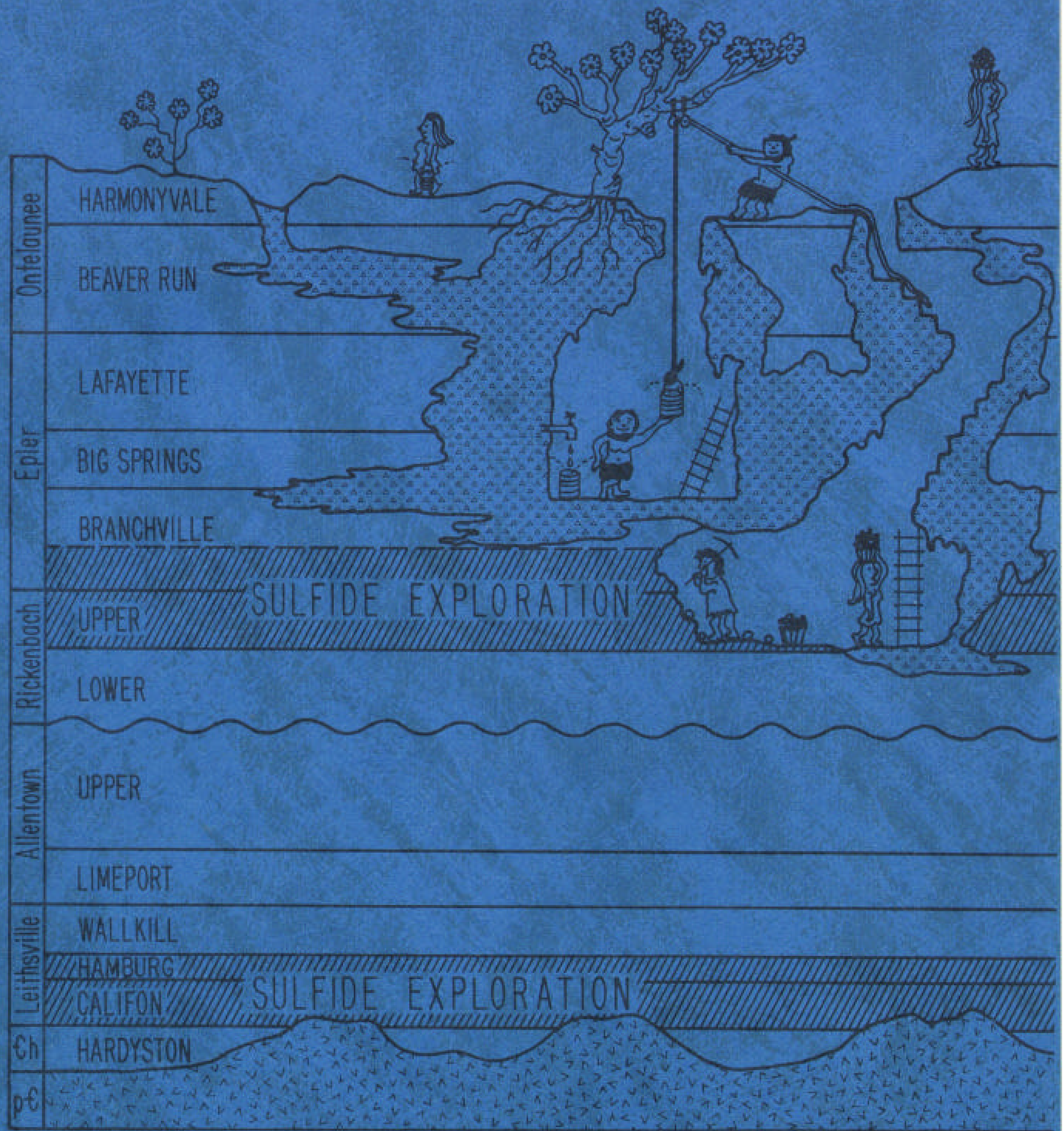
42nd. FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

GUIDEBOOK



Stroudsburg, Pa • October 6th. and 7th., 1977

Hosts: New Jersey Division of Water Resources
New Jersey Geological Survey
Rider College Geology Department

GUIDEBOOK FOR THE

42ND ANNUAL FIELD CONFERENCE OF PENNSYLVANIA GEOLOGISTS

OCTOBER 6-8, 1977

STRATIGRAPHY AND APPLIED GEOLOGY OF THE LOWER PALEOZOIC CARBONATES IN NORTHWESTERN NEW JERSEY

HOSTS:
- NEW JERSEY DIVISION OF WATER RESOURCES
- RIDER COLLEGE, GEOSCIENCE DEPARTMENT
- NEW JERSEY GEOLOGICAL SURVEY

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MEREDITH E. JOHNSON
E.M. LEHIGH UNIVERSITY, 1918
NEW JERSEY STATE GEOLOGIST
1937 to 1958

by

Frank J. Markewicz

The New Jersey Division of Water Resources is proud to dedicate the 1977 Field Conference of Pennsylvania Geologists guidebook to the former State Geologist of New Jersey, Meredith E. Johnson.

Mr. Johnson served as Assistant State Geologist under State Geologist Henry Kummel before becoming State Geologist in 1937. He served in this capacity until his retirement in 1958.

Everyone who knew Mr. Johnson remembers him as a gentleman and professional geologist. He was interested and well experienced in the various disciplines of geology. He was willing and ready to help the student, as well as the professional geologist. His friendship and cooperation with well drillers and company geologists is well remembered to this day.

His inspiration, his casual but firm approach, and his ability to convey responsibility to young "budding" geologists provided the impetus for "getting on" with projects or ideas. The writer vividly remembers the discussion on the heavy mineral program with Mr. Johnson, when he said "looks like you have something here, go ahead and do what you think is necessary."

In 1956, when the Pennsylvania Field Conference was held in New Jersey, I remember Meredith informing me that this was a most important event because it was an occasion when the professionals, the academicians, and the students had an opportunity to gather together to observe and discuss the geology covered by the field trip. Now, twenty-one years later, it is appropriate to remember Meredith E. Johnson and recall the inspiration that he gave to others.

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STRATIGRAPHY AND APPLIED GEOLOGY OF THE LOWER PALEOZOIC CARBONATES IN NORTHWESTERN NEW JERSEY

by

Frank J. Markewicz and Richard Dalton

INTRODUCTION

In the field trip guidebook the Cambro-Ordovician carbonate formations that will be examined consist of the following:

Cambrian	Ordovician (Beekmantown)
Allentown	Ontelaunee
Leithsville	Epler
	Rickenbach

The intent of this field trip is to present the subdivision of the Cambro-Ordovician "Kittatinny" carbonate sequence as proposed by F. Markewicz and R. Dalton, and to cite some case histories of environmental, geohydrologic, and engineering problems. Without a workable and recognizable subdivision, application of field geology to everyday problems would be impossible. The senior author remembers only too well the many dilemmas with regard to problems involving water well yields, sinkholes, engineering and economic problems, etc., and the inability to relate the on-site problem to a formation, much less any definitive member of a formation. This became frustrating as similar problems repeated and it was unknown whether the previous occurrence could be related "stratigraphically" with the present problem. In essence, the idea developed through sheer necessity that "there must be a better way" in which to relate applied geologic problems to the stratigraphy of the "Kittatinny" sequence of rocks.

Certain units such as the lower Allentown are unique in their sedimentary characteristics, and they were easily recognized and stratigraphically positioned. However, the rest of the dolomite sequence was poorly understood, resulting in much stratigraphic and structural confusion. Because of the lack of a definitive formational or member status breakdown, many interpretations involving structure, stratigraphy, and engineering characteristics were seriously hampered or wrongly interpreted. It was common to observe an outcrop or look at drill core and wonder just what part of the "Kittatinny" the rock belonged to. Field work by F. Markewicz in eastern Pennsylvania and parts of southern New York revealed that certain key horizons in those states could be correlated with similar stratigraphic horizons in New Jersey. Mapping of the High Bridge Quadrangle (Markewicz, 1967, open file) formed the early basis for being able to subdivide the "Kittatinny" into a member subdivision as later field work progressed.

The authors have subdivided the "Kittatinny Limestone" into distinct, usable members (Table I), enabling the structure, stratigraphy, environmental, economic, and ground-water aspects of the different members to be better understood and utilized. Because of the amount of "Kittatinny" in Warren and Sussex counties

Table I

SUBDIVISION OF THE KITTATINNY LIMESTONE

<table>
<tr><th></th><th>Formation Name used on N.J. Geol. Map</th><th>Formations recognized by H.B.Kummel & Others</th><th>Formations Recognized by A.A.Drake & F.J.Markewicz</th><th colspan="3">Current Stratigraphy as used by F. J. Markewicz and R. F. Dalton</th></tr>
<tr><td rowspan="7">LOWER ORDOVICIAN</td><td rowspan="12">KITTATINNY LIMESTONE</td><td rowspan="7">Beekmantown</td><td rowspan="5">Epler</td><td rowspan="2">Ontelaunee Formation</td><td colspan="2">Harmonyville mbr.</td></tr>
<tr><td colspan="2">Beaver Run mbr.</td></tr>
<tr><td rowspan="3">Epler Formation</td><td colspan="2">Lafayette mbr.</td></tr>
<tr><td colspan="2">Big Springs mbr.</td></tr>
<tr><td colspan="2">Branchville mbr.</td></tr>
<tr><td rowspan="2">Rickenbach</td><td rowspan="2">Rickenbach Formation</td><td>Hope mbr.</td><td rowspan="2">Crooked Swamp Dolomite Facies</td></tr>
<tr><td>Lower mbr.</td></tr>
<tr><td rowspan="5">CAMBRIAN</td><td rowspan="2">Allentown</td><td rowspan="2">Allentown</td><td rowspan="2">Allentown Formation</td><td colspan="2">Upper mbr.</td></tr>
<tr><td colspan="2">Limeport mbr.</td></tr>
<tr><td rowspan="3">Tomstown</td><td rowspan="3">Leithsville</td><td rowspan="3">Leithsville Formation</td><td colspan="2">Walkill mbr.</td></tr>
<tr><td colspan="2">Hamburg mbr.</td></tr>
<tr><td colspan="2">Califon mbr.</td></tr>
</table>

The table indicates the present stratigraphy used in New Jersey and its correlation to those formational names used by earlier workers.

and its impact on regional planning, the necessity of being able to recognize the different units has become imperative. The authors have found, over the years, that the different formations and certain units (members) in the "Kittatinny" have varying properties in terms of ground-water yield, pollution potential, engineering characteristics and economic possibilities.

Attempts have been made through studies of insoluble residues, calcite-dolomite ratios, quartz grain studies, and faunal distribution to map the dolomites, but the results have not proved successful in regard to a definitive, practical subdivision for use in applied geologic problems. In addition to the general lack of knowledge regarding the thick carbonate sequence, structural complexities have confused matters, especially in those regions where an abnormally thick or thin "Kittatinny" section is present.

Drake and others did not map a member subdivision in New Jersey, consequently differences in the field mapping and structural interpretation will develop as further mapping is done toward the Delaware River in New Jersey.

The two-day field trip will concentrate in Sussex and Warren counties of northwestern New Jersey. Routes followed are shown on Figure 1. There are seven stops planned for the first day and six for the second day. Regional geology of the two-day field trip is shown on the Geologic Map of New Jersey.

The first day of the field trip will include stops at Precambrian, Hardyston, and the carbonate members of the Leithsville, Allentown, Rickenbach, Epler, and Ontelaunee Formations. The second day is devoted mainly to Beekmantown stratigraphy, applied geology, pegmatite dikelets, and explanation of mapping and structural interpretations, with the use of a formation member breakdown.

ACKNOWLEDGMENTS

The field trip committee is grateful to the Pennsylvania Topographic and Geologic Survey, especially D. Hoskins for their cooperation, general guidance, logistics, and overall supervision of field trip organization.

Walter J. Spink, Rider College Geology Department, kindly consented to be a bus leader and a field trip stop leader. Dr. Spink has mapped Martinsburg rocks in northern New Jersey and will lead the group in a discussion of the Martinsburg and the Beekmantown at Stop 2 on the second day.

Robert Metsger, geologist with the New Jersey Zinc Company at Ogdensburg, will be the field trip leader at Stop 4 on the first day. Mr. Metsger's extended knowledge of the Franklin Marble will prove interesting at the Limecrest Products Company quarry stop at Limecrest, New Jersey.

Special acknowledgment is given to Mr. Karl Birns, Chief of the Office of Special Services, Division of Water Resources, who endorsed and helped arrange the field trip with the Pennsylvania Geologic Survey.

We acknowledge the New Jersey Bureau of Geology and Topography, Kemble Widmer, State Geologist, and Carol S. Lucey, Supervising Geologist, who provided drafting, reproduction, typing, and editing.

The patience of Edith Wargo, Edna Conroy, Jean Starkey, and Lucie Calasso is sincerely acknowledged for their typing of various sections of the manuscript.

Final typing was accomplished by JoAnn Bowman, Mary Ann Miller, Donna Snyder, and Marjorie Steel of the Pennsylvania Geological Survey. Illustrations were drafted by Virginia Milewski and Albert Van Olden of the Pennsylvania Geological Survey. Editing and proofreading were performed by Sandra Blust and Donald Hoskins of the Pennsylvania Geological Survey.

The field conference hosts appreciate the cooperation and courtesy of the following companies in allowing the trip participants to visit their facilities:

Limestone Products Corporation
Oxford Stone Company
Hamburg Quarry Company
Conrail System

PRECAMBRIAN ROCKS

The Precambrian in northern New Jersey consists of metasedimentary gneisses, marble and probable metavolcanics that are intercalated with bands, lenses, pods, or discrete bodies of calc-silicates, skarn, amphibolite, and other related facies. These rocks have been invaded concordantly and discordantly by igneous bodies, sheets, or phacoliths of various granites, diorites, pegmatites, and local cross-cutting mafic dikes. The inferred sequence of intrusion, oldest to youngest, is: quartz diorite and related facies, albite-oligoclase granite facies, and the hornblende granites with genetically related pegmatites. Migmatitization is common throughout the entire Precambrian sequence in New Jersey. It is often difficult when mapping not to be overly generous with term "migmatite" because of its abundance in many types of Precambrian rock.

Precambrian rocks in New Jersey were divided for many years into five principal types, based upon color and limited mineralogic classification. This subdivision is:

Pochuck Gneiss - Dark granular gneiss composed of pyroxene, hornblende, oligoclase, and magnetite; probably igneous in part.

Byram Gneiss - Gray granitoid gneiss composed of microcline, microperthite, quartz, hornblende or pyroxene, and sometimes mica.

Losee Gneiss - White granitoid gneiss composed of oligoclase, quartz, and occasionally orthoclase, pyroxene, hornblende and biotite.

Granite - Coarse grained, rudely foliated hornblende granite, rich in zircon, titanite, and allanite (northern border of Sussex County).

Franklin Marble - Coarse white marble, magnesian in part, containing graphite, chronodite, pyroxene, and other minerals. Contains zinc ores in Sussex County.

In addition to the Precambrian above, there are younger igneous units in northern New Jersey consisting of nepheline syenite, volcanic breccia, and mafic and alkalic dikes of various composition. Until the recent discovery of pegmatite dikelets intruded into the middle of the Epler Formation in Phillipsburg, there has been no known report of any granitic igneous material intruding any formation above the lower Hardyston. A description of the pegmatite at Phillipsburg and its relationship with the pegmatite in the Hardyston south of Easton is given later in the text.

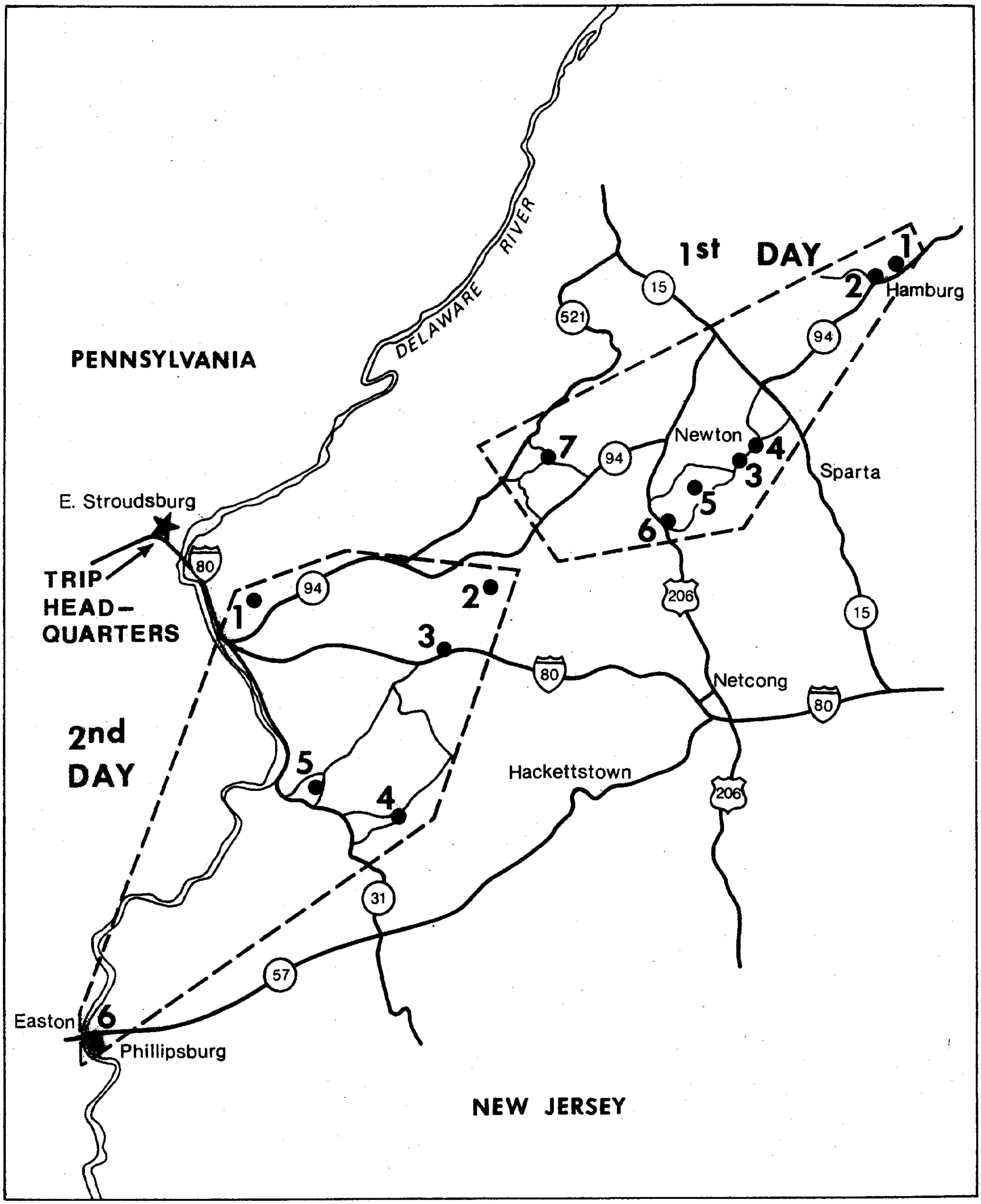

PENNSYLVANIA
DELAWARE RIVER
1st DAY
Hamburg
Newton
Sparta
E. Stroudsburg
TRIP HEAD-QUARTERS
2nd DAY
Netcong
Hackettstown
Easton
Phillipsburg
NEW JERSEY

Figure 1

The principal early work on the Precambrian in northern New Jersey was by Rogers 1836, Kitchell 1855-56-57, Cook 1868, Nason 1889, Wolff 1894 and others. A major step toward a more modern approach of Precambrian subdivision, based upon lithologic composition, was undertaken by A. F. Buddington and several of his students: Sims and Leonard 1952, Baker 1956, Buddington and Baker 1961, Hotz 1952, and Sims and Leonard 1952. New Jersey Zinc Company geologists followed a somewhat comparable classification in their study of the Franklin-Sterling region. Drake 1967, in his Frenchtown and Bloomsbury Quadrangle mapping, continued the mineralogic type subdivision as presented by Buddington, Sims and others. Markewicz 1967, followed the same procedure in the mapping of the High Bridge Quadrangle (unpublished). Smith 1969, utilized a similar subdivision in his regional mapping of northern New Jersey.

In addition to the usual rock forming and accessory minerals mentioned by Sims, Drake, and others, the following primary uranium-thorium, and rare-earth minerals are occasionally found in the granites, certain gneisses, and the different facies of pegmatite.

uraninite	doverite	perrierite
thoriznite	huttonite	radioactive sphene
uranothorite	spencite	radioactive zircon
fergusonite	monazite	allanite
		thorite

Secondary radioactive minerals include:

autunite	gummite	uranophane
torbernite	thorogummite	carnotite
	kasolite	

PRECAMBRIAN - PALEOZOIC UNCONFORMITY

In the normal stratigraphic progression sequence, the Hardyston Quartzite unconformably overlies the Precambrian crystalline rocks, however, there are more than several areas in northern New Jersey where lower Leithsville dolomite rests directly on the Precambrian. Although only occasionally exposed, the Precambrian-Lower Paleozoic contact has been observed at enough localities in order to understand some of its characteristics. At some exposures in northern New Jersey the Hardyston may be less than two feet thick, which includes a foot of dirty sandy dolomite to calcareous sandstone/calcarenite that is transitional into the basal Leithsville. At one particular outcrop where the contact can be traced for more than a hundred feet, it was noted that the Hardyston (less than two feet thick) was deposited in only the deeper troughs in the Precambrian, whereas dirty sandy dolomite was in contact with the Precambrian in the highs above the troughs. This indicates that the Hardyston was definitely non-deposited above certain elevations during Lower Cambrian time. Hague and others (1956, page 456) indicate that -

"Locally, the Hardyston is missing and the rock just above the Precambrian unconformity is a pure dolomite, which indicates that the Precambrian erosion surface was quite irregular and that the Hardyston was probably formed in depressions on this surface. Hardyston-like conglomerates have been found as fissure and cave fillings in the Franklin band of marble considerable distances below the Precambrian erosion surface."

It is difficult to imagine that the Precambrian with its long period of exposure prior to Hardyston deposition was without appreciable relief. The compositional and textural variability of the gneisses and granites, with their respective weathering resistance to erosional processes, strongly suggest that an irregular surface must have existed prior to Hardyston deposition. In contrast to the above, if the Precambrian surface were basically gentle, then a moderate to possibly thick regolith zone would have been present upon which the Hardyston was deposited. This is not what the field evidence shows; any paleosol zone noted has not been in excess of more than several inches.

It is the opinion of the authors that the Precambrian topography just prior to Cambrian deposition was irregular, with local deep weathered joints, shallow basins, and intermediate uniform sloping to fairly level plateaus with interspersed irregular topography. This helps explain the variable thickness and lithology of the Hardyston. Kummel (1940) states that the Hardyston is from 5 to 200 feet thick. Other publications give a thickness of 300 feet.

The Precambrian surface, upon which the Hardyston was deposited, probably ranged from smooth to one strewn with sand, pebbles and boulders (see Figure 3) up to 25 feet in diameter. At some places it was mantled with a true soil horizon. Miller and others (1939) mention the presence of an amorphous material called "pinite" at the contact in their Northampton County, Pennsylvania report. During the course of an engineering geology study in the Round Valley area of New Jersey, Markewicz observed a Hardyston encased Precambrian boulder some two feet in diameter resting on Precambrian bedrock. In the Clinton-Allerton-Califon region, several Precambrian-Hardyston contacts contain very coarse-grained to boulder-size Precambrian material at the contact.

HARDYSTON FORMATION

In 1840 Rogers first mentioned the occurrence of "a white quartzose sandstone, somewhat coarse and friable" overlying the Primary (Precambrian) rocks in New Jersey. This related to his Formation I of the Lower (Paleozoic) Secondary rocks. Until 1890, geologists suggested that this formation was correlative with the Upper Cambrian "Potsdam" of New York. In 1891 Nason described a trilobite, Olenellus fauna from rocks near Franklin as being Lower Cambrian in age. Wolff and Brooks 1898, named this formation "Hardistonville" from the town in Sussex County near Franklin Furnace.

In 1901 Kummel and Weller named the formation Hardyston, as a correction of Wolff and Brooks, "Hardistonville". All later workers refer to this Lower Cambrian sedimentary sequence as Hardyston and correlate it with the Chickies Quartzite of Pennsylvania and the Poughquag of New York.

Among those who have worked on the Hardyston in eastern Pennsylvania and New Jersey, there is some disagreement on the conditions of deposition. Ludlum 1940, states "the pre-Cambrian land surface must have been one of gentle relief just prior to submergence" whereas Hague and others (1956, p. 456) indicate "that the Precambrian erosion surface was quite irregular and that the Hardyston was probably formed in depressions on this surface".

Fossils recognized as Olenellus thompsoni and Skolithos linearis have been found at various locations in the state. Olenellus occurs most abundantly in Warren County in the upper calcareous beds of the formation. Skolithos typically occurs in the lower-massive gray, brown or purplish siliceous quartzite and/or sandstone beds. B. Howell (1943) published a paper on "Skolithes" from eastern Pennsylvania. Large blocks of Hardyston talus containing numerous Skolithos tubes occur just north of the New Jersey-New York border near Glenwood, New Jersey.

The topographic form at or near the contact of the Precambrian-Hardyston varies from a smooth uniform slope without any visible "Hardyston bench" to a moderately well defined bench that is readily recognized in the field or on air photos. In some areas a subtle to well developed depression along the Precambrian-Hardyston contact is due to weathering of the greater feldspar content in the basal Hardyston. This is usually followed downslope by a slight to prominent topographic bench formed by the more resistant siliceous beds that lie above the basal feldspar bearing units. The typical Hardyston land form, where it is more than 50 feet thick, is a narrow to broad bench perched on the slope surface above the valley bottom. Complete sections of Hardyston are rarely exposed except where it is very thin, less than 5-10 feet. The Precambrian-Hardyston contact is more commonly observed than the Hardyston-Leithsville contact, which is generally at a lower downslope elevation and covered with colluvium.

The formation varies in thickness from less than one foot to estimates of more than 200 feet thick. In general, the authors would estimate the Hardyston to be on the average of 100 feet thick or less.

Basal Hardyston composition and rock texture can vary from one region to another or even within the confines of a local outcrop. This reflects on the provenance of the sediments coming into the Cambrian sea and the residual detritus lying on the Precambrian surface. This is not surprising, considering the irregularity of the Precambrian surface and the variable composition of the Precambrian rocks which supplied the source materials for the Hardyston.

The Hardyston consists of a varied assemblage of lithologies and colors but generally is a vitreous, light pink, steel gray or brown, locally arkosic, fine to coarse-grained, resistant quartzite with variations both horizontally and vertically. Quartzitic calcarenites generally form the very thin Hardyston occurrences. Basal units are commonly pebble conglomerates containing Precambrian gneiss and granite pebbles. Above the coarse basal beds, the rock is finer grained, but there can be medium to coarse-grained interbeds with local coarse conglomerate units consisting of light to dark gray to pink, locally iron-stained pebbles or granules. Some shaly interbeds may be present but these are more abundant in the upper or transitional facies of the Hardyston. Cross bedding, cut and fill, and graded compositional bedding are strictly local features. Typically, the siliceous facies of the Hardyston is massive, blocky, with poorly developed sedimentary features, making it difficult to visually extract any depositional information from these massive beds. This is especially true of small isolated outcrops. Occasional streaks or lenses of heavy mineral, fine grained detritus, or heterogenous compositional layering provide the necessary information for sedimentary interpretation.

Quartz, the dominant mineral, is clear to milky, angular to well rounded, and ranges from fine sand to pebbles more than two inches in length. Feldspar, white to pink perthite, and microcline is variable in content throughout the formation, but is most abundant in the basal section. Plagioclase is subordinate to rare. Heavy mineral content is generally low, with black opaques and zircons being the most common. Depending upon the immediate source area, monazite, garnet, sphene, and tourmaline can be important accessory minerals. In the vicinity of Chester, where Markewicz has mapped a monazite bearing gneiss, monazite is an important heavy mineral in the Hardyston. Near its contact with the Franklin ore body detrital Franklinite has been found, indicating a local source area for the sediments.

At some outcrops where the Hardyston is less than ten feet thick and one is fortunate enough to have found a moderate amount of exposure, one may become perplexed when observing that at one point the Hardyston is fine to medium grained, gray, pyritic quartzite, while at the other end it is a dark gray dolomitic sandstone. Is the dolomitic sandstone still Hardyston? Other variants of the formation consist of one to two feet of quartzitic material succeeded by a pebbly, sometimes calcareous shale to sandstone grading upward into a very dense, exceptionally hard dolomitic quartzite succeeded by an undulating transition zone above which lies a sandy dolomite. There are many depositional variants of the Hardyston which are not understood because of lack of study. This is especially true where the Hardyston is less than fifty feet thick.

The lithologic sequence and transition zone thickness between the Hardyston and Leithsville varies from one locality to another. There are two general transitions that can be considered for initial field interpretation, provided an exposure is present or drill core is available:

(1) a generally thin transition zone of quartzitic sandstone to calcareous sandstone or siltstone to sandy impure dolomitic rock to siliceous Leithsville dolomite;

(2) a much thicker alternating section of varicolored, dense, sometimes pebbly, quartzitic sandstones, shales, argillitic shales, and siltstones with thin, interbedded to lenticular, sandy, and/or dolomitic stringers and beds that become more calcareous by grading upward into lower Leithsville lithology.

The following relationship is given as a possible rule of thumb application but is not proposed as an absolute field criteria:

(1) where the Hardyston-Leithsville transition zone is predominantly sandy or a calcarenite, the Hardyston Formation will be thin, less than 50 feet thick.

(2) when a varicolored shaly-silty Hardyston-Leithsville transition zone is present, it may indicate a much thicker Hardyston section.

If the Hardyston is more than 50 feet thick, the possibilities for sulfides in the lower Leithsville are lessened, but if the Hardyston section is 25 feet thick or less, there is a greater potential for sulfide mineralization in the lower Leithsville.

LEITHSVILLE FORMATION

Weller (1900) used the general term "Kittatinny Limestone" for Cambro-Ordovician carbonate rocks of northern New Jersey and identified them with similar units in Virginia, Maryland, Pennsylvania and New York. In his "Annual Report of the State Geologist, 1900", page 4, he states, "This limestone formation has a great thickness which is estimated at from 2,700 to 3,000 feet. It is designated the Kittatinny Limestone because it is the great limestone formation of the Kittatinny Valley..."

The Lower Cambrian Leithsville Formation named by Wherry (1909) in Pennsylvania is the equivalent of the Tomstown Formation described by Miller and others (1939) in eastern Pennsylvania and New Jersey. Stose (1906), Bascom and others (1931), Hills (1935), Howell and others (1950) studied Leithsville rocks in eastern Pennsylvania.

Avery Drake (1961, 1967b)mapped the Leithsville Formation on the Frenchtown and Bloomsbury Quadrangles and Markewicz (1967) used the term Leithsville on the High Bridge Quadrangle. Wherry (1909) assigned a Lower-Middle Cambrian age to the Leithsville, whereas Willard (1961) infers that it is Middle Cambrian. No fossil evidence had been found to establish its age until the discovery of the Lower Cambrian fossil Hyolithellus micans in the early part of the 1960's, Markewicz (1964 unpublished), in rubbly dolomitic beds in the basal Leithsville at Califon, New Jersey and also near Monroe in southern New York State (Figures 2 and 4). A single opercula was recently found north of Easton, Pennsylvania. In addition, the fossil Archaeocyathus has been found in basal Leithsville dolomite at Franklin, Califon, Wantage, New Jersey and Easton, Pennsylvania. It is most prolific immediately above the Hardyston-Leithsville contact but has been noted in the lower part of the Wallkill Member. A recent paper by Palmer and Rozanov (1976) describes the original Archaeocyathus found in New Jersey by George Banino at Franklin. Kummel (1940, p. 68) referring to the lower portion of the "Kittatinny" limestone states:

> "They are correlated with the Tomstown Limestone of southern Pennsylvania because of their position and character. If the correlation is correct, they are Lower Cambrian in age."

The Leithsville Formation is subdivided into three members, based upon field work by Markewicz 1964-68 and Markewicz and Dalton 1968-72. The members are:

Wallkill Member

Hamburg Member

Califon Member

Califon Member

The Califon Member is the basal Leithsville unit and is named after the Hyolithellus micans and Archaeocyathus bearing dolomite exposed in an abandoned quarry near Califon, New Jersey. It can be from 40 to 150 feet thick, but is typically 100 feet thick. The lower, undulating contact with the Hardyston and the upper contact with the Hamburg can be seen at the Califon locality.

It consists essentially of two distinct lithologies that could, with further detailed work, be subdivided into additional units; however, the present subdivision is practical and easily recognized for applied geologic work (Figure 5). This subdivision is:

1. The upper section, which underlies the Hamburg Member, varies from 20 to 50 feet thick and consists of:

   very fine to cryptogranular, light gray to locally light greenish gray, dense, sharp breaking dolomite, locally laminated, in beds 6" to 20" thick, containing scattered quartz grains and micro to mega wedges or clots of crystalline carbonate, floating in the fine grained dolomite matrix. The unit weathers into distinct, uniform, planar beds that have a buff to cream color, smooth surface, thin, exterior rind in contrast to the dark to medium gray, raspy to silty textured, weathered surface of the lower part of the member.

2. The lower 20 to 100 feet section (thickness dependent on locality) varies from gray to dark gray, sparkly to bright (on fresh surface), fine to medium, megacrystalline, strongly stylolitic, ruditic, patchy textured dolomite.

   Bedding appears massive and somewhat indistinct except on weathered surfaces which reveals the undulating, profusely stylolitic, lumpy to thinly bedded character of the rock. The weathered surface readily expresses the lumpy nature and ruditic texture of the rock. Quartz, typically frosted, is present in the lower 6-8 feet of the member.

   Pyritic seams, masses, lenses or clots are discontinuous, but generally present along a given plane. Pyrite is typically oxidized on weathered surfaces, resulting in strong staining of the surface. Where the oxidation is mature, only a rust stained vug is present.

At some localities, the lower part of the Califon Member consists, in part, of a massive bedded, well healed, internal breccia, giving the rock a mottled, gray, mosaic pattern that is best seen on the weathered surface. This internally crackled or brecciated rock, which may be a biorudite, in part, is not as strongly stylolitic as the lumpy, thinly bedded facies. Scattered clots, or open geode-like vugs, lined with white to light gray dolomite, give the rock a distinct mottled appearance. This rock type has been observed in drill core north of Hamburg and in outcrop on Bushkill Drive in the northwestern part of Easton, Pennsylvania.

Where the Califon Member is very thin, it is postulated that the lower section was not deposited, possibly because of highs in the Precambrian surface.

At the first and third stop of the first day of the field trip, good exposures of the stylolitic beds of the Califon Member can be seen. At the third stop of the first day, the contact between the Califon Member and the overlying Hamburg Member is exposed.

Hamburg Member

The type section for the Hamburg Member is approximately one-half mile south of the town of Hamburg, where it forms a sharp, razorback hill. At this locality it is approximately 85 to 100 feet thick. The section is covered at its base and top, however the position and location of the adjacent lithologies indicate that a major portion of the member is exposed. The Hamburg has been observed by Markewicz in various parts of southern New York, eastern Pennsylvania and is known to be present near Amsterdam, New York.

The member is best described as a rhythmically bedded series of sedimentary cycles, representative of mud flat to intertidal and possible lagoonal environments. The member is estimated to be from 35 to 100 feet thick, depending upon locality. Typically, the same compositional lithology of a complete cycle is repeated throughout the member at any given locality; however, the overall lithology at any given exposure will generally consist of one of the following types:

1. Dark, organic, laminated to thinly bedded, fine grained, dense dolomites and shales with intercalated, thin siltstone and fine sandstone beds, lenses or stringers. The thinly bedded, ribbony units are distinctive and have been referenced to being similar to the ribbony units within the Shady Formation at Austinville, Virginia, where it is the host for a zinc-lead deposit. Small scale cross bedding, scour and fill, compaction, and sediment flow structures are readily evident on the fresh surface and in drill core. Pyrite occurs as disseminated grains, small masses and veins.

2. Dark to light gray, locally brownish gray to green cyclical units of fine to coarse sandstone, (locally quartzitic) siltstone, shale and very fine grained to cryptogranular, dense, conchoidal-breaking dolomite. A unit cycle consists of a lower siliceous unit grading upward to carbonate. A typical cycle begins with fine to coarse (occasional ½" pebbles) sand in beds from 2 inches to more than 12 inches in thickness deposited on the scour and fill surface (Figure 6) of the underlying dolomite which forms the top of the previous cycle. The sandstone grades upward through thin bedded to laminated arenaceous shales or siltstones into laminated calcareous shales or siltstones that grade upward into dense, sharp breaking dolomite. Typically, the beds weather to a yellowish brown, tan, or pinkish gray color depending on the compositional lithology.

3. Thinly bedded to ribbons, brown to brick or bright red, occasionally green shales, siltstones and sandstones, to low grade orthoquartzites. This facies resembles and has been mistaken for some of the varicolored lithologies found in the "Martinsburg" near Clinton, New Jersey. A distinctive "red" section was present as a prominent sharp knoll south of Andover before being removed by a quarry operator. The red color at this particular location may have been derived from the decomposition and deposition of minerals from the iron-rich rocks of the Precambrian in the vicinity of Andover.

4. Brownish weathered, thinly bedded, to strongly laminated siliceous to calcareous, phyllite intercalated with thinly bedded, locally lens-like to laminated dolomite and chert containing sandstone and sandy phyllite. This is the "damourite shale" unit as described in the early reports on the "Kittatinny" of New Jersey. This facies is generally thinner in overall thickness than the above varieties.

Figure 2

Large Precambrian boulder encased by Hardyston sediments. Outcrop located near type section of Califon Member.

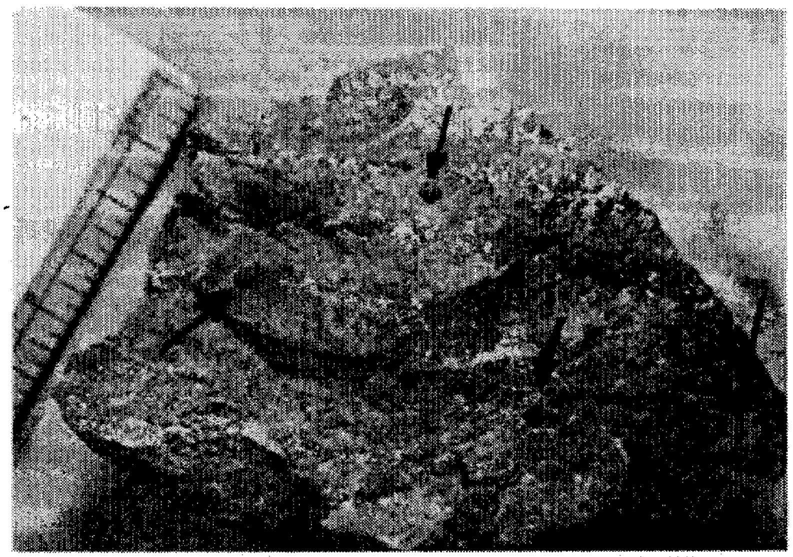


Figure 3

Hyolithellus opercula in Califon Member dolomite.

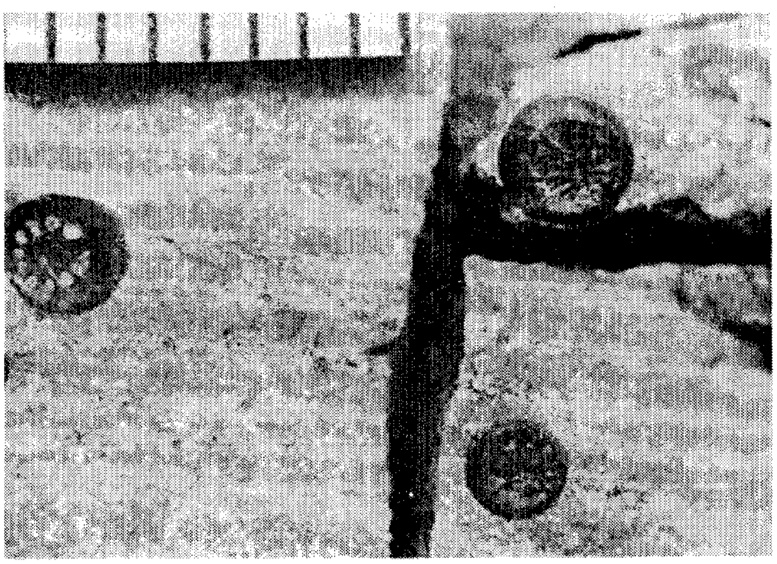
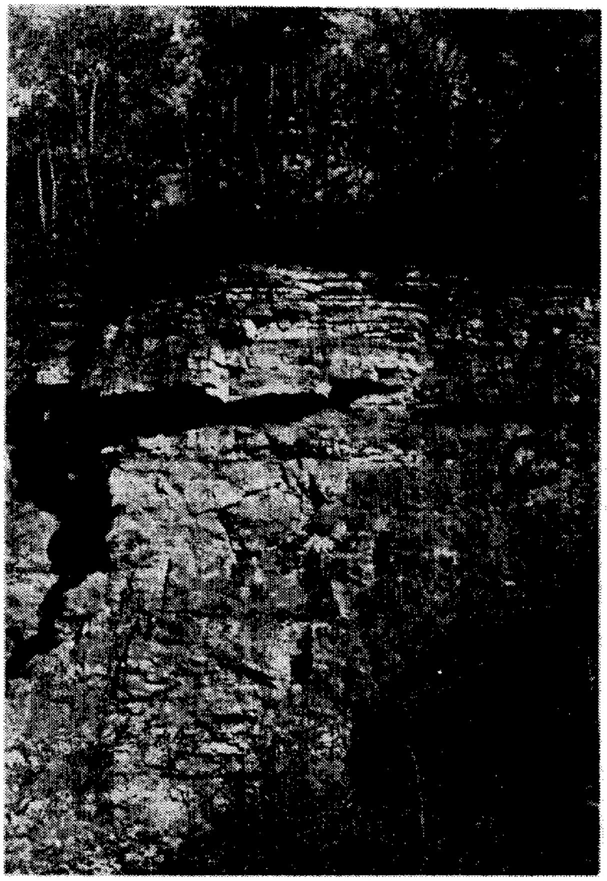


Figure 4

Hyolithellus opercula in Califon Member from Califon, N.J., showing muscle attachment scars.



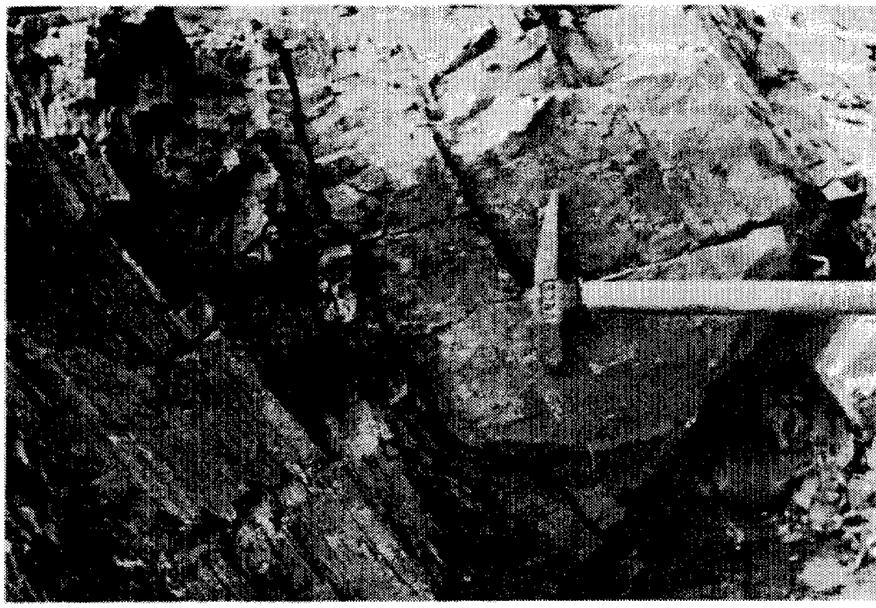


Figure 5

A - Basal part of Hamburg
B - Upper part of Califon
C - Upper section of lower part of Califon Member

NOTE: Stepped overhang from A to C

Figure 6

Hamburg Member at type locality. Line drawn along contact of scour and fill surface between sandstone above and dolomite below.

Figure 7

Photo shows ridge formed by Hamburg Member at Wallkill type locality north of Hamburg.

Wallkill Member

The Wallkill Member which overlies the Hamburg Member forms the upper part of the Leithsville Formation. It is poorly to rarely exposed, because it generally forms a topographic low in stream valleys or other low-lying areas, and is covered by stream alluvium or glacial deposits.

The Wallkill Member is named after the dark gray, patchy dolomite that lies above the shaly, arenaceous Hamburg Member (Figure 7) on the east side of the Wallkill Valley north of Hamburg. It consists in the lower part of fine to medium grained, rubbly to lumpy bedded, stylolitic, locally vuggy, mottled, patchy to ruditic textured, sparkly dolomite, in beds from several inches to more than 1.5 feet thick (Figure 8). Beds weather dark gray, lumpy to irregular in form, with a mosaic patchwork because of the clast to breccia-like texture of the rock.

Although not exposed at the above location, based upon other isolated exposures in northern New Jersey, the upper half of the Wallkill Member is considered to be a fine to medium-grained, locally coarse, crystalline dolomite with some beds of algal-like structures and large oölites and pisolites. The upper part appears to be transitional into the lower part of the Limeport Member of the Allentown Formation. Overall, the Wallkill Member is considered to be from 350 to 500 feet thick. At the type section, it is estimated to be about 400 to 500 feet thick. This would make the Leithsville at this location about 650 to 700 feet thick.

It is estimated that the Leithsville in New Jersey varies from 500 to 800 feet thick. Drake (1969) estimates the Leithsville to be 1,000 feet thick; however, the writers conclude on the basis of field work in many parts of northern New Jersey, that the Leithsville can vary a great deal in thickness but is generally less than 1,000 feet thick.

The lower part of the Wallkill, the entire Hamburg and Califon Members are considered to be potential sulfide-bearing horizons. Sphalerite, galena, fluorite, and some chalcopyrite have been found at several localities. A prospect containing sphalerite and galena was found by the authors in 1969 in the lower part of the Wallkill and in much of the Hamburg Member in Lafayette Township of Sussex County. Some of this rock will be available for inspection on the field trip.

ALLENTOWN FORMATION

The name Allentown was proposed by Wherry (1909) for the thick sequence of oolitic dolomite overlying the Leithsville in eastern Pennsylvania. Miller and others (1939) mapped the Allentown. B. L. Miller (1939) used the name Conococheague in the Lehigh Valley instead of Allentown, later he reverted to the local name. Howell and others (1950) subdivided the Allentown into the Limeport and Allentown Formations. This was based on the presence of both early and late upper Cambrian faunas, with the absence of a middle upper Cambrian fauna. The early late Cambrian and late Cambrian faunas were first recognized in New Jersey by Weller (1900 and 1903) at Newton and Andover in the upper 200 feet of the Allentown.

Drake (1965) did not follow the twofold subdivision of the Allentown, instead he mapped the entire sequence as a single unit. He places his lower contact at the first appearance of cryptozoa and oölites and his upper contact at the last cryptozoa bed. Drake (1969) states that the Cambrian-Ordovician boundary in Maryland is 400-500 feet below the Conococheague-Beekmantown contact.

In New Jersey, two mappable units are present within the Allentown. For the lower member, the name "Limeport" is being reintroduced, having been redefined on the basis of lithic and sedimentary features. The upper member, pending further work, is referred to as Upper Allentown.

Limeport Member

The Limeport Member consists of fine to medium crystalline, thin to thick, cyclically bedded, light to dark gray dolomite. The rock weathers to an alternating sequence of buff-cream, light and dark beds (Figure 9). Oolites, cryptozoa, ripple marks, mud cracks, cross bedding and chip conglomerates predominate the member. Many forms of algal structures are present, ranging from thin mats to large thick colones (see discussion on sedimentation, Stop 2, Day 1, by Rick Majors).

Quartz occurs as floating grains or in thin beds or lenses. Black chert lenses, beds or nodules are much more common than in the underlying Leithsville. There are many thin argillaceous dolomite to shaly beds present throughout the section. Dessication features and possible paleo-soil zones can be found. The Limeport Member varies from 400 to 700 feet thick through most of New Jersey. In the northwestern portion of the state, the unit thickens greatly at the expense of the upper member.

The transition zone between the upper member and the Limeport is gradational with oolites and cryptozoa becoming less abundant going upward. The contact in the field is placed at the last common appearance of cryptozoa and oolites and the appearance of uniformly textured, thick bedded dolomite.

Upper Allentown Member

The Upper Allentown is equivalent to the Allentown as defined by Howell and others (1950) which was estimated to be 400-500 feet thick. In the Hamburg area it is up to 1,000 to 1,200 feet thick. In northwestern New Jersey the upper member thins to less than 500 feet thick.

The Upper Allentown is generally much more massive and thick-bedded than the Limeport Member, with some beds being finely laminated. The beds, from one to six feet in thickness, vary from a fine to medium crystalline, light to dark gray dolomite. Some beds may be mottled and/or pitted. Chert occurs as thin beds, discontinuous lenses and knots. In contrast to the Limeport, stromalites and oolite beds are infrequently found.

The upper 100 to 200 feet of the Allentown becomes more siliceous by a greater content of sandy dolomite and local quartzite beds. There are at least two distinct interbedded quartzites (up to 20 feet thick) in the upper 100 feet. The upper quartzite consists of a very sandy conglomerate zone overlain by a steel gray, dense, quartzite which is a distinct scour and fill. The contact between the Allentown and the Rickenbach is placed at the quartzite conglomerate zone which is about 75 feet above a distinct section of thin bedded, mottled dolomite containing local oölites, cryptozoa, and silt beds.

RICKENBACH FORMATION

The Rickenbach Formation, as defined by Hobson (1963), consists of a thick to thin-bedded, light to medium-dark gray, microcrystalline to coarsely megacrystalline dolomite which occupies the stratigraphic interval between the Allentown and the Epler Formations. He subdivided the formation into an upper and lower member.

The Rickenbach, in this field guide, is divided into an upper (Hope) member and a lower (unnamed) member and a distinct facies named the Crooked Swamp Dolomite.

Lower Rickenbach Member

The lower member of the Rickenbach consists of thin to medium-bedded, cream to dark gray, weathered beds with thin, sandy dolomite bands to locally quartzose beds containing some chip conglomerates. Some beds are massive, with local mottling, and weather to a lumpy, raspy surface. The texture of the lower member is fine to medium-grained, with local coarse grained beds containing pits, partially filled clots, as well as lenses, knots, and beds of chert. Pyrite can be scattered throughout the section. The lower member is from 75 to 150 feet thick and is well developed near Hope.

The transition between the Lower Rickenbach and the Hope Member is gradational, with the rock becoming darker and very fine grained to aphanitic, with interbeds of very dark gray to almost black dolomite.

Hope Member

The Hope Member can be up to 175 feet in thickness. It consists of light to gray, weathered, aphanitic to finely crystalline, medium-bedded dolomite that is interbedded with darker gray, weathered, more coarsely crystalline, medium to massive-bedded dolomite. The aphanitic beds may contain a sandy zone at the base. There can also be a very distinctive internal brecciation or crackling (Figure 10) which seems to be related to the paleo-karstification of the carbonate sequence. The coarser beds can contain clots of quartz and white dolomite. At the Route 80 section, Stop 3, Day 1, a black, botryoidal, hydrocarbon mineral has been found in the Hope Member in the quartz clots.

There are several chert beds and zones present in this member. The most distinctive of these chert horizons is a marker bed which we have termed the "7 cherts". This marker bed occurs in a dark gray, fine to medium crystalline, massive dolomite bed approximately five feet thick. The upper half contains seven distinct beds of arching cherts three to six feet long and up to three inches thick. These cherts have been recognized at various localities from southern New York to eastern Pennsylvania.

Approximately 50 feet above the "7 cherts" is a second zone of discontinuous knots and lenses of chert, some of which may be convex upward; in addition, algal structures occur in and above this zone.

The contact between the Rickenbach and the Epler Formations is placed 50 feet above the upper chert horizon.

Crooked Swamp Dolomite

The Crooked Swamp Dolomite facies of the Rickenbach Formation consists of light gray to gray, fine to coarse grained, euhedral dolomite and is best developed near Crooked Swamp, 1.5 miles north of the town of Lafayette in Sussex County. Individual beds of the Crooked Swamp dolomite facies can be found throughout the Rickenbach, but the thicker beds are more common in the upper part of the formation. The dolomite crystals can be surrounded by a fine, clayey material which may be kaolinite. Many of the beds contain pits and clots commonly filled with dolomite, quartz and kaolinite. The individual beds range from two to six feet thick with some indistinctly laminated.

At the type location, the Crooked Swamp Dolomite approaches 150 to 200 feet in thickness and thins rapidly both north and south to about 25 feet. As the unit thins, a distinctive conglomerate is developed in the upper Rickenbach and in the basal part of the Epler Formation.

This facies may represent a series of reefs (Figure 11) or a later dolomitization replacement of finer grained rock.

Samples of the Crooked Swamp Dolomite have been compared to the samples of the Kingsport Formation of eastern Tennessee. The two units cannot be separated by visual identification. The basal part of the Epler, especially where the conglomerate is developed, is lithologically similar to the Mascot Dolomite of Tennessee. The Mascot and Kingsport occupy a similar stratigraphic interval as the Epler and Rickenbach. It is possible that the light gray to gray, medium to coarse crystalline facies of the Kingsport is correlative with our Crooked Swamp Dolomite facies.

EPLER FORMATION

The Epler as defined by Hobson (1963) consists of an interbedded sequence of dolomite and limestone. Drake (1965) places his lower contact at the lowest limestone bed following the work of Hobson. His upper Epler contact is placed at the unconformity between the "Kittatinny" and the Jacksonburg. Drake (1969, p. 87) states that "The Ontelaunee of Pennsylvania is absent in the Delaware Valley because of the pronounced unconformity at the top of the Beekmantown" and (op cit) that "A different Epler lithology is present at each place the upper contact has been observed . . . Epler lithologies, however, appear to underlie the Jacksonburg as far west as Nazareth, Pennsylvania."

In the outcrop area northeast of where Drake worked, the Epler is mainly dolomite, except for occasional limestone lenses found in the middle of the formation (Figure 12). We do not put the Rickenbach-Epler contact at the lowest limestone bed; instead, the contact has been placed at a massive chert zone above which the lithic features are different from the underlying rock.

The Epler Formation has been subdivided into the following members:

Lafayette Member

Big Springs Member

Branchville Member

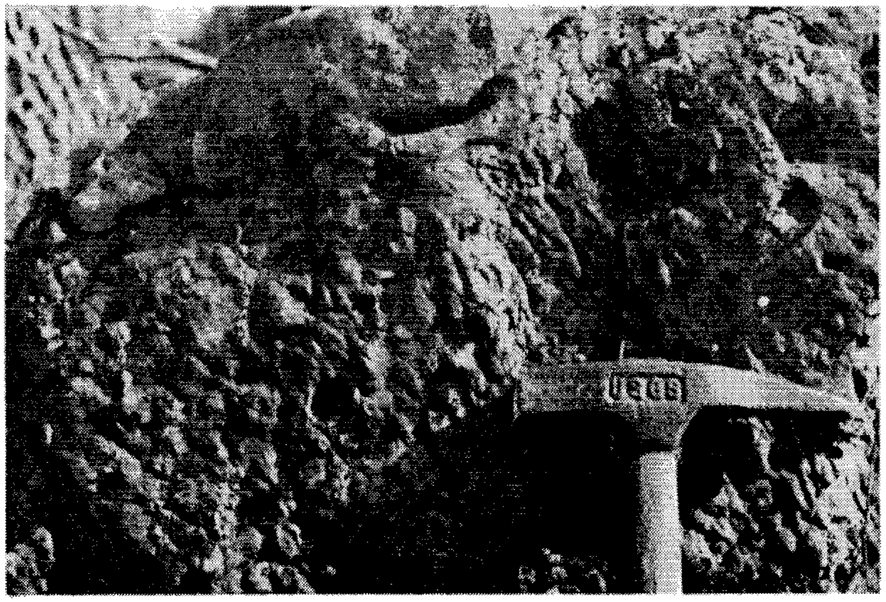


Figure 8

Wallkill Member at type locality. Photo shows patchy-ruditic texture on weathered surface.

Figure 9

Typical alternating light and dark beds of Limeport Member, Route 94.

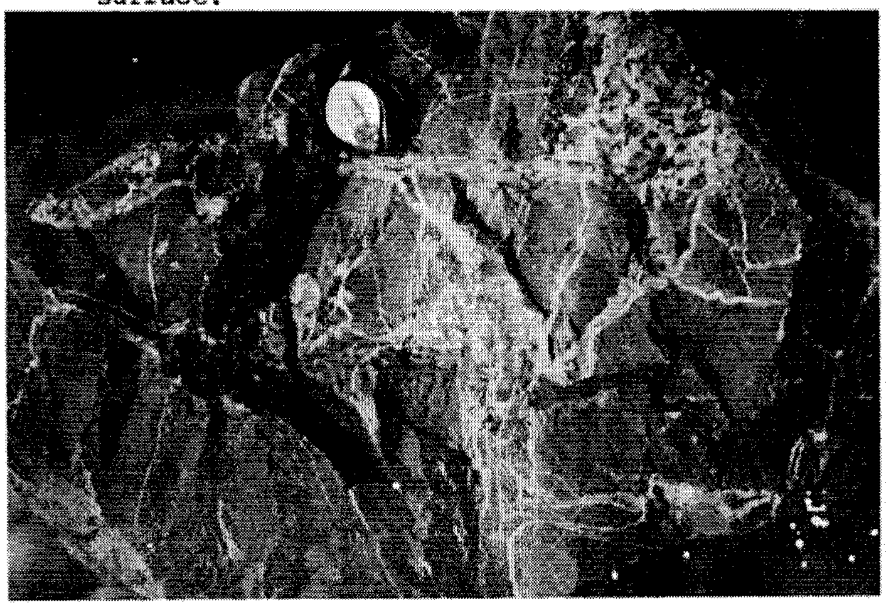


Figure 10

Calcite-dolomite filled crackle breccia in the Hope Member at the Hainesburg railroad cut. Stop 1, Day 2.

Figure 11

The Crooked Swamp Dolomite facies showing the breccia and intertonguing which may be related to reef development, near Newton.

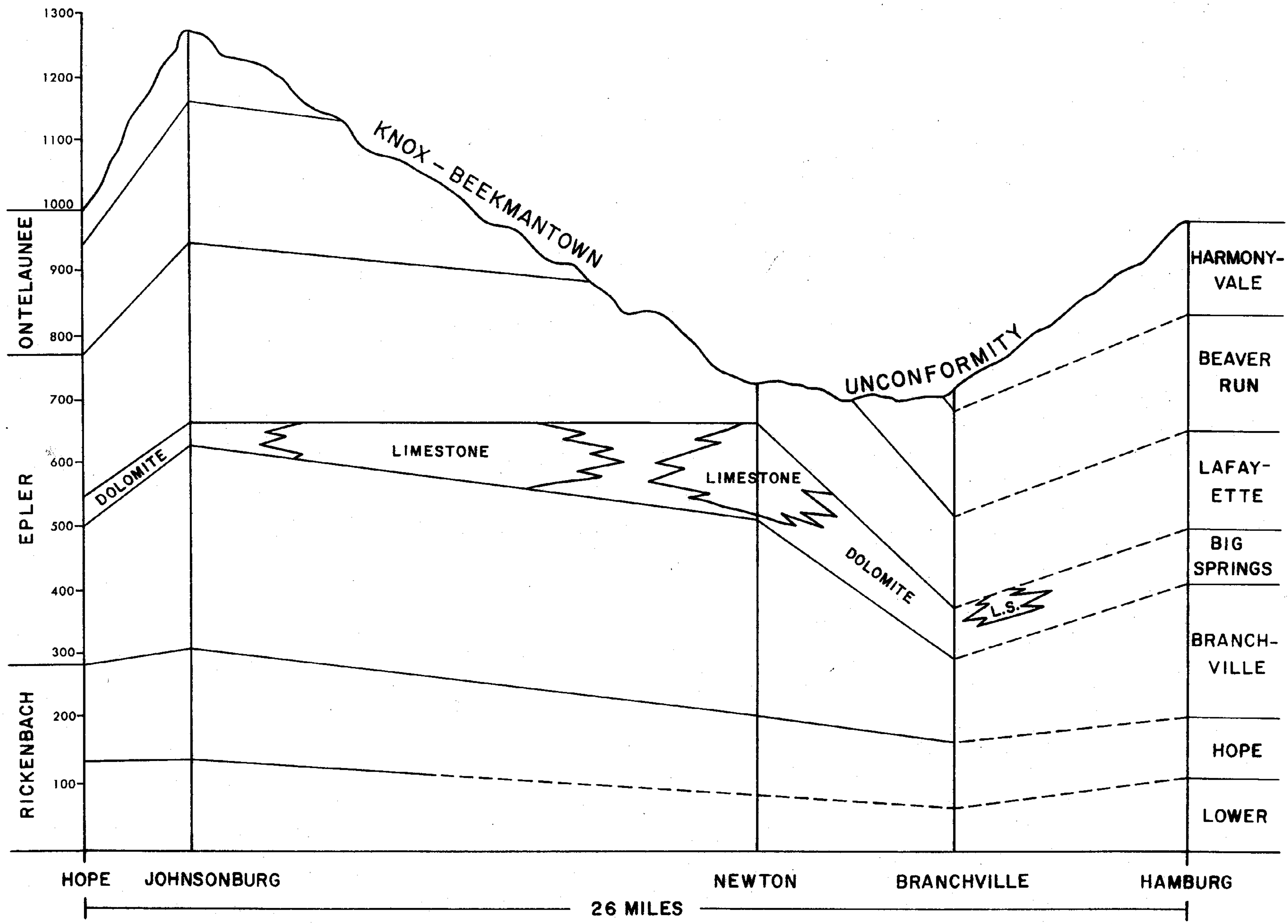


Figure 12

Diagram showing member correlation for the Rickenbach, the Epler, and Ontelaunee Formations from Hope to Hamburg.

Branchville Member

The Branchville Member typically contains two distinct lithic units. The lower unit ranges from 0 to 50 feet thick and is a variable sequence of very fine to coarse grained, light to dark gray, medium to massive bedded dolomite with some distinct laminated beds. Chert, shale, oölites, and cryptozoa can also occur. At some localities the lowermost part of the lower unit consists of a variable thickness of reddish, pinkish and/or greenish, cryptocrystalline, conchoidal fracturing, sandy dolomite with some white porcelanite chert.

Above the lower part of the Branchville Member is a 150 to 200 foot thick unit that consists of a very fine to fine grained, medium to dark gray, massive, finely laminated dolomite (Figure 13). In the upper part of this member there are some thin, siliceous to shaley interbeds similar to the Big Springs Member. Weathered surfaces generally are reddish brown to buff colored.

Big Springs Member

Above the Branchville Member a 40 to 150 foot thick section of variable dolomite and limestone is named the Big Springs Member. In the type area near Hamburg, the Big Springs generally consists of a light to medium gray, fine to medium grained dolomite with local green to pink bands or lenses consisting of siliceous dolomite, quartzite and/or siliceous shale. The dolomite beds are from one to three inches thick with shaly and quartzitic interbeds ranging from one-quarter to one inch thick. The siliceous beds weather in strong relief (Figure 14) giving the rock a ribbed appearance. This unit contains cross-bedding, chip conglomerates, cut and fill, oölites, chert, and red and green argillitic dolomite. The weathered surface has a distinctive bright red to yellow-orange rind. Some of the interbeds may weather to porous, siliceous ribs.

In the northeastern portion of the outcrop area there may be occasional limestone lenses, which may replace all or part of the unit; but the distinctive sedimentary features of the member are generally retained. The limestone weathers to powder blue with green or red-brown siliceous interbeds. From Newton, southwest toward the Delaware River, the Big Springs Member is predominantly a limestone which can change both laterally and vertically to a dolomite in many outcrops. The dolomite lenses are generally encased by a siliceous rind.

Lafayette Member

The Lafayette Member ranges from 50 to 250 feet thick and is similar to the Branchville Member. Two recognizable units occur within the Lafayette Member. The lower portion, which is generally fine to medium grained, black, sparkly, massive bedded dolomite, contains some beds of light to medium gray, fine grained dolomite with shaly laminations. The fine grained beds weather to an orange-gray color. Some chert is present along with some siliceous beds. The upper unit is a finely laminated, massive, light to medium gray, very fine to fine grained, cream to orange-gray weathered dolomite. The laminations stand out in relief on the weathered surface. Chert occurs as beds and clots. The Lafayette Member is transitional with the Ontelaunee Formation through an intercalaction of medium gray, very fine grained, laminated dolomite and medium gray, slightly sparkly, fetid dolomite. The Lafayette Member contains zones of breccia, which have caused confusion among many workers in the "Kittatinny" of New Jersey. These will be discussed in the section on the paleosolution breccia.

ONTELAUNEE FORMATION

The Ontelaunee Formation was recognized in New Jersey by Dalton and Markewicz (1972), Markewicz and Dalton (1974 and 1976). Field work on the Ontelaunee in Pennsylvania by Markewicz during 1965-66 indicated that it is similar with the upper part of the "Kittatinny" in New Jersey. Hobson (1963, p. 75), in referring to the Ontelaunee, states that "A mappable unit of dolomite has not been recognized to date in the Lehigh River and Delaware River areas...". Drake (1969, p. 87), also, does not recognize the Ontelaunee in New Jersey.

The thickness of the formation is dependent on the amount of erosion represented by the Knox-Beekmantown Unconformity. At Sarepta Quarry, Stop 5, Day 2, there is evidence for over 200 feet of erosion in a very short distance. In the Phillipsburg area the Ontelaunee probably exceeds 800 feet in thickness. The formation has been divided into the following members:

Harmonyvale Member

Beaver Run Member

Beaver Run Member

The Beaver Run Member is 150 to 200 feet thick and contains three recognizable units. The lower part, about 50 feet thick, is a massive, medium to coarsely crystalline, black, sparkly, fetid dolomite. The individual dolomite euhedra are characteristically zoned. Some laminated beds, along with a little chert, can be present. Above is a 50 to 100 foot thick, massive dolomite similar to the lower part, except that there is a large amount of bedded, anastomosing, rugose, and knotted chert. Individual chert beds can be as much as ten feet thick. Many silicified fossils have been found in this section. The upper portion, which can be as much as 50 feet thick, is a massive, fine to medium grained, black, sparkly, fetid dolomite, generally with little chert.

Fossils found in the Beaver Run Member include straight nautiloids, brachiopods, gastropods, corals, bryozoa, and conulariids. Typically they occur in the middle part of the member. Occasional fossils along with an asphalt-like hydrocarbon can be found in the upper part of the member. The hydrocarbon occurs both as small masses or clots and as an interstitial material between the dolomite euhedra.

The transitional zone, with the overlying Harmonyvale Member, is an alternating sequence of thin, coarse-grained beds, alternating chert beds, and dense, fine-grained beds.

Harmonyvale Member

The Harmonyvale Member is the highest of the Lower Ordovician rocks present in New Jersey. Its thickness (in excess of 220 feet) is determined by the amount of erosion on the unconformity. At many localities, the Harmonyvale has been completely removed and the Jacksonburg is deposited directly on the Beaver Run. This member consists of a dense, fine-grained to cryptocrystalline, conchoidal-fracturing, stylolitic dolomite in one to five foot beds that weather to a light cream gray color. Some of these beds will make a ringing sound when struck with a hammer. There are many medium crystalline, mottled, fetid beds that weather to a silty gray surface. Floating frosted quartz grains, sometimes rutilated, and chert beds up to several feet thick may be present. Some beds weather to a strongly dissected crosshatch surface (Figure 15), referred to as elephant hide rock (Hobson 1963). This surface is due to solutional action on a myriad of closely spaced fractures. The fractures are filled with a siliceous material that weathers to thin raised ribs on the rock surface. There are also many sets of thin, wispy, carbonaceous microfractures or seams present in some beds.

A zone of grayish chert occurs about 50 to 60 feet above the base. Along strike this chert grades into four-foot thick lenticular limestone beds at the type locality. The limestone contains fossils. About 20 feet above the limestone is a very fine-grained bed containing peculiar structures composed of ovoid concentric rings up to eight inches in length. These structures, termed oncolites, are found in most Harmonyvale sections at about the same distance above the Beaver Run-Harmonyvale contact. Fossils in the Harmonyvale include gastropods (Figure 16), brachiopods, and trilobites as well as the oncolites.

The reasons for correlating the Beaver Run and Harmonyvale Members to the Ontelaunee of Pennsylvania (Figure 17) are as follows: (1) The Big Springs Member of the Epler can be correlated with Hobson's "60 foot fossil zone" by similar fossils that have been found in the Big Springs limestone facies and by similar lithologies; (2) Hobson (1963) places his Epler-Ontelaunee contact at the highest limestone bed and approximately 100 feet below a massive chert zone. This chert section is probably equivalent to the middle part of the Beaver Run. Hobson states that the cherts are characterized by rugose or colloform chert; and (3) he also states that nautiloids are <u>not</u> found in Epler. In the Beaver Run Member we have found many nautiloids, gastropods, and other fossils. In the Harmonyvale Member, linguloid brachiopods, trilobites and gastropods have been found. The gastropods are similar to those seen high in the Ontelaunee of Pennsylvania by Markewicz. The base of the Ontelaunee, as we define it, does not coincide exactly with that of Hobson, since he places the contact at the change from limestone to dolomite and we place it at the change from the fine-grained laminated dolomites of Lafayette Member to the coarser-grained dolomites of Beaver Run Member. From the description of Hobson's measured sections, it appears that he includes a portion of what we call the Lafayette Member in the Ontelaunee.

<u>Paleo-Solution Breccia</u>

As mentioned under the description of the Lafayette Member, zones of paleo-solution breccia occur in the upper part of the "Kittatinny". These breccias have been interpreted as fault breccias by some workers and as intraformational conglomerates by others. Hobson (1963, p. 65) states that the massive breccia zones at Carpentersville are possibly fault related, although they do not look like fault breccias. They are commonly found in the Lafayette Member of the Epler Formation with similar breccias occurring in the Rickenbach (Figure 18) and Ontelaunee as well. At some localities, the breccia has been traced from the lower part of the Beaver Run Member down through the Epler into the top of the Rickenbach, with a few short covered zones. The breccia may consist of angular blocks of laminated dolomite and rounded cobbles, very large slightly tilted blocks of laminated dolomite (Figure 19), or a zone of small fragments of slightly rotated laminated dolomite.

At some localities the breccia has filled tube-like channels in the rock. Generally, the breccia to wall rock contact shows no evidence of faulting. The clasts within the breccia, at many localities, consist of a heterogeneous assemblage which have been derived from the overlying units as well as the unit con-

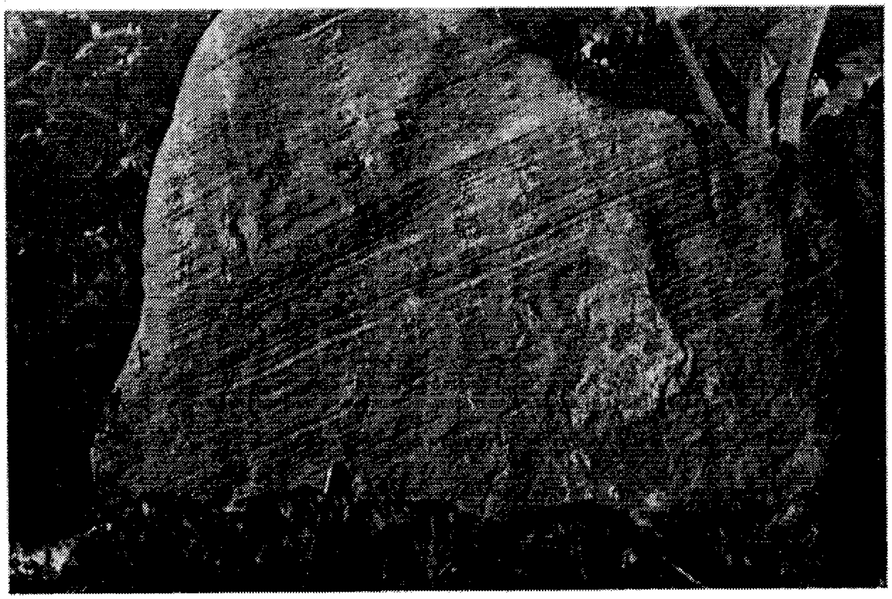


Figure 13

Finely laminated dolomite of the Branchville Member of the Epler, near Hamburg.

Figure 14

Differential weathering of the Big Springs Member, Route 80, Stop 3, Day 2.

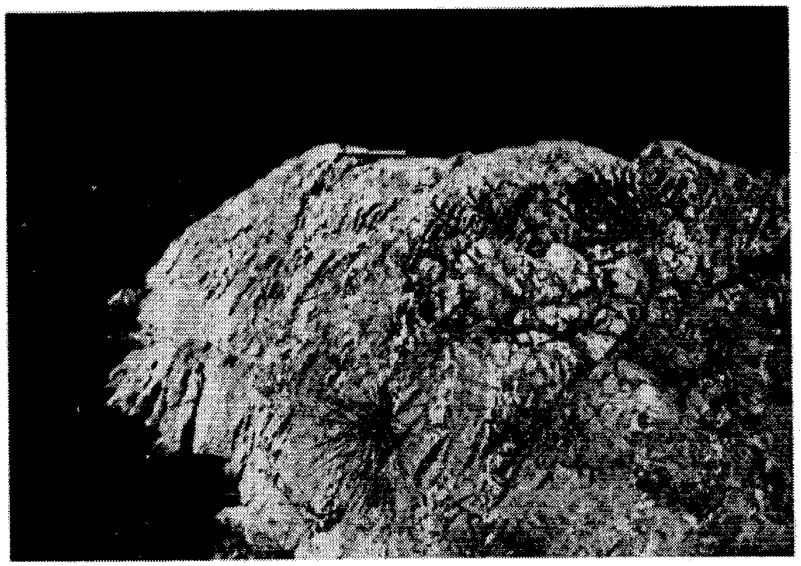


Figure 15

Outcrop of the strongly checked (elephant hide rock) Harmonyvale Member on bank of Mulhockoway Creek northwest of Clinton.

Figure 16

Silicified gastropods from Harmonyvale Member at Sarepta.

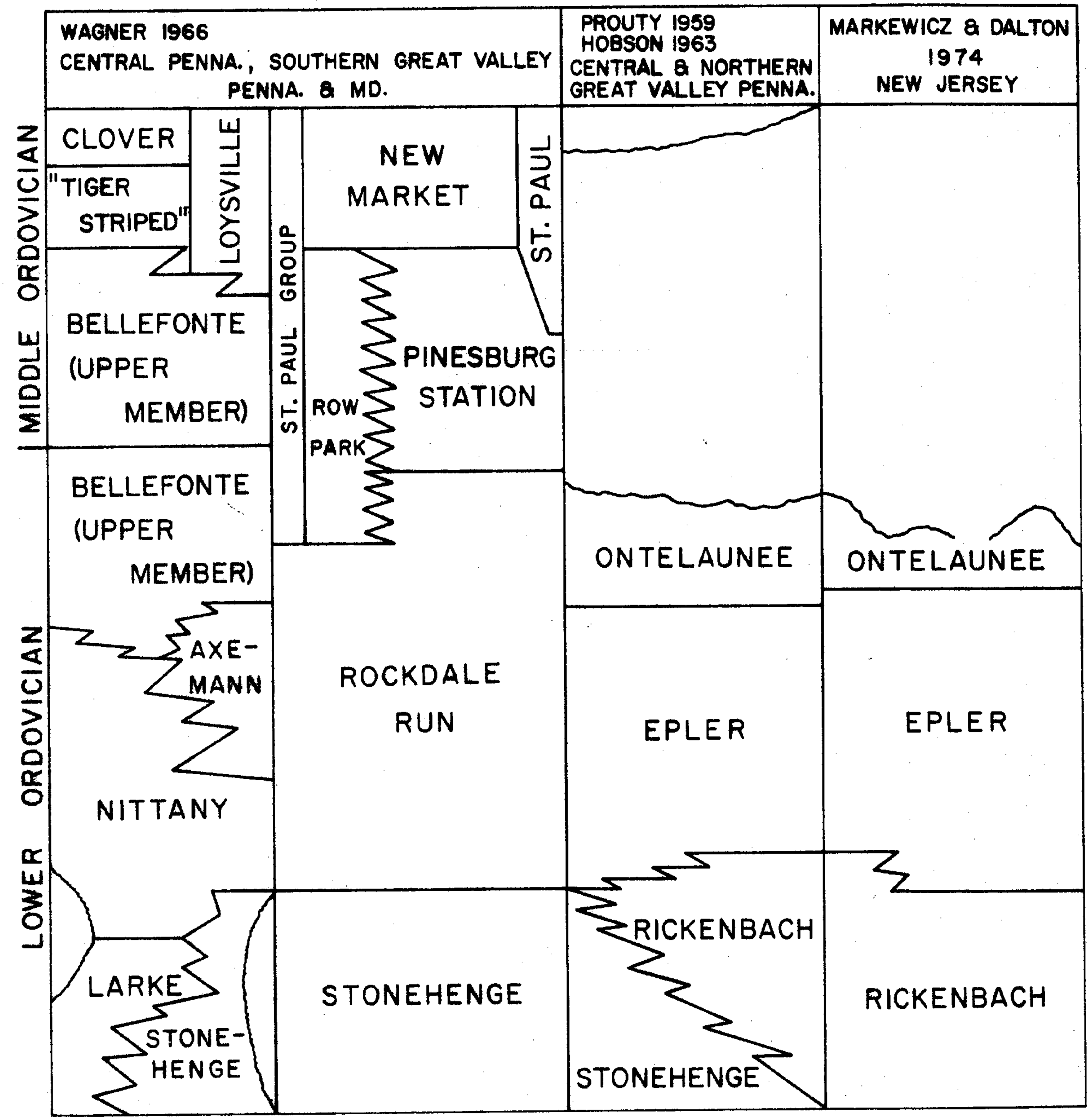


Figure 17

Composite Correlation Chart

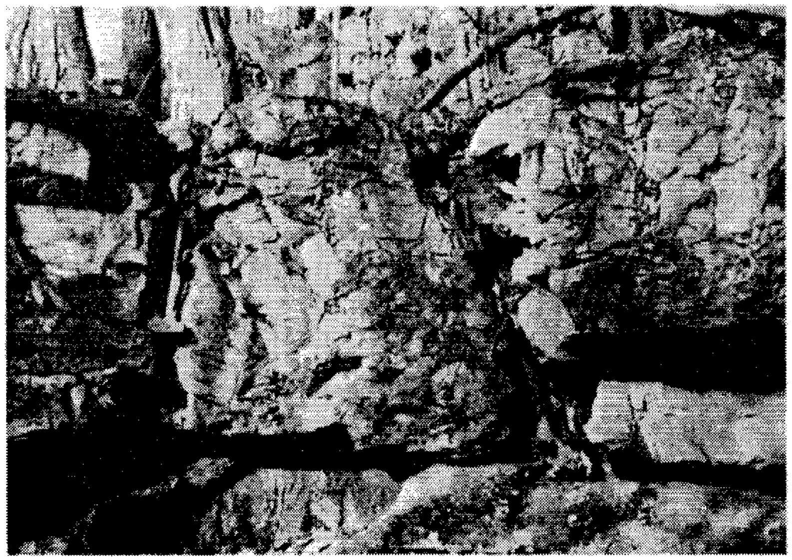


Figure 18

Massive paleo-solution breccia in upper Rickenbach Formation, near Hamburg.

Figure 19

Paleo-solution breccia showing the random orientation of the clasts, Lafayette Member, near Beaver Run.

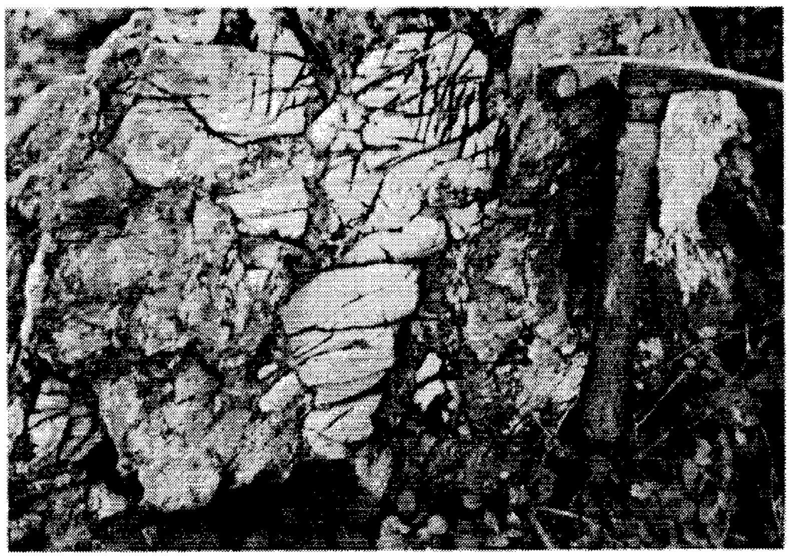


Figure 20

Paleo-solution breccia containing fragments of Harmonyvale Member, near Hope.

Figure 21

Green argillaceous material containing leached cavities which may have been residual dolomite fragments, near Asbury.

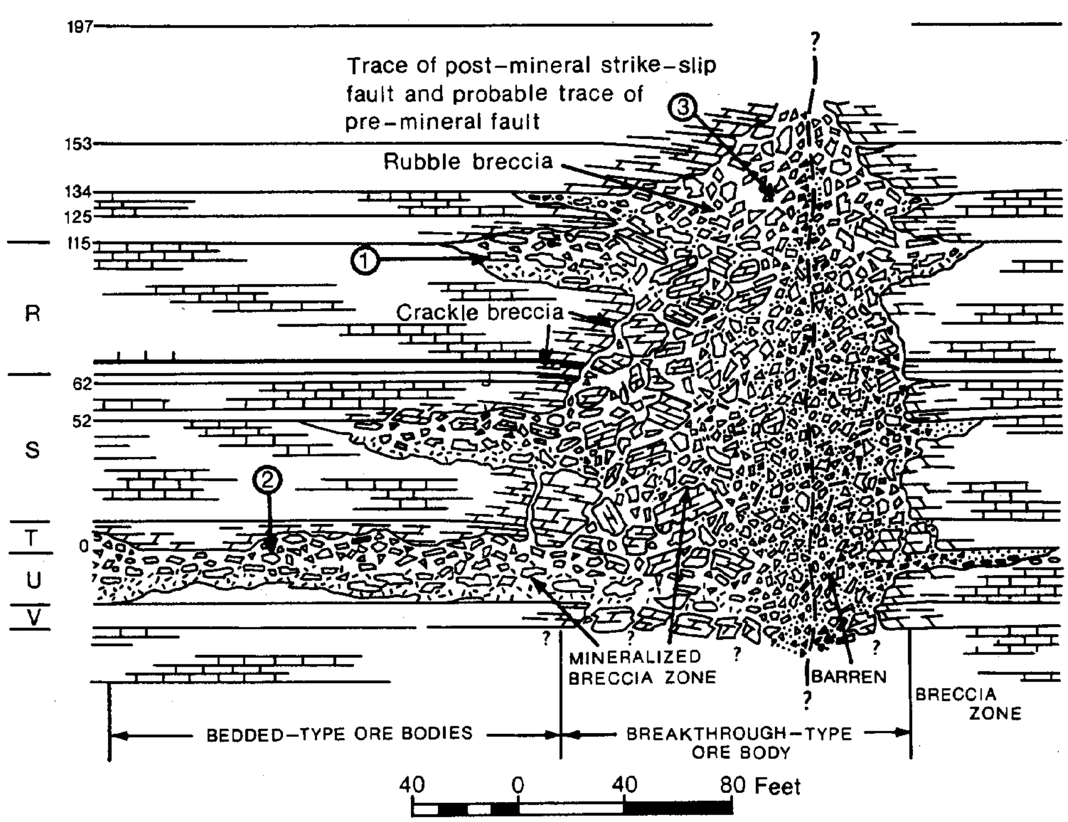


Figure 22

Relationship between crackle breccia and rubble breccia (from Hardeman, and others, 1969, fig. 4) taining the breccia (Figure 20). The interstitial material around the fragments is commonly a red to greenish silt, similar to the material found in present day karst deposits.

Some beds of dolomite contain a peculiar crackle breccia which consists of angular fragments measuring from one-quarter inch to greater than four inches in size, with the individual fragments showing little to no rotation. It is commonly found in a 50 to 200 foot thick zone, which extends from the lower part of the Branchville Member of the Epler down into the Hope Member of the Rickenbach in the dense, finely crystalline dark beds. The crackling can disappear both vertically and horizontally in a few tens of feet. Within this zone of crackling, the breccia will be confined selectively to the finer grained beds with little evidence of crackling in the coarser interbeds.

The filling material between the fragments typically consists of a white to light gray crystalline calcite and/or dolomite. In some areas such as Friedensville, Pennsylvania, the filling material is a light, honey colored sphalerite.

The crackle breccia is important because of its use as a possible ore (sphalerite) guide and, in some cases, for use in stratigraphic interpretation. At several localities in New Jersey, sphalerite has been found in association with the crackle breccia. Its similarity with the Friedensville crackle breccia is striking because it is difficult or impossible, even for the experienced geologist, to distinguish one from the other. Examples of both will be seen in outcrop and specimens at Stop 1, Day 2.

The true origin of these breccias is related to the karstification of the upper portions of the Kittatinny during the erosional period prior to Jacksonburg deposition (the Knox-Beekmantown Unconformity). The relationship of the crackle breccia to the massive breccias (rubble breccia) is shown in Figure 22. The origin of the crackling is probably related to the tension release fractures as found associated with present day cave passages.

The most important paleo-karst breccia occurrence is near Beaver Run, Sussex County (Figure 23). At this locality, 1.9 miles west of Route 94 on Beaver Run Road, a breccia 300 to 400 feet wide can be traced downward for several hundred feet perpendicular to bedding. It is postulated that this breccia, before erosion, was 3-4,000 feet long. A few hundred feet to the south and higher on the hillside, one of the most unusual stratigraphic units present in the region is found. It occupies the interval between the Ontelaunee and Jacksonburg Formations.

This unit consists of green siltstones with leached cavities and shards of chert (Figure 21), green siltstones and argillites, shales, and calcareous sandstones to pebble conglomerate. The green siltstone with cavities is in contact with the lower part of the Harmonyvale. This green unit is about 200 feet thick and has a strike length of about 3,000 feet. It thins rapidly, both to the north and to the south, and is overlain by typical Jacksonburg. Based on the relationships observed at this locality, it is the opinion of the authors that the green unit is filling a paleo-sinkhole. Figure 24 indicates the relationship between the development of the breccia and the downcutting during karstification.

The contact with the dolomite was dug out at this locality. A very dark, manganese-rich, soft, earthy, soil-like zone occurs at the contact. The top of

GENERALIZED SECTION OF PALEOSOLUTION SYSTEM SOUTH OF HAMBURG

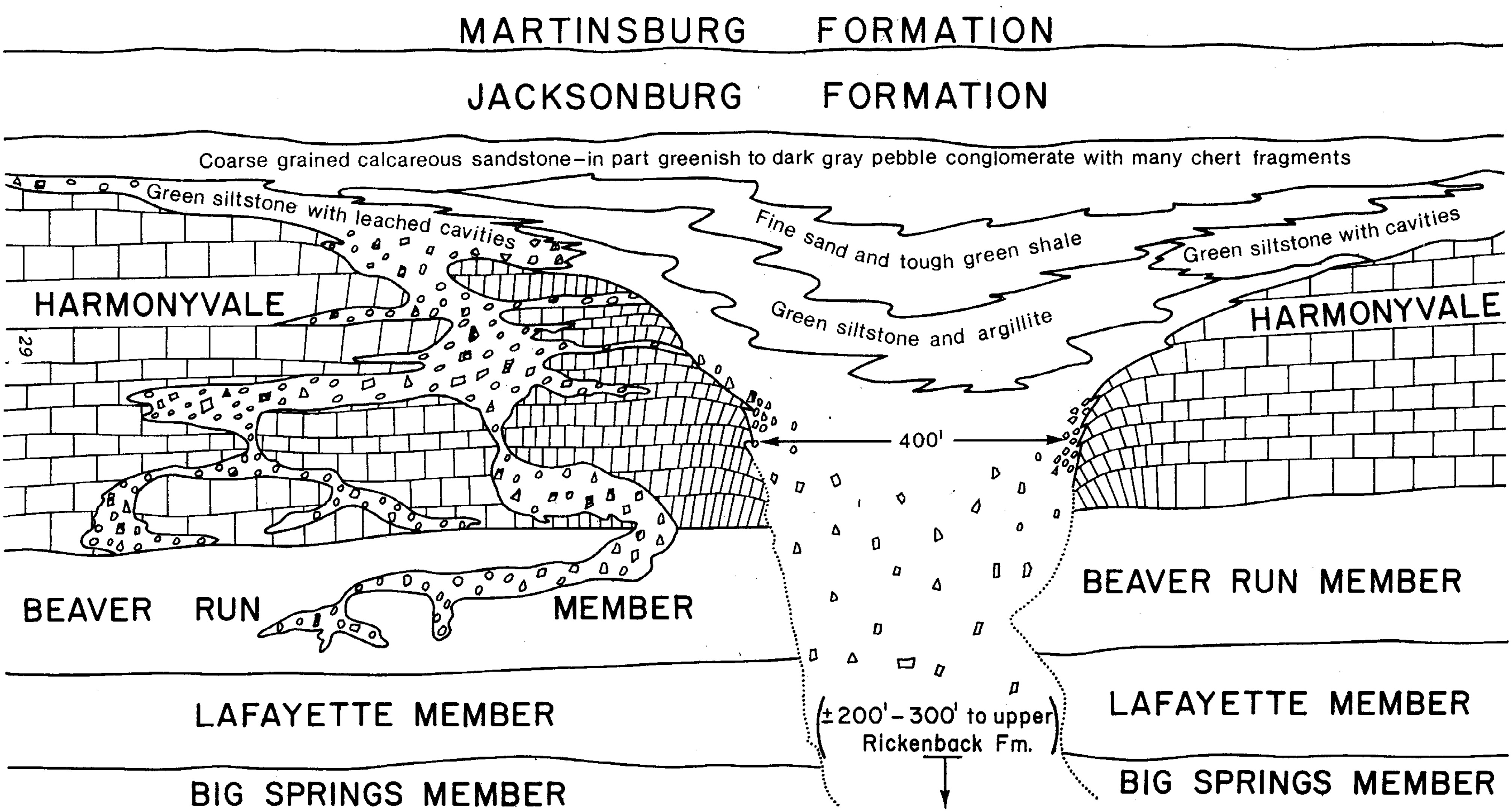


Figure 23

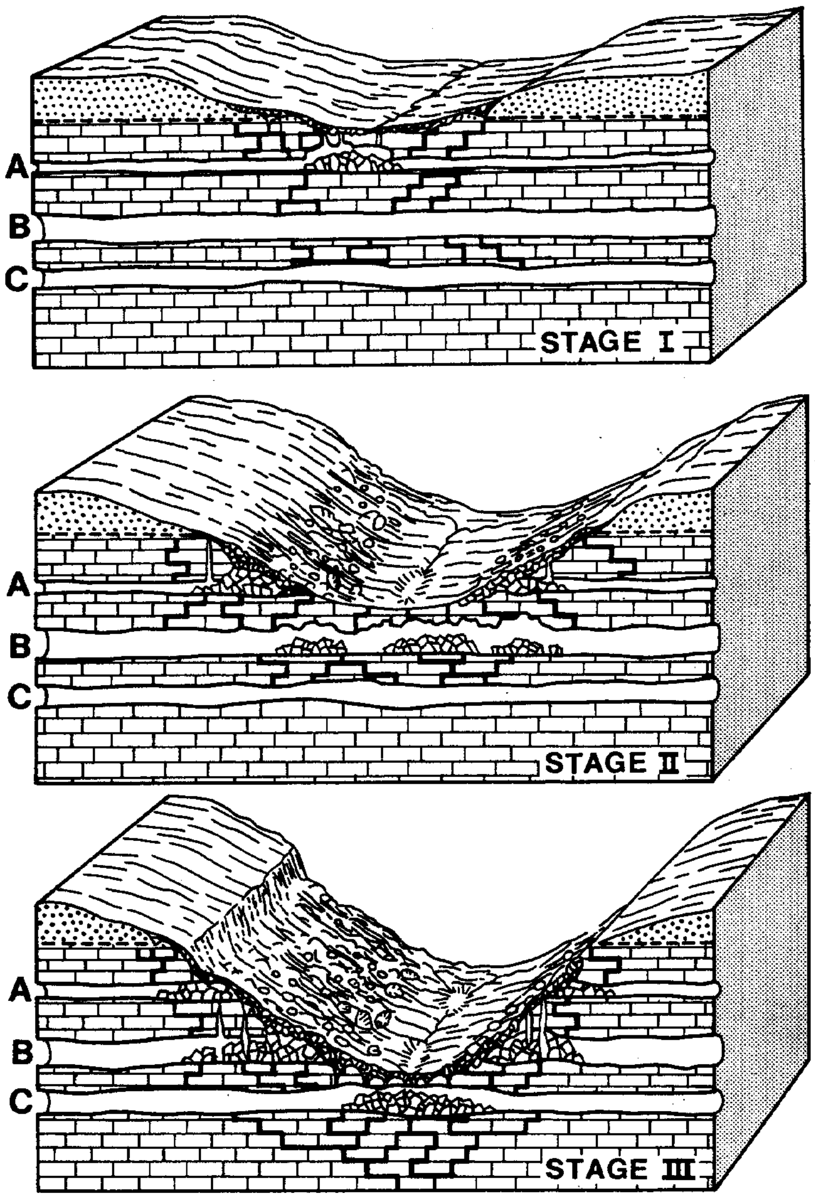


Figure 24

Relationship between the downcutting during karstification and development of breccias (breakdown) (from Bruckner, 1966, fig. 2) the Harmonyvale is irregular and the beds are parted by a thin quartz-dolomite filled fracture system. Many of the filled fractures show a definite curving pattern with the top of the fractures bending in the same direction that the bedding is sagging, toward the center of the sinkhole.

This green unit has been found at several other localities. At one, near Swartzwood Lake, beds of massive conglomerate are interbedded with greenish argillaceous beds for a stratigraphic thickness of greater than 85 feet. The conglomerate beds are up to 25 feet thick with the intervening argillaceous beds up to 10 feet thick. This "pre" Jacksonburg unit represents the filling of some of the sinkholes, developed on the paleokarst surface, with the residual soil and rock fragments.

A similar unit known as the Dot Formation occurs at the top of the Knox unconformity in Tennessee. The following description is from Hardeman and others (1969, p. 41):

> "The basal facies of the Dot Formation is a series of argillaceous conglomerate, limestone, and shale units that fill irregularities on the Knox erosion surface. At the mine the basal beds of the Dot can be subdivided into four lithologic units (fig.1). The lower unit (Ods) is greenish-gray shale with interbeds of argillaceous dolomitic limestone that contains abundant small chert fragments. This is directly overlain by a thin zone of lutite-textured grayish limestone (Odll). These units are present in the western part of the map area but pinch out against the unconformity in the central part of the mine (fig. 1). Overlying the lower limestone (Odll) unit is a massively bedded, yellow-weathering argillite (Oda) which contains abundant angular chert and dolomite clasts as much as three inches in diameter. This unit is succeeded by massively bedded, bluish-gray limestone which contains very thin discontinuous lentils of fine-crystalline dolomite (Odul)."

The green unit is unique, not only because of its stratigraphic position and lithology, but also its relationship with major paleosolution breccia bodies for use as a guide in sulfide exploration.

JACKSONBURG FORMATION

The Jacksonburg Formation was first named by Kummel (in Spencer and others, 1908) for the exposures at Jacksonburg, New Jersey. A systematic examination of the type section was done by Weller (1903). A trench was started at the Kittatinny-Jacksonburg contact and excavated uphill almost to the Martinsburg contact, a thickness of more than 122 feet.

The Jacksonburg was divided into a "cement rock" (upper) and the "cement limestone" (lower), by Kummel (1901). Prouty (1959) postulated a tentative correlation with the Hershey and Myerstown of central eastern Pennsylvania, with the "cement rock" and "cement limestone" in eastern Pennsylvania. It is likely that this correlation is valid for New Jersey.

The lower contact between the "cement limestone" with the "Kittatinny" is a pronounced karst unformity. At the Sarepta Quarry locality, the Jacksonburg has been deposited in a trough incised at least 300 feet into the Ontelaunee Formation with the bottom of the trough not being exposed.

The "cement limestone" is medium to dark gray, fine to coarsely crystalline limestone which locally is a high calcium limestone. There are some light to medium gray calcarenite beds. At many localities, the basal part of the formation contains thin to thick beds of conglomerate. One of the thickest conglomerate sections is along Route 80 near Hope, where 275 ± feet of conglomerate has been measured. It is now possible, with the dolomite member subdivision, to recognize many of the individual cobbles in the conglomerate. The "cement limestone" has been estimated to be about 200 to 300 feet thick, Kummel (1900) and Drake (1969).

The "cement rock" consists of a dark gray to black, argillaceous limestone that has a pronounced cleavage. It contains some beds of coarsely crystalline limestone. Kummel (1900) and Drake (1969) estimate the "cement rock" to be in excess of 600 feet thick at some localities.

PEGMATITE DIKELETS IN THE ORDOVICIAN ROCKS AT PHILLIPSBURG

In Phillipsburg, a series of thin granitic pegmatite dikelets are intruded into the lower Ordovician carbonates (Dalton and Markewicz, 1976). A search of the literature reveals that the only reported occurrence of a pegmatite intruding rocks younger than the Precambrian are those at Morgan Hill, Pennsylvania (Fraser, 1936 and Miller, 1939). The pegmatites at Morgan Hill intrude up to 10 feet into the lower Hardyston Formation.

The pegmatite veins at Phillipsburg are about 2½ miles north of Morgan Hill. According to the Easton Quadrangle Geologic Map (Drake, 1967), the occurrence at Phillipsburg has intruded the Rickenbach Formation about 700 feet south of the axis of the Easton Antiform. Preliminary mapping in the area by the authors does not agree with the local geology as shown on the Easton Quadrangle. Our interpretation indicates that the pegmatite intruded both the Rickenbach and Epler Formations.

The Phillipsburg pegmatite, as well as the one at Morgan Hill, fall on the C-C' section line of the Easton Geologic Map. Figure 25 is that portion of the C-C' section which contains both pegmatites. Section (a) is from the Easton Quadrangle, and Section (b) is our interpretation.

The pegmatite occurs as narrow lenses and dikes that have intruded both concordantly and discordantly with the bedding. The lowest occurrence of the pegmatite dikelets is near the Rickenbach-Allentown contact. They become more common toward the top of the Branchville Member of the Epler with greatest amount of pegmatitic intrusion in the Big Springs Member. Some dikelets are also present in the Lafayette Member. In all, about 600 feet of stratigraphic section has been intruded by the pegmatite.

Thin section examination of the Phillipsburg pegmatite indicates that the mineralogy is very simple, consisting principally of quartz and feldspar. The quartz commonly occurs as irregular masses except at the wall rock contact where it has a saw-toothed appearance. It frequently shows some evidence of straining.

The feldspar is mostly microcline, much of it occurring as granophyric intergrowth with quartz. There is some microperthite present with the plagioclase

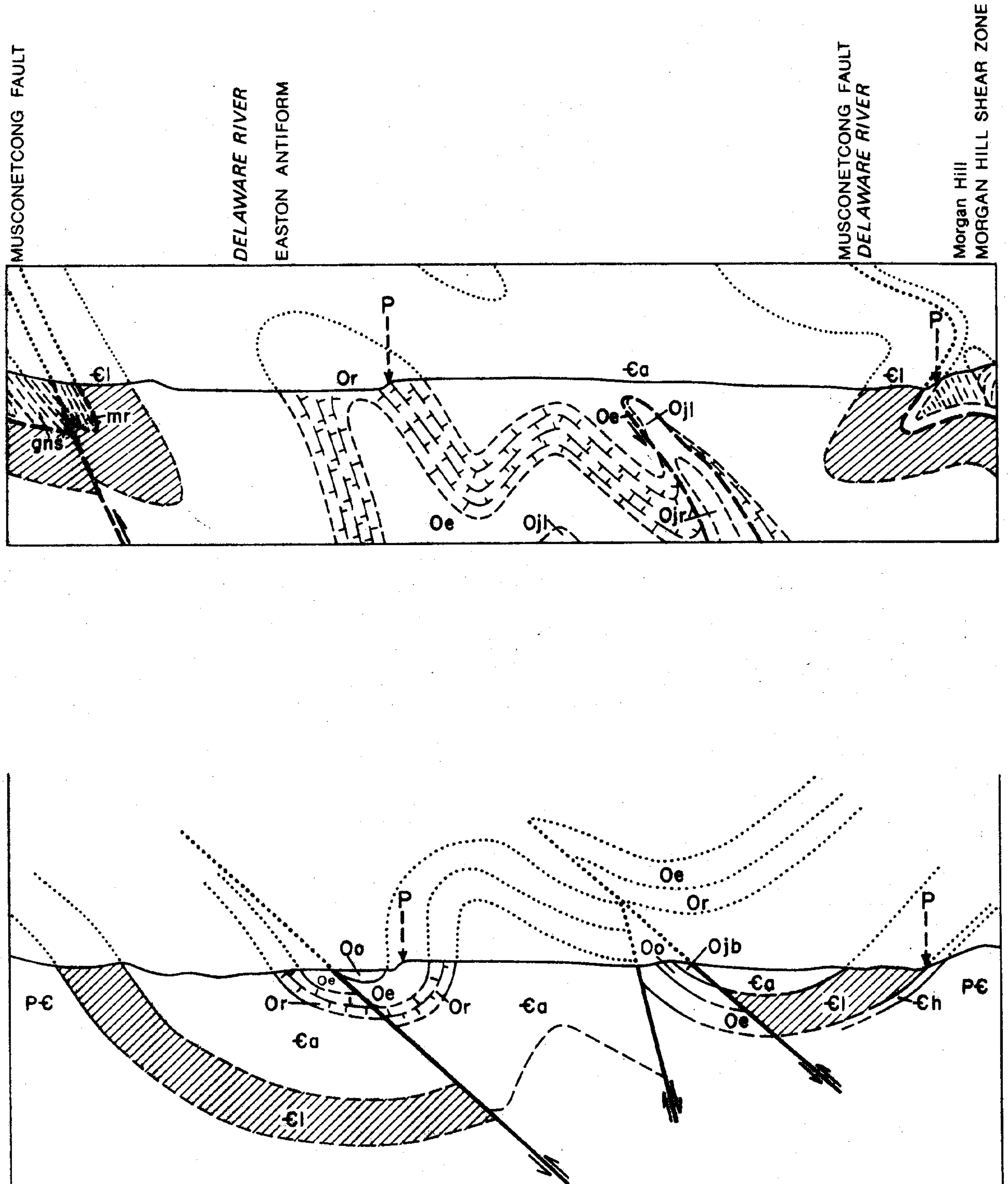


Figure 25

Comparison between Drake, 1969, and Dalton and Markewicz, 1976, along the C-C' with the pegmatite occurrences (P) located.

showing a strong alteration to sericite. The accessory minerals present are tourmaline, apatite, and magnetite or hematite. Tourmaline occurs as micro-needles in both quartz and feldspar.

The wall rock and the dolomite inclusions show intense alteration. The individual carbonate grains that are in direct contact with the quartz are, in part, replaced by the quartz. Many of the dolomite grains show strong zoning and there is some alteration to either hypersthene or biotite.

The mineralogy of the Morgan Hill pegmatite is the same as the Phillipsburg material, consisting of quartz and microperthite, with magnetite, apatite and tourmaline as accessory minerals. The similar mineralogy and proximity to the Phillipsburg pegmatite suggests that the two pegmatites are genetically related.

Drake (1969) mentions that the Morgan Hill pegmatites may have been remobilized from the nearby microperthite alaskite during nappe emplacement. The authors feel that the occurrence of the Phillipsburg pegmatite, over 2,000 feet stratigraphically higher than the Morgan Hill pegmatite, indicates more than a remobilization of an alaskite or similar material. The mineral assemblage and intense alteration of the wall rock would indicate a probable igneous origin for the pegmatite.

APPLIED GEOLOGY

A few case histories involving applied geology are given below to relate the fact that whatever is withdrawn from, deposited upon or within the earth, either intentionally or accidentally, is a geologic problem. Any earth-bound problems should be investigated and evaluated by a qualified geologist who should be able to devise a solution or a sound technical recommendation.

Although our capabilities and professional expertise with regard to everyday problems that affect the earth are being recognized more each day, it is a sad reminder to the profession when we stop to think about how many geologically related problems are still being performed by the non-geologist.

In New Jersey, all applications for land disposal and environmental impact statements are reviewed by Division of Water Resources geologists to assure that ground and surface water standards will not be violated. These applications include spray irrigation, sludge disposal, solid waste disposal, certain septic systems, industrial lagoons, and other disposal systems. In addition, all water pollution cases where ground water has been polluted are required to be examined by a Division geologist. Therefore, it is important to know the geology with regard to any effluent discharge or waste disposal, whether it be intentional or accidental. The geologist then recommends, and possibly supervises, the implementation of a suitable monitoring, protection, or clean-up program. In some instances, the geologist helps prepare the case for litigation in court and serves as an expert witness.

It is interesting to note that we have won or settled nearly all of the cases that have been litigated. Some of these cases have involved the joint effort of geologists and engineers.

Case Histories

No. 1. Upper Limeport Member - Water Supply

Company X, located in Sussex County, wanted to expand their manufacturing process, which would require an additional moderate water supply. However, because their present 400-foot well produced less than 12 gpm, they had to drop the expansion program. It was determined that the well is in the lower part of the Upper Allentown, which is only a fair water producer.

Field work indicated that the eastern part of the company's property, where some of the expansion would be, was within a reasonable drilling depth to the upper part of the Limeport Member, which is a good water producer.

The company was able to expand their production facilities because a 258-foot deep well, finished in the upper part of the Limeport Member, yields about 255 gallons of water per minute.

No. 2. Harmonyvale Member - Water Supply and Septic Drainage

The geohydrology of a proposed development project in Warren County was reviewed, relative to domestic water wells and waste water (septic) discharge.

Lithologic examination of several small outcrops, presence of thin overburden, and the regional structure revealed that the proposed development was underlain by the Harmonyvale Member of the Ontelaunee Formation. Aware that the Harmonyvale is a poor water yielder, it was recommended that the developer increase the lot size, alter the septic system layout, and consider the feasibility of a central supply well located in a more distant but geologically more favorable site containing glacial gravels underlain by the lower part of the Beaver Run Member, which is considered by the writers to be a better water yielder than the Harmonyvale Member.

The developer and his engineer took exception to the above recommendations, especially on the water supply, by stating that several homes in the general area had no water problem. Not easily convinced, the writers contacted two local home owners with the following results:

Homeowner #1 - had no real idea of his water supply, except that the well was quite deep.

Homeowner #2 - thought they had sufficient water for their needs, but their well was quite deep which, of course, provides for storage. However, a young member of the family reminded his parent, in front of the geologist, about the night the garden hose was left on to trickle water into a trough for the calf; the next morning THERE WAS NO WATER WHATSOEVER, and it was not until the late afternoon that there was enough water in the well to supply the house.

Because of our recommendations, the development has not gotten approval from the municipality.

No. 3. Harmonyvale Member - Proposed Condominium vs Institutional Facility - Water Supply

A proposed large condominium project, located on open property northwest of an institutional facility, was carefully reviewed with regard to the existing water supply for the institution. The main water supply for the institution is a large capacity spring located near the northwest end of the property.

A convincing but "geologically deficient" report, written by an engineering concern for the proposed development, was reviewed and found to be lacking on the geology or the source of water supply for the institution. Although well written, the report failed in its attempt to properly describe the geology beneath the proposed development and its relationship to the spring.

Examination of several very small Harmonyvale outcrops on the institutional property, and the subsequent finding of an additional small outcrop, enabled us to reconstruct the subsurface geology. This has greatly helped the institution's position on the relationship of the supply spring and its dependence in great part on the geology beneath the proposed condominium.

Project temporarily suspended; may go to court, but our position is strong, based upon our geologic knowledge.

No. 4. Branchville - Lower Beaver Run Member - Liquid Sludge Disposal Field

A proposed liquid sludge disposal site engineered by a consulting firm supplied the following information:

1) size of disposal field
2) quantity of discharge
3) turnover rate of section application
4) composition of liquid sludge
5) vegetative cover and cutting program
6) proposed boring program to define overburden type and depth

The report lacked formation recognition beneath the disposal field, or any data with regard to the geohydrologic potential of the underlying rock, except to say that it was "Kittatinny".

Examination of the disposal field proper revealed no available outcrops; however, a small rock cut at the plant site was sufficient to identify it as the upper part of the Branchville Member. By projection, we were able to identify the Beaver Run Member as the underlying rock beneath the disposal field. Borings and monitor wells (poor to fair yield from monitor wells) substantiated the presence of the probable middle part of the Beaver Run Member.

Disposal field, sludge application method and rate, were approved because the underlying Beaver Run Member is not a prime aquifer and there are no nearby wells drawing from the member. In addition, there is sufficient thickness of suitable overburden for some attenuation of liquid sludge discharge, a fairly deep ground-water level, and the chemical composition is not obnoxious.

In addition to the above disposal location, two offsite sludge disposal fields were proposed by the company, to be utilized in the "non-growing" months when there is no nutrient uptake by select grasses grown at the plant disposal field. The proposed disposal areas located on farmers' fields about six miles from the plant are located in the Pequest drainage area, which is part of an upper recharge area for the Pequest well field.

The offsite fields, selected by the consultant, are underlain by the Wallkill Member of the Leithsville Formation at one location and on the lower part of the Upper Allentown at the other location. The consultants had no idea where, in the dolomite sequence, the proposed disposal fields were located. Field investigation by a Division geologist resulted in determining the stratigraphic units involved at the sites. Knowledge of the engineering and hydrologic characteristics of the members at the proposed disposal sites constituted the prime input in the evaluation process. Consequently, the Wallkill Member site was not permitted because it is a prime aquifer, and several important restrictions were written into the engineering plan on the upper Allentown disposal site. In addition to the main restrictions, which included preventing sludge application on some land, a further condition for site approval on the Allentown was the filling in and field density compaction with natural materials any and all groundhog holes.

No. 5. Leithsville through Ontelaunee Formations - Landfill Engineering Proposal

Engineering plans for a solid waste disposal facility, located on land determined to be underlain by the Leithsville, Allentown, Rickenbach, Epler, Ontelaunee and Jacksonburg Formations, were carefully reviewed and extensively engineered because of the regional carbonate geology and its proximity to an important aquifer system. Many restrictions, including an extensive boring program, permeability tests, direction of ground-water flow, use of an artificial liner, in addition to the non-removal of any of the natural tight underlying silty clay, were written into the conditions for approval.

In addition to the above, the single most important condition for approval was the removal of approximately 30 per cent of the property acreage from any landfilling. This particular acreage was determined to be underlain by the upper part of the Wallkill and much of the Limeport Members, which are important aquifers in northern New Jersey. Overburden lying on these members was determined to be somewhat permeable. Any leachate migration into these prime carbonate aquifers would constitute a serious threat to ground-water quality in the immediate area.

When apprised of the geology and the geohydrologic characteristics, the applicant and his geologic consultant had no objection to our restrictions because they realized it was to their benefit not to be in a position whereby landfill leachate could migrate into the aquifers.

No. 6. Hamburg and Califon Members - Water Supply for Town

A well site, located by projection for intersection into the lower Leithsville, encountered difficulty during drilling and the consulting engineers began to suspect that the site might prove to be a dud. Confident of the ground-water potential in the lower Leithsville, the field discussions held with the driller encouraged him to push ahead of the "trouble zone". Once beyond the trouble zone, the drill encountered leached dolomite bedrock and, after proper development work, the 260-foot well produced in excess of 1,300 gpm with less than a 1.5 foot drawdown.

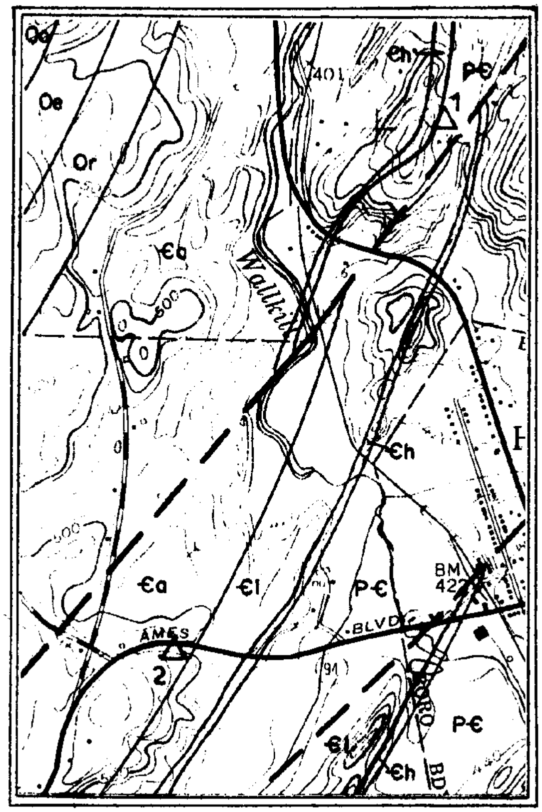
GEOLOGIC UNITS AT THE FIELD TRIP STOPS

Period	Formation	Member	Day 1, Stop 1	Day 1, Stop 2	Day 1, Stop 3	Day 1, Stop 4	Day 1, Stop 5	Day 1, Stop 6	Day 1, Stop 7	Day 2, Stop 1	Day 2, Stop 2	Day 2, Stop 3	Day 2, Stop 4	Day 2, Stop 5	Day 2, Stop 6
ORDOVICIAN	Martinsburg										X				
	Jacksonburg								X		X			X	
	Ontelaunee	Harmonyvale												X	
		Beaver Run					X		X		X				
	Epler	Lafayette					X		X		X	X			X
		Big Springs					X		X		X	X			X
		Branchville					X					X			X
	Rickenbach	Hope					X	X		X		X			
		Crooked Swamp Dolomite Facies					X	X		X		X			
		Lower					X					X			
CAMBRIAN	Allentown	Upper					X	X							
		Limeport		X											
	Leithsville	Wallkill			X										
		Hamburg			X										
		Califon	X		X										
	Hardyston		X		X										
PRE-CAMBRIAN	Marble Gneiss		X		X	X									

ROAD LOG DAY 1

Mileage	
0.0	Start at Holiday Inn - leave parking lot, turn right onto Route 209 south.
0.3	Enter I-80 east.
1.1	Exposures of Onondaga Formation.
2.3	Enter toll gate, exposures of Poxono Island Formation.
2.7	Cross Delaware River.
2.9	Exposures of the High Falls Formation on the left side of the road.
3.3	View Delaware Gap - the gap is in the Shawangunk Conglomerate. Fossils have been found in the lower beds (Johnson and Fox, 1968).
7.3	Exposures of upper Allentown in road cuts.
7.4	Exit to Route 94 north.
9.7	Outcrop on left is the Big Springs Member of the Epler Formation - limestone facies.
10.0	Enter Hainesburg - The Paulins Kill is on the right.
10.7	Rolling topography formed by glacial deposits on the Allentown Formation. The valley is bounded on both sides by the Martinsburg Formation.
12.3	Exposures of the Limeport Member of the Allentown Formation.
13.1	Hill on the left is underlain by the Crooked Swamp Dolomite facies of the Rickenbach Formation.
15.1	Type section for the Jacksonburg Limestone located on hill in Jacksonburg north of Route 94.
15.9	Entering Blairstown.
16.3	Cross the Paulins Kill.
16.9	Outcrop of Martinsburg Formation.
19.1	Enter Marksboro.
23.9	Extensive outcrops of shale of the Martinsburg Formation. Fossils have been found in the multicolored lower shale beds near here.
28.5	Newton city limits.

Mileage	
29.5	Junction Route 206, turn left, then turn right within 200 feet onto Routes 206 and 94. Newton is the location for one of Weller's "Kittatinny Limestone" fossil localities in the upper Allentown.
30.6	Exposure on the left, behind A & P store, is the Allentown Dolomite faulted on top of the Martinsburg Shale.
31.9	Turn right on Route 94 north.
33.4	Entrance to Hyper Humus, the largest peat producer in New Jersey.
33.5	Exposure of the Lafayette Member of the Epler Formation on the left.
34.0	Bear right.
34.6	Junction of Routes 94 and 15.
34.9	Turn left on Route 94 north.
37.9	Enter Monroe.
39.1	"Big Springs," one of the larger springs in Sussex County is on the left. It is discharging from the lower part of the upper Allentown.
39.7	North Church, underlain by glacial deposits. Wells 298 feet deep have not reached rock.
41.4	Exposures of the Limeport Member of the Allentown Formation.
42.3	Turn left at the light, enter Route 23 north.
42.9	Exposure of Precambrian gneiss on the left.
43.05	Turn right into Hamburg Quarry entrance. Exposures of the Hamburg Member of the Leithsville Formation on both sides of the road.
43.4	STOP 1.



Legend

△ - Stop
Oo - Ontelaunee formation
Oe - Epler formation
Or - Rickenbach formation
€a - Allentown formation
€h - Hardyston formation
€l - Leithsville formation
P€ - Precambrian gneisses, granites, etc.

Figure 26
Topography based on the Hamburg 7 1/2-minute quadrangle
geology by Markewicz and Dalton, 1973

Leader - Frank Markewicz

Location: Hamburg Quarry at Hamburg, New Jersey, located approximately 1.5 miles north of Hamburg on Route 23.

Geologic Setting (see Figure 26)

The quarry is located within the Highlands region of New Jersey. Precambrian gneisses, some granite, a mafic dike, Hardyston Quartzite and the Califon Member of the Leithsville Formation are present. These rocks are crushed to produce a mixed quarry stone product. There are several NW trending cross faults in the quarry.

The Precambrian Consists of

a) quartz, oligoclase, biotite, chlorite gneiss with accessory black opaques.

b) minor granitic material consisting of granite and thin pegmatites.

c) brecciated pegmatite located in south wall consists of feldspar, chloritic material, accessory black opaques and some carbonate. Brecciation may be due to regional faulting or intrusion by mafic dike.

d) mafic dike consists of feldspar, amphiboles/pyroxenes, biotite, accessory black opaques, pyrite and minor carbonate.

Geologic Features in Precambrian

a) northwest trending dike cross cuts Precambrian.

b) ptygmatic folding.

c) relict to wispy inclusions in granites/gneisses.

d) sharp (cold) contact of dike with gneiss.

e) breakage of gneiss adjacent to dike.

f) thin pegmatite bands.

g) minor radioactive minerals in granitic rock.

Hardyston Quartzite

The Hardyston is very thin in the quarry, being from 0 to 7 ft. in thickness. It consists of rounded quartz, some feldspar, pyrite, carbonate, zircon, and black opaques which may contain Franklinite in addition to magnetite and ilmenite. Franklinite is present in the Hardyston in the Franklin district, indicating a nearby detritus source. During an early visit to the quarry no Hardyston was present at one location, the Leithsville being in direct contact with the Precambrian.

Geologic Features in Hardyston

a) irregular contact with Precambrian.

b) oxidized sulphide staining at contact.

c) mineralogy of quartzite, note feldspar, twinning can be seen with hand lens.

d) disseminated pyrite.

e) contact with Leithsville Califon Member is placed at first appearance of dolomite - an irregular scour and fill type contact.

Leithsville Formation - Califon Member

The lower section of the Califon Member is exposed for some 25 to 35 ft. in the northwest wall of the quarry. From local measurements the Califon Member should be about 60-75 ft. thick in the quarry area. The Califon is more sandy at this locality and is less stylolitic or internally broken or brecciated as at other exposures. Oölites and pisolites are common in the upper "quarry bench" part of the member. Rock is medium to dark gray, fine to medium crystalline, locally patchy to ruditic textured pyritic dolomite with some pelletal or "pisolitic" dolomite.

The bottom 6 to 15 inches above the Hardyston contact is a contrasting colored, wavy, somewhat mottled dolomite with vertical to horizontal structures resembling large worm borings. This unit is particularly fossiliferous at other localities.

There is an absence of fluorite in the Califon Member at this locality; however, a few grains of sphalerite and chalcopyrite was found about 8-10 ft. above the contact with the Hardyston.

Archeocyathus, one *Hyolithellus* opercula, probable worm borings, and possible replaced brachiopod valves were noted during a field visit.

Geologic Features in the Califon Member

a) observed 6-15 inch zone above contact with Hardyston - note irregular, different colored lenses, fossils, vertical to nearly horizontal worm (?) tubes.

b) presence of sandy beds above contact - disappearance of quartz about 6 ft. above contact.

c) texture, structure, stylolites, lumpy nature of the member.

d) scattered clots containing white to light gray crystalline calcite/dolomite.

e) veneer of mammillary calcite on quarry blocks - contains some cemented angular dolomite fragments.

f) abundance of oölites - pisolites in upper bench section of member.

g) presence of pyrite as disseminated grains, in lenses, masses or irregular clots.

h) wispy, dark colored, carbonaceous shaly streaks in 6-15 inch zone above Hardyston contact.

i) increase of stylolites going upward in section.

j) look for *Archeocyathus*, *Hyolithellus* opercula , worm borings/tracks, possible brachiopod shell outlines replaced by calcite/dolomite.

k) look for sphalerite-fluorite - possible galena.

Mileage

43.8	Return to and turn left on Route 23 south.
44.5	Turn right at the light onto Route 94 south.
45.2	STOP 2.

Leader - Richard Dalton. Note the discussion in the text of the sedimentary facies of the Allentown by Richard P. Major.

Location: Road cut on Route 94, 0.7 miles south of Hamburg, New Jersey.

Geologic Setting (see Figure 26)

This road cut in the Allentown Formation is located at the eastern edge of the Valley and Ridge Province. The contact between the Precambrian gneiss with the basal Cambrian sediments is approximately 1000 feet east in the valley (projected from just north of Route 94).

Exposed at this stop is the Limeport Member of the Allentown Formation. There is about 300 feet of rock exposed here, almost a complete section of the member. Both the upper and lower contacts are covered.

Geologic Features

Look for the various sedimentary features discussed below.

ALLENTOWN DOLOMITE, HAMBURG LOCATION

by

Richard P. Major
Amoco Production Company
P. O. Box 50879
New Orleans, LA 70150

The Allentown Dolomite is the Upper Cambrian formation of the Kittatinny Group. Wherry (1909) made the first stratigraphic dissection of the Kittatinny, and named the stromatolitic and oölitic portion of this group the Allentown Limestone. The Allentown was dated on the basis of Dresbachian and Trempealeauian fauna (Weller, 1900, 1903). Howell and others (1950) divided the Allentown into the Dresbachian Limeport Limestone and the Trempealeauian Allentown Limestone, hypothesizing a Franconian disconformity. Subsequent workers have found no evidence for this disconformity, and the original Allentown Dolomite Formation has been reinstated (Drake, 1969). Dalton and Markewicz (1972) have proposed division of the Allentown to recognize the especially oölite and stromatolite rich lower portion as the Limeport Member (which is exposed at this location).

The Allentown Dolomite is composed of fine- to medium-grained (crystalline), medium-gray to dark-gray dolomite which is characteristically thin-bedded and commonly weathers light-gray (buff) and dark-gray in alternate beds. Stylolites, quartz veins, detrital quartz and feldspar (microcline), and chert occur in this formation. Fossils are extremely rare (with the exception of algae). These rocks have been recrystallized during dolomitization and tectonic recrystallization, and may have been subjected to low-grade regional metamorphism (Drake, 1969).

Dolomitic Mudstone Facies

Most of the rocks of this facies are textureless and very finely crystalline. The rocks may appear very faintly laminated or very thin-bedded and shaly. The crystals of these rocks are primarily medium silt size dolomite, most crystals having longest dimensions less than 50 um. Locally this facies may be more coarsely crystalline (dolomitic wackestone).

This facies is the lithified and dolomitized equivalent of lime mud. The dolomitic mudstone facies is interpreted to have been deposited in a lagoonal or tidal flat environment.

Dolomitic Grainstone Facies

The rocks of this facies are medium-grained (crystalline), although they may be locally coarse-grained, composed of interlocking crystals normally between 100 and 300 um. in longest dimension, with single crystals up to 900 um. in coarse grainstone. This facies is commonly cross-bedded. Grainstone may coarsen upward and (or) grade into or be interbedded with oölite grainstone.

The grainstone facies is interpreted to have been deposited in tidal channels and on shoals within the carbonate platform.

Dolomitic Oölite Grainstone Facies

The rocks of the dolomitic oölite grainstone facies range from very fine-grained oölite to coarse, "pisolitic" oolite. Individual oöids may range from 450 to larger than 900 um. in longest dimension (note especially the very coarse oölite beds at the southwest end of this exposure). These rocks are always grain supported, although a moderate amount of muddy matrix is present in some samples (oölite packstone). Oölite grainstone often forms the substrate and/or matrix for stromatolites, and in some instances stromatolites appear to have been buried by oölite sediment. This facies is locally cross-bedded, and cross-beds indicating two different current directions have been observed in close stratigraphic proximity.

The oölite grainstone facies is interpreted to have been deposited on shoals which experience nearly constant wave and current agitation. Cross-bedding indicating divergent current directions suggest some oölite grainstone may have been deposited on tidal deltas associated with tidal channels, such as are currently forming in the Persian Gulf (Kendall and Skipwith, 1969).

Churned Dolomite Facies

The rocks of this facies contain a mottled mixture of fine to silty mudstone with fine to coarse grainstone stringers. The mudstone portions of these rocks have a rounded, patchy, or lumpy appearance, and the grainstone portions may have either a patchy or "stringy" appearance. Rounded spherical or elongate mud (faecal?) pellets, less than 2 cm. in longest dimension, are found in these rocks. Bedding or laminations are absent.

This facies is interpreted to be the lithified equivalent of burrow mottled sediment. Lack of preserved skeletal material suggests these sediments were bioturbated by soft-bodied animals, perhaps annelids.

Dolomitic Algal Boundstone Facies

The rocks of this facies originated through the sediment-binding and/or carbonate-precipitating activity of non-skeletal algae. Four types of algal sediments are recognized in this formation: cryptalgalaminates, stromatolites, oncolites, and stromatolites (organo-sedimentary terminology is that of Aitken, 1967). Both cryptalgalaminates and domal and digital type stromatolites occur at this location.

These rocks are interpreted to have been deposited primarily in the intertidal zone of a tidal flat, with cryptalgalaminates possibly the result of lower supertidal sedimentation.

Dolomitic Intraformational Conglomerate Facies

The rocks of this facies contain intraclasts which were originally composed of indurated or partially lithified mudstone, grainstone, or algal boundstone sediment. These intraclasts range from flat, angular rip-up clasts, which dominate, to rounded, spherical clasts. The angular clasts commonly have an imbricate structure. Rounded clasts are rarely composed of algal boundstone.

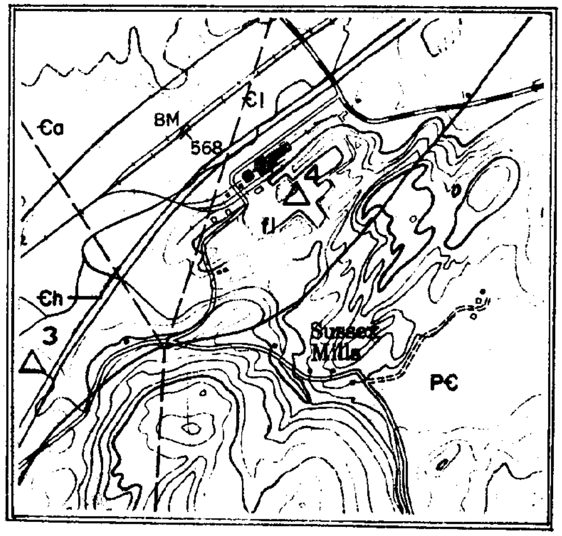
The rocks of this facies are interpreted to have been deposited in the supratidal environment, where periodic wetting and drying cause dessication and storm tides lift and abrade flat slabs of sediment. Rounded clasts may have been transported seaward via tidal channels.

Zadnik (1960) studied the Allentown Dolomite in two quarries in Carpentersville, New Jersey. He interpreted these six lithofacies as forming asymmetric, regressive cycles (ascending stratigraphically: mudstone, grainstone, oölite grainstone, churned dolomite, algal boundstone, and intraformational conglomerate).

The generally cyclic arrangement of the six lithofacies of this formation is evident regionally in northwestern New Jersey. This facies can be visualized as forming in bands parallel to the shoreline in a "Shaw-Irwin" type epeiric sea (Shaw, 1964; Irwin, 1965). However, the extremely rapid facies changes and commonly incomplete cycles suggest this epeiric sea was punctuated with shoals and lagoons.

Mileage

51.9	Continue straight across at the junction of Routes 15 and 94.
52.4	Glacial erratic on right is a boulder of paleosolution breccia from the Beekmantown.
53.8	Turn left onto County Route 468.
54.5	Turn right onto Houses Gap Road.
54.8	Discharge from quarry is on the left.
55.3	STOP 3



Legend

Δ - Stop
Ꞓa - Allentown formation
Ꞓl - Leithsville formation
fl - Franklin limestone
PꞒ - Precambrian gneisses, granites, etc.

Figure 27
Topography based on the Newton East 7 1/2-minute quadrangle
geology by Markewicz and Dalton, 1973

Leader - Frank Markewicz

Location: Limestone Products Co. Quarry - south end, near sand-gravel operation.

Geologic Setting (see Figure 27)

Stop 3 is located south of the quarry proper approximately 0.4 mile. The upper part of the Califon, a complete section of the Hamburg, and about 5 ft. of the lower Wallkill Member are exposed or present as quarry blocks. This location constitutes the headwaters of the Pequest Watershed and is locally referred to as Germany Flats - an important glacial/dolomite aquifer sequence for Sussex County.

Contact with Hardyston or Precambrian is not exposed at the stop; however, in the woods north of the main quarry a small exposure revealed the Califon to be in direct contact with the Franklin Marble - no Hardyston is present - clots and masses of sphalerite were found in an irregular zone some 3 ft. thick above the contact with the marble.

Geologic Features in the Califon Member

a) note texture, stylolitic nature and bedding of the Califon Member.

b) lumpy nature of stylolitic bedding planes on exposed quarry blocks.

c) abundance of unusual features, i.e., rain drop, gas pitting (?), scour cavities with hydrous iron crusts, ruditic texture, bioturbation, and weathering of the dolomite.

d) note pyrite as lenses, pods, etc.

e) transition to fine-grained, dense rock near contact with Hamburg Member.

f) presence of *Archeocyathus*, worm borings/tracks, probable brachiopod shell replacement.

Hamburg Member

a) contrast of lithology with Califon Member - presence of cycles.

b) dense sharp breaking character of rock.

c) floating, rounded quartz grains in fine grained to aphanitic textured dolomite.

d) presence of quartz sand seams, pods, lenses.

e) pyrite content - look for minute crystals of light colored sphalerite.

f) mud cracks, some filled with well frosted wind-blown quartz.

g) ripple marks - cross bedding.

h) scour and fill, compaction, slump features, graded bedding, corrugated lamination and crenulation features.

Wallkill Member

a) 5 ft. exposed, consisting of gray, fine-medium crystalline dolomite.

NOTE: Turn around and return to quarry.

Mileage

55.9 STOP 4 and lunch

Leader - Robert W. Metsger

Location (see Figures 27 and 28) The Limecrest Quarry at Sparta Junction

Notes on the Precambrian Metalimestones of Northern New Jersey

by

Robert W. Metsger

The Limecrest quarry of the Limestone Products Corporation of America is located three miles WNW of Sparta center on Houses Corner Road about a mile and three quarters SW of its intersection with N.J. Route 15.

The pit is at the extreme northwestern edge of the Reading Prong of the New England physiographic province, bordering on the Great Valley. It provides what is probably the best surface exposure of the Precambrian metalimestone in northern New Jersey.

Although the metalimestones occur in several bands, isolated from each other by complex folding, faulting, and subsequent erosion, two principal bands are recognized in northern New Jersey. They have been studied chiefly in the Wallkill Valley area because one of them, the Franklin band, contains the uniquely mineralized Franklin and Sterling Hill zinc-iron-manganese ore deposits. The second principal band, called the Wildcat band, is separated from the Franklin band by roughly a thousand feet of heterogeneously mixed gneisses which comprise a unit aptly designated the "Miscellaneous gneiss" by Buddington and Baker (1970) but more commonly called the Cork Hill gneiss.

In the Wallkill Valley the marble-gneiss sequence dips southeasterly at about 55° with the Cork Hill unit sandwiched between the overlying Franklin band and the underlying Wildcat marble. At Limecrest the dip is more gentle, at about 35° eastward. Here the Franklin band is bottom-most.

The regional structural pattern is interpreted by Hague and others (1956) and Buddington and Baker (1970) as a group of northeast trending overturned isoclinal folds. Generally the folds plunge from 10° - 30°NE. Normal faulting predominates in the area with the faults dipping from about 70° to vertical and striking parallel with the predominantly NE trend of the Precambrian rocks. The contacts between the gneisses and metalimestones are straight to broadly warped and reveal none of the complex folding seen within the marbles themselves. Although the several metalimestone bands are petrographically indistinguishable from one another, Hague and others (1956) considered the marble at Limecrest to be a part of the Franklin band.

The metalimestone is a medium to coarsely crystalline calcite marble characterized by bands of disseminated silicates (tremolite, phlogopite, chondrodite, etc.), pyrite, and graphite. The latter is ubiquitous in the metalimestones except where they are associated with the ores at Franklin and Ogdensburg and in halos around certain pegmatitic bodies. Inhomogeneities in grain size appear to be, at least in part, a function of mineral banding. Calcite grain diameters range from less than a centimeter to as much as sixty centimeters. In general, the sparsely mineralized calcite has a coarser texture than that which is heavily mineralized. It might be said that the calcite grain size varies inversely with the concentration of other minerals contained within it. It also appears that the calcite grains are flattened in planes parallel with the mineral banding of the marble.

The contacts of the metalimestones with adjacent gneissic units are commonly characterized by increasingly abundant coarse crystals of pyroxene, garnet, spinel, biotite, apatite and feldspar as the gneiss is approached. Grain diameters reach as much as 3 - 6 centimeters. Also common at the contacts are clots of white to pale yellow sphalerite. Dithizone analyses by the New Jersey Zinc Company of drill cores passing through marble into gneiss showed the presence of anomalously high traces of zinc at such contacts.

A characteristic of the metalimestone belts is the presence within them of inclusions of "miscellaneous gneiss" which range from a few centimeters to many meters in diameter. They are not boudins but rather are far removed from the parent band. Were they isolated in an igneous rock rather than a marble they would be unquestionably called zenoliths.

Those xenolithoids which are composed of carbonate free amphibilite, for example, typically have borders of randomly oriented 2.5 - 3 cm. crystals of pyroxene, garnet, biotite and/or gahnite crystals. On the other hand, those fragments having some carbonate content generally have no obvious reaction rims.

Some xenolithoids are crossed by quartz filled fractures which terminate at the fragment boundaries. They clearly belong to the fragment and not to the enclosing marble.

The ore bodies at Franklin and Sterling Hill have afforded the best opportunities to study the metalimestone structure in some detail. The distinctive bands of willemite, franklinite, and zincite as well as those of more common calc-silicate minerals have made it possible to trace folding in the marble that would be otherwise obscure. A variety of textures, especially at Sterling Hill, reveal that ore and adjacent calc-silicates were originally carbonate free granulites. Certain distinctive graphite-phlogopite-chondrodite-pyrrhotite bands in the marble wall rock and a fluorite band at the contact between ore and marble as well as recognizable bands within the ore itself suggest that the ore was at one time stratiform.

Ore textures grade from massive granulose and gneissose to disseminated "pepper and salt." The appearance of the gradation suggests that the ore minerals as well as the adjacent calc-silicates were friable masses which became disaggregated within an extremely plastic or, in part, even fluid carbonate (Figure 31).

The shape of the ore body itself suggests a huge flow pattern influenced by a broken band of brittle gneiss fragments which it has engulfed. Where the sharply angular gneiss blocks are near ore, the ore banding is bent around them. Where they are isolated in marble, the flow pattern is revealed by contorted silicate and graphite bands (Figure 29).

EXPLANATION

QUATERNARY

Qal — Alluvium and moraine

CAMBRIAN AND ORDOVICIAN

co — Cambro-Ordovician sediments

PRECAMBRIAN

gr — Granite

by — Byram gneiss

gd — Granodiorite gneiss

ol — Oligoclase gneiss--possibly the same as

gh — Hornblende granite with some alaskitic facies

gp — Pyroxene granite with local pyroxene syenitic facies

ROCKS OF UNCERTAIN ORIGIN

gm — Quartz-microcline granite-like gneiss

gno — Losee gneiss of type locality. Quartz oligoclase gneiss.

ORTHOGNEISS

gnsh/gnsp — gnsh Hornblende syenite gneiss; gnsp Pyroxene syenite

METASEDIMENTARY AND METASOMATIC ROCKS

fb/wb — Marble. Franklin band. Wildcat band.

gnh — Hypersthene biotite quartz-oligoclase gneiss, in part with a very little accessory graphite

gnab — Mixed gneisses: quartz-bearing hornblende and pyroxene-plagioclase gneiss, biotite mafic gneisses, local interbeds of sillimanitic or garnetiferous quartz-microcline gneiss

gnp — Pyroxene quartz-plagioclase gneisses

gnbg — Biotite quartz-plagioclase and other gneisses

gne — Epidote-scapolite-quartz gneisses interlayered with pyroxenic and hornblendic quartz-microcline gneiss

mi — Microcline gneiss

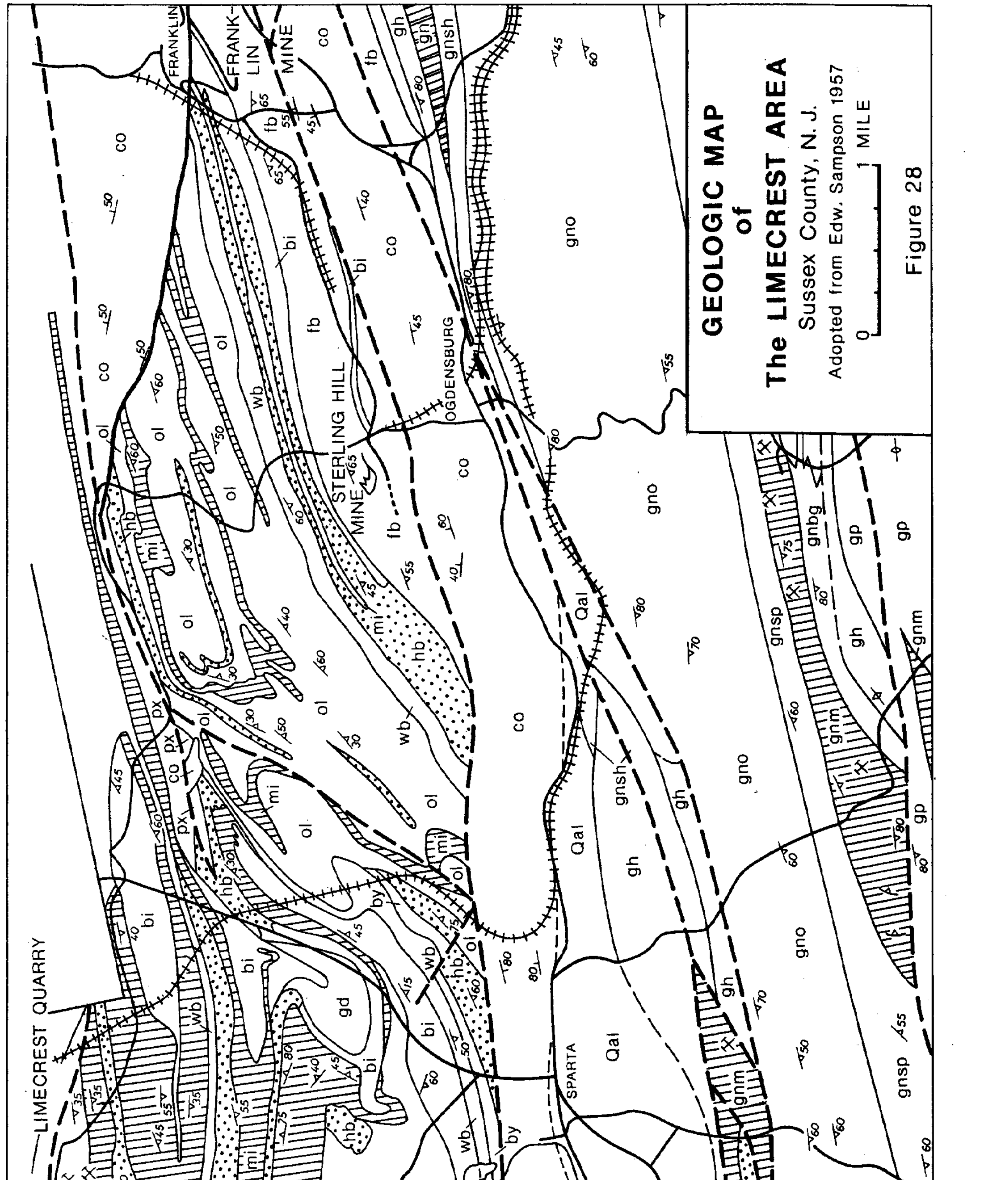
gnm — Quartz-potash feldspar gneisses, in part seamed with pegmatite. Host to magnetite mineralization.

am — Amphibolite

hb — Hornblende gneiss, including calcareous facies

bi — Biotite gneiss

px — Pyroxene gneiss and related rocks, including calcareous facies



GEOLOGIC MAP of The LIMECREST AREA

Sussex County, N. J.

Adopted from Edw. Sampson 1957

Figure 28

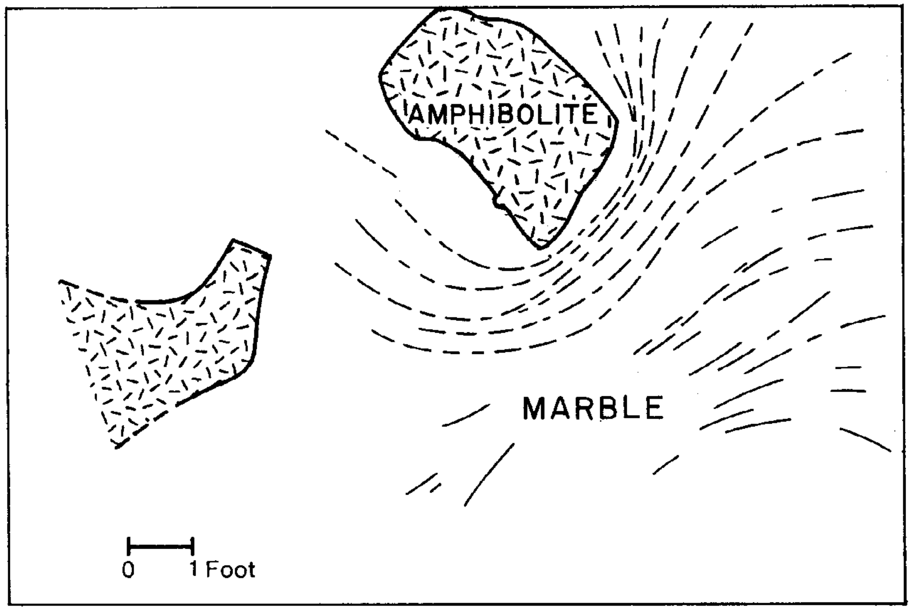


Figure 29

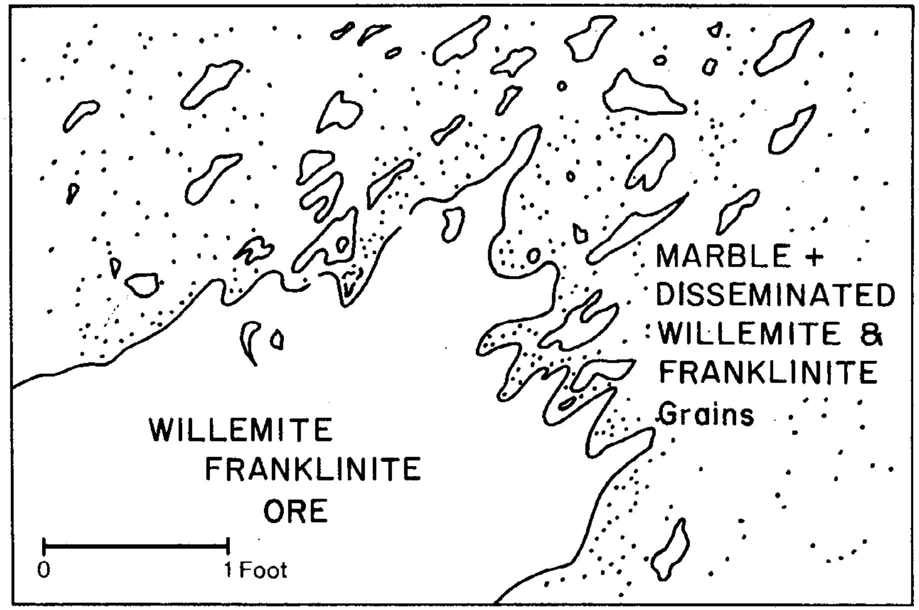


Figure 31

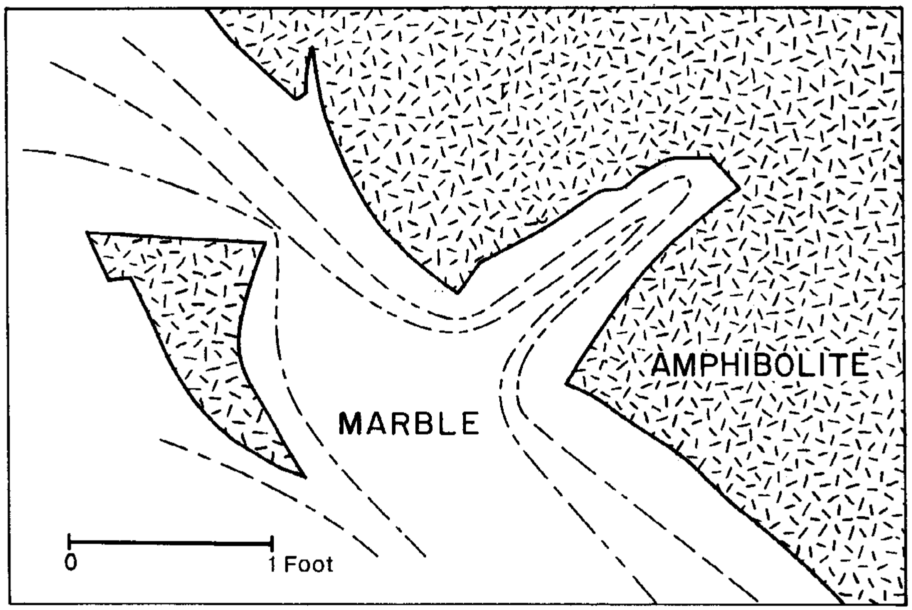


Figure 30

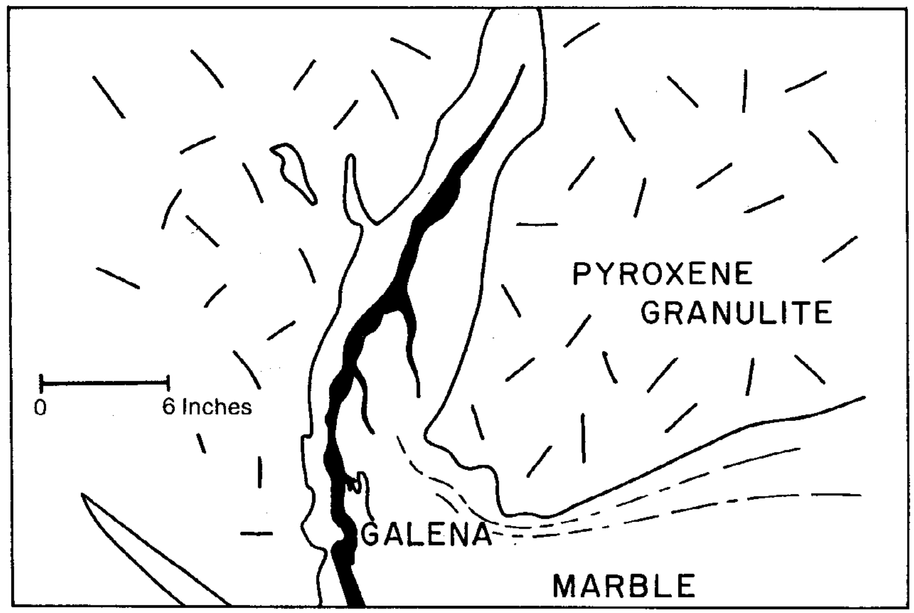


Figure 32

When the average density of the entire ore body (3.02) is considered together with the visual evidence for the plasticity of the enclosing marble (d + 2.75) it seems almost a certainty that the complex fold pattern of the ore body is due to its movement through the marble. The density contrast between ore and marble seems sufficient for gravity, in addition to tectonism, to have played an important part. It has therefore been proposed (Metsger, and others, 1967) that the ore body acquired its present shape as it sank through the limestone as an inverted diapir.

Marble "dikes" are common in the gneisses and granulites associated with the metalimestones. They were formed when the mobile carbonate flowed into fissures in the more brittle rocks (Figure 30). One such dike was observed in a pyroxene granulite fragment in the core of the Sterling ore body (Figure 32). The dike contained a vein of galena which occupied a fracture in the marble. The lead age of the galena, manifestly of more recent origin than the surrounding rock, was 1100 x 10^6 years.

From observations, chiefly in the Sterling Hill mine, it appears that the Precambrian history of the metalimestones and of the enclosed zinc, iron, manganese ores was somewhat as follows.

1. Deposition of a series of limestones and siliceous sediments and volcanics beneath the sea. Within the carbonate horizon at least one metal rich bed was deposited.

2. The sedimentary series was folded and then --

3. forced to a depth where sillimanite grade metamorphic conditions prevailed. During this stage the granulites and gneisses were formed from the siliceous and volcanic units. The metal rich horizon was metamorphosed to a granulose silicate and oxide band and the calcareous units to marble.

4. The region continued to subside until ambient conditions prevailed in which the gneisses and the ore were essentially unmodified while the marble became extremely plastic or, perhaps, fluid. During this period, currents in the viscous carbonates tore relatively thin bands of gneiss apart and produced complexly contorted folds in the less friable ore and calc-silicate zones. Because of the low viscosity of the enclosing carbonate, the more friable bands of ore and calc-silicates disaggregated to produce the "pepper and salt" texture so common in certain parts of the marble units.

5. The subsidence was arrested and the region uplifted. As a result, uniquely metamorphosed ore deposits folded in complex flow patterns have been preserved which otherwise would have been destroyed by absorption into the mantle.

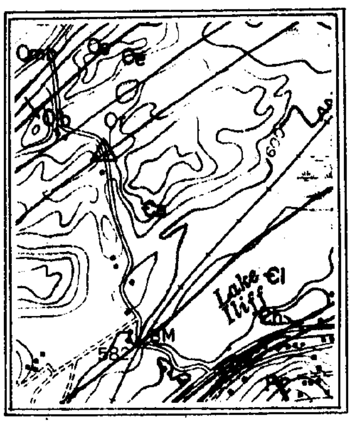
At the close of the Precambrian the metalimestones were exposed at the surface. Zones of rubble breccia have been observed in the Sterling Hill ore body and in drill cores which may be genetically related to the erosion surface that existed at that time. The brecciated zones cross-cut the ore structure and are comprised of rock and ore fragments, often mixed, in a matrix of the lithified insoluble residues from the marble and ore. Fragments range from a few centimeters to as much as a meter in diameter. The dimensions of the zones are measured in tens to hundreds of feet, with the principal dimensions vertical.

In general the marbles are quite pure calcite. Dolomitization has taken place principally along fractures and joints related to faulting of Paleozoic or more recent age. Such dolomitized marble is recognizable in quarry walls as a buff coloration against the pure white to gray color of the calcitic rock.

NOTE: Turn around and head south from quarry on Lime Crest Road.

<u>Mileage</u>

56.8	Bear left at fork.
57.6	Cross over County Route 616.
58.7	Turn right onto Lake Illif Road.
	NOTE: The lake is underlain by the Leithsville Formation.
59.3	STOP 5



Legend

- △ - Stop
- Omb - Martinsburg formation
- Ojb - Jacksonburg formation
- Oo - Ontelaunee formation
- Oe - Epler formation
- Or - Rickenbach formation
- €a - Allentown formation
- €l - Leithsville formation
- €h - Hardyston formation
- P€ - Precambrian gneisses, granites, etc.

Figure 33
Topography based on the Newton East 7 1/2-minute quadrangle
geology by Markewicz and Dalton, 1973

Leaders - Richard Dalton and Frank Markewicz

Location: The Lake Illif stop is located on Lake Illif Road 0.6 miles west of its intersection with County Route 616.

Geologic Setting (see Figure 33)

The Lake Illif section is the most complete exposure of the dolomite sequence from the Precambrian to the Jacksonburg Limestone. The Hardyston Formation and lowermost Leithsville are exposed about 1/4 mile south on Route 616. Lake Illif is underlain by the Leithsville. The first exposures seen on Lake Illif Road are of the Limeport Member of the Allentown. From the lake until Stop 5 the route is on the Allentown. Note the rugged exposures off the road.

The units seen will be uppermost Allentown, Rickenbach, Epler, and Ontelaunee Formation.

Geologic Features of Uppermost Allentown Dolomite

a) just east of house on the north side of the road is a massive platy to shaly interbedded dolomite which may be the equivalent to the Evans marker in Eastern Pennsylvania.

b) at the rise in the road just west of the house typical upper Allentown is seen. Features to note:

    1) the massive beds

    2) fine grained rock

    3) the chert

    4) the smooth texture of the weathered rock surface

    5) the lack of exotic features such as cryptozoa and oolites

    6) the quartz zone

c) in front of the house on the south side is the Allentown-Rickenbach contact (not well exposed). Features to note:

    1) the contrast between the lithologies of the Allentown with the Rickenbach

    2) the dark undulating massive beds

    3) the coarser texture of the Rickenbach

    4) the ruditic to mottled nature of the rock

    5) especially note the coarse-grained light gray bed of the Crooked Swamp Dolomite facies

d) walk in the woods, on the south side of the road, behind the houses, up section. Observe the change in lithology across the Rickenbach-Epler contact. Features to note:

    1) the mottling of the Rickenbach

    2) the coarser texture of the Rickenbach

3) the laminated dolomite of the Branchville Member of the Epler

4) look for sphalerite near the contact

5) the siliceous to shardy nature of the Big Springs Member

6) notice the color of the Big Springs

e) walk out to the road and observe large exposure breccia on the north side of the road. We feel that the breccia is of paleokarst origin. In the woods on the north side of the road is the Epler-Ontelaunee contact. Features to note:

1) the various boulders and fragments in the breccia

2) the interstitial material between the breccia blocks

3) notice the similarities between the Lafayette and Branchville Members

4) the change of lithology across the contact between the Lafayette Member and the Beaver Run Member (of the Ontelaunee Formation)

5) odor of the broken rock can be useful in identifying the units; check the both units

6) notice the rugose cherts of the Beaver Run

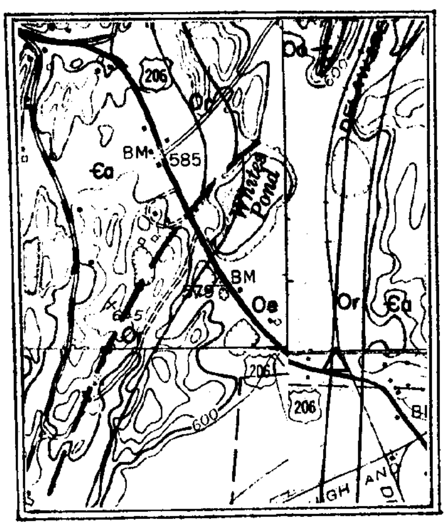
<u>Mileage</u>

59.5 Turn left onto Goodale Road.

NOTE: This is a narrow dirt road.

62.4 Turn left on Route 206 south.

63.0 STOP 6.



Legend

Δ - Stop
Oo - Ontelaunee formation
Oe - Epler formation
Or - Rickenbach formation
€a - Allentown formation

Figure 34
Topography based on the Newton East, Newton West, Stanhope, and Tranquility 7 1/2-minute quadrangles--geology by Markewicz and Dalton, 1973

Leader - Richard Dalton

Location: This stop is on the north side of Route 206 where the abandoned right-of-way of the Sussex Branch of the D. L. & W. Railroad crosses 206 at the Andover Borough boundary.

Geologic Setting (see Figure 34)

The location of this stop is again on the eastern side of the Valley and Ridge physiographic province. The sedimentary rocks of the Andover area are intensely folded. The units seen here are the uppermost Allentown and the Rickenbach. The reason for this stop is to point out an important marker bed in the Rickenbach, the "7 cherts."

Geologic Features

a) in the woods

1) the Allentown-Rickenbach contact

2) section of Crooked Swamp dolomite facies. Notice the distinctive texture.

b) in the road outcrop, the middle part of the Hope Member

1) the "7 cherts"

2) the sequence from the coarse-grained light beds to the dense fine-grained dark beds

3) sand, both floating and as beds

4) mottling

5) the crackling in some beds

NOTE: Turn around and proceed north on Route 206.

Mileage

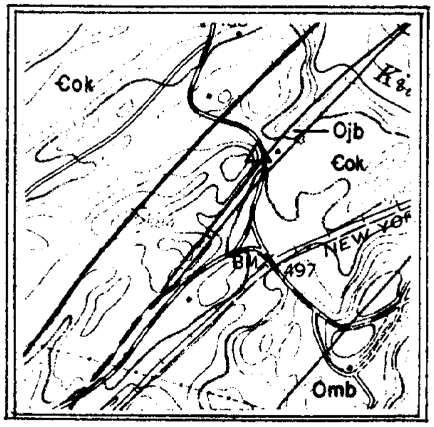
65.1	Turn left onto Fredon Road.
66.5	Bear left at the fork.
67.1	Exposures of the Beaver Run Member of the Ontelaunee Formation on the right.
67.5	Cross Route 519.
68.3	View of the Paulins Kill Valley with Kittatinny Mountain in the distance.

Mileage

68.65 Cross Route 94.

70.6 Bear right at the intersection of County Routes 619 and 610.

70.6 STOP 7.



Legend

Δ - Stop
Omb - Martinsburg formation
Ojb - Jacksonburg formation
Єok - Kittatinny limestone

Figure 35
Topography based on the Newton West 7 1/2 minute quadrangle
geology from Atlas Sheet 21 Geologic Overlay

Leader - Richard Dalton

Location: The location of this stop is on County Route 610 about 2.2 miles northwest of Route 94, next to the county garage.

Geologic Setting (see Figure 35)

The two faults shown on the map extend for several miles to the northwest. Reconnaissance work in the area indicates that to the west of the northern fault is the Allentown Formation. Exposed at the west end of the cut is the Ontelaunee Formation.

On the hill, several hundred feet south of the road, is the Big Springs Member of the Epler. On the east side of the hill in a small exposure is the Jacksonburg Limestone.

The majority of the exposure is on interbedded sequence of massive conglomerate and an argillaceous material. The generalized section starting at the west end of the cut is as follows:

Massive broken dolomite of the Ontelaunee Formation	35'
Coarse conglomerate bed	25'
Argillaceous bed	6'
Conglomerate bed	5'
Argillaceous bed	10'

Mixed - conglomerate in an argillaceous bed	5'
Conglomerate bed	4'
Argillaceous bed	10'
Conglomerate bed	10'
Covered zone	35'
Jacksonburg limestone	4'

Some of the argillaceous beds on fresh surface had a greenish cast. This material looks similar to the argillaceous material near Beaver Run (see discussion of paleokarst). We feel the origin of this interbedded conglomerate sequence is related to the paleokarst surface and that the argillaceous material may be the original residual limestone soil.

Geologic Features

a) the intense breakage in the dolomite due to the northern fault

b) the strike and dip of the dolomite vs. the conglomerate

c) the local fetid beds in the dolomite

d) the irregular contact between the conglomerate and the dolomite

e) the different dolomite blocks in the conglomerate - some of these can be identified

f) the filling material between the dolomite clasts

g) the granular quartz and/or chert filling in parts of the lower conglomerate

h) the fine-grained argillaceous interbeds

i) the lack of fossils, so characteristic of the Jacksonburg, in the fine-grained bed

j) the lack of lime

k) notice the weathered character of the conglomerate

NOTE: Turn around and proceed to junction of Route 619 and 610.

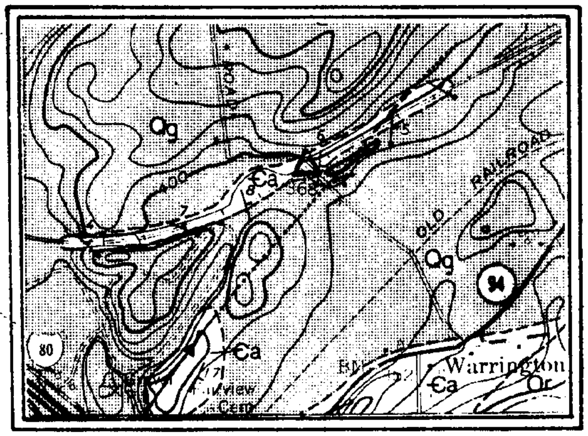
Mileage

71.0	Bear left on County Route 610.
72.9	Turn right on Route 94 south and proceed back to motel.
108.6	Enter motel lot.

ROAD LOG - DAY 2

Mileage

0.0	Leave motel and proceed to Route 94 north (see Day 1 for directions to Route 94.
8.2	Turn left on Stark Road.
8.6	STOP 1.



Legend
Δ Stop
Qg glacial deposits
Or Rickenbach formation
Ꞓa Allentown formation

Figure 36
Geologic Map
from Drake, and others, 1969

Leaders - Richard Dalton and Frank Markewicz

Location - The railroad cut on the Delaware-Lackawanna line of Con-Rail under the Stark Road overpass.

Geologic Setting (see Figure 36)

This area, according to the published geologic quadrangle (Drake and others, 1969), is an exposure of the Allentown Formation. Reconnaissance mapping in the area indicates that the rocks exposed from the overpass to the east belong to the Rickenbach.

The lower contact with the Allentown is exposed in a small quarry to the west and the upper contact with the Epler is on the hill above the cut to the north.

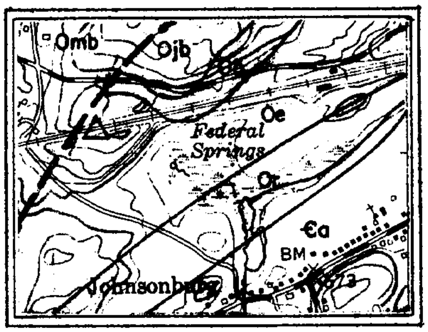
The unit exposed here is the Hope Member of the Rickenbach. The unique feature of this stop is the crackle breccia. When blocks of the breccia and zinc ore from Friedensville are placed together, they cannot be told apart.

Geologic Features

a) Cherts
b) Crackle breccia
c) Carbonate filling
d) Crooked Swamp dolomite beds
e) Algal structures
f) Solution breccia

Mileage

8.75	Turn around area and proceed back to Route 94.
9.35	Turn left on Route 94 north.
18.8	Turn right at fork on Blairstown-Johnsonburg Road.
19.7	Crossroads, Stop, then straight across.
21.4	Turn right at crossroads.
21.6	STOP 2. Note: Buses follow directions to pickup area.



Legend

Δ - Stop
Omb - Martinsburg formation
Ojb - Jacksonburg formation
Oo - Ontelaunee formation
Oe - Epler formation
Or - Rickenbach formation
€a - Allentown formation

Figure 37
Topography based on the Blairstown 7 1/2-minute quadrangle
geology from field maps

Leader - Walter J. Spink, Department of Geosciences, Rider College.

Location - Delaware, Lackawanna and Western railroad cut, 0.4 miles north of Johnsonburg, N.J.

Geologic Setting (see Figure 37)

Lafayette and Big Springs Member strata (Epler Formation) are step faulted over the Martinsburg Formation. Numerous bedding plane faults and step faults occur within the Epler Formation. Intensity of deformation within the Epler Formation increases from east to west as the Epler-Martinsburg step fault is approached. Major drag folding of Epler strata occurs adjacent to this fault. Martinsburg strata are not noticeably drag folded below the fault. Instead, numerous shear planes with associated tension fractures have been produced.

Lithology

A. Epler Formation

1. Lafayette Member

a. medium-gray, medium-grained dolomite with silty/sandy layers etched into relief where weathered; massive dolomite where unweathered.

2. Big Springs Member

   a. medium-grained, medium-gray irregularly bedded dolomitic limestone and massive bedded dolomite, dolomitic limestone weathers light gray

B. Martinsburg Formation

   1. dark gray slate and interbedded sandstone (probably graywacke)

Geologic Features to Note

A. Lafayette and Big Springs lithologies

B. Numerous step faults within the Big Springs Member

C. Lafayette strata strike N5°E and dip from essentially horizontal to 25°SE toward the west

D. On north side of tracks carbonate strata strike N32°E and dip 32°SE, a massive breccia zone occurs within these strata

E. Big Springs strata near the Epler-Martinsburg fault strike N77°E and dip from 20° to 50°SE

F. The step fault separating the Martinsburg and Epler Formations strikes N43°E and dips 82°SE

G. Major drag folding of Big Springs strata adjacent to the Epler-Martinsburg fault

H. Shearing within the Martinsburg Formation

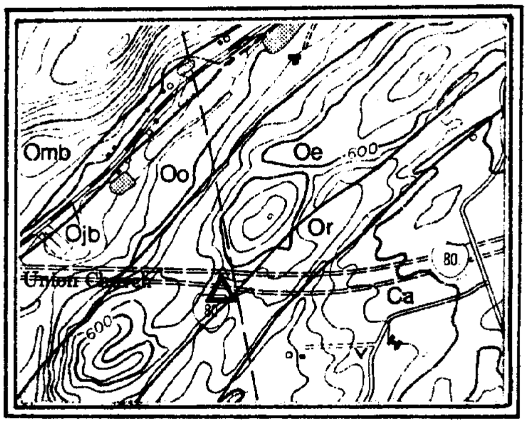
NOTE: Buses proceed

Mileage

22.1	Turn left on County Route 519.
22.6	Turn left on Johnsonburg-Marksboro Road.
22.9	Turn left.
23.2	Turn left and turn around and park in dirt road to the right to load. Then continue straight and back out onto the paved road.
23.4	Turn right at intersection. The rock exposure across the road is the upper part of the Branchville Member of the Epler Formation.
23.8	Turn right on County Route 519 and proceed through Johnsonburg.
24.75	The continuation of the fault seen at Stop 2.
28.7	Cross under Route 80.

Mileage

28.85	Exposure on the right is the Jacksonburg conglomerate.
30.3	Turn right in Hope on County Route 521.
31.3	Enter Route 80 east. Exposures of Martinsburg Formation in the ramp.
31.7	Exposures of the Jacksonburg conglomerate. The conglomerate at this locale contained a large amount of limonite.
32.65	STOP 3.



Legend

△ - Stop
Omb - Martinsburg formation
Ojb - Jacksonburg formation
Oo - Ontelaunee formation
Oe - Epler formation
Or - Rickenbach formation
€a - Allentown formation

Figure 38
Topography based on Blairstown 7 1/2-minute quadrangle
geology from field maps

Leaders - Richard Dalton and Frank Markewicz

Location - Route I-80 1.3 miles east of the Route 521 Hope entrance/exits. Exposures in both the east and westbound lanes will be examined. (Be careful.)

Geologic Setting (see Figure 38)

This series of cuts starts in the Allentown just east of the overpass. We will be limiting this stop to the Rickenbach and Epler Formations.

The large mountain to the east is Jenny Jump Mountain, which some geologists feel has been thrust out over the Paleozoic sediments. The large hill to the west of the stop is the Mount Herman thrust block. It is the opinion of the authors that Jenny Jump is rooted on the east side, not a block of Precambrian floating on the lower Paleozoic sediments.

Geologic Features

A. The Rickenbach Formation reaches a near maximum of 290 feet at this stop. Both the upper and lower members are present here. This is the type locality for the Hope Member.

The important features of the Rickenbach at this stop are the following:

1. The comparison of the lithologies of the lower member with the Hope Member.

2. The clots with the botryoidal hydrocarbon. A chemical spot test on the hydrocarbon done several years ago indicated vanadium. This has never been substantiated.

3. The sand in the aphanitic beds of the Hope Member.

4. The "7 cherts".

5. The upper chert horizon.

6. The algal structures.

7. The sphalerite. There is a section of 225 feet containing sphalerite at this stop.

B. The Epler will also be examined at this stop. There are complete sections of the Branchville and Big Springs Members along with a partial section of the Lafayette Member.

The important features for the Epler at this stop are:

1. Notice the change from the medium to massive bedded alternating sequence of the Rickenbach to the very massive bedded laminated dolomites of the Branchville Member of the Epler.

2. Although not as well seen here, notice the similarities between the Branchville and the Lafayette Members.

3. The Big Springs Member is a dolomite here as opposed to the last stop where it is a limestone, yet similarities can be found such as the siliceous interbeds, the color to which the dolomites weather and the distinct change to the Lafayette Member at both stops.

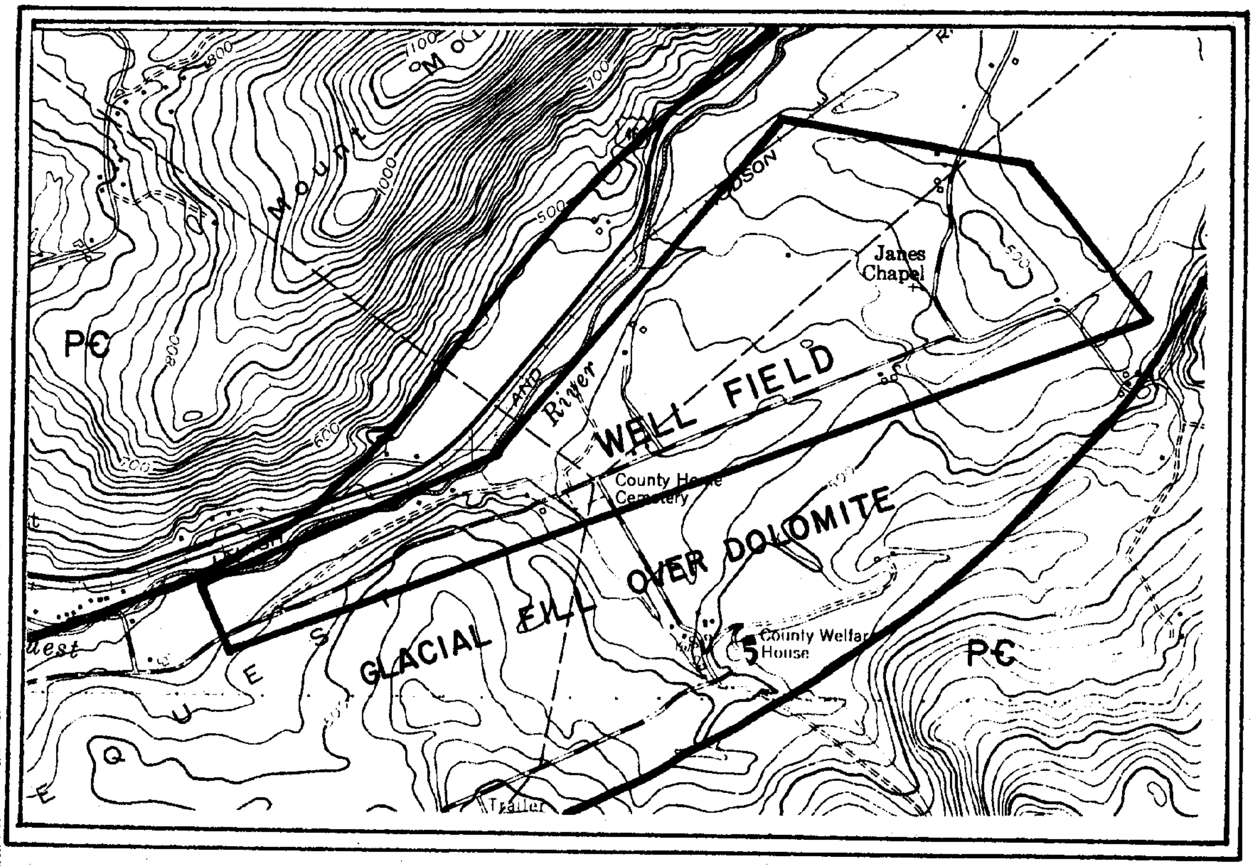
4. The Lafayette Member contains a breccia, which to the south thickens and cuts downward to the Big Springs Member.

NOTE: Buses proceed.

33.0	Cross over island into westbound lane.
33.1	Pick-up area.
35.4	Exit to County Route 521 south and Hope.

Mileage

35.65	Turn left on County Route 521.
35.9	Turn left on County Route 519.
36.0	Turn right on Jenny Jump-Hope Road. Note: Steep hill ahead.
36.8	Start climbing Jenny Jump Mountain.
39.7	View of Great Meadows on the left.
40.7	Turn right on Route 46.
40.9	Outcropping of the Hardyston quartzite on the right.
41.4	Exposure of stratified drift on the left.
42.0	Bear left at fork on Pequest Road (10 ton bridge).
44.2	STOP 4 - Lunch



Legend

PЄ - Precambrian gneisses, granites, etc.

Figure 39
Topography from the Washington 7 1/2-minute quadrangle
geology from field maps

Geologic Setting (See Figure 39)

The Pequest property is situated on and underlain by one of the most unique assemblages of permeable geologic materials found in the northern part of the state. This hydrologically efficient ground water system not only discharges large volumes of water into the Pequest River, but is capable of yielding large quantities of water from shallow wells. The Fish and Game property in the Pequest area is the southern or downstream terminus of a major watershed that consists of some 108 square miles. This large watershed, extending northeast from Pequest some 18 miles, includes drainage from Great Meadows, Tranquillity-Allamuchy, Johnsonburg, Springdale-Andover and northeastward to a point just south of Newton. All the water from the above watershed flows as surface and ground water, either in the Pequest drainage system or through sand, gravel and limestone to the Pequest area.

The uniqueness of the area is related to the fact that the valley is bounded by granitic rock on the southeast and northwest. The granitic rock is overlain at the lower elevations by limestone which, at still lower elevations, is overlain by an extensive deposit of permeable sand, gravel, and boulders. There are several important aquicludes toward the northern end of the proposed well field.

Rain water, flowing downslope from the granite ridges, enters the limestone and sand and gravel at lower elevations. This sand and gravel, acting as a subterranean reservoir, extends from Vienna to Pequest.

Rapid recharge from precipitation into the highly permeable overburden, ease of hydrologic transmission to the ground water table, and storage and discharge are contained within this efficient system. They system, based upon the geologic/hydrologic studies to date, will only be effective and pollution free as long as the surrounding natural condition exists.

Geohydrologic studies to date indicate that the hydraulic system of the Pequest area is capable of producing 5 - 7000 gallons of water per minute from shallow wells and springs. Two small diameter (6 inch) test wells drilled confirmed the presence of abundant water-bearing sand and gravel. Preliminary pumping tests on these wells indicated a potential of 800 to 1000 gallons per minute from individual wells without serious effect or communication on adjacent wells that might be located some 700 to 800 feet apart.

It is tentatively estimated that 5 to 7000 gallons of water per minute can be pumped from the upper 10 feet of the ground water reservoir from five to seven wells spread out over a distance of some 5000 feet. In the event of a drought, the lower 20 to 30 feet of the underground water reservoir should provide sufficient water for the hatchery.

A large diameter (16 inch) test-production well was drilled after the six inch wells. The well was test pumped for 72 hours at a discharge rate of 1800 to 2800 gallons per minute. Ground water levels during the test were constantly monitored and recorded. These observations show a very shallow drawdown on the ground water table, thus indicating that large amounts of water can be withdrawn from the rock and sand and gravel aquifer. Rock aquifers include the Limeport, Wallkill, Hamburg and Califon Members.

During the 72-hour pump test of the 16 inch test-production well, there were 8.2 million gallons of water pumped as measured by instrumentation at the discharge end of the pipe. Calculations based upon the drawdown data from gages, recorders, and porosity studies indicate that there were 8.1 million gallons of water removed from the formation with less than a 2.0 ft. drawdown over approximately 181 acre feet of water. Withdrawal of 5000 gpm would be spread out over approximately 450 acres.

Applied Geology and Historical Background Discussion

Geohydrologic Features

a. Coarseness and content of glacial materials

b. There is no artificial gravel pack around the well screen - developing of natural materials provides for gravel pack

c. Recognition of dolomite boulders as to member origin

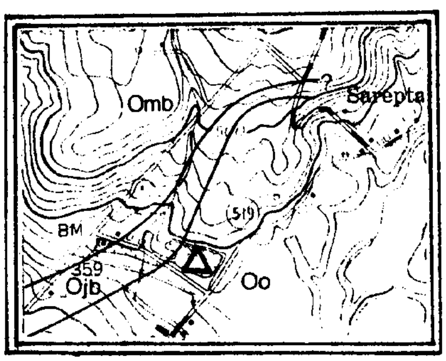
d. Note original well screens fabricated from 50 gal. drums

e. Pond and "barrel well" used as observation points during pump test

f. Pumping rate of well and discharge at outlet pipe

Mileage

45.2	Turn right (one lane, 6-ton bridge)
45.7	Turn left on Route 46 west
47.2	Junction of Routes 31 and 46. Stay on Route 46
48.4	Traffic light
49.8	Turn right onto Sarepta Road. (10-ton bridge)
50.9	Turn left on Ledge Road and park
50.9	STOP 5



Legend

- Stop
Omb - Martinsburg formation
Ojb - Jacksonburg formation
Oo - Ontelaunee formation

Figure 40
Topography based on Belvidere 7 1/2-minute quadrangle
geology from field maps

Leader - Frank Markewicz

Location - Sarepta Quarry, located on north side of Sarepta-Hope Road approximately 1.2 miles northeast of Route 46.

Geologic Setting (see Figure 40)
Harmonyvale Member only. Beaver Run Member lies beneath quarry floor.

The eastern section of the quarry is wholly within the Harmonyvale Member of the Ontelaunee Formation in contrast to the western portion which consists of Harmonyvale in the lower part and the Jacksonburg Formation in the upper part of the face. The Jacksonburg contact (unconformity) cuts across the Harmonyvale bedding; consequently, the extreme western section of the quarry face is entirely Jacksonburg limestone. Over two hundred feet of Harmonyvale was measured above the eastern section of the quarry. The differential between the east and west section of the quarry indicates how steep and deep the erosional surface is incised into the top of the Beekmantown.

At many localities, much or all of the Harmonyvale is missing due to erosion during the Beekmantown hiatus. Erosion progressed down into the Beaver Run Member or lower. At some places erosion has removed most of the Beaver Run, leaving only a thin section of the Lafayette Member of the Epler.

The formation member subdivision in the Ontelaunee and Epler gives the most accurate measurement to date on how much rock was removed at any given locality during the Beekmantown hiatus.

A small, inaccessible section high in the quarry face shows that the paleo-solution breccia was eroded and subsequently overlain by a band of basal Jacksonburg conglomerate. When Meredith E. Johnson and Markewicz looked at this section many years ago the question was asked why the differences in the types of "conglomerates" present - of course it was unknown at the time that the lower angular material was a solution breccia.

Much of the dense fine-grained Harmonyvale is finely fractured. This fracturing feature, which is quite widespread in the member, aids in correlation work. It is the "elephant hide" texture exhibited on weathered surfaces as described by Hobson, 1963. This texture has been noted by Markewicz in the Ontelaunee of Lancaster Valley and in outcrops closer to the Delaware River.

At Sarepta quarry the Harmonyvale consists of several interbedded lithologies that include:

1. Very fine to medium-grained to crystalline-dense dolomite (locally effervescent) in beds from 6 inches to more than 2 feet thick. Some beds give a mild fetid odor when struck. Chert pods, lenses, or knots are common in certain horizons. Some cherts have an oncoid structure pattern. Thin bands of floating, rounded, frosted ± quartz are common. Dark sparry calcite, wispy, dark-colored streaks, *Lingula*, stylolites, and the finely fractured pattern are local to common features in this rock type. Rock weathers yellowish-gray with a strong checked to gash pattern in Hobson's "elephant hide".

2. Gray to dark gray, part ruditic textured, somewhat sparkly dolomite that gives a mild to strong fetid odor when struck. Dark sparry calcite, wispy streaks, minor chert, rough raspy weathered surface, and internal breccia are common features. The fine fracture pattern is not prevalent in this facies.

3. An upper facies consisting of lenticular to irregular bedded limy dolomite and siliceous, shaly to argillitic lenticular dolomite and megacrystalline limestone. Low coiled gastropods (Figure 16) are present in this unit. This unit, based upon work by Markewicz in Pennsylvania, is considered to be the top of the Ontelaunee.

Near the unconformity a series of en echelon quartz calcite/dolomite filled dilation (tension) fractures are interpreted to be part of the dissolution process in the Harmonyvale during late Beekmantown time. The fractures are related to the solution stoping process and collapse of the overlying dolomite as large blocks or small sized rubble breccia. Fracture filling occurred post-solution action. The present unconformity contact as seen in outcrop (between Jacksonburg and Harmonyvale) is interpreted to be approximately the same line or contact along which the collapse zone occurred in the dissolution process of the dolomite or limestone. This process which has been studied by economic geologists in the zinc bearing district of Tennessee, Tennessee Report of Investigations #23, 1969, is used as an ore guide in exploration work, see Figure 22.

Geologic Features to Note in the Quarry

Harmonyvale Member

1. bedding - texture - lithology
2. mild H_2S odor in mottled rock
3. finely fractured pattern in dense rock - note disorientation along a given bedding plane
4. floating quartz - much of it contains fine rutile needles
5. oncolites
6. wispy, faint, dark colored parallel to cross-cutting streaks (any suggestions on what these are; they have been noted in Ontelaunee in Pennsylvania)
7. presence and type of stylolites
8. knotty to podular type chert
9. *Lingula* and other fossil fragments
10. coiled gastropods occur at top of section in siliceous/shaly beds, see Figure 16. (have not been found at the quarry)
11. presence of smokey sparry calcite in crystalline clots

Unconformity

1. angle of unconformity as related to dolomite bedding
2. tension-stopping fractures in dolomite near contact with Jacksonburg
3. irregularity of unconformity surface
4. presence of water seepage at contact

Jacksonburg

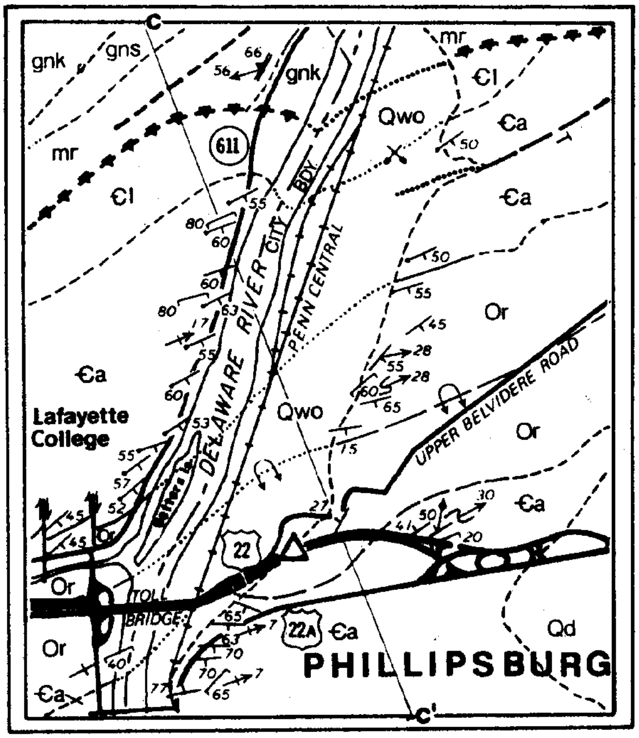
1. character of lithology
2. presence of dolomite clasts
3. fossils
4. presence of living snails in area of Jacksonburg lithology in contrast to absence on dolomitic rocks
5. absence of Jacksonburg conglomerate along contact

Mileage

51.1	Turn left on Chapel Hill Road - bump ahead.
52.2	Cross Route 46.
52.5	Hoffman LaRoche plant on the right.
53.6	Bear left.
54.0	Straight at the traffic light.
54.7	View of the Martens Creek Power Plant on right in the distance.
55.4	Junction with County Route 519. Continue south on County Route 519.
61.2	Turn right, then left on Marble Hill Road.
64.2	Turn left at bottom of hill. Narrow road ahead.
65.2	Landfill in glacial material overlying the Leithsville.
65.85	Exposures of the Harmonyvale Member of the Ontelaunee.
66.15	Turn right.
66.35	Turn left on Broad Street.
66.55	Turn left into Bridge Commission offices.

Mileage

66.6 STOP 6.



Legend
Δ - Stop
Qwo - outwash
Qcl - older drift
Qr - Rickenbach formatic
Ca - Allentown formation
Cl - Leithsville formati
gnk - potassic feldspar gneiss
gns - sillimanite gneiss
mr - dolomite marble

Figure 41
Geologic map from Drake, 1967

Leader - Richard Dalton

Location - The large exposures just south of the Delaware River Bridge Commission Offices at Phillipsburg.

Geologic Setting (see Figures 41 and 25)

According to the Easton Geologic Map by Drake (1967) the rocks exposed here are those of the Rickenbach and Allentown Formations, approximately 700 feet south of the axis of his Easton Antiform. Mapping by the authors indicates that the Rickenbach, Epler and Ontelaunee Formations are present.

A swarm of pegmatite dikelets have intruded into the Rickenbach and Epler Formations at this stop.

Geologic Features

A. The Rickenbach Formation

   1. The occasional dikes

B. The Epler, all three members are present here

   1. The number of dikelets increase in the Big Springs Member

   2. The crosscutting of the pegmatite

   3. The contacts of the pegmatite

   4. The highly altered nature of the Big Springs

Mileage

66.6	Turn around in parking lot and turn right on Broad Street.
66.8	Turn right and follow sign to toll bridge. Proceed back to motel via Route 22 to Route 33. Take Route 33 to Route 80 east. Then take Route 80 to Route 209 and the motel. Approximately 40 miles.
106.00	Enter motel.
	End of 1977 Field Conference of Pennsylvania Geologists.

POSSIBLE THESIS PROBLEMS

GENERAL

Ground water potential of the Cambro-Ordovician carbonates.

Engineering geology, land disposal, and pollution potential of the Cambro-Ordovician carbonates to regional planning.

The importance of the member subdivision as related to structural problems in the Cambro-Ordovician carbonates.

Origin of the crackle breccia in the Beekmantown, and its significance to sulfide exploration.

Origin and relationship of the paleo-solution breccia to the Beekmantown unconformity.

Karstification and erosion at the end of the Beekmantown.

Subsurface disposal potential in the Cambro-Ordovician carbonates.

Hydrocarbon potential of the Cambro-Ordovician carbonates beneath the Appalachian Plateau.

Cambro-Ordovician carbonate topography and its significance to regional planning.

Possible continuity of the sulfide bearing zone in lower Beekmantown equivalents from the northeast U.S. to Tennessee.

Leithsville Formation

Depositional environment, sedimentology, and paleontology of the Leithsville Formation Members.

Zinc-lead mineralization in the Leithsville Formation and its similarity with the Austinville, Virginia deposit.

Relationship of the Precambrian surface to Hardyston-Leithsville deposition.

Correlation of the Leithsville Members with Pennsylvania and New York.

Allentown Formation

Environmental - economic importance of the Allentown Formation with regional planning.

Rickenbach Formation

Depositional environment and sedimentology of the Rickenbach Formation.

Environmental - economic importance of the Rickenbach Formation with regional planning.

Correlation of the Rickenbach Formation with Pennsylvania, New York, and its possible similarity with the Kingsport Formation of Tennessee.

Origin, sedimentology and stratigraphy of the Crooked Swamp Dolomite Facies, and its potential use as an injection - storage medium in a closed system for hazardous liquids or hydrocarbon storage.

Epler Formation

Depositional environment, sedimentology and paleontology of the Epler Formation.

Environmental - economic importance of the Epler Formation with regional planning.

Correlation of the Epler Formation with Pennsylvania, New York, and its possible similarity with the Mascot Formation of Tennessee.

Detailed geology of the Big Springs Member of the Epler Formation.

Ontelaunee Formation

Depositional environment, sedimentology and paleontology of the Ontelaunee Formation.

Environmental - economic importance of the Ontelaunee Formation with regional planning.

Correlation of the Ontelaunee Formation with Pennsylvania and New York.

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Section 1

LEITHSVILLE FORMATION - CALIFON MEMBER

Location of Section

The Califon Member type section occurs in an abandoned quarry located on the east side of Route 518 approximately 1.3 miles north of Califon.

	Thickness (feet)
LEITHSVILLE FORMATION	
HAMBURG MEMBER	
Lower part forms top of quarry face.	total exposed ± 12'
CALIFON MEMBER	
Description from quarry face and fallen fragments. Very fine grained to cryptogranular, light to greenish gray, dense dolomite in distinct uniform beds from 4 inches to 2 feet thick. Some intercalated shiny, ± phyllitic, siliceous shale (damourite beds of earlier workers). Distinct dolomite bedding and very fine to aphanitic texture with curved breaking surface and cream colored, smooth textured, thin rinded, weathered surface distinguishes it from the underlying section.	22'
Description from quarry face, fallen fragments and direct contact. Gray to dark gray, massive appearing, slightly stylolitic, rubbly bedded, fine to medium crystalline dolomite in beds from 6 inches to 2 feet thick. Bedding is more distinct than the bedding in the 22 foot section below, but less distinct and uniform than the section above. The unit represents a transitional facies between the very fine grained dolomite above and the fine to medium crystalline rock below. Local oxidized pyrite seams, masses, and clots on the weathered surface. Scattered sphalerite found in the lower part of the section.	20'
Description by direct rock contact. Gray to dark gray, fine to medium crystalline, sparkly dolomite in massive beds laced with numerous, wavy, almost corrugated-like stylolitic partings spaced from 1 inch to 16 feet apart. Although the fresh surfaced rock is massive in appearance, it weathers to a undulating thin, rubbly bedded surface which exhibits the many subtle sedimentary features.	22'3"

The dolomite has a mottled, patchy, ruditic, lumpy to locally thinly laminate texture with some scourfill, internal breakage/brecciation, gash/tension fracture fillings, and scattered irregular to lens like or clotted masses of oxidized pyrite. Pyrite oxidation gives a distinct rust stain to the rock surface.

Local, churned, bioruditic dolomite units in the lower part of the section contain Archeocyathus and replaced shell fragments. Stylolitic cycles are present in the lower part of the section.

Dark gray, fine to medium grained, somewhat sparkly, moderately stylolitic, lumpy to irregular bedded dolomite in beds 3 inches to 1 foot thick. Local internal breakage with ruditic texture and scattered calcite-dolomite clots. Mild fetid odor when struck.	9'6"
Gray, fine grained, massive dolomite in beds 1 to 2½ feet thick with local stylolites, hydrous iron concentrations, sulphide weathering and worm tracks on weathered bedding surfaces. Unit more uniform than underlying section.	6'6"
Dark gray, fine to medium grained, somewhat sparkly, mottled to uniform textured, stylolitic to lumpy bedded, internally crackled but healed dolomite. Breccia fragments or clasts have mosaic-like texture on weathered surface. Pyritic lenses, pods or seams locally present. Iron crusts and pyrite oxidation staining scattered throughout the section. Micro to 2 inch crystalline calcite-dolomite filled clots and several poorly developed algal structures are evident at some horizons.	17'3"

Fossiliferous - Archeocyathus, Hyolithellus* worm borings, Scolithus tracks (?), and other unknown fossils.

Total Califon Member	100'6"

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*Hyolithellus opercula, Markewicz, 1968 (open file) (figures 3 and 4) from the Califon Member at Califon range from 1.5 mm to 4 mm in diameter and are black in color. No body shell has been found at this location, the specimens consist of both the interior and exterior surfaces. Muscle scars are very distinct in some specimens. Opercula from the Monroe, New York location are more numerous and varied in number of muscle scars, opercula color, size, plus an occasional body tube can be found.

HARDYSTON QUARTZITE

total exposed 2.5' - 5'

Gray, dense, sharp breaking quartzite, siliceous in lower part grading through siliceous siltstone-shale to calcareous quartzite in upper part. Quartz frosted in upper part of section.

Hardyston composed of boulders, pebbles, and sand, mainly of granitic origin in lower part. Rock predominantly quartz but can be strongly arkosic locally. At many places it is very difficult to nearly impossible to distinguish the contact between the Hardyston and the Precambrian. Figure 2 shows 1½ foot granite boulder surrounded by Hardyston sediments.

Note:

In some areas the basal Califon Member contains a significant amount of fluorite and or sphalerite. It is noted in the text that where the Hardyston Formation is thin; pyrite, fluorite, sphalerite and occasionally galena can be found in the basal Leithsville Formation. Where the Hardyston is thick; 40 to 50 feet or thicker, mineralization is much less evident to absent in the lower part of the Califon Member.

Section 2

LEITHSVILLE FORMATION - HAMBURG MEMBER

Location of Section

The Hamburg Member type location is a prominent, steep sided hill located .5 miles west of Hamburg on Route 94 and .3 miles south of Route 94.

Thickness (feet)

LEITHSVILLE FORMATION

HAMBURG MEMBER

Upper part of member covered. ± 10' - 15'

Description for the entire section is lumped because of the rhythmic repetition of the individual cycles. Except for some minor variations in lithologies and thickness, the individual cycles are basically similar. Each cycle begins on the scour and fill surface of 54 feet 8 inches the underlying terminal dolomite bed of the previous cycle. The cycle is silica rich at the base and grades upward through lithic units containing less silica and increasing amounts of carbonate.

The individual, thicker, quartz rich units at the base of some cycles can be very dense quartzite, similar to the Hardyston. Quartz was derived from the Hardyston or from isolated Precambrian highs that existed in the area. Many depositional, compactional and other sedimentary structures are present.

These include:

ripple marks	intraformational conglomerate
mud cracks	imbricate lined clasts
cross bedding	soft sediment folding
scour and fill	rain prints
graded bedding	compaction structures
flowage casts	

Base of cycle. Fine to very coarse, occasionally pebbly, rounded, ± frosted, arkosic, quartz sandstone deposited on a scour and fill surface. Feldspar twinning visible with the hand lens in some sandstone. Sandstone units from 2 inches to massive beds more than 14 inches thick, grade upward into laminated fine sandstone, siltstone, and arenaceous shale units. Loading, minor

scour and fill, ripple marks and mud cracks are present. Arenaceous unit grades subtly upward into calcareous units consisting of distinct thin to 2 foot thick beds of dense, very fine grained to crytogranular, sharp breaking dolomite containing occasional thin shale partings and floating frosted quartz.	
Lower part of member covered.	20' - 25'
Total Hamburg Member	95'

CALIFON MEMBER

The Califon Member here consists of gray to dark gray, medium crystalline, rubbly to platy weathering dolomite in the lower part of the section grading upward to buff weathering, dense, hard, very fine grained to nearly cryptogranular dolomite typical of the Hamburg Member. Partially exposed.	35' - 40'
Covered, contact with Hardyston not exposed.	±6
Total Califon Member	46'

HARDYSTON FORMATION

Covered except for small exposure near contact with Precambrian.	10' - 12'

PRECAMBRIAN

Note: At some localities the dark, organic laminated to ribbony shale and dolomites of the Hamburg may contain sphalerite, galena, fluorite, and some chalcopyrite. At a location north of Lafayette drill core contained sufficient mineralization whereby zinc-lead companies were interested in exploration drilling. Because of other interests the project did not move ahead.

Some drill core descriptions from the drill-hole are given below.

	Drill core depths not true unit thickness
Light gray, very fine grained dolomite with few dark interbeds, little sand and some pyrite.	16'6" - 18'
17'5" Fluorite in clots	

Light to medium gray, fine grained dolomite with scattered fine sand. Unknown tan colored blebs scattered throughout. Some shaly interbeds and aphanitic dolomite near bottom. 54'8" - 58-8"

56'1" - 56'2" Area rich in tan blebs

56'11" Sphalerite streak

57'6" - 57'7½" Pyrite rich

57'7" Fluorite

57'10" Sphalerite, small clot

58'1" - 58'6" Fluorite, scattered

Similar to above, but with thin, dark, shaly, ribbon-like laminations. Some sections aphanitic with a greenish-gray cast. Some blebs are present. Toward the bottom the ribbony nature becomes more pronounced. A few breccia fragments. 58'8" - 66'1"

58'8" - 59'5½" Sphalerite, scattered

59'6½" Galena, a grain

60'1½" - 604½" Galena and sphalerite, scattered. An unknown translucent green mineral is associated with some of the sphalerite and pyrite.

60'11½" Galena, a grain

65'3½" Sphalerite, a grain

65'3½" - 65'6" Galena, on fracture

65'8" - 65'8½" Galena, on fracture

65'11" - 66'1/2" Galena, on fracture

Very fine grained to aphanitic, greenish-gray, dense dolomite with numerous shards filling the fracture. 66'1" - 66'10"

Gray to dark gray, very fine grained, laminated, shaly dolomite with anastomosing zones. Scattered zones of blebs, sand and pyrite. 66'10" - 72'4"

68'1/2" - 68'1" Sphalerite clots associated with tan colored blebs.

69'2½" Galena, a few grains

Rock similar to last section, but the sand is replaced by dark silt and shale from thin lines to seams 1/2 inch thick. Some subtle laminations, but unit is mainly a thinly bedded, alternating light and dark gray sequence.	26'6" - 47'1"
Light gray, fine grained dolomite with some very dark shards or plates scattered throughout. There are a few thin, very dark interbeds.	47'1" - 48'
Dark gray, very fine grained, laminated dolomite with some light gray interbeds. Bedding - 60° to core.	48' - 48'8"
48'2" Sphalerite in a streak	
Light gray, laminated dolomite similar to 47'1" - 48'	48'8" - 49'8"
48'8" - 49'3" Sphalerite, scattered	
48'10" - 49' Fluorite	
49'3" - 49'8" Sphalerite - 1/2% and fluorite	
Dark gray interbedded sequence similar to above.	49'8" - 50'2"
48' - 48'8" Bedding - 40°	
49'8" - 50'2" Sphalerite, scattered - 1/2% fluorite and galena	
Light gray dolomite similar to 47'1" - 48'	50'2" - 52'3"
50'2" - 50'4" Sphalerite, scattered	
50'5" - 50'6" Sphalerite, scattered	
50'7" Galena, a grain	
50'8" Sphalerite, a few grains	
50'9" - 51'1" Sphalerite and galena, scattered. The sphalerite occurs in both large and small clots and is a filling in veinlets.	
50'9" - 51'3" Pyrite rich area	
Gray to dark gray, very fine grained, brecciated dolomite; with calcite, dolomite and quartz filling around breccia fragments. Sphalerite and some fluorite scattered throughout entire section.	52'3" - 54'8"

Light gray, very fine grained to aphanitic dolomite with a few shaly beds.	72'4" - 73'6"
Medium gray, very fine grained to aphanitic dolomite with light and dark gray interbeds. Many of the dark beds are shaly. This section shows many small breaks. Bedding - 75°	73'6" - 80'4"
79'8" - 80'4" Pyrite, finely laced throughout	
Light gray, very fine grained dolomite with shaly seamlets from 81'6" to the bottom.	80'4" - 82'6"
Section similar to 73'6" - 80'4" with some scattered sandy beds.	82'6" - 89'6"
85'3" Sphalerite? Disseminated clot	
87' - 88' Pyrite zone	
89'4" Galena, small clot in fracture	
Light to medium gray, very fine grained, generally nonlaminated dolomite with some very fine sand and silt. Section somewhat brecciated.	89'6" - 93'
Light gray, very fine grained dolomite with large amount of fine to coarse sand. Some scattered pyrite. Bedding - 45°	93' - 94'2"

Note:

Several thin mineralized zones at the above prospect contained up to 7% zinc.

Section 3

LEITHSVILLE FORMATION - WALLKILL MEMBER

Location of Section

The Wallkill Member is named from exposures located on the east side of the Wallkill Valley approximately 1.8 miles northwest of the town of Hamburg.

	Thickness (feet)
LEITHSVILLE FORMATION	
WALLKILL MEMBER	
Upper part of member covered in valley bottom.	± 200'
Gray to dark gray, fine to medium grained, sparkly, crystalline dolomite. Weathers into flat, platy beds several inches to 1.5 feet in thickness. Rough textured to slight raspy, weathered surface with bleached surface rind up to 1 inch in thickness. Rock contains small, ovoid shaped, bleached patches similar to bleached surface rind.	6'
Covered section	135'
Gray to dark gray, fine to medium crystalline, sparkly dolomite in lumpy to undulating beds 6 inches to 2 feet thick. Rock appears massive, but is, upon close examination, composed of mottled, patchy, mosaic to clast-like, ruditic textured, crystalline dolomite with scattered 1 to 3 inch vugs. Clast neighbors similar to dissimilar. Local curved structures replaced by micro calcite-dolomite, resemble fossil shell outlines. Lumpy to rubbly bedding less evident than in lower part of section. Weathered surface irregular, pitted, raspy texture.	23'4"
Covered	29'
Fine to medium grained, crystalline, gray to dark gray, mottled, ruditic textured, bioclastic, sparkly dolomite in beds 4 inches to 3 feet thick. Locally, thinly laminate. Bedding irregular to lumpy, with irregular mosaic type patchwork outlined on dark weathered surfaces. Internal	35'

breakage appearance may be due to dissimilar clast neighbors exhibiting a very ruditic textured rock on the weathered surface. Clasts micro to 2 inches across. Scattered hairline to distinct while calcite-dolomite stringers. Local algal like structures. Scattered, micro to 1 inch geodes lined or crusted with white dolomite-calcite. Probable worm borings and several definite Archeocyathus-like forms.

Covered	22'
Total Wallkill Member	448'

Top of Hamburg Member

Hamburg Member, estimated thickness	65'

Top of Califon Member

Califon Member, estimated thickness	105'

Top of Hardyston Quartzite

The following drill hole description is from the same locality where the above section was measured.

Drill Hole in the lower part of the Califon Member at the Wallkill Member locality. Hole is 53 vertical feet above Hardyston Formation.	Drill core depth Note true unit thickness
Overburden	0' - 4'
Dolomite gray, fine grained, granular to crystalline, silty, sandy. Some local weathering.	4' - 13'9"
Local breccia	5'4"
2 inch cavity	8'3"
Brecciated but well healed dolomite with some pyrite in small clots and as disseminated	
Crystals. Local weathering.	8'4"
Cavity	10'9" - 10'10"
Cavity	11'1" - 11'2"
Cavity	12'5" - 12'7"
Cavity	13'1" - 13'3"
Breccia, nearly vertical with core length	12'
Deformed oolites	13'

1 inch of broken weathered core. Cavities throughout this section.	13'9" - 18'2"
Dolomite breccia, rock splotched with white calcite clots and seams. Abundant micro-sized pyrite rims breccia fragments.	18'2" - 25'7"
Dolomite fine to medium grained. Patchy, ruditic texture with light and dark gray splotches. Some pyrite.	25-7" - 35'8"
Pyrite more abundant. Circular patches may be worm borings.	28'4"
Heavy pyrite zone, solid for several inches or more, massive to distinct colloform.	29'6" - 31'6"
Bedding - 45^{o}	33'8"
Flake of graphite at 34 feet. Some quartz present as grains and crystals.	
Gray, fine grained, granular, sandy dolomite with scattered carbonate clots. Pyrite disseminated and also as rims around carbonate clots.	35'8" - 42'8"
Sandy, brecciated dolomite with carbonate filling around breccia fragments. Fossils including Archeocyathus.	36'6"
Gray, fine grained, granular, sandy to brecciated, rubbly dolomite. Pyrite lenses and as disseminated grains in siliceous zones.	42'8" - 47'1"
End of breccia zone from last run.	43'8"
Some pale green grains, sphalerite	44'2" - 45'3"
Note: The sand contains feldspar and some graphite grains.	
Gray, fine grained dolomite with sand, some breccia, and pyritic zones.	47'1" - 53'4"
Hardyston Quartzite Contact	53'4"
Hardyston Quartzite	53'9"
Precambrian Mica gneiss, mainly phlogopite and some chlorite?	53'9" - 55'10"

Section 4

ALLENTOWN TO ONTELAUNEE

Location of Section

The location is on the abandoned Lehigh and New England Railroad right-of-way 4,000 feet south of Route 206 near Branchville. From the railroad, the section was measured cross country, to the west, for a distance of approximately 1 mile to a small swamp where the Martinsburg Shale is exposed on the west side.

	Thickness (feet)
JACKSONBURG FORMATION	
Covered zone of limestone.	Not measured
ONTELAUNEE FORMATION	
Total measured thickness.	186'
HARMONYVALE MEMBER	
Covered zone.	28'
BEAVER RUN MEMBER	
Typical, fetid, massive, cherty, rugose dolomite, bedding very indistinct, contains many thin discontinuous quartz filled seamlets and fractures due to structural deformation.	39'
More massive chert coming in, but still rugose, individual dolomite beds also present.	10'
Typical, massive chert ± 5 inches thick at top, chert mottled-grayish at bottom.	28'
Less chert, decreases toward the top. Rock more dolomitic, still has coarse texture. Chert becomes more abundant as clots and knots, less rugose and not anastomosing bedding very indistinct. Many chert clots-knots are grayish, fossil gastropod noted, etched out and replaced by silica, 1 1/4" in diameter.	35'
Same, thinner bedded, less cherty. 1 inch chert bed, rock more distinct as dolomite, chert still occurs as clot-knots. Dark, medium crystalline, ± fetid rock	48'

becomes more laminated toward base. (N26°E 46°S). Lower dolomite, dark, medium crystalline, mottled, massive bedded in beds 1 to 4 feet thick, shreds of chert, some knots-clots, locally rugose, indistinct fossil outlines. Some chert knots up to 1 foot in diameter are lenticular.

Total Beaver Run Member	160'

EPLER FORMATION

Total measured thickness.	369'

LAFAYETTE MEMBER

Covered, but top 6 feet could be Beaver Run or Lafayette, have both lithologies. At west end of covered zone some medium gray, finely crystalline, laminated, platy to thin bedded dolomite, local knots of gray to black chert. (N20°E 56°S).	43'
Laminated section. Massive to thin bedded, fine to medium crystalline, to grained dolomite. Even to local lumpy bedded, thin seamlets to laminae of silica-hard shale. Many quartz filled seamlets and scattered local quartz clots and knots. Local sparkly, fetid, dark beds. Rock varies from very fine grained to medium, sparkly type at bottom of 25 foot section. Beginning to pick up shardy type material. (N40°E 46°S).	84'
Laminated section with dark, lumpy, mottled, ruditic texture, slightly fetid, some local thin quartz filled fractures. Also fine to medium grained, typical structureless dolomite beds. (N32°E 40°S).	18'
Total Lafayette Member	145'

BIG SPRINGS MEMBER

± covered zone. Some nearby outcrops contain local ortho quartzite lenses. Hard ribbed, silty to siliceous bandlets form prominent projections on rock surface. (N37°E 61°S) on intercalated, platy shale and dolomite.	36'
Same, but more dolomite, more massive, less shaly, less ribbing.	18'
Typical shaly dolomite section.	22'
Total Big Springs Member	86'

BRANCHVILLE MEMBER

Massive to medium bedded, fine grained dolomite, with some shards and quartz filled fractures and seams 1/4 inch thick. Bedding 57°.	32'
Laminated section, massive bedded, dark, medium grained to crystalline dolomite with quartz fractures, some local chert pods. More chert coming in toward base.	66'
Same, local 3 foot zone with shards of Big Springs type material. Still laminated type massive rock. (N32°E 50°S).	32'
Massive dolomite, ± laminated section has gray shaly beds up to 2 inches thick.	8'
Total Branchville Member	138'

RICKENBACH FORMATION	157'

HOPE MEMBER

Gray, fine to medium grained, massive to platy dolomite with local, very dark, coarse crystalline, sandy, lumpy beds.	15'
Mostly covered, bottom of section gray, medium grained, massive dolomite with local chert and scattered pods of grayish type, shardy silica to argillitic lenses. (N30°E 35°S).	29'
Massive, gray to dark gray, fine to medium grained dolomite with massive, cherty horizons and quartz sand beds; some typical cream-colored weathering, tough beds. Local Crooked Swamp type coarse dolomite beds 2.5 to 30 feet thick, platy bedded. Local, well-mottled beds, also mottled chert, worm burrows? Local 6 inch black chert bed. Local seams of hard, gray, material. "7 cherts" at base of section.	
Mostly covered.	42'
Total Hope Member	86'

LOWER MEMBER

Intercalated sequence of fine to medium grained, tough dolomite with beds up to 5 feet thick local Crooked Swamp type dolomite in beds 1 to 3 feet thick. (N34°E 44°S).	23'

Massive, thinly laminated, reddish-brown weathering, very fine grained dolomite with some white quartz seams and knots. At bottom is 2 foot thick chert zone with 1 to 2 inch black, very fine grained seams of chert intercalated with 1 to 2 inch beds of dark gray, fine to coarsely crystalline, sparkly dolomite with minor mineralized clots and veins. Rock ± mottled-weathers silty. (N25°E 43°S).	10'
Gray to dark gray, massive, fine to medium crystalline, grained dolomite.	38'
Total Lower Member	71'
ALLENTOWN FORMATION	1,570'
UPPER MEMBER	
Sandy dolomite, much quartz sand, also chip conglomerate in sandy dolomite with 1/2 to 2 inch quartzite beds. At bottom, intercalated cream colored, smooth weathering dolomite beds.	7'
Mostly covered, local outcrop, fine to medium grained, dark dolomite.	33'
Interfingering sequence of quartz sand, ortho quartzite and dolomite. Bedding 75°.	11'
Massive, dull, fine to medium grained dolomite.	15'
Covered, except for thin bed of light gray, sparkly dolomite.	46'
Partially covered, ± 12 foot thick outcrop consists of light gray, coarse crystalline, lumpy type dolomite with some breakage.	27'
Fine to medium grained dolomite with gray, ortho quartzite seams and sandy beds. (N30°E 60°S).	13'
Fine to medium, ± crystalline, massive beds, with local clots and some sand. 2 inch tough silica sand bed at bottom. Some sparkly dolomite at base.	10'
Gray to dark gray, fine to medium grained, massive dolomite with oolitic black chert in stringers 1/4 to 2 inch thick, chert zone 1 foot thick.	18'

Mostly covered but few scattered outcrops are fine to medium grained dolomite.	57'
Fine to medium grained, dull dolomite with a chert horizon at base. Chert discontinuous, occurs as pods, knots and shards, sandy horizon at base. Some chert knots are oolitic.	33'
Massive, dull dolomite with scattered chert knots and clots. Some quartz filled fractures coming in.	12'
Same, but there are beds of mottled, dark, almost rubbly type dolomite, also some coarser crystalline dolomite seams coming in. 2 to 6 inch shale bed at base.	6'
Dolomite, same as above, going downward rock looks more rubbly, mottled, more crystalline. Chert zone, 6 inches thick, occurs in discontinuous lenses. (N45^{o}E 7^{o}S).	15'
Same, beds of rubbly, mottled, generally light colored to local dark dolomite.	10'
Mostly talus but much of it same as above.	16'
Covered-river flood plain 122 feet.	84'

MEASURED SECTION CONTINUES ACROSS RIVER

River approximate with - 40 feet.	23'
Covered zone, from river bank to first outcrop.	108'
Massive, medium crystalline dolomite in even to undulose beds. Scattered white to gray clots up to 3 inches thick, somewhat mottled rock with local, thin laminae, weathers gray. Scattered thin carbonaceous shale seams. A few beds have leached, brownish stained cavities, containing rounded, mammillary type calcium carbonate aggregates. (N18^{o}E 36^{o}S).	13'
Section offset to north $\pm$ 400 feet. Part of above section may be repeated. Gray to dark gray, fine to medium grained, locally crystalline, somewhat mottled dolomite, contains some clots, many filled with quartz and calcite. Beds range from 1 to 6 inches thick. Somewhat undulose. Weathers gray, dull type surface has slight silt residual. Some local black chert zones occur as discontinous lenses and as laminated white and	28'

black chert. Variegated chert may be algal heads. (N12°E 41°S).

Mostly covered. Dirty, rubbly, undulose type dolomite. 26'

Gray to dark gray, medium to coarsely crystalline dolomite in beds from a few inches to one foot thick. It is unevenly bedded, mottled, and clotted, with a few styolites. Local chert and shaly seams in discontinuous lenses. Clots of silica and calcite from microscopic size to three inches across. (N18°E 26°S). 27'

Gray to dark gray, fine to medium grained, locally crystalline, somewhat pitted dolomite in beds from 1 to 4 inches thick. Many pits filled with brown stained calcite, dolomite, and euhedral quartz. This is an alternating sequence of fine grained dolomite and mottled, rubbly dolomite. 11'

Same, somewhat darker and mottled. 40'

Mostly covered, a few beds of fine grained dolomite with clots and beds of dark, dirty, mottled dolomite. (N10°E 10°S). 42'

Mostly covered. Top of section has dolomite similar to previous outcrop. This covered section occupies a sharp ravine. 60'

Light gray, cleaner, even bedded, fine grained, nonclotted dolomite. (N13°E 40°E). 35'

Gray, fine grained, thinly bedded dolomite with some sandy horizons. 39'

Platy bedded dolomite containing a few brownish stained clots, weathers cream colored. 38'

Gray, fine grained dolomite in beds a few inches to one foot thick. At top of section is white quartz. One foot bed of ruditic, fairly coarse, crystal dolomite occurs at base of section. 22'

Mostly covered. Rubbly, dark gray, medium grained, dirty dolomite with few quartz clots. At base becomes lighter gray, finer grained and not as dirty. 24'

Mostly covered, dirty, gray, thin bedded dolomite. Base of section is a lighter gray, finer grained dolomite containing open pits.	28'
Mostly covered, gray, fine grained dolomite.	16'
Total Upper Member	989'

LIMEPORT MEMBER

Dolomite, in beds from 6 inch to 1 foot thick. Weathers cream colored. Has local calcite and dolomite clots and some sand.	22'
Dolomite with a 6 inch quartzite zone at top of section. Fine to very fine grained, hard dolomite, weathers to a cream color. Has thinly spaced fractures, some of which are filled with quartz. Some discontinuous argillite like beds.	28'
Dolomite, weathering to cream color in beds from few inches to 2 feet thick, fine grained, tough dolomite with algal like structures, local mottling, and discontinuous sandy and shaly lenses. This section mostly covered. (N10^{o}E 29^{o}E).	34'
Gray, fine grained, tough, thin bedded sandy dolomite. A few local, chert lenses. Rock weathers cream to tan color.	14'
Gray, fine grained, tough, thinly-bedded dolomite, grading to light gray, thin bedded, cream weathering, laminated beds.	18'
Mostly covered, at top of section light gray dolomite in beds 1 foot thick, has open pits. At bottom of section dolomite is gray and medium grained.	22'
Light gray dolomite at top of section. Sandy, medium grained, light gray dolomite in middle and dark gray dolomite at bottom, a typical Allentown cyclic sequence.	24'
Mostly covered, some well leached, sandy dolomite.	24'
Covered.	24'
Mostly covered, some dark gray, medium grained dolomite, brown, leached siltstone noted.	40'

Mostly covered, at base of section rock thinly bedded, dark to medium gray, fine to medium grained, somewhat rubbly dolomite. Few cream-colored weathered, thinly laminated dolomite beds with possible algal heads. (N8^{o}E 15^{o}E).	9'
Thin bedded dolomite, from few inches to 1 1/2 feet thick, weathers gray to cream colored, contains sand horizons, both as floating sand grains and as sand beds. Oolites noted and a poor cryptozoa, cut and fill, cross bedding, and chip conglomerate.	20'
Covered.	4'
Gray, medium to fine grained, massive dolomite in beds from 1 to 6 inches thick. Local euhedral quartz in small to 8 inch diameter clots.	3'
Thin to platy bedded dolomite, oolitic.	3'
Dark gray, platy bedded dolomite.	5'
Massive bedded, styolitic, thinly laminated, light gray dolomite.	3'
Dark gray, slightly shaly, oolitic dolomite.	2'
Light gray weathering, massive, very fine grained dolomite with thin, shaly laminae and some styolites.	5'
Thinly laminated, dark gray, fine grained dolomite.	1'
Dark gray, massive, rubbly, oolitic bed. Top of section has less oolite and is transitional with rock above.	2'
Very thin bedded, light gray, shaly horizon.	1'
Covered, from talus to west side of road.	57'
Gray, medium crystalline, dirty, rubbly dolomite, much silt.	25'
Same as above.	10'
Darker gray, coarser grained dolomite with some chert shards. Some oolitic beds. Toward base of section dolomite becomes lighter gray and finer grained.	8'

Covered, gray, medium to fine grained, sandy dolomite in a small exposure.	56'
Gray to dark gray, medium grained dolomite with oolites, cryptozoa and sandy beds.	11'
Mostly covered, some thinly bedded, dark gray, medium grained, oolitic dolomite.	30'
Mostly covered.	45'
Mostly covered. Top of section consists of alternating light and dark beds. Bottom of section is swamp edge, fault in swamp?	31'

Note: This may be either upper Leithsville or lower most Allentown.

Total Limeport Member	581'

Section 5

RICKENBACH FORMATION

Location of Section

The location is on Route 80 near the County Route 521 exit, north of Hope. The section starts in the upper Allentown just east of where Shilo Road crosses Route 80 and continues west to the last exposures of dolomite before Route 519.

	Thickness (feet)
ALLENTOWN FORMATION	
Light to dark gray, fine to medium grained, thin to massive bedded dolomite. There are numberous beds of chip conglomerate, oolites and cryptozoa. Some of the beds are extensively worm bored. Sand becomes more common toward the top.	total measured 161'10"
RICKENBACH FORMATION	Total measured 290'
LOWER MEMBER	
Medium gray, medium to coarsely crystalline dolomite. Weathers with a silty rind. Somewhat platy bedded, has a mottled texture, and weathers to lumpy beds.	1'8"
Massive bed of light to medium gray weathering, fine to medium gray dolomite. Has a mottled appearance and weathers to a rubbly texture. Some very fine quartz sand knots.	2'
Fine grained, mottled, lumpy bedded dolomite weathering to a light buff color. At top bedding becomes platy. At top is a 1 foot zone of medium crystalline, purplish-light gray dolomite with some pits and clots.	4'6"
Massive, mottled, internally brecciated, dark gray, finely crystalline dolomite. Bed has an upper rolling surface and at top a zone of thin irregular laminae.	3'
Medium gray, pitted, clotted, weathering surface on which dolomite clots have about 1/2 inch relief and are fetid. Rock is somewhat laminated. Near top are a few pods of black chert. In top 16 inches is a large pebble conglomerate with pebbles up to 3 inches, which are fine grained and light gray weathering in a darker gray weathering matrix. Some cross bedding present at top.	3'

Light gray, weathering, sandy dolomite which is dark gray, aphanitic with thin laminae of medium grained sand up to 1 inch thick, weathering to a brown color. In upper half, dolomite is less sandy. See some distinctive probable oncolites in part chertified. Some well developed stylolites and sand beds in the finer grained dolomite. Locally abundant, fairly well weathered pyrite. 13'

Argillitic dolomite which is gray to dark gray, weathering light to gray. 5"

At base is a large pebble conglomerate with an almost quartzitic matrix. Massive bedded, mottled, rubbly, somewhat conglomeratic dolomite with abundant quartz and dolomite filled clots and lenses. Local lenses of very fine grained, gray dolomite which is dark gray on fresh surface and very tough. Rock has a somewhat purple-brown cast and some sulfide clots weathered to limonite. Near top is a 0 to 2 foot zone of irregular black chert in clots and lenses. At top is a 1 inch zone of the ruditic dolomite containing internal brecciation. Chert zone near top has a 3 inch zone of chert at top and bottom with chert free zone between, and every couple of feet there is a tie of black chert from top to bottom as if chert was filling around large dolomite blocks. 12'

Very ruditic to conglomeratic dolomite with cryptozoan-like structures. Rock is dark gray, weathering to a silty, mottled rind of light and dark gray. Upper contact is very undulose. 2'

Very mottled, thoroughly burrowed dolomite which pinches and swells along strike. 1'

Medium to light medium gray, fine grained dolomite weathering to a silty surface. Has a somewhat mottled look, especially near the base. There are few knots and seams of iron stained shale. Rock weathers to a mottled surface with a silty rind. Fault with about 9 foot displacement. 5'

Dark, medium gray, very finely crystalline dolomite, weathers dark gray with a silty surface. Rock is somewhat mottled and has small pits on the weathered surface. Several clots with orange dolomite and local clots of pyrite. To top is some conglomeratic, finer grained dolomite, weathering to a cream color. 6'

Very silty dolomite, weathering to a shaly dolomite. It is brownish, medium gray and is mottled on the weathered surface.	1'
Fine grained, silty, dark gray weathering dolomite.	3'
At base is a fine grained, medium dark gray dolomite. Above is rubbly bedded, very mottled dolomite. Observe what seems to be vertical worm tubes on a weathered surface. Becomes somewhat laminated at the top. Fine grained dolomite, somewhat brecciated by a nearby fault. Dolomite is gray to dark gray, weathering very light-buff gray.	3'
Covered.	12'
Rubbly bedded, light gray, finely crystalline, mottled dolomite weathering to a pitted surface. Bedding is irregular and somewhat platy.	5'
Covered.	7'
(N70^{o}E14^{o}N) Mottled, clotty dolomite. Rock is fine to medium grained, weathering to a grainy, dark gray surface with irregular quartz knots and buff mottled zones. Strong, fetid odor in the quartz knots.	13'
Dark gray, grainy weathering surface on a medium dark gray dolomite. Becomes somewhat clotty to the top. In upper half are faint, irregular laminae.	2'8"
At base is 6 inch zone of fine chip conglomerate in a laminated sequence weathering to a medium grained surface. Rock is fine grained and dark gray. Above is a medium gray, medium grained dolomite, weathering to a dark gray, smooth surface. At top are rosette clots of white quartz and dolomite which are slightly fetid. Somewhat mottled with borings. On fresh surface rock is medium gray and fine grained.	4'
Covered.	11'
Very fine grained, medium dark gray dolomite at the base of which there is a laminated zone.	1'
Massive dolomite with stylolites both along and across bedding along which is a 1/8 inch zone of weathered pyrite. Rock is medium gray, fine grained dolomite weathered to a mottled appearance and seems to be somewhat brecciated.	6'

Aphanitic, light medium gray, conchoidally fracturing dolomite, weathering cream to buff, laminated rock with a few, thin sandy seams in the middle of the zone.	1'2"
Very sandy conglomeratic dolomite. The sand is fine grained and confined to the lower half. Conglomerate pebbles become coarser to top and are buff weathering and very fine grained in a sandy matrix. Rock is light gray and medium grained.	1'
Dolomitic sandstone with fine grained sand occurring in lenticular beds with some dolomite pebbles. Local pyrite. Rock is medium grained and medium gray, weathering to a brownish buff color.	24'
Total Lower Member	125'7"

HOPE MEMBER

Very sandy dolomite. Sand occurs as bands and beds surrounding a dolomite pebble conglomerate. The pebbles are fine grained. On weathered surface, contorted bedded and dolomite pebbles are visible. Discontinuous stylolite seams have concentration of pyrite along them. In middle of section is a grain of sphalerite. At top is a 1 foot bed of silty, crystalline dolomite weathering to a gray sandy surface.	5'
Very thin black shale at base. Above is an aphanitic, dark gray dolomite weathering brownish medium gray. At top is another brownish silty weathering shale zone.	1'4"
Breccia conglomerate, weathering to a pitted surface. Local sulfide clots up to 1 foot in diameter are now leached to limonite. Rock is medium grained, medium gray with local beds of very fine grained oolitic dolomite.	2'6"
A quartz knot contains unknown black mineral. Discontinuous, aphanitic sandy zone at base. Above is medium crystalline, medium dark gray, with local knots of unknown black mineral.	1'6"
Light medium gray, fine to medium crystalline dolomite weathering to a brown, silty, somewhat laminated surface with local clots of limonite and orange stained dolomite clots. At top are some large pale green to dark brown sphalerite grains in dolomite clots which are cut by thin dolomite filled vertical seams (has red cross painted on it).	1'8"

Rock is a medium crystalline, medium gray weathering to a dark gray, grainy surface. Several large clots of sphalerite noted. Has abundant limonite scales. Sphalerite in a 1 inch dolomite pod with some local brecciation.	1'
Medium dark to dark gray, finely crystalline dolomite crossed by many vertical dolomite filled fractures which contain fine pyrite. Pyrite is also scattered in dolomite. Rock has a mottled appearance and is quite clotty at top with many dolomite filled irregular shaped clots. In one of the brecciated clots there is a dark sphalerite grain 1/4 inch across.	2'8"
Darker gray dolomite with very local black chert at base and crescent shaped dolomite shaped clots convex up. Some zones of internal brecciation with breccia pieces concentrated at the bottom. In one of these clots are some small grains of sphalerite.	1'10"
Sparkly dolomite in 2 to 3 foot beds. Rock is finely crystalline, medium gray dolomite. There are a few small dolomite filled clots with some black sparry dolomite.	6'6"
Aphanitic, sandy, platy to thin bedded, medium dark gray dolomite with fine sand.	1'9"
Beds 4 feet thick with thin undulose shale beds between. Rock is medium gray and finely crystalline. Local pyrite noted.	1'
Somewhat rubbly, very clotty dolomite which is finely crystalline, medium gray, with a reddish purplish cast. There are abundant rosette shaped clots of white dolomite with local internal brecciation, some of which contain the unknown black mineral. Rock is locally laminated and there are beds of dolomite filled breccia about 3 feet thick.	3'7"
Ruditic, rubbly dolomite, less clotty than previous section. Few local clots and pits with dolomite and euhedral quartz and few grains of the unknown black mineral. Each dolomite grain is surrounded by a black shale-like matrix. Rock is medium crystalline, medium dark gray with a purplish cast, weathering to a very silty rind.	9'6"

Medium crystalline, light to light medium gray, Crooked Swamp-like dolomite in massive beds. No clots are observed. At top is some discontinuous formally sulphide rich zones now weathered to limonite.	2'2"
Very fine grained, dark gray dolomite with some scattered sand and vertical dolomite veins, one of which, contains a small clot of sphalerite.	8"
Light to light medium gray, medium crystalline Crooked Swamp-type dolomite, free of fractures and clots. There is a 1/8 inch shale seam at the base. Fault ($N50^{\circ}80^{\circ}W$) with west side down.	1'6"
Mottled, ruditic, clotty dolomite, medium to medium coarsely crystalline, light medium gray and somewhat laminated. There are the remains of a 2 foot sulfide clot now leached and weathered.	10'
Fine grained, medium dark to dark gray dolomite which is quite sandy at the base, the sand being medium to coarse grained. Rock is cut by thin dolomite filled vertical fractures, many of which contain sphalerite grains. There are local pyrite clots. Thin lenses of lighter colored dolomite are present.	1'
Clotty, medium dark gray, finely crystalline dolomite cut by dolomite filled vertical fractures and dolomite filled clots. Sphalerite is abundant in many clots which are related to thin fractures. Some internally brecciated clots contain large grains of sphalerite.	1'2"
Massive dark gray, fine to medium crystalline dolomite. At base is very mottled and somewhat internally brecciated. Toward top are crescent shaped, convex up chert bands, 3 to 4 feet long and up to 3 inches thick. Along a fracture surface there is a veneer of yellow sphalerite. In a few small clots is some of the unknown black mineral. There are a few internally brecciated clots also. <u>Note</u>: This is the "7 cherts" marker.	6'
Massive, medium crystalline, medium gray, Crooked Swamp-type dolomite. Bedding is broadly undulating. At the base are anastomozing shale seams and stylolites.	2'10"

Aphanitic, dark gray, laminated dolomite with scattered sphalerite grains in vertical fractures. At the base is a 1 inch black shale seam.	10"
Massive, medium crystalline, medium gray dolomite. At top is a discontinuous black chert. Rock is quite clotty up to 3 inches across, filled with dolomite. There are a few scattered sphalerite grains in some of the smaller clots. Some of the clots have a fetid odor.	1'4"
Dense, fine grained, tough, medium dark gray dolomite in beds 1 to 1 1/2 feet thick. In the middle is a thin shaly to cherty horizon 1 to 2 inches thick. A few clots are present which have a fetid odor. There are a few thin stylolite zones. At base is a zone of internal brecciation. Rock is crossed by numerous thin vertical fractures. There is a small clot with pale brown sphalerite.	5'8"
Medium crystalline, medium gray dolomite. At top is a 1 1/2 to 2 inch shaly horizon. Dolomite has some internal brecciation. In a rosette shaped dolomite clot is a grain of brown sphalerite.	10"
Dense, fine grained, medium dark gray dolomite with many vertical fractures which contain dark brown sphalerite grains. At base is a 2 inch sandy zone cut by a sphalerite bearing grain.	1'2"
Medium gray, medium crystalline, massive dolomite with thin shale seams separated undulating beds. To top rock becomes somewhat laminated. There are some thin pyrite rich seams, one of which contains sphalerite, and local small knots of chert. Dark brown sphalerite grain found in a clot cut by vertical fractures. Fault with west side down. Dark gray, finely crystalline dolomite which is cut by vertical dolomite filled fractures and many dolomite filled clots, some of which have sphalerite, which is pale to dark brown colored. Clots have no odor. There is finely disseminated pyrite in the dolomite.	5'4"
Medium dark gray, medium crystalline dolomite containing clots. Clots are extended along bedding and contain the black shaly matrix material. Some clots have the unknown black mineral.	2'5"

Cherty zone with discontinuous lenses and knots of black chert in dolomite. The chert is somewhat convex up. There are a few dolomite clots. Dolomite is medium to coarse grained, medium dark gray. Sphalerite may be present in the chert. Some of the chert has faint concentric banding. At top is a thin discontinuous shale zone.	1'1"
Fine grained, medium dark gray dolomite with many vertical fractures. Base is somewhat laminated. Light gray weathering, aphenitic, dark gray dolomite, somewhat laminated.	1'11"
Cherty, sandy dolomite. Lower half is quite sandy with medium grained, medium gray dolomite. Above there are many knots of black chert. Locally some black shaly matrix around dolomite grains.	1'8"
Massive, medium crystalline, medium gray, platty bedded dolomite. In the middle is a continuous zone of internal brecciation up to 4 inches thick filled with dolomite. Rock cut by vertical fractures. One clot contains a dark brown sphalerite grain. On the weathered surface, the rock appears laminated.	4"
Very dense, very fine grained, medium dark gray dolomite which becomes more sandy at the top. A few rosette clots of dolomite and a few clots of quartz noted. One dolomite clot has sphalerite. This clot has thin veining leading into it.	2'6"
Medium to coarsely crystalline, light medium to medium gray dolomite. At base is a 1 inch brecciated zone and stringers of black chert. In the middle are black shaly stringers above which are more chert stringers. At top is a coarse sand zone.	3'5"
(N23°E20°W). Dense, fine grained, dark gray dolomite. Weathers lighter near base than upper part. Upper half has much internal brecciation filled with dolomite. Several clots containing brown sphalerite are associated with vertical fractures. Becomes somewhat more coarsely crystalline to top.	2'4"
3 to 10 inch beds of finely grained, dense, medium gray dolomite with thin shaly seams. Thin stylolite seams parallel to the bedding. Some small dolomite clots, some of which contain black sparry dolomite. Some local clots, some of which contain black sparry dolomite. Some local clots of pyrite.	6'10"

Dense, fine grained medium dark gray dolomite which has a small amount of disseminated pyrite. There are a few thin vertical fractures. One small clot has a sphalerite grain. At top is a 0 to 2 inch breccia zone.	11'
Very fined grained, medium dark gray dolomite with local small dolomite filled clots. Stylolites, thin vertical fractures and some internal brecciation are noted. Pyrite is concentrated along stylolites. At base is a clot with some sphalerite.	3'10"
Medium dark gray, dense, finely crystalline dolomite, weathering light buff gray. Thin dolomite filled vertical fractures, some quartz seams and some stylolites are noted. There are several large grains of sphalerite in clots cut by thin dolomite seams.	1'
Clotty, fine grained, dark gray dolomite cut by many dolomite seams with much small internal brecciation. Clots are not fetid nor is the rock. Few local pyrite clots. Rock has a mottled appearance.	4'2"
Ruditic dolomite with a reddish-brown cast. Rock is gray, medium crystalline mottled dolomite. Offset to east bound lane.	2'6"
Fine grained, dark gray, dense dolomite cut by some vertical dolomite fractures offset by small styolites. Local internal brecciation and clots with black sparry calcite noted.	4'5"
Covered.	12'
Fine grained, dary gray, dense dolomite.	1'
Mottled, cherty, slightly fetid dolomite, light medium to medium gray, medium crystalline dolomite. Rock cut by some thin dolomite seams. On weathered surface, rock is somewhat laminated with thin silt seams. Black shaly matrix surrounds some dolomite grains. Chert is in stringers and knots up to 1 inch thick, rossette-like clots of white dolomite have a somewhat fetid odor.	5'
Total Hope Member	167'
Total Epler Formation	421'

BRANCHVILLE MEMBER

Generally a massive, laminated, fine to medium grained dark gray dolomite. The rock weathers with the laminae in relief. There are some argillitic shale beds. Chert is present, not common. 209'

BIG SPRINGS MEMBER

An interbedded sequence of shaly to siliceous dolomite with dense fine grained dolomite. The siliceous interbeds have a green cast and weather in strong relief. There are pinch and swell features and chevron folds present in this member. 41'2"

LAFAYETTE MEMBER

A massive, laminated dolomite similar to the Branchville Member. In the lower part of the member there are many thin greenish shaly interbeds. There is a large paleo solution breccia that occupies the upper portion of the member. 171'

Note: The total thickness not measured here due to the development of the breccia.

Total Ontelaunee Formation 203'

BEAVER RUN MEMBER

A massive, fetid, medium to coarse crystalline dolomite. There is a large amount of bedded and rugose chert in the middle part of the member. Fossils have been found in the cherts. 151'

HARMONYVALE MEMBER

A partly covered section of dense very fine grained smooth weathering dolomite. Some of the beds are slightly fetid. Styolites and black sparry-calcite clots are present. 54'

Section 6

EPLER FORMATION

Location of Section

The section is located in a road cut 1,000 feet east of the Newton town line, near Drakes Pond Road, in Newton.

	Thickness (feet)
EPLER FORMATION	Total measured 518'
LAFAYETTE MEMBER	
Light to medium gray, fine to medium grained, laminated, massive bedded dolomite. There is a 4 foot zone of coarse indistinct breccia in the middle of the section. Toward the bottom the rock becomes more crystalline and sparkly.	Total measured 55'5"
BIG SPRINGS MEMBER	
Limestone facies. Massive section of gray, fine to medium grained, strongly mottled, slightly calcareous dolomite, weathering with a strong silt residue on the surface. Near the top of road cut are a few fairly good lime beds, but at base of cut the rock is not a limestone. There is a 2 inch argillaceous zone at 6 feet 6 inches. Somewhat arenaceous with a ruditic texture.	7'
Typical Epler limestone with anastomosing silt bands. Limestone bands range from microscopic to 2 inches thick. Lenses of mottled silty dolomite. Becomes more dolomitic at the bottom.	6'7"
Limestone is aphanitic to fine to medium crystalline partially a calcarenite where it is coarser grained. Possibly fossiliferous. Local sparry calcite clots and stylolites. On weathered surface, rock has strong mottled texture.	
Slightly calcareous, fine to medium grained dolomite, light gray color.	3'3"
Limestone section is very lenticular and going up face it thins to a narrow shaly section.	1'2"

Gray, fine grained, styolitic dolomite. At base is a thin, shaly zone which becomes irregular toward top of cut and bifurcates upward. Cross bedding shows right side up.	3'11"
Massive gray, meidum to crystalline dolomite containing a few shaly seams and some indistinct styolites. At top of cut is a lens of dirty aphanitic limestone forming a pod within the dolomite.	5'
Silty, lenticular limestone becoming over 6 feet thick toward the top of the cut.	2'8"
Calcareous, light gray, medium to coarsely crystalline dolomite with many carbonaceous seamlets. Weathers to a silty residue.	3'
Mixed sequence of lenticular limestone and a strongly calcareous dolomite. Somewhat more coarsely crystalline than previous rock and somewhat styolitic and massive bedded. Thin 1/2 inch shaly horizon. At the base there is a 6 inch limestone conglomerate with coarse grains between fragments and also black, carbonaceous, shaly material in matrix.	4'
Gray, mottled, slightly calcareous, fine to medium grained dolomite, cross cut with a number of quartz filled fractures.	2'4"
Mixed sequence of dolomite and limestone. Beds range from 2 to 18 inches thick. Somewhat mottled with shaly seams toward the top of the cut.	1'10"
Dolomite, somewhat mottled, weathering to a strong silty residue. Ranges from fine to coarsely crystalline and contains a few sparry calcite clots toward top of cut. Passes into typical limestone toward top of cut. Fossils found about 10 inches from top in a thin shaly bed.	3'4"
Sequence of aphanitic limestone weathering to a very light color with strong silt laminae. Cross bedding, silt residue and drag features seen in this section. Limestone is shardy in appearance, fragments float in a silt matrix.	10'
Mostly covered. In woods is a 15 foot section of weathered calcareous shale, probably similar to material seen in road cut. Thin seams about 1 inch long containing probable chalcopyrite with some dark sparry calcite.	26'6"

In woods, a weathered outcrop. To top of section is calcareous shale with thin limestone seams in silt matrix. Weathers to red color typical of the dolomite facies. Down section, thin bedded and more shaly. Underside of ledges show few sparry calcite crystals and possible fossil fragments. Limestone ranges from "blue lime" to more crystalline calcarenite. 42'

Same type of lenticular limestone and shale with the limestone beds a little thicker. Weather with a ribbed surface. To base limestone diminishes and becomes more silty. 21'

Dirty silty zone with slight carbonate content. Mostly shale. Limestone lenses not present. Much shearing. 20'

Total Big Springs Member 151'7"

Total measured 311'

BRANCHVILLE MEMBER

Mostly covered.

Light to medium gray, fine to medium grained, massive, laminated dolomite.

Section 7

ONTELAUNEE FORMATION - HARMONYVALE MEMBER

Location of Section

Section is located near Belvidere in an abandoned quarry located 1.1 miles north of Route 46 on Sarepta Road. The measurements start at highest dolomite exposures on the hill above the quarry and proceed downward to the quarry floor.

	Thickness (feet)
ONTELAUNEE FORMATION	
HARMONYVALE MEMBER	
Covered to Jacksonburg.	
Gray, fine grained, yellow weathering, lumpy bedded dolomite with lenses of massive chert. Chert seams to be filling veins.	2'
Light gray to gray, massive, lumpy bedded, finely laminated chert.	1.5'
Intercalated sequence of megacrystalline dolomite with a gray to dark gray, spongy sandy to cherty beds. Chert beds contain both high and low spire gastropods as well as a tube type fossil.	5.5'
Light gray, finely crystalline, light gray weathering, checked dolomite. Contains scattered lenses of spongy chert in the upper 1 foot. Gastropods are present.	3.3'
Gray, aphanitic, locally finely laminated dolomite.	2'
Gray, megacrystalline to finely crystalline, yellow weathering checked, dense dolomite. An 8 inch thick chert 11.5 feet above the base of unit.	17.5'
Light gray to gray spongy chert, may be fossiliferous.	2.2'
Covered.	5.5'
Gray, megacrystalline to finely crystalline, locally fetid, light weathering, checked dolomite containing local sparry calcite.	7'

Massive dark gray spongy weathering chert.	1.5'
Gray, microcystalline, finely checked, massive, fetid dolomite. Weathers with a thin, light gray to white rind.	11.6'
Covered.	7.6'
Finely crystalline, sparkly, massive, dense yellow weathering, checked, dolomite. A 4 inch chert near the top and a 6 inch chert in the middle of the unit. The lower chert is light gray to gray and contains pyrite. It grades laterally into massive lenses or pods of white quartz.	17.5'
Brown weathering, black chert.	0.2'
Covered zone containing cherts.	8'
Light gray, finely crystalline, sparkly dolomite.	2'
Covered.	11.6'
Gray, very fine grained, dense, white to very light gray weathering, slightly fetid, strongly checked, dolomite. There is a 1.3 foot discontinuous chert near the top.	19'
Finely checked chert.	0.3' to 1'
Gray, fine grained to megacrystalline massive, highly checked dolomite weathering to a smooth yellowish brown rind. Locally the rock is finely laminated. There is a 1 to 3 inch chert 3 feet from the top. The upper one half of the unit is so finely checked and gashed that the weathered surface resembles elephant hide. Oncolites, some chertified occur in the upper 1 foot.	9'
Dark gray, microcrystalline, slightly fetid, finely checked dolomite with discontinuous to anastomosing chert scattered throughout. There are many 1/4 to 2 inch flat chert plates in the upper part. Much of the unit contains thin, wispy carbonaceous seams.	3.5'
Finely laminated dolomite with a local basal chip conglomerate. Some chert chips are present in the upper part. Several indistinct linguloid brachiopods noted.	1.3'
Sheared chert which grades into a dolomite on strike.	0.3' to 1'

Finely crystalline, fetid dolomite with a large amount of floating quartz.	0.6'
Dark gray, microcrystalline, massive, dense, finely checked dolomite with black sparry calcite filling the checking in the upper 2 feet.	4.5'
Gray, finely crystalline, fetid dolomite with wispy chert stringers. There is a prominent discontinuous black chert at the base.	1.5'
Mottled dolomite with floating, rounded quartz.	0.5'
Gray, microcrystalline dolomite.	0.6'
Zone of dolomite chips which are surrounded by highly polished floating quartz.	0.3'
Gray very fine grained, checked dolomite with black sparry calcite clots. There is a 1 inch discontinuous chert in the middle.	1.2'
Dolomite containing a large amount of highly polished quartz.	0.3'
Bed of mixed, broken dolomite and chert.	1'
Gray, finely crystalline, dense, slightly fetid checked dolomite with black sparry calcite, a discontinuous 1 inch black chert bed near the base and some highly polished floating quartz. Near the top are the wispy dark lines, noted an oncolite.	4.1'
Gray, microcrystalline, fetid, styolitic, checked dolomite. There are scattered clasts or clots of chert as well as several prominent carbonaceous shale beds.	4'
Gray, finely crystalline, massive, fetid dolomite, mottled in the lower 1/3, containing local styolites and black sparry calcite.	2.5'
Dark gray, microcrystalline, dense, smooth breaking, finely checked dolomite in alternating light and dark beds. There is a 1/2 inch carbonaceous shale at the top.	2.5'
Gray, finely crystalline, mottled, strongly fetid dolomite. Locally styolitic with a ruditic texture.	4'
Very dark gray, aphanitic, finely checked, fetid dolomite with a yellowish weathering near the base. Some sand and relic cryptozoan like structures are present.	2.5'

Chert, sheared, mottled, containing dolomite fillings. On strike it separates and coalesces and has a pyritic shale at the base.	0.6'
Dense, very fine grained, slightly fetid, checked dolomite with dark wispy lines.	0.9'
Chert, tough, sheared, locally shaly with scattered pyrite.	1.3'
Dark gray, laminated, microcrystalline, slightly fetid, checked dolomite. Local black sparry calcite, chert masses and styolites present.	8.1'
Very fine grained, mottled dolomite. Mottling caused by light gray siliceous to cherty stringers parallel to bedding. The upper 1/2 contains a 2 to 4 inch zone of floating quartz which is overlain by a 6 inch dark dolomite to cherty bed.	6'
Dark gray, finely crystalline dolomite with many styolites.	1.5'
Bed containing dolomite euhedral in a matrix of chert and asphaltic like material in the lower half. The upper part has a large amount of highly polished quartz.	0.3'
Chert, shale, dolomite and sand with ruditic texture.	0.5'
Carbonaceous shale.	0.1'
Medium gray, very fine grained, massive slightly fetid, checked, styolitic dolomite with black, sparry calcite filled gash veins and subtle horizontal to vertical wispy seams which may be related to carbonaceous layers.	5'
Very dark gray, slightly fetid medium crystalline checked dolomite with light and dark mottling in lower foot. The entire unit contains discontinuous blebs and clots of chert parallel to bedding.	3.1'
Black, calcareous shale containing pyrite.	0.1'
Very dark gray, aphanitic, laminated, slightly checked dolomite. Local, black, sparry calcite. Carbonaceous layers separate the subbeds. In the upper half are streaks of polished quartz.	13.5'
Total Harmonyvale Member	216.4'

The contact with the Beaver Run Member is probably 20 feet below the quarry floor. This is based on the occurrence of the oncolite type fossil.

SEDIMENTARY ROCKS

Cenozoic

Quaternary—Recent deposits of the last 10,000 years are chiefly beach sands forming Sandy Hook and the offshore bars. Pleistocene or ice age starting 1,000,000 years ago. Widespread thin deposits of till and outwash covering older formations are not shown on this map. Mineral production—peat moss, sand, and gravel.

Tertiary—Starting 70,000,000 years ago. Unconsolidated sands, gravels, and clays. Forms the outer Coastal Plain. Marked by three different periods of invasion by sea, separated by erosional periods of dry land. Mineral production—brick and terracotta clays; glass sands; ilmenite (titanium ore).

Mesozoic

Cretaceous—Starting 125,000,000 years ago. Unconsolidated sands, clays, and greensand marls Forms the inner Coastal Plain. Appalachian Province uplifted and coast depressed; fast moving rivers deposited sediments in marine environment. Mineral production—fireclay, brick clay, greensand marls.

Triassic—Starting 200,000,000 years ago. Shales, argillites, sandstone, and some conglomerates. Forms Piedmont Plain. Appalachian Mts. uplifted and long thin depressed basins formed between ridges; fast moving rivers deposited sediments in these basins. Mineral production—Stockton sandstone (brownstone) for building stone; negligible amounts of copper found in some shales.

Paleozoic

Devonian—Starting 330,000,000 years ago. Sediments occur in two areas, 1) fossiliferous, calcareous shales and limestones in Appalachian Plateau, 2) sandy shales, sandstones, and conglomerates in valley south of Greenwood Lake in Highlands. No significant mineral production.

Silurian—Starting 360,000,000 years ago. Coarse conglomerates, sandstone, shale and, limestone. Occur to the southeast of Devonian sediments. From early Devonian, when sea receded to early Upper Silurian, N.J. was dry land.In late Silurian, the sea receded for a very short period and then re-invaded land. No significant mineral production.

Ordovician—Starting 420,000,000 years ago. Limestone, shales, and slates. Found in the Highlands and Appalachian Plateau. Three different invasions of land by sea, with erosional periods of dry land in between. Mineral production—cement rock and slate.

Cambrian—Starting 500,000,000 years ago. Quartzite followed by limestone. Found in the Highlands and Appalachian Plateau. During first and last parts of Cambrian time N.J. was covered by seas, while in Middle Cambrian time it was dry land

Precambrian—Franklin limestone—more than 500,000,000 years old. Typically a white crystalline limestone. Found in a narrow belt and a few isolated masses in the Highlands. Mineral production—zinc deposits at Franklin and Ogdensburg; limestone for flux and cement rock.

IGNEOUS ROCKS

Triassic—Diabase and Basalt—The same basic rock formed from cooling molten material. Differ in texture. Diabase is coarse grained due to slow cooling beneath the surface while basalt is fine grained due to quick cooling of lava at the surface. Diabase forms the Palisades and its extensions to the south in the Princeton area. Basalt forms the Watchung Mts. and the two small masses at New Germantown and Sand Brook. Diabase and basalt are extensively quarried for concrete, road metal, and railroad ballast.

Precambrian—Gneiss and Granite. Granite is a coarse grained igneous rock characterized by predominant alkali feldspar and quartz. Gneiss is a crystalline rock with a secondary rough foliation developed as a result of pressure on the solidified rock; bands or lenses in gneisses are commonly unlike. Metamorphic rocks are included in this zone, some of them having been derived from sediments. These rocks form "The Highlands of New Jersey". Mineral production—magnetite (iron ore), crushed stone and prospects for uranium, monazite, and rare earths.

DEPT. OF CONSERVATION AND ECONOMIC DEVELOPMENT
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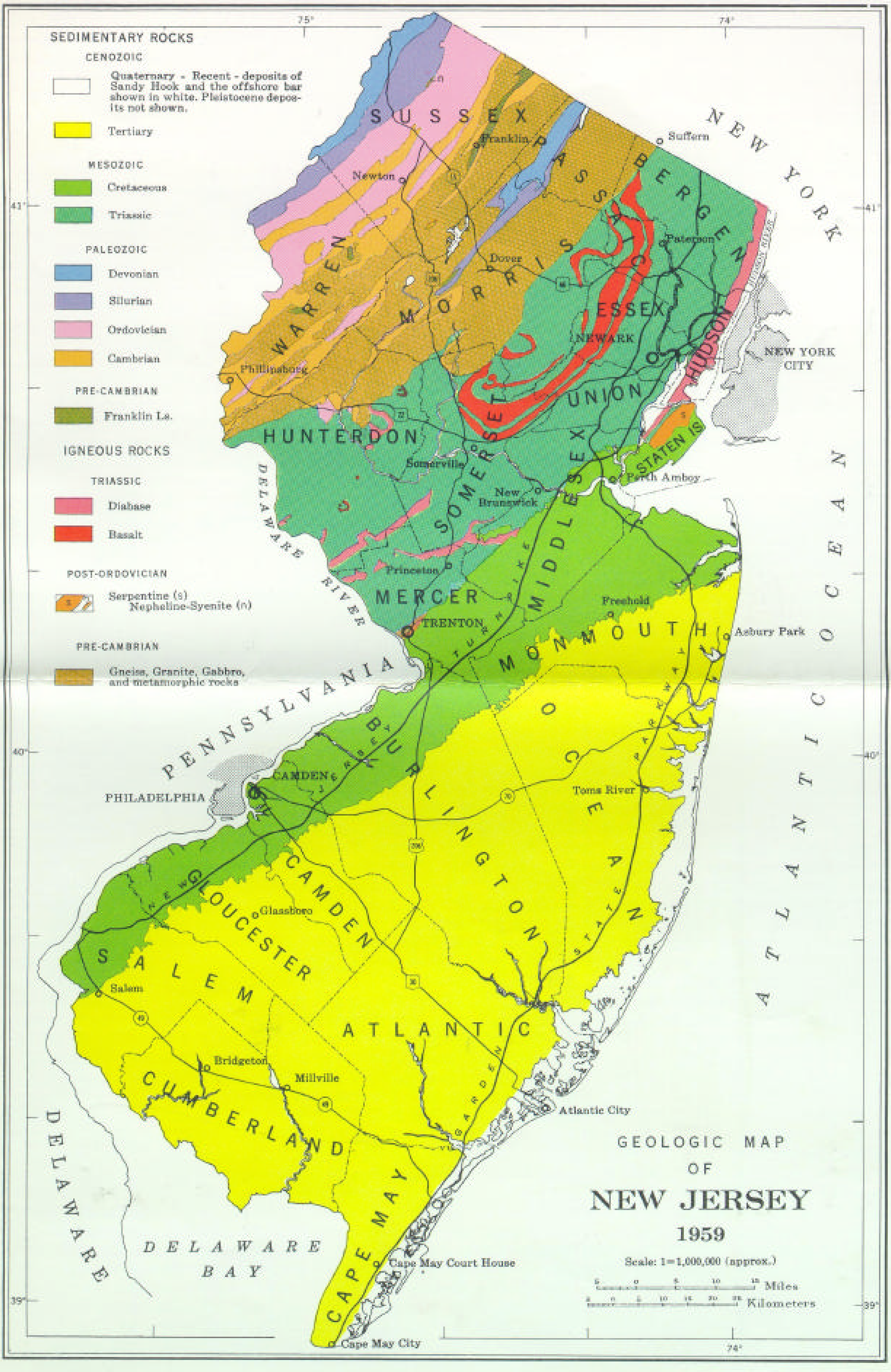

GEOLOGIC MAP OF NEW JERSEY 1959

Scale: 1=1,000,000 (approx.)

Miles

Kilometers