of the Ramapo fault. In the Stanton Station area, the Jutland rocks are only in fault contact with the Triassic rocks.

The Jutland-Clinton area contains the largest continuous mass of the Jutland sequence rocks in the state and has been studied by many geologists. The old Lehigh Valley Railroad cuts completely across sequence from its contact with the Cambrian-Ordovician carbonates to where the Jutland rocks are covered by the Triassic rocks. During the exploration and construction of the Spruce Run Reservoir a series of nine borings on two rows over 1,500 feet apart indicated that the Jutland rocks were in fault contact with both the Jacksonburg Limestone and the rocks of the Kittatinny Supergroup along a southwesterly dipping thrust fault. The Peapack-Gladstone valley contains the second largest area of the Jutland rocks. Mapping by Volkert (2018) indicates they are in fault contact with the upper Beekmantown carbonates with no Jacksonburg present in the entire valley. Monteverde and others (2015) and Herman and others (1992) show the Jutland in contact with both the Cambrian-Ordovication carbonates and the Jacksonburg Limestone along a thrust fault.

As mentioned above, Stose (1946) suggested the varicolored shales of eastern Pennsylvania, his "Hamburg klippe" and similar rocks in detached areas of New Jersey were correlative to the Taconic sequence of New York. Extensive graptolite collections from the rocks of the Hamburg klippe and Martinsburg Formation of eastern Berks and western Lehigh Counties were described by Wright and Stephens (1978) and Wright and others (1979). The rocks of the eastern part of the Hamburg klippe were subdivided into two formations by Lash and Drake (1984) and Lash and others (1984) using lithologies and interpreted tectonic history along with graptolites and conodonts identified by others to establish age control.

Lash and Drake (1984) subdivided the eastern end of the Hamburg klippe into two tectonic slices; the upper Richmond slice and the lower Greenwich slice with each containing a single formation. The upper Richmond slice consisted of the Virginville Formation, which was described as a sequence of quartzose rocks, micritic limestone, peloidal limestone, calcarenite, carbonate-clast conglomerate and black shale and mudstone. They divided the Virginville into three members, and on page 22 cited written communications from J. E. Repetski (1978, 1979, 1980) as the source for determining the age of the units as being from Late Cambrian to late Early Ordovician (Arenigian). Yet Lash and others (1984, fig. 46) characterized the two lower members of the Virginville as Upper Cambrian and the upper member as upper Middle Ordovician (Llandeilian) age with no explanation for the age difference between the two reports.

The lower Greenwich slice, named the Windsor Township Formation, was subdivided into three members. It is younger than the overlying Richmond slice, and consists of graywacke and shale with lesser amounts of limestone, chert and conglomerate (Lash and Drake, 1984, p. 3). Lash and others (1984, p. 19) indicated the interbedded graywacke and olive-green siltstone and shale contained graptolites representative of the *Nemagraptus gracilis* Zone citing Wright and others (1978, 1979), Lash (1980), and Lash and Drake (1984), and possibly *Glyptograptus teretiusculus* Zone (Wright and others, 1978, 1979). Lash and others (1984) further qualified the graptolite zone assignments by indicating that Wright and others (1978, 1979) used the zonal classifications of Riva (1972, 1974) while the U.S. Geological Survey and associated workers followed the classification of Berry (1962, 1970, 1971). Both the Riva and Berry classifications have a *Nemagraptus gracilis* Zone with the age of the base being the same, but Riva's zone had a much longer duration and included a portion of Berry's younger *Climacograptus bicornis* Zone. Since some graptolite faunas were identified as from the *Nemagraptus gracilis* Zone of Berry (1962, 1970, 1971), Lash and others (1984) indicated the majority of the turbidite and hemipelagic deposits of the Greenwich slice were likely deposited during the lower part of Riva's *N. gracilis* Zone. In addition, they stated that some of the limestone megaclasts, based on conodonts, were of an Early Ordovician age citing Bergström and others (1972). Then on page 13 they referred to the Jutland klippe rocks of Perissoratis and others (1979), which ranged in age from Early to Middle Ordovician (graptolite zones 2-4 to graptolite zones 11-12 of Berry, 1960, 1968), as being similar to the limestone, chert, and variegated shale of Windsor Township Formation. They, however, cited no graptolite data from the Windsor Township Formation as containing graptolites older than possibly the *Glyptograptus teretiusculus* Zone. They reference only some Early Ordovician conodont data from limestone interbedded with the red shales. This may be the Repetski (1984) data included in Lash and others (1984).

Wright and Stephens (1978) and Wright and others (1979) describe graptolite and shelly faunas from both the Martinsburg Formation and the Hamburg klippe rocks of Berks and Lehigh Counties, Pennsylvania. Because their emphasis was more on the Martinsburg Formation and the sandstones of Shochary Ridge than the adjacent rocks of the Hamburg klippe, their graptolite collections from the klippe rocks were limited. Wright and Stephens (1978, table 1) listed 18 localities containing graptolites with the four localities from the klippe rocks being in the *N. gracilis* Zone of Riva (1969). Wright and others (1979, p. 1178) indicated they investigated 350 outcrops with 120 new graptolite localities and collected a shelly fauna from 50 localities. They indicated that the graptolites were identified by John Riva following his zonation for the northern Appalachians (Riva, 1974). Their table 1 only lists the number of localities where a particular species was found, not the various species by locality. This makes it impossible to compare their faunal assemblages and zones with the Jutland data. All 14 localities within the Hamburg klippe (Wright and others, 1979, fig. 2) contained graptolites of the *N. gracilis* zone of Riva (1974). On page 1178 they stated:

> The oldest fossils found in the area, graptolites of the *Nemagraptus gracilis* Zone, occur within the Hamburg klippe (fig. 2) and come from a variety of klippe lithologies including dark olive shale, metabentonites and graywackes. No fossils younger than the *Nemagraptus gracilis* Zone have been found within the limits of the klippe as shown on figure 2, nor have any isolated blocks of klippe lithologies and/or *Nemagraptus gracilis* Zone been found beyond this boundary.

The fact that Wright and Stephens (1978), Wright and others (1979), and Stephens and others (1982) all stated the youngest graptolite zone in the eastern part of the Hamburg klippe was the *N. gracilis* Zone of Riva (1969, 1974) would imply they found no Martinsburg age rocks within the boundary of the klippe. Wright and others (1979, p. 1184) stated that where the southern edge of the allochthon could be mapped, the *Diplograptus multidens*-bearing shale (Martinsburg Formation) was absent and the allochthon sat on Middle Ordovician carbonate platform deposits. Stephens and others (1982, p. 19) discussed the theory proposed by Platt and others (1972), that the suggested olive shale and graywake within the klippe represented a Martinsburg matrix encasing the exotic lithologies including the red shales, ribbon limestones, and volcanics. They stated that the only fossils found in the olive shale and graywake have been indicative of the *Nemagraptus gracilis* Zone or older, with no fossils of "normal" Martinsburg age having been found in the klippe itself to date.

Graptolite faunas from the western part of the Hamburg klippe are described by Ganis and others (2001), and Ganis (2005). Ganis and others (2001) mapped the stratigraphy of the western end of the Hamburg klippe as a single formation, the Dauphin Formation, with three members. Graptolite and conodont data were used as control. Their figure 4 indicates the Dauphin ranges in age from early Arenig to upper Llanvirn time with some older olistoliths. The figure also depicts the age for the base Martinsburg both east and west of the Hamburg klippe as about mid *C. bicornis* Zone based on the graptolite zones for Newfoundland of Williams (1995), Williams and Stevens (1988), and mid *D. multidens* Zone, based on the graptolite zones for the Northern Appalachians of Riva (1969, 1974). They cited Epstein and Berry (1973) and Parris and Cruikshank (1992) as their references for the *C. bicornis* age interpretation for the base of the Martinsburg in eastern Pennsylvania. Ganis and others (2001, p. 115) stated there was no evidence of any rock deposition between the time of the Dauphin and the earliest Martinsburg (late Da 4 through early *C. bicornis* Zones). They further stated that:

> Within the limits of the Hamburg klippe are belts of turbiditic flysch and wildflysch deposits that have yielded graptolites of upper *C. bicornis* Zone (*D. multidens* Zone of Riva, 1969, 1974) through the younger *D. clingani* (*C. americanus* Zone of Riva, 1969, 1974; Berry, 1960, 1970, 1971) that should be retained within the Martinsburg Formation.

In the discussion on the correlation of their stratigraphic framework for the western part of the Hamburg klippe to the eastern part of the klippe of Lash and Drake (1984) Ganis and others (2001, pg. 125) indicate it would be challenging due to the lack of biostratigraphic control in the eastern part of the klippe.

As indicated above, Ganis and others (2001) cited Parris and Cruikshank (1992) for a *C. bicornis* Zone determination for the lower Martinsburg Formation in New Jersey. This would be Parris and others (1992) graptolite locality 22 at Middleville, New Jersey. At this site the Martinsburg is exposed within 35 feet of the Jacksonburg Limestone. According to Sherwood (1964, p. 19) and Drake and others (1996), the Jacksonburg is conformable with the Martinsburg Formation in New Jersey and eastern Pennsylvania. Parris and others (1993) and Parris and others (2001) described two additional localities with faunas from the lowest part of the Bushkill Member (lowest member) of the Martinsburg Formation, one from an outlier within the Highlands near Port Murray and one from the Kittatinny Valley near Monroe, Sussex County. Both localities have graptolitic and shelly faunas, but at Port Murray, Warren County, the shelly fauna was too poorly preserved to identify. Using graptolites, the age of the base of the Martinsburg Formation at both locations is *Corynoides americanus* Subzone of the *Orthograptus amplexicaulus* Zone of Berry (1960). At the Monroe locality, the units appear conformable with the Jacksonburg Limestone being exposed less than 30 feet stratigraphically below the Martinsburg Formation, a covered distance similar to that at the Middleville, Sussex County locality (Parris and Cruikshank, 1992). All three of these lower Bushkill localities contained *Glyptograptus euglyphus,* but it was the two described by Parris and others (1993), and Parris and others (2001) that defined the age of the base of the Martinsburg as the *Orthograptus amplexicaulus* Zone, not the older *C. bicornis* Zone (postulated in Parris and Cruikshank, 1992) because they both contained *O. amplexicaulus* in addition to *G. euglyphus*. The Monroe locality is the lowest (oldest) dated occurrence of the Martinsburg in New Jersey because it contains a shelly fauna similar to the fauna found in the underlying Jacksonburg, with many of the same taxa.

The upper part of the Jacksonburg Limestone had been correlated with the Hull and Sherman Falls of the New York Standard Column by Miller (1937). Harris and others (1995, p. 6) stated, based on conodonts, the Jacksonburg is no older than late Middle Ordovician (now Upper Ordovician), (Kirkfieldian Stage), *Plectodina tenuis* Zone. Harris and others (1995) also described a Jacksonburg fauna from the Clinton area as an *Amorphognathus superbus* Zone fauna of the North Atlantic Realm which was different from the North American Midcontinent Realm faunas found in the Jacksonburg outliers in the Highlands and the Jacksonburg of the Kittatinny Valley. Barnett (1965) collected conodonts from eight localities identified as the Jacksonburg Limestone, with three being from eastern Pennsylvania and five being from New Jersey. One of the New Jersey locations was the type locality at Jacksonburg and one was from just south of Clinton. Barnett (1965, p. 66) indicated the Jacksonburg Limestone conodont fauna from Clinton bore a striking resemblance to three faunas from limestones in Wales rather than the Midcontinent fauna of the Jacksonburg Limestone of the Highlands, and Valley and Ridge Provinces only a few miles to the northwest of Clinton locality.

At first glance, the Jutland rocks seem related to the Hamburg klippe sequence (Ganis and Wise, 2008 use the name Martinsburg/Dauphin Foreland Segment for the Hamburg rocks and Codegone and others, 2012 retain the name Hamburg Klippe) because the Jutland and Hamburg rocks have similar lithologies, and both rest on Cambrian and Ordovician carbonate shelf rocks, but some questions exist. The Jutland rocks are located on the southeast side of the crystalline Highlands and underlie the rocks of the Mesozoic Basin of the Piedmont Province. The Hamburg klippe sequence is on the northwest side of the Highlands-Reading Prong in the Valley and Ridge Province. The Jutland sequence, in the Clinton area, sits on Upper Ordovician limestones equivalent in age to the Jacksonburg Limestone in addition to Cambrian and Lower Ordovician carbonate shelf rocks similar to the ones that the Hamburg klippe overlies in eastern Pennsylvania. The Jacksonburg Limestone, or its equivalent near Clinton, contains a North Atlantic conodont fauna that is more similar to the fauna from the Pen-y-garnedd, the Gelli-grin, and the Crug Limestones of Wales (Barnett, 1965, p. 66). The Jacksonburg Limestone, a few miles to the north, within the Highlands Province and the Valley and Ridge Province of eastern Pennsylvania and New Jersey contains a Midcontinent conodont fauna as opposed to the North Atlantic fauna. The Cambrian and Lower Ordovician shelf rocks in the Valley and Ridge, Highlands, and Piedmont Provinces all contain Midcontinent conodont faunas. Therefore, it is possible that the Upper Ordovician Jacksonburg like rocks were transported in just prior to the emplacement of the older Jutland rocks. The Jutland sequence has over 1,400 feet of section below the oldest rocks, dated as Late Cambrian by conodonts. The lowermost part of the Jutland, in places, is lithologically similar and could be confused with the Martinsburg Formation when looking at a single outcrop, but when the rock is examined closely it is substantially different and does not display the cleavage that is characteristic of the Martinsburg of both the Highlands and Valley and Ridge Provinces. In the Jutland-Clinton area the rocks are extensively folded and faulted, but the rocks have remained as a coherent mass as indicated by several marker horizons that can be traced throughout the entire area. Whereas the Hamburg klippe stratigraphy is extremely chaotic as discussed by the authors cited above.

A comparison of table 3, a listing of all the graptolites identified in the Jutland sequence, to the graptolites found in the eastern part of the Hamburg klippe (Wright and Stephens, 1978, and Wright and others, 1979) and the western part described by Ganis and others, (2001) has about ten to twelve common species with the Jutland. Even though there are some common species between the Jutland rocks and both the eastern and western parts of the Hamburg Klippe it may not be possible to correlate the New Jersey rocks to the Hamburg klippe section due to the substantial lack of common species. The Jutland sequence has more species in common with the Deepkill and Normanskill as described by Berry (1962) than with the Hamburg klippe sequence. Fossil evidence also indicates the Jutland sequence has a more complete sequence of rocks from the Late Cambrian through the Late Ordovician than the eastern part of the Hamburg klippe.

As discussed earlier, a nearly complete section of rock in a quarry was sampled by Parris and others (1998) with graptolites representative of zones 8 (Isograptus) through 10 (Hustedograptus cf. H. teretiusculus) being identified. They included a fourth nearby locality, in the same quarry area, that was identified by Finney in 1991 as being from the N. gracilis Zone (Zone 11). The graptolite Nemagraptus gracilis was identified by Weller and confirmed by Ruedemann (Weller, 1903), and Climacograptus bicornis was identified by Berry (Perissoratis and others, 1979). All of the Parris and others (1998) localities are from the varicolored shales and siltstones characteristic of the upper part of the Jutland sequence, not rocks which resemble the Martinsburg Formation. Graptolites representative of zones 2 to 4 up to and including the Climacograptus bicornis Zone (Zone 12) graptolites, have been found in the Jutland rocks of the Clinton and Annandale area. The Peapack-Gladstone (Chester) area has yielded only one graptolite locality, which was identified, by Finney in 1991, to the N. gracilis or C. bicornis zones. Two conodont localities, possibly from the same shale pit as the graptolite sample were identified as Middle Ordovician (Ethington and others, 1958) and late Early or early Middle Ordovician (Oepikodus evae to Baltoniodus navis zones) by Harris and others (1995). The Jutland sequence in the Peapack-Gladstone valley has limited exposure and has not been mapped at the detail of the Clinton area but based on the lack of certain distinct marker horizons and the few fossil identifications to date it is likely that only the Hensfoot Formation is present in the Peapack-Gladstone area. No fossils have been found in the other occurrences of the Jutland type rocks along the northwestern edge of the Newark Basin or the one out in the basin at Stanton Station.

Appendix A

The Tables

Table A1

Graptolite Data

Locality	Collected by or location name	Latitude*	Longitude*	Cross reference	Identification by/ or report**	Zone***
1	Dodge 1 (Hedgehaven Farm)	40 38 32	74 57 28	Perissoratis 1	1, 4	2 to 4
2	Dodge 4	40 37 22	74 56 28	Perissoratis 2	1, 4	2 to 4
3	Dodge 2	40 38 03	74 56 40	Perissoratis 3	1, 4	9?
4	Dodge 3	40 38 03	74 56 40	Perissoratis 4	1, 4	9?
5	Weller Locality	40 37 22	74 57 38	Perissoratis 5	2, 4	11 to 12
6	Twitchell 1914	40 37 23	74 57 04	Perissoratis 6	3, 4	11
7	Perissoratis 7	40 37 53	74 57 23		4	11
8	Perissoratis 8	40 37 51	74 57 20		4	12
9	Perissoratis 9	40 37 35	74 57 08		4	10?
10	Perissoratis 10	40 38 07	74 56 49		4	12?
11	Perissoratis 11	40 38 09	74 56 45		4	10
12	Perissoratis 12	40 38 08	74 56 41		4	10?
13	Perissoratis 13	40 38 08	74 56 39		4	10?
14	Perissoratis 14	40 38 07	74 56 33		4	11 to 12
15	Perissoratis 15	40 37 56	74 57 54		4	4 to 8
16	Perissoratis 16	40 38 02	74 57 47		4	11 to 12
17	Volkert Locality	40 37 20	74 57 32		6	10 to 11
18	Union Courthouse	40 37 36	74 57 45		7, 8	*D. clingani* Zone, Zone 11
19	Clinton Block	40 37 54	74 57 07		9	8
20	Clinton Block	40 37 54	74 57 07		9	9
21	Clinton Block	40 37 54	74 57 07		9	10
22	Clinton Block	40 38 03	74 56 53	FJM locality 1(a)	5, 9	*N. gracilis* to *C. bicornis* Zones, Zone 11
23	FJM Locality 1	40 38 02	74 56 55		5	*Isograptus* to *P. tentaculatus* Zones
24	FJM Locality 2	40 37 58	74 57 04		5	*Isograptus* Zone
25	FJM Locality 3	40 38 01	74 56 40		5	*N. gracilis* to *C. bicornis* Zones?
26	FJM Locality 4	40 38 02	74 56 50		5	*H. teretiusculus* to *C. bicornis* Zones

Table A1 (con't)

27	FJM Locality 4 rear National gas stop	40 38 02	74 56 50		5	*P. etheridgei to H. teretiusculus* Zones
28	FJM Locality 4(a)	40 37 52	74 56 55		5	*P. etheridgei to C. bicornis* Zones
29	FJM Locality 6	40 38 04	74 56 58		5	*C. bicornis* Zone (classic Normanskill Shale)
30	Twitchell Locality	40 37 23	74 57 04	Perissoratis 6	5	Mid to Upper Ordovician
30	20 ft. above Twitchell	40 37 23	74 57 04	Perissoratis 6	5	*P. etheridgei to C. bicornis* Zones
30	20 ft. below Twitchell	40 37 23	74 57 04	Perissoratis 6	5	*C. bicornis* Zone
31	FJM Locality J-35	40 37 57	74 57 52		5	*C. bicornis* Zone
32	FJM Locality J-41	40 37 58	74 56 56		5	*P. etheridgei to H. teretiusculus* Zones
33	FJM Locality 7	40 38 06	74 56 49		5	??
34	Jennings shale pit	40 46 15	74 38 32		5	*N. gracilis* to *C. bicornis* Zones
35	S & P Hedgehaven Farm	40 38 32	74 57 28		10	*P. etheridgei* Zone

* Latitude and longitude are degrees, minutes and seconds in NAD 83.

** 1. Harry W. Dodge Senior Thesis (1952)
2. Weller (1903)
3. Rudolf Ruedemann 1931 letter to H. B. Kümmel about Twitchell's 1914 locality
4. Perissoratis and others (1979)
5. Stanley Finney 1991 letter to R. Dalton
6. Clair Carter 10/05/84 report to Jack Epstein
7. Clair Carter10/22/84 report to Jack Epstein
8. Parris and Cruikshank (1986)
9. Parris and others (1998)
10. Subramanian and Parris (2016)

*** Only the zones of Berry (1960 & 1968) from Perissoratis and others (1979), Parris and Cruikshank (1986), Parris and others (1998) and the Finney zones (based on Ross and others, 1982) are listed. The Dodge identifications used Deepkill zones of Ruedmann (1947 p. 61 & 63) and are not used on this table since Berry converted Dodge's data to his zonation for Perissoratis (1974) and Perissoratis and others (1979).

Table A2

Conodont Data

Locality	Collected by or location name	Latitude*	Longitude*	Cross reference or USGS no.	Identification by/or report **	Age or zone By cited Report***
101	Markewicz Conodont, Clinton	40 38 06	74 56 59		1	Middle Ordovician
102	4-23-74A	40 38 05	74 57 03	USGS 8675-CO	2	early Middle Ordovician
103	4-23-74B	40 37 18	74 52 59	Barnett, 1965, 11251-CO	2, 3	latest Middle Ordovician/ *Am. superbus*
104	8674-CO	40 38 07	74 57 57	8674-CO	2	Middle Ordovician
105	9105-CO Drake, Chester	40 46 19	74 38 30	9105-CO	2	late Early or early Middle Ordovician/*Oe. evae to Ba. navis*
106	Markewicz Conodont, Chester	40 46 15	74 38 32		1	early Middle Ordovician
107	HB-337	40 38 14	74 53 51	11280-CO	2	latest Cambrian
108	HB-359	40 38 18	74 57 39	11235-CO		early Middle Ordovician
109	HB-367	40 38 15	74 56 51	11252-CO	2	Early Ordovician/ *C. angulatus or R. manitouensis*
110	HBNJ-468	40 38 01	74 57 53	11250-CO	2	early to middle Middle Ordovician (latest Arenigian to Llanvirnian).
111	HBNJ-469-1	40 38 01	74 57 04	11277-CO	2	early Middle Ordovician
112	HBNJ-469-2	40 38 00	74 57 05	11278-CO	2	earliest Middle Ordovician
113	HBNJ-470	40 38 10	74 57 14	11253-CO	2	early to middle Middle Ordovician (latest Arenigian to Llandeilian)
114	Pt-18	40 37 21	74 56 18	11243-CO	2	latest Cambrian or earliest Ordovician

Table A2 (con't)

Locality	Collected by or location name	Latitude*	Longitude*	Cross reference or USGS no.	Identification by/or report **	Age or zone By cited Report***
115	PT-NJ-35	40 37 02	74 56 11	11244-CO	2	Cambrian or earliest Ordovician
116	PT-NJ-44	40 36 44	74 56 33	11245-CO	2	Cambrian or earliest Ordovician
117	PT-NJ-98	40 37 15	74 56 36	11246-CO	2	Late Cambrian or earliest Ordovician

Note: all localities are from the Jutland rocks except for locality 103 which is in the Jacksonburg Formation.

* Latitude and longitude are degrees, minutes and seconds in NAD 83.

** 1 - Ethington and others, 1958
2 - Harris and others, 1995
3 - Barnett, 1965

*** The ages cited are those used in the various reports and may not match figure 2 of this report since it follows the International Commission on Stratigraphy.

Table A3

Graptolites Found In Jutland Klippe Sequence

Genus and Species	Reference *
Acrograptus sp. cf. *A. nicholsoni* (Lapworth)	3, 4, 6, **
Acrograptus sp. cf. *A. nicholsoni* var. *planus* Elles and Wood	6, **
Adelograptus sp. cf. *A. pusillus* (Ruedemann)	3, 4, 6
Adelograptus lapworthi (Ruedemann)	3, 4, 6
Araneograptus sp. cf. *A. murrayi (*Hall)	6, **
Araneograptus murrayi (Hall)	3, 4, **
Archiclimacograptus sp. cf. *A. riddelensis* Harris	6, **
Archiclimacograptus angulatus Bulman	8, 1, **
Archiclimacograptus arctus (Elles and Wood)	6, **
Archiclimacograptus decoratus Harris and Thomas	4, 6, **
Archiclimacograptus modestus (Ruedemann)	6, 8, 9, 10, **
Archiclimacograptus phyllophorus (Gurley)	1, 6, **
Archiclimacograptus riddelensis (Harris)	4, 6, **
Callograptus sp. cf. *C. salteri* Hall	4, 5, 6
Callograptus salteri (Hall)	3
Climacograptus bicornis Hall	4, 6
Climacograptus bicornis Hall?	6, 11
Clonograptus sp.	4, 5, 6
Cryptograptus?	8, 11
Cryptograptus sp.	8, 11
*Cryptograptus antennariu*s (Hall)	3, 4, 6
Cryptograptus tricornis (Carruthers)	4, 6, 8, 11, 12
Dicellograptus?	8, 11
Dicellograptus sp.	4, 6, 7, 8, 9, 10
dichograptidae, genus indet.	8
dichograptidae	6
Dicranograptus? sp	9
Dicranograptus sp	6, 7, 8, 13
Dicranograptus sp. cf. *D. kirki* Ruedemann	7, 8
Dicranograptus cf. *D. kirki* Ruedemann	9, 10
Dicranograptus nicholsoni?	11
Dicranograptus ramosus (Hall)	1, 6, 7, 8, 9, 10
Dictyonema sp. cf. *D. quadrangulare* Hall	4,5,6
Dictyonema amplum (Ruedemann)	3, 4,
Didymograptus bifidus (Hall)	3, 4,
Diplacanthograptus sp. cf. *D. caudatus* (Lapworth)	10, **
Diplacanthograptus caudatus?	11, **
Diplacanthograptus spiniferus?	11, **

Table A3 (con't)

Genus and Species	Reference *
Expansograptus sp.	11, **
Expansograptus sp. cf. *D. extensus* Hall	8, **
Expansograptus extensus (Hall)	3, 4, **
Expansograptus sagitticaulis Gurley	7,8, **
Glossograptus sp.	8, 11, 12
Glossograptus sp. cf. *G. hystrix* Ruedemann	3, 4, 6
Glossograptus ciliatus Emmons	7, 8, 11
Goniograptus sp.	11
Goniograptus thureaui var. *postremus* (Ruedemann)	3, 4,
Hallograptus?	8, 11
Hallograptus? sp.	6
Hallograptus sp.	11
Hustedograptus sp. cf. *H. teretiusculus* (Hissinger)	6
Hustedograptus angustifolius (Hall)	2, 6, **
Hustedograptus teretiusculus (Hissinger)	4, 8, 12
Isograptus?	11
Isograptus sp.	8, 11, 12
Isograptus victoriae Harris?	11
Isograptus victoriae maximus Harris	8, 11, 12
Isograptus victoriae maximus Harris?	12
Isograptus victoriae ssp.?	12
Jiangxigraptus divaricatus var. salopiensis Elles and Wood	8, 9, 10, **
Jiangxigraptus sextans (Hall)	2, 4, 5, 6, **
Jiangxigraptus smithi Ruedemann	4, 5, 6, **
Jiangxigraptus sp. cf. *J. divaricatus* (Hall)	2, 4, 5, 6, **
Nemagraptus?	8, 11
Nemagraptus? sp.	11
Nemagraptus sp.	6, 13
Nemagraptus? *gracilis*?	11
Nemagraptus gracilis?	11
Nemagraptus gracilis (Hall)	1, 4
Ningxiagraptus? *trentonensis* (Ruedemann)	11, **
Normalograptus brevis (Elles and Wood)	11, **
Normalograptus euglyphus (Lapworth)	11, **
Orthograptus sp.	4, 6, 11
Orthograptus quadrimucronatus (Hall)?	11
Paralossograptus sp. cf. *holmi* Bulman	8, **
Paraglossograptus holmi?	12, **
Parisograptus sp. (*I. caduceus* or *I. forcipiformis*)	11, **
Parisograptus forcipiformis (Ruedemann)	8, 11, **

Table A3 (con't)

Genus and Species	Reference *
Pseudisograptus sp.	8, 12
Pseudoclimacograptus? sp.	9, 10
Pseudoclimacograptus sp.	6, 7, 8, 11, 13
Pseudoclimacograptus modestus or *scharenberi*	11
Pseudoclimacograptus scharenbergi (Lapworth)	8
Pseudoclimacograptus scharenbergi cf. var. *stenostoma* (Bulman)	4, 5, 6
Pseudotrigonograptus ensiformis (Hall)	8, 11, 12
Pterograptus sp.	11
? *Reteograptus geintizianus* Hall	8
Retiograptus sp.	4, 6
Reteograptus geinitzianus Hall	1, 6, 11, 12
sigmagraptid	11
Sigmagraptus or *Holmograptus*	12
Styracograptus tubuliferus?	11, **
Tetragraptus sp.	11, 12
Tetragraptus sp. cf. *T. bigsbyi* Hall or *T. serra* Brongniart	8
Tetragraptus sp. cf. *T. quadribrachiatus* (Hall)	4, 5, 6, 13
Tetragraptus bigsbyi (Hall)	11
Tetragraptus clarkei (Ruedemann)	3, 4,
Tetragraptus quadribrachiatus (Hall)	3, 4,
Tetragraptus serra (Brongniart)	11
Xiphograptus? sp.	11
Xiphograptus svalbardensis (Archer and Fortey)	8, 12

*Source of graptolite identifications or reference they were published in.

**Graptolite names updated by Dr. Charles E. Mitchell, December 16, 2018 letter to William Graff on file at the New Jersey Geological and Water Survey (see table B in Appendix B for a listing of graptolites as originally identified).

1. Weller (1903)
2. R. Ruedemann letter to H. B. Kümmel 4/6/1931
3. H. Dodge Senior Thesis (1952)
4. Constantine Perissoratis MS Thesis (1974)
5. Dodge and Newman collected graptolites in 1964, reference from Perissoratis MS Thesis 1974, p. 18 indicates Berry identified the graptolites collected by Dodge and Newman in 1964.
6. Perissoratis and others (1979)
7. Parris and Cruikshank (1986)
8. Parris and others (1998
9. Clair Carter 10/05/1984 report to Jack Epstein (Volkert site)
10. Clair Carter 10/22/1984 report to Jack Epstein (Union Courthouse site)
11. Stanley Finney letter to Richard Dalton dated 10/16/1991
12. Stanley Finney letter to David Parris dated 10/7/1996, cited in Parris and others (1998)
13. Subramanian and Parris (2016)

Table A4

Graptolite Taxa Of The Jutland Klippe Sequence Of New Jersey

Graptolite taxa of the Jutland klippe rocks of New Jersey provides the graptolite zone; and other information. See Table A4 Supplementary Notes for more information.

Locality #1: *Adelograptus lapworthi* (Ruedemann)
Adelograptus sp. cf. *A. pusillus* (Ruedemann)
Callograptus sp. cf. *C. salteri* (Hall)
Clonograptus sp.
Dictyonema sp. cf. *D. quadrangulare* (Hall)
Dictyonema sp. cf. *D. murrayi* (Hall)
Tetragraptus sp. cf. *T. quadribrachiatus* (Hall)

Correlation: Berry's Zones 2-4, according to Perissoratis and others (1979).

In addition to the species listed above which are from Perissoratis and others (1979), some additional species were identified by Dodge (1952) and listed in Perissoratis (1974). According to Perissoratis (1974, p. 18) Newman and Dodge (1964) recollected the Hedgehaven Farm site and the graptolites were identified by William Berry. Perissoratis further indicates that he did not collect this site. The additional species identified by Berry were:

Dictyonema sp.
Didymograptus sp.

Additional species identified by Dodge (see Supplementary Note 2) and listed in Parissoratis (1974), but not in Perissoratis and others (1979) were:

Dictyonema amplum (Ruedemann)
Didmograptus bifidus (Hall)
Didmograptus extensus (Hall)
Goniograptus thureaui (McCoy) var. *postremus* (Ruedemann)
*Tetragraptus clark*ei (Ruedemann).

Specimens collected by New Jersey State Museum (NJSM) in 1994 and originally believed to be from the original Dodge Hedgehaven Farm site are in repository at the museum and are catalogued as NJSM GP16566 and GP16131 (see Locality 35 below).

Locality #2: *Adelograptus lapworthi* (Ruedemann)
Tetragraptus sp. cf. *T. quadribrachiatus* (Hall)

Correlation: Berry's Zones 2-4, according to Perissoratis et al. (1979)

Additional species identified by Dodge (see Supplementary Note 2 below) and listed in Parissoratis (1974) were:

Tetragraptus clarkei (Ruedemann).

Table A4 (con't)

Locality 3: *Cryptograptus antennarius* (Hall)
Didymograptus sp. cf. *D. nicholsoni* (Lapworth)
Glossograptus sp. cf. *G. hystrix* (Ruedemann)

Correlation: Berry's Zone 9 (probable), according to Perissoratis et al., (1979)

Locality 4: *Cryptograptus antennarius* (Hall)
Dichograptidae

Correlation: Berry's Zone 9 (probable), according to Perissoratis et al., (1979)
Additional species identified by Dodge (see Supplementaary Note 2 below) and listed in Parissoratis (1974) were

Clonograptus flexilus (Hall)? (a fragment).

Locality 5: *Climacograptus phyllophorus* (Gurley)
Dicranograptus ramosus (Hall)
Nemagraptus sp.
Reteograptus geinitzianus (Hall)

Correlation: Berry's Zones 11-12, according to Perissoratis et al., (1979)

This is Weller's (1903) locality and he used *Ceonograptus gracilus* (Hall) as did R. Ruedemann who identified the graptolite samples for Weller whereas Berry used *Nemagraptus* sp. without looking at the sample.

Locality 6: *Pseudoclimacograptus scharenbergi* (Lapworth)
Diplograptus angustifolius (Hall)
Dicellograptus sp. cf. *D. divaricatus* (Hall)
Dicellograptus sextans (Hall)
Dicellograptus smithi (Ruedemann)
Dicranograptus sp.
Glyptograptus sp.
Pseudoclimacograptus scharenbergi cf. var. *stenostoma* (Bulman)

Correlation: Berry's Zone 11, according to Perissoratis and others (1979).

This is the Twitchell 1914 locality identified by Ruedemann in 1931. Recollected by Neuman and Dodge (1964) and identified by Berry. Some specimens from this site are in repository at the New Jersey State Museum, catalogued as NJSM GP8132 and GP10914 - 10920.

Locality 7: *Pseudoclimacograptus scharenbergi* cf. var. *stenostoma* (Bulman)
Climacograptus sp. cf. *C. riddelensis* (Harris)
Cryptograptus tricornis (Caruthers)
Glyptograptus sp.
Orthograptus sp.
Retiograptus sp.

Correlation: Berry's Zone 11, according to Perissoratis and others (1979).

Table A4 (con't)

Locality 8: *Climacograptus bicornis* (Hall)?
Pseudoclimacograptus scharenbergi cf. var. *stenostoma* (Bulman)
Glyptograptus sp.

Correlation: Berry's Zone 12, according to Perissoratis and others (1979).

Locality 9: *Amplexograptus arctus (Elles and Wood)*
Climacograptus sp. cf. *C. riddelensis* (Harris)
Diplograptus sp.
Glyptograptus sp.
Pseudoclimacograptus sp.

Correlation: Berry's Zone 10 (probable), according to Perissoratis and others (1979).

Locality 10: *Climacograptus bicornis* (Hall)
Cryptograptus tricornis (Carruthers)
Glyptograptus sp.

Correlation: Berry's Zone 12 (probable), according to Perissoratis and others (1979).

Locality 11: *Climacograptus riddelensis* Harris
Cryptograptus tricornis (Carruthers)
Diplograptus decoratus (Harris and Thomas)
Hustedograptus sp. cf. *H. teretiusculus* (Hissinger)

Correlation: Berry's Zone 10, according to Perissoratis and others (1979).

Locality 12/13: *Amplexograptus* sp.
Cryptograptus tricornis (Carruthers)
Diplograptus? sp.
Glyptograptus sp.
Hallograptus? sp.
Pseudoclimacograptus sp.

Correlation: Berry's Zone 10 (probable), according to Perissoratis (1979).

Locality 14: *Climacograptus* sp.

Correlation: Berry's Zones 11-12, according to Perissoratis and others (1979).

Locality 15: *Didymograptus* sp. cf. *D. nicholsoni* var. *planus* (Elles and Wood)

Correlation: Berry's Zones 4-8, according to Perissoratis and others (1979).

Table A4 (con't)

Locality 16: *Dicellograptus* sp.

Correlation: Berry's Zones 11-12, according to Perissoratis and others (1979).

Locality 17: *Pseudoclimacograptus modestus* (Ruedemann)
Dicellograptus divaricatus var. *salopiensis* (Elles and Wood)
Dicellograptus sp.
Dicranograptus? sp.
Didymograptus? sp.
Didymograptus sagitticaulis (Gurley)
Climacograptus sp.
Glyptograptus? sp.

Correlation: Berry's Zone 11, according to Parris and others (1998).

These specimens are in repository at the New Jersey State Museum (NJSM) catalogued as NJSM GP12725.

Locality 18: *Didymograptus sagitticaulis* (Gurley)
Didymograptus sp.
Dicellograptus sp.
Dicranograptus sp. cf. *D. kirki* (Ruedemann)
Dicranograptus ramosus (Hall)
Dicranograptus sp.
Glossograptus ciliatus (Emmons)
Climacograptus sp.
Pseudoclimacograptus sp.

Correlation: Berry's Zone 11, according to Parris and others (1998).

All specimens from this site are in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP12240, 12241, 12243, 12245, 12247, 12514, 12536, 12543, 12548-12252, 12735-12738, 12740, 12742, 12902, 12904, 12906, 12908, 12910, 12911, 12913, 12915, 12916, 13471, 13531, 13544.

Locality 19: *Isograptus forcipiformis* (Ruedemann)
Didymograptus sp. cf. *D. extensus* (Hall)
Pseudotrigonograptus ensiformis (Hall)
Tetragraptus sp. cf. *bigsbyi* (Hall or *serra* Brongniart)
Xiphograptus svalbardensis (Archer and Fortey)
Isograptus victoriae maximus (Harris)
Pseudisograptus sp.

Correlation: Berry's Zone 8, according to Parris and others (1998).

Specimens from this site are in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP16481-16490.

Table A4 (con't)

Locality 20: *Isograptus* sp.
Cryptograptus tricornis (Carruthers)
Glossograptus sp. cf. *holmi* (Bulman)
Climacograptus sp.

Correlation: Berry's Zone 9, according to Parris and others (1998).

Specimens from this site are in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP16564.

Locality 21: *Hustedograptus teretiusculus* (Hissinger)
Dichograptidae, genus indet.
Pseudoclimacograptus angulatus (Bulman)
Cryptograptus tricornis (Carruthers)
?*Reteograptus geinitzianus* (Hall)
Climacograptus sp.

Correlation: Berry's Zone 10, according to Parris and others (1998).

Specimens from this site are in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP16565.

Note: localities 22 to 34 were collected by Frank Markewicz in the 1950's and 1960's and were identified by Dr. Stanley Finney (letter to Richard Dalton dated October 16, 1991). All the ages by Finney are based on the chart of Ross and others (1982). The specimens are in the custody of the New Jersey State Museum; but are currently uncatalogued. All the localities are from the Clinton area of Hunterdon County except for one from near Chester, Morris County, New Jersey.

Locality 22: *Hallograptus*?
Dicellograptus?
Nemagraptus?
Glyptograptus?
Climacograptus sp.
Didymograptus sp.
Glossograptus sp.
Cryptograptus sp.
Pseudoclimacograptus sp.

Correlation: Berry's Zone 11, according to Parris and others (1998).

Finney (1991) correlation for this locality: *N. gracillis* to *C. bicornis* zones; upper Whiterockian to lower Mohawkin; upper Llandeilo to lower Caradoc. Specimens are badly cleaved and difficult to identify.

Locality 23: *Isograptus forcipiformis* (Ruedemann)
Didymograptus sp.
Tetragraptus sp.
Xiphograptus? sp.
Isograptus victoriae (Harris?)

Table A4 (con't)

Correlation: *Isograptu*s to *P. tentaculatus* zones; lower to middle Whiterockian; upper Arenig to lower Llanvirn, according to Finney (1991).

Locality 24: *Dictyonema* sp.
Didymograptus (*Expansograptus*) sp.
Goniograptus sp.
Isograptus?
Isograptus sp. (*I. caduceus* or *I. forcipiformis*)
*Isograptus victoriae maximus (*Harris)
Pseudotrigononograptus ensiformis (Hall)
Tetragraptus sp.
Tetragraptus bigsbyi (Hall)
Tetragraptus serra (Brongniart)

Correlation: *Isograptus* Zone; lower Whiterockian; mid to upper Arenig, according to Finney (1991).

Locality 25: *Cryptograptus tricornis* (Carruthers)
Glossograptus sp.
Glyptograptus sp.
Pseudoclimacograptus sp.
Nemagraptus? sp.

Correlation: *P. etheridgei* to *O. quadrimucronatus* Zone; but *Nemacograptus* identification, if correct would restrict correlation to *N. gracillis* to *C. bicornis* zones; uppermost Whiterockian to lowest Mohawkian. Note specimens were coated with a spray to protect them which made identification difficult, according to Finney (1991).

Locality 26: *Climacograptus* sp.
Cryptograptus tricornis (Carruthers)
Didymograptus sp.
Glossograptus sp.
Glyptograptus sp.
Nemagraptus? sp.
Orthograptus sp.
Tetragraptus sp.

Correlation: *G. teretitusculus* to *C. bicornis* zones; uppermost Whiterockian to lower Mohawkian; Llandeilo to lower Caradoc, according to Finney (1991).

Locality 27: *Cryptograptus tricornis* (Carruthers)
Didymograptus sp.
Isograptus sp.
Pseudoclimacograptus sp.
sigmagraptid

Correlation: *P. etheridgei* to *H. teretiusculus* zones; upper Whiterockian; Llanvirn to lower Llandeilo, according to Finney (1991).

Table A4 (con't)

Locality 28: *Cryptograptus*?
Glyptograptus sp.
Pseudoclimacograptus sp.
dichograptid stripe fragment

Correlation: very uncertain; *P. etheridgei* to *C. bicornis* zones; upper Whiterockian to lower Mohawkian; Llanvirn to Caradoc, according to Finney (1991).

Locality 29: *Climacograptus* sp.
Climacograptus brevis (Elles and Wood)
Cryptograptus sp.
Didymograptus sp.
Glossograptus ciliatus Emmons
Glyptograptus sp.
Leptograptus trentonensis
Nemagraptus? *gracilis*?
Orthograptus quadrimucronatus (Hall)?
Pseudoclimacograptus sp.
dendroid fragmen
t

Correlation: *C. bicornis* Zone; (same age as classic Normanskill Shale); lower Mohawkian; lower Cardoc, according to Finney (1991).

Locality 30: Locality 30 is the same location as Locality 6 above. That locality was originally collected by Assistant State Geologist M. W. Twitchell in 1914 and the graptolites were identified by Ruedemann (letter to State Geologist H. B. Kümmel in 1931). It was later recollected by Newman and Dodge (1964) and the graptolites were identified by Berry. The graptolites identified below were collected from three levels about 20 feet apart by Frank Markewicz in 1950 - 1960 and were identified by Finney in 1991. It is not clear if the beds collected by Markewicz are the exact beds that Twitchell and later Neuman and Dodge collected or that several species in the Markewicz collection better defined the zone interpretation since Locality 6 was identified as Berry's Zone 11, according to Perissoratis and others (1979). One bed in this collection is identified as *C. bicornis* Zone (Zone 12 of Berry 1960, 1968) and the other two beds are more uncertain as to the exact zone.

Lower bed: *Climacograptus bicornis*?
C. brevis (Elles and Wood)
C. caudatus?
C. spiniferus?
C. tubuliferus?
Cryptograptus sp.
Glossograptus sp.
Glyptograptus sp.
Hallograptus sp.
Nemagraptus?
Pseudoclimacograptus sp.
Reteograptus geintzianus (Hall)

Correlation: *C. bicornis* Zone; (same age as classic Normanskill Shale); lower Mohawkian; lower Cardoc.

Table A4 (con't)

Middle bed: *Climacograptus* sp.

Correlation: Middle to Upper Ordovician.

Upper bed: *Glyptograptus euglyphus* (Lapworth)
Pseudoclimacograptus sp.

Correlation: uncertain; *P. etheridgei* to *C. bicornis* zones; upper Whiterockian to lower Mohawkian; Llanvirn to lower Caradoc, according to Finney (1991).

Locality 31: *Dicranograptus nicholsoni*?
Pseudoclimacograptus modestus (Ruedemann) *or scharenbergi* (Lapworth)

Correlation: *C. bicornis* Zone; lower Mohawkian; lower Caradoc, according to Finney (1991).

Parris et al. (1998) incorrectly ascribed some specimens in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP1877 and identified as *Pseudoclimacograptus scharenbergi* (Lapworth) to Locality 16 of Perissoratis et al. (1979), but based on the labeling they are more likely from this nearby locality collected by Frank Markewicz in 1966. (See supplemental notes below).

Locality 32: *Cryptograptus* sp.
Glossograptus sp.
Pseudoclimacograptus?
Pterograptus sp.
nemagraptid?

Correlation: *P. etheridei* to *G. teretiusculus* zones; upper Whiterockian; Llanvirn to lower Llandeilo, according to Finney (1991).

Locality 33

Correlation: Many shapes similar to the graptolites *Nemagraptus* and *Pleurograptus*, but cannot determine if they are even graptolites, according to Finney (1991).

Locality 34: This locality is in the Peapack-Gladstone valley klippe about 18 miles to the northeast of the Jutland klippe.

Nemagraptus gracilis?

Correlation: *N. gracilis* to *C. bicornis* zones; upper Whiterockian to lower Mohawkian; Llandeilo to lower Caradoc, according to Finney (1991).

Locality 35: This locality is on the old Hedgehaven Farm but is not the original Dodge Hedgehaven Farm site (Locality 1).

Climacograptus sp.
Pseudoclimacograptus sp.
etragraptus sp. cf. *T. quadribrachiatus* (Hall)

Nemagraptus sp.
Dicranograptus sp.

Correlation: *Paraglossograptus etheridgei* Zone, according to Subramanian and Parris (2016) but based on *Nemagraptus* and *Dicranograptus* it would be upper *H. teretiusculus* to lower *C. bicornis* zones.

All specimens from this site are in repository at the New Jersey State Museum (NJSM), catalogued as NJSM GP11566, 24049, 24050, 24051, 24052, 24053, 24054, 24055, 24056.

Supplemental Notes On The Jutland Area Graptolite Taxa

1. Parris and others (1998), Appendix 1, included a consideration of all published specimens since the work of Weller, but did include some errors in style of citation and interpretation. The list has been revised accordingly. As originally noted, it was necessary to accept the work of some previous authors rather uncritically, since the specimens were not placed in public repositories and seem to be lost in many cases. The New Jersey State Museum is the repository for all specimens that can now be located. Localities 1 through 16 of Parris and others (1998) are the localities discussed in Perissoratis and others (1979). Localities 17 through 22 are new localities described Parris and other (1998). The rest of the localities on this table are ones not previously described.

2. Manuscript names cannot be validly cited if they were never described in a publication, and this is apparently the case for specimens in Harry Dodge's senior thesis and other theses and letters. The specimens described by Dodge (1952) are mostly well illustrated and current identifications would probably differ little from those given by him; B. F. Howell assisted him with identifications. It would be incorrect to use the manuscript names if the taxon was never officially published, especially if the specimens cannot be found.

3. Correct listing of a species with a complete scientific name should include the original author of the taxon. Meticulous publications, such as the monograph of Ruedemann (1947) will list the author unparenthetically if the taxon is exactly as he or she described it. If it is different, such as a species being listed in a different or newly described genus, the author's name should be in parentheses. We have reviewed the list of Parris and others (1998) and a few revisions were made.

4. A significant mistake was made in the work of Parris and others (1998) regarding the listing of *Pseudoclimacograptus scharenbergi* (Lapworth) for Locality 16. This was based on a specimen that was collected in 1995 (NJSM GP1187), but when we reviewed it, it was found to be from what was believed to be Locality 15, not Locality 16, presumably a typographical mistake. The original field label is extant, making the correction a certainty. However, the Perissoratis locations have been determined by plotting their locations from a preprint map in the GSA Bulletin to the High Bridge 7 ½ minute quadrangle map. Since the GSA map has only a couple roads and no topography the locations can be off by several hundred or more feet.

Another problem with the assumption that *Pseudoclimacograptus scharenbergi* (Lapworth) collected in 1995 was from Locality 15 of Perissoratis (1974) is that Frank Markewicz has a field station, J-35 that plots about 200 feet east of where Perrisoratis 15 plots and it contains *Pseudoclimacograptus* (Locality 31 this table). Based on Markewicz's field notes from 1966, the rocks are near vertical to slightly overturned to the east so Locality 15 would be several hundred feet lower in the section, hence older. Based on the geology of the area it is likely that NJSM GP1187 was collected at or in the same beds as J-35, not Perissoratis's Locality 15. This is further supported by the fact that conodont locality HBNJ- 468 (Harris and others, 1995) is a few hundred feet southwest of Locality 16 and is older, similar in age to Locality 15. Therefore NJSM GP1187 is attributed to Locality 31.

5. Localities 1 through 22 are from Parris and others (1998) and localities 22 through 34 are localities collected by Frank Markewicz in the 1950's- 1960's and were identified in a letter from

Dr. Stanley Finney to Richard Dalton in 1991. The zone numbers of localities 1-22 follow those of Berry (1960, 1968) and the zone terminology for localities 22-34 follows Ross and others (1982).

6. Although neither accessioned nor catalogued, many specimens collected by Frank Markewicz are at the New Jersey State Museum and available for research. Locality data for these specimens seem to be sufficient.

7. See Table A1 for locational information of all the graptolite localities from the Jutland type rocks.

8. All names on this table are as identified by the original workers or as noted above.

Appendix B

This appendix includes a table listing all the graptolites identified by previous workers. Over the years as the science became better some of the graptolites were reassigned and the names have been changed. Table A3 of the report is a revised version of this table. Dr. Charles E. Mitchell during his review of the Jutland report kindly made revisions to the many of the graptolite names based on current usage. He suggested removal of some items that were identified only to genus, since it would be problematic reassign them without examining the actual specimens.

The first graptolites were found in New Jersey, at both Branchville and Jutland, by Dr. Stewart Weller with the ones at Branchville being identified in the Annual Report for the Year 1900. Footnotes in both the Annual Report and in the Report on Paleontology, Volume III, The Paleozoic Faunas, Dr. Weller acknowledges the assistance provided by Dr. Rudolph Ruedemann in identification of the graptolites from both the typical Hudson River Formation (now Martinsburg Formation) at Branchville, and the varicolored shales at Jutland. In 1931, Dr. Ruedemann, identified a collection of graptolites made by M. W. Twitchell from an additional Jutland railroad cut, which were provided to him by Dr. Henry B. Kümmel, State Geologist.

A number of localities containing graptolites were found in the 1950s and 1960s in the Jutland area. Harry Dodge, for his senior thesis at Princeton in 1952 collected and identified the graptolites from four localities under the tutelage of Professor Benjamin F. Howell. During the late 1950s and 1960s Frank Markewicz found 15 additional graptolite localities. The graptolites Markewicz found were identified by Dr. Stanley Finney in 1991. Graptolites collected by Constantine Perissoratis for his Master of Arts Thesis at the City University of New York, in 1974 were all identified by Dr. W.B.N. Berry. Dr. Berry also provided Perissoratis with information on some previous collections by Dodge and Neuman and Drake which he had identified. Perisssoratis (1974 and Perissoratis and others 1979) describe 16 localities which include the Weller Jutland and Twitchell railroad cuts and the four Dodge localities. The New Jersey State Museum began collecting graptolites from the Jutland rocks beginning in 1984 and published several papers over the years. Most of those graptolites were identified by Dr. Stanley Finney with some also identified by Dr. Clair Carter (U.S. Geological Survey). Also, in 1984 Rich Volkert of the New Jersey Geological Survey found a third locality in the Jutland railroad cuts. These graptolites were identified by Dr. Clair Carter.

The original Weller Jutland railroad cut collection, the Twitchell collection (also from the railroad cut), the Volkert collection, the graptolites collected by the New Jersey State Museum and the Frank Markewicz collection (currently not catalogued) are at the State Museum. The graptolites collected by Dodge, by Dodge and Neuman, and by Perissoratis could never be located.

Seven photographs of some of the graptolites found in the Jutland rocks have been included in this appendix. Figures 1 to 4 are from Dodge (1952) and as indicated above he identified those graptolites. The graptolites collected by Dodge are the oldest identified from the Jutland rocks. Figures 5 to 7 are from Markewicz (1967). The graptolites in these three figures were identified by Finney in 1991.

Table B

Graptolites Identified by Previous Workers

Genus and Species	Reference*
Adelograptus sp. cf. *A. pusillus* (Ruedemann)	3, 4, 6
Adelograptus lapworthi (Ruedemann)	3, 4, 6
Amplexograptus sp.	6
Amplexograptus arctus (Elles and Wood)	6
Callograptus sp. cf. *C. salteri* Hall	4, 5, 6
Callograptus salteri (Hall)	3
Climacograptus sp.	4, 6, 7, 8, 9, 10, 11, 12, 13
Climacograptus bicornis Hall?	6, 11
Climacograptus bicornis Hall	4, 6
Climacograptus brevis Elles and Wood	11
Climacograptus caudatus?	11
Climacograptus sp. cf. *C. caudatus* Lapworth	10
Climacograptus phyllophorus Gurley	1, 6
Climacograptus sp. cf. *C. riddelensis* Harris	6
Climacograptus riddelensis Harris	4, 6
Climacograptus spiniferus?	11
Climacograptus tubuliferus?	11
Clonograptus sp.	4, 5, 6
Cryptograptus?	8, 11
Cryptograptus sp.	8, 11
Cryptograptus antennarius (Hall)	3, 4, 6
Cryptograptus tricornis (Carruthers)	4, 6, 8, 11, 12
Dicellograptus?	8, 11
Dicellograptus sp.	4, 6, 7, 8, 9, 10
Dicellograptus sp. cf. D. *divaricatus* (Hall)	2, 4, 5, 6
Dicellograptus divaricatus var. salopiensis Elles and Wood	8, 9, 10
Dicellograptus sextans (Hall)	2, 4, 5, 6
Dicellograptus smithi Ruedemann	4, 5, 6
dichograptidae, genus indet.	8
dichograptidae	6
Dicranograptus? sp	9
Dicranograptus sp	6, 7, 8, 13
Dicranograptus cf. *D. kirki* Ruedemann	9, 10
Dicranograptus sp. cf. *D. kirki* Ruedemann	7, 8
Dicranograptus nicholsoni?	11
Dicranograptus ramosus (Hall)	1, 6, 7, 8, 9, 10
Dictyonema sp.	4, 5, 11

Table B (con't)

Genus and Species	Reference*
Dictyonema amplum (Ruedemann)	3, 4,
Dictyonema sp. cf. *D. murrayi* Hall	6
Dictyonema murrayi (Hall)	3, 4,
Dictyonema sp. cf. *D. quadrangulare* Hall	4, 5, 6
Didymograptus? sp.	9, 10
Didymograptus sp.	4, 5, 7, 8, 11
Didymograptus bifidus (Hall)	3, 4,
Didymograptus sp. cf. *D. extensus* Hall	8
Didymograptus extensus (Hall)	3, 4,
Didymograptus sp. cf. *D. nicholsoni* (Lapworth)	3, 4, 6
Didymograptus sp. cf. *D. nicholsoni* var. *planus* Elles and Wood	6
Didymograptus sagitticaulis Gurley	7,8
Didymograptus (*Expansograptus*) sp.	11
Diplograptus? *sp.*	6
Diplograptus sp.	4, 6
Diplograptus angustifolius (Hall)	2, 6
Diplograptus decoratus Harris and Thomas	4, 6
Glossograptus sp.	8, 11, 12
Glossograptus ciliatus Emmons	7, 8, 11
Glossograptus sp. cf. *holmi* Bulman	8
Glossograptus holmi?	12
Glossograptus sp. cf. *G. hystrix* Ruedemann	3, 4, 6
Glyptograptus?	8, 11
Glyptograptus? sp.	8, 9, 10
Glyptograptus sp.	4, 6, 11, 12
Glyptograptus euglyphus (Lapworth)	11
Goniograptus sp.	11
Goniograptus thureaui var. *postremus* (Ruedemann)	3, 4,
Hallograptus?	8, 11
Hallograptus? sp.	6
Hallograptus sp.	11
Hustedograptus sp. cf. *H. teretiusculus* (Hissinger)	6
Hustedograptus teretiusculus (Hissinger)	4, 8, 12
Isograptus?	11
Isograptus sp.	8, 11, 12
Isograptus sp. (*I. caduceus* or *I. forcipiformis*)	11
Isograptus forcipiformis (Ruedemann)	8, 11
Isograptus victoriae Harris?	11
Isograptus victoriae ssp.?	12

Table B (con't)

Genus and Species	Reference*
Isograptus victoriae maximus Harris?	12
Isograptus victoriae maximus Harris	8, 11, 12
Leptograptus trentonensis	11
Nemagraptus?	8, 11
Nemagraptus? sp.	11
Nemagraptus sp.	6, 13
Nemagraptus? *gracilis*?	11
Nemagraptus gracilis?	11
Nemagraptus gracilis (Hall)	1, 4
Orthograptus sp.	4, 6, 11
Orthograptus quadrimucronatus (Hall)?	11
Pseudisograptus sp.	8, 12
Pseudoclimacograptus? sp.	9, 10
Pseudoclimacograptus sp.	6, 7, 8, 11, 13
Pseudoclimacograptus angulatus Bulman	8, 12
Pseudoclimacograptus modestus or *scharenberi*	11
Pseudoclimacograptus modestus (Ruedemann)	6, 8, 9, 10
Pseudoclimacograptus scharenbergi (Lapworth)	8
Pseudoclimacograptus scharenbergi cf. var. *stenostoma* (Bulman)	4, 5, 6
Pseudotrigonograptus ensiformis (Hall)	8, 11, 12
Pterograptus sp.	11
Retiograptus sp.	4, 6
Reteograptus geinitzianus Hall	1, 6, 11, 12
? *Reteograptus geintizianus* Hall	8
sigmagraptid	11
Sigmagraptus or *Holmograptus*	12
Tetragraptus sp.	11, 12
Tetragraptus sp. cf. *T. bigsbyi* Hall or *T. serra* Brongniart	8
Tetragraptus bigsbyi (Hall)	11
Tetragraptus clarkei (Ruedemann)	3, 4,
Tetragraptus sp. cf. *T. quadribrachiatus* (Hall)	4, 5, 6, 13
Tetragraptus quadribrachiatus (Hall)	3, 4,
Tetragraptus serra (Brongniart)	11
Xiphograptus? sp.	11
Xiphograptus svalbardensis (Archer and Fortey)	8, 12

*Source of graptolite identifications or reference they were published in.

Table B (con't)

1. Weller (1903)
2. R. Ruedemann letter to H. B. Kümmel, 4/6/1931.
3. H. Dodge Senior Thesis (1952)
4. Constantine Perissoratis MS Thesis (1974)
5. Dodge and Newman collected graptolites in 1964, reference from Perissoratis MS Thesis 1974, p. 18 indicates Berry identified the graptolites collected by Dodge and Newman in 1964.
6. Perissoratis and others (1979)
7. Parris and Cruikshank (1986)
8. Parris and others (1998)
9. Claire Carter report to Jack Epstein (Volkert site), 10/05/1984.
10. Claire Carter report to Jack Epstein (Union Courthouse site), 10/22/1984.
11. Stanley Finney letter to Richard Dalton dated 10/16/1991.
12. Stanley Finney letter to David Parris dated 10/7/1996, cited in Parris and others (1998).
13. Subramanian and Parris (2016)

Listing of graptolites found in Jutland klippe sequence as identified in the original works. Note *Nemagraptus gracilis* (Hall) was originally listed as *Coenograptus gracilis* (Hall) in Weller (1903) and the name was changed to *Nemagraptus gracills* (Hall) by Bayley and others (1914) in their listing of the graptolites at Jutland. Many of the graptolite names were updated by Dr. Charles E. Mitchell in 2018 and are on Table A3 of this report.

Graptolites Found In The Jutlands Rocks

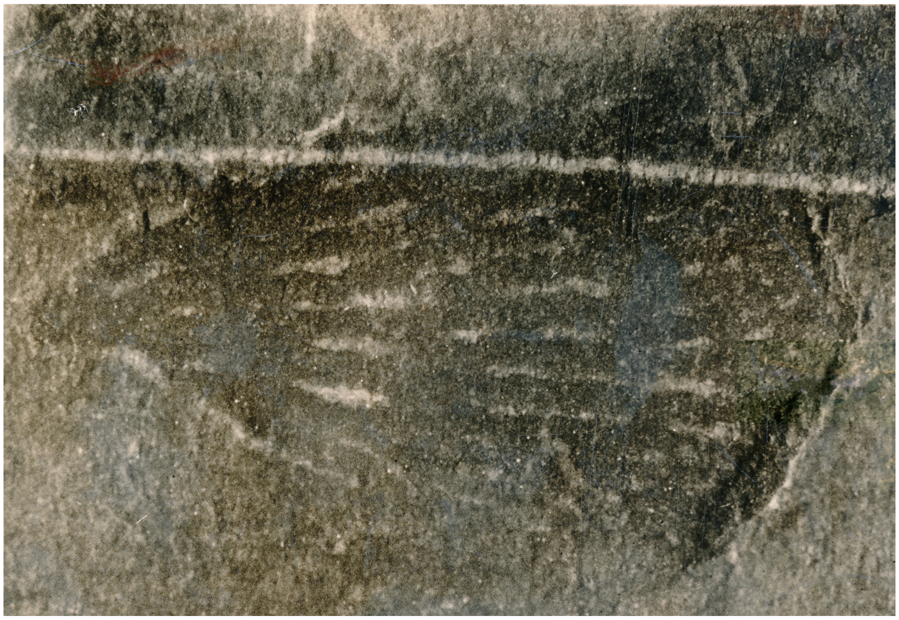


Figure B1. Dodge Plate II - Dodge locality 1 (locality 1 on Table A1 of this report), *Callograptus salteri*.

Figure B2. Dodge Plate III - Dodge locality 1 (locality 1 on Table A1 of this report), *Dictyonema murrayi* and *Tetragraptus clarkei*.

Images (con't)

Figure B3. Dodge Plate IV - Dodge locality 1 (locality 1 on Table A1 of this report), *Tetragraptus quadribranchiatus*.

Images (con’t)

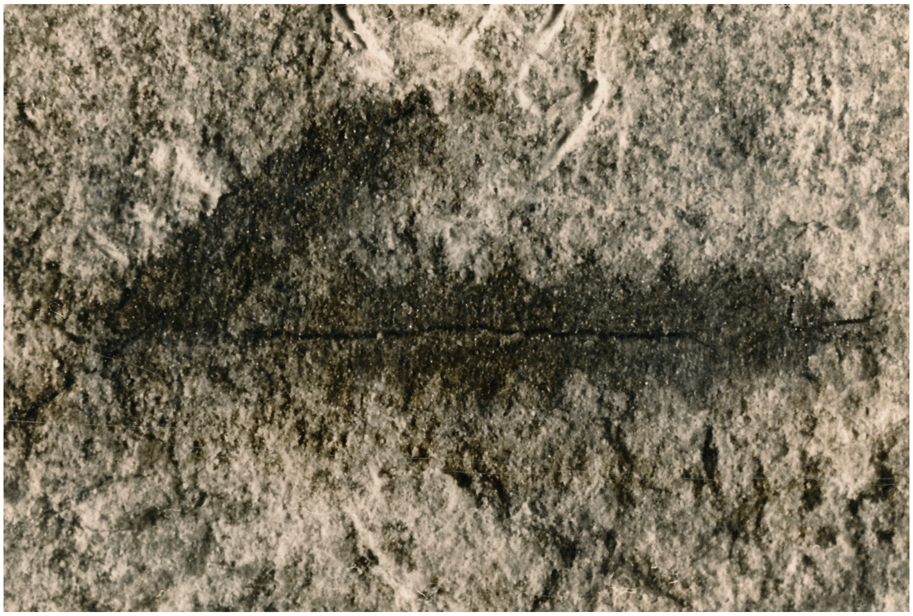


Figure B4. Dodge Plate V - Dodge locality 2 (locality 3 on Table A1 of this report), *Cryptograptus antennarius*.

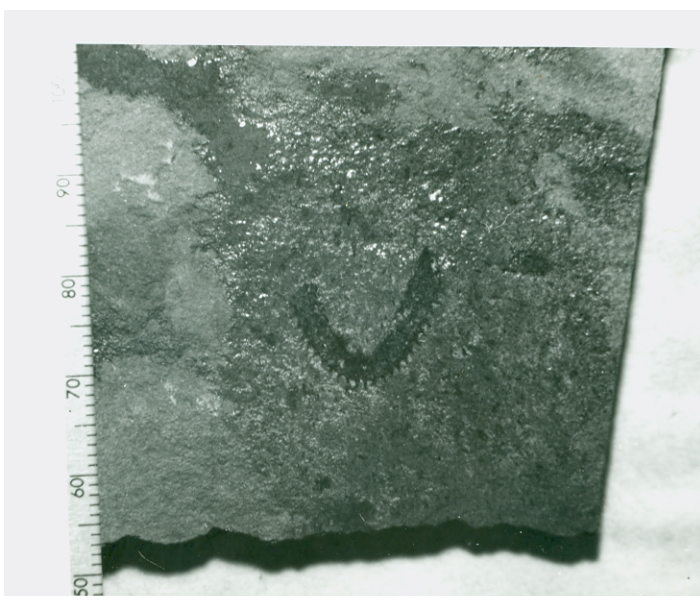


Figure B5. Markewicz fig. 39 - FJM local 2-4 (locality 24 on Table A1 of this report), *Isograptus victoriae maximus*.

Images (con't)

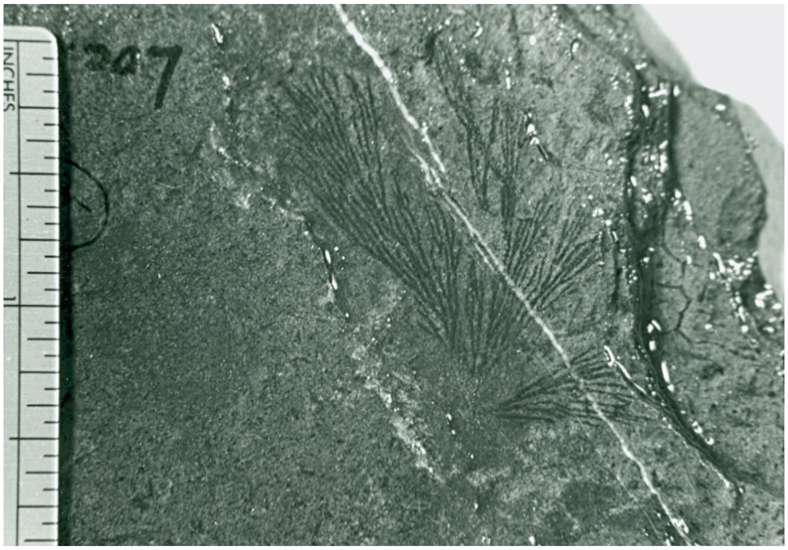


Figure B6. Markewicz fig. 43 - FJM local 2-5 (locality 24 on Table A1 of this report), *Goniograptus sp.*

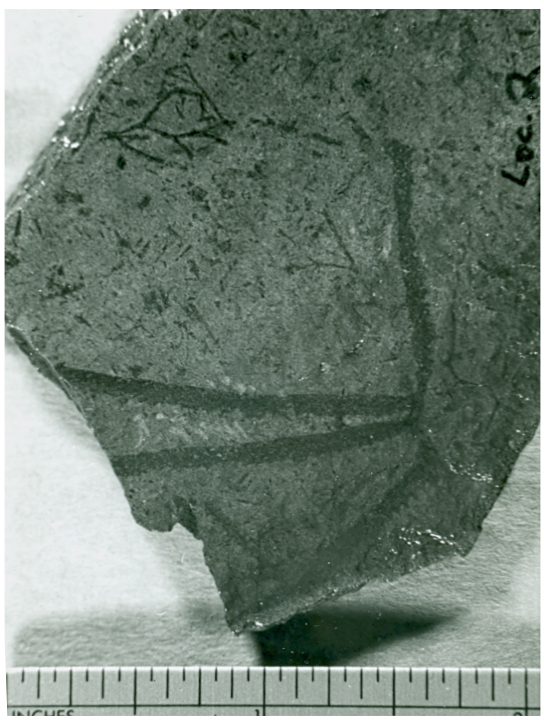


Figure B7. Markewicz fig. 44 - FJM local 2-2 (locality 24 on Table A1 of this report), *Goniograptus sp.* and *Tetragraptus serra.*

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