Eighteenth Annual Field Conference
Of Pennsylvania Geologists

Sussex County, New Jersey

GUIDEBOOK OF FIELD TRIPS

(1) Friday afternoon, May 30, 1952
  Pleistocene Geology
  Leader: Paul Mac. Clintock

(2) Saturday (all day), May 31, 1952
  Trip A: Dikes of Special Petrologic Interest
  Leader: Charles Milton

  Trip B: Silurian and Devonian Stratigraphy
  Leader: Henry Herpers

(3) Sunday morning, June 1, 1952
  Trip A: Cambro-Ordovician and Pre-Cambrian Rocks
  Leader: Meredith E. Johnson

  Trip B: Silurian-Devonian Section at Nearpass Quarries
  Leader: Henry Herpers

Host organization: Bureau of Geology & Topography
                 N. J. Department of Conservation & Economic Development
STRATIGRAPHIC COLUMN

in

SUSSEX COUNTY, N. J.

Quaternary System
Recent deposits. Swamp muck, alluvium, etc.
*Wisconsin Glacial deposits Recessional & ground moraines, glacio-fluvial deposits, etc.

Unconformity Uplift & Erosion

Triassic System
*Diabase dikes

Unconformity Appalachian Revolution

Devonian System
Marcellus shale. Fissile black shale.
*Onondaga ls. Dense, grey, fossiliferous ls.

*Esopus shale. Cherty in part.

*Port Ewen shale. Limestone in north, becoming arenaceous to southwest.
Becroft ls. Grey shale.

*New Scotland formation. Gray fossiliferous ls.

*Coeymans ls. Grey shale. Fossiliferous. Limestone at base.

Grey, crystalline, fossiliferous ls.

Silurian System
*Manlius ls. Grey, fine-grained fossiliferous ls.
*Rondout ls. Dark grey "cement rock". Many ostracods.

*Bossardville ls. Dark grey, thinly-laminated "ribbon" ls.

*Poxono Island shale. Groenish shale.
*Bloomsburg red beds. Red shale and sandy shale. Green beds present.
Shawangunk cgl. Grey conglomerate and quartzite.
Unconformity

*Igneous rocks of post-Ordovician age.

Taconic orogeny

Nepheline syenite, basic igneous rocks.

Ordovician System

*Martinsburg slate.
*Jacksonburg ls.
*Kittatinny ls. (partim)

Dark grey slate. Sandy toward top.
Dark grey, fossiliferous ls.
Grey magnesian ls.

Cambrian System

*Kittatinny ls. (partim)
*Hardyston quartzite.

Grey magnesian ls.
Grey quartzite.

Unconformity

Orogeny.

Pre-Cambrian rocks

*Franklin's, Losee, Byram & Pochuck gneisses. *Pegmatitic & granitic dike-like intrusives.

*Rocks to be studied on field trips of this Conference.
PLEISTOCENE GEOLOGY

Leader: Paul MacClintock

Itinerary for Friday afternoon, May 30, 1952.

Mileage

0 Cochran House. Cars will leave about 12:40 and proceed individually west
one block on Spring Street to traffic light, then right on Water Street
(Route 31) to

5 Assembly point, junction Routes 31 and 6A (at 1:00 o'clock).

5 Turn right (East) on Route 6A.

8 Turn left on road toward Warwick, Hamburg, etc. Note fresh terminal
moraine topography.

13 North Church. Follow route 31 to the north side of cemetery and park
beside road.

13.1 STOP 1. NORTH CHURCH DELTA. (At about 1:30).

"The North Church delta plain is a striking feature. Its greatest
width from east to west is a little more than one and one-fourth miles.
Its greatest length from north to south is five-eighths of a mile. Its
average elevation is 630 feet above the sea, and it rises from twenty to
100 feet above its surroundings. The top of the plain slopes gently from
north to south, its planeness being interrupted only by a few shallow
depressions.

"Along its southern and eastern margins its outline is lobate and its
slopes steep. The outline and the slope of the front are such as are
characteristic of deltas . . ."

"The northward slope of the plain is very different in topography and
outline from the southern. Here the plain breaks up into a succession of
hillocks and kettles at a level lower than the top of the plain. Some of
the kettles are eighty feet deep . . ."

"It is evident that the conditions which obtained on the north flank
of the plain while the drift of the plain was being deposited, were
totally unlike those on the southern. The steep slopes and lobate margin
of the plain on the south, point to the conclusion that the North Church
plain is a glacial delta, built out into a temporary lake, whose waters
had an elevation of 620 to 630 feet. The knolls, ridges and kettles of
the northern slope indicate deposition against an ice front of irregular
outline. There can be no doubt that the margin of the ice was at the
line of these kames when the delta plain was formed, and constituted the
barrier which held in the lake on the north."
Mileage


Continue north on Route 3 to Hamburg.

15 Hamburg. Turn sharp left on Route 23. Follow Route 23 to summit of Kittatinny Mountain in High Point Park.

29 Bear right, follow signs to the Monument.

30 **STOP 2.** High Point Monument (at about 2:30). Striae and friction cracks on the Shawangunk conglomerate showing ice movement toward the south. "Striae show ice movement west of south. Two types of curved 'chatter marks' are shown, (1) crescentic crack and (2) lunar gouge or friction crack. The first is made by tension in the rock, the horns point downstream, and the crack dips steeply upstream. The second is made by local shearing as the ice drags forward small amounts of the upper part of the rock, the horns point upstream, and the crack dips gently downstream. It is sort of a thrust fault dipping downstream."


Back to Route 23 and turn right to Port Jervis.

36 Join Route U. S. 6 to center of Port Jervis. Continue through Port Jervis and west on N. Y. Route 97 through Sparrow Bush for one mile (where N. Y. Route 42 turns to right).

Bear left on black-top road down Shingle Kill Valley. Stop beyond railroad bridge and climb the embankment.

41 **STOP 3.** (at about 3:30) Looped moraine across Delaware Valley.

The embankment here loops across the Delaware Valley. It is made of kame gravel (i.e. coarse, poorly sorted gravel deposited at the edge of the glacier).

Retrace route to lookout point beside road, just west of Port Jervis.

44 **STOP 4.** (at about 4:30) Striae and friction cracks on rock ledges showing ice movement toward the northwest, up the Delaware Valley.

"The striae and friction cracks show that ice of this episode of the glaciation moved northwest, up the Delaware Valley to deposit the frontal moraine near Sparrow Bush. We think this was the Cary substage of the Wisconsin stage of the Pleistocene. (Reference - MacClintock and Feltier. Wisconsin glacial stadia in New Jersey. Bull. G.S.A. vol. 60, p. 1971, 1949).

Back to center of Port Jervis, turn right on U.S. Route 6 and 209 south to Milford.

52 At Milford turn left on U. S. 206 and follow to

80 Newton - end of trip (at about 6:00).
DIKES OF SPECIAL PETROLOGIC INTEREST

IN SUSSEX COUNTY, N.J.*

Leader: Charles Milton

ITINERARY FOR TRIP A, SATURDAY, MAY 31.

Outline of Itinerary

STOP 1. Bostonite dike
STOP 2. Nephelite syenite dike with natrolite-andradite-allanite.
STOP 3. Minor cuachitite volcanic plugs
STOP 4. Main nephelite syenite mass
STOP 5. Small tinguaite dike in Martinsburg shale
Stop 6. Rutan Hill, a complex volcanic plug

LUNCH

STOP 7. Limestone quarry; Franklin Limestone with kugel minette dikes, (Mrs. Marburg's house).
STOP 8. Limestone quarry with scapolite "gabbro" and kugel minette.
STOP 9. Limestone quarry with arkosic (?) dike
STOP 10. Buckwheat Pit, with great dike of kugel minette
STOP 11. Triassic diabase

* Publication authorized by the Director, U.S. Geological Survey
INTRODUCTION: FEATURES OF SPECIAL PETROLOGIC INTEREST IN SUSSEX COUNTY

Sussex County, New Jersey, is of unusual interest to the geologist, petrologist, and mineralogist. The areal geology, of course, exemplifies the regional Appalachian stratigraphy, extending with but minor variations northeast and southwest. Typical of this stratigraphy are the sedimentary rocks of early and middle Paleozoic age and the older granitic and schistose rocks. These, and the widespread glacial deposits, will be observed on other trips. To the mineralogist, especially, Sussex County immediately brings to mind Franklin and Ogdensburg, among the most renowned mineral localities in North America. Today, however, we shall confine our attention to less well known, but nevertheless notable, features of petrological interest.

Within the northern half of Sussex County are three apparently unrelated assemblages of unmetamorphosed igneous rocks. First, is an alkalic suite consisting of a great body of nephelite syenite, markedly differentiated, with a satellite suite of volcanic plugs and tinguatic and bostonitic dikes. All these have caused greater or less metamorphism in the sedimentary rocks they have intruded, for the most part Martinsburg shale of Ordovician age. Second, are five isolated occurrences of an unusual lamprophyre, termed kugel minette. This rock has certain textural features which have occasioned extensive discussion for over a hundred years. Third, are four occurrences of recently discovered Triassic diabase, altogether distinct from the other igneous rocks. The general distribution of these three suites is shown in Figure 1. Besides these, we shall briefly examine other rock types of uncommon metamorphic character: an enigmatic igneous-sedimentary(?) rock, an exposure of scapolite ("gefleckter") gabbro, a chondrodite-rich marble, and others as time permits.

The morning will be spent in examining six representative exposures of the alkalic suite, near Boenerville, a petrographic province in miniature. In this small area of a little over 50 square miles is a complex suite of related alkalic rocks whose counterpart appears to exist in only one other locality in the eastern United States: namely, in west-central Virginia. A similar assemblage, in many respects, is found in central Arkansas; in the Monteregian hills around Montreal, Quebec, and various New England localities may contain more or less distantly related rock types. In the afternoon, there will be five stops, covering various dike rocks which have no evident relation to the nephelite syenite complex: these include the kugel minettes, to be seen at three localities; a peculiar arkosic(?) dike(?) apparently unique in this region; and, finally, a typical representative of Triassic diabase, only recently recognized. It should be realized that these are but a very few of some scores of alkalic and other dikes and related bodies exposed in the area; however, a fair idea of the regional igneous petrology will be gained by study of the exposures to be visited today.

The sketch map, Figure 1, shows the location of Sussex County and the three major suites of dike rocks in the county.
ITINERARY

Newton East, N. J., quadrangle*

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<th>Details</th>
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<td>0.0</td>
<td>Leaving Newton, (from the Cochran Hotel) we travel NNE on U. S. 206 (N. J. S31) to Ross Corner.</td>
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<tr>
<td>5.2</td>
<td>Turn left (continuing on U. S. 206 - N. J. S31) through Augusta to Branchville</td>
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<tr>
<td>8.0</td>
<td>Turn right at D. L. and W. R. R. station and proceed north to end of Branchville Playground.</td>
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<tr>
<td>8.5</td>
<td>STOP 1. Bostonite dike.</td>
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</table>

This is the southern end of a series of interrupted exposures of bostonite which may be traced several miles north to Beemerville. They are not shown on the Franklin Furnace Folio map. It is interesting to note that the northernmost exposures of alkalic rocks in Sussex County, a few hundred feet north of Rutan Hill, about 9 miles distant, are also bostonite. This highly alkalic rock, essentially alkali feldspar, appears to represent the final semi-hydrothermal stage of volcanic activity in this region.

Superficially, the bostonite greatly resembles the indurated gray sandy Martinsburg shale which it intrudes. Indeed, its igneous character is hardly recognized until, usually with a hand lens, minute laths of feldspar are noted. The cleavage surfaces of this feldspar, reflecting light, identify the bostonite as a porphyritic igneous rock. Numerous other unmapped exposures of bostonite occur in the vicinity of Branchville.

At this locality, as well as elsewhere, a slight metamorphic induration of the shale can be seen, and the bostonite exposure forms a noticeable topographic feature owing to its greater resistance to erosion.

Microscopic examination of the bostonite (Figure 3) reveals that extensive hydrothermal alteration of porphyritic nephelite took place, producing a mass of obscure micaceous substances ("pinite"). There is also much calcite, some of which may be due to weathering, but much of which is undoubtedly of hydrothermal origin. The groundmass of the rock is a potassic feldspar which shows a hypidiomorphic structure. Chloritic replacements of mafic minerals are present, often abundant. Relatively coarse apatite is present.

* Quadrangle map references are to topographic maps published by Corps of Engineers, U. S. Army.
The appearance of the bostonite, as is true of alkalic rocks in general, is quite variable; for example, the bostonite at Branchville differs in appearance from the bostonite at Rutan Hill (figures 7 and 8) whose igneous character is immediately recognizable. The magmas giving rise to these alkalic rocks are of comparatively small volume and rich in "volatile" mineralizers; crystallization occurs under a diversity of physical conditions. Furthermore, hydrothermal solutions have caused marked deuteric effects.

Bostonites are defined by Rosenbusch and Osann as light-yellow, gray, gray-green or whitish (dike) rocks which are dense and compact, of very fine grain, rough and trachytic, having a peculiar silky sheen, and which consist substantially of alkali feldspar (microcline without microcline twinning, microcline-microperthite, anorthoclase, or rarely orthoclase). Colored minerals, such as biotite or iron amphibole, and accessories, such as apatite, zircon, or iron oxide, are either very scanty or absent. Commonly a little quartz is present (quartz bostonite); rarely, sodalite or its alteration products are found. Porphyritic development of feldspar gives rise to bostonite porphyry. On weathering, bostonite assumes a dull brown color, with some development of iron carbonates. The feldspar crystals are definitely tabular and are most commonly in parallel alignment, this causing the typical silky appearance of the bostonite. In some bostonites, however, the feldspar is in random orientation. All the other subordinate minerals are interstitial to the feldspar. The general structure is panidiomorphic granular trachytopic.

Mileage

Bostonites occur associated with alkali syenite and nephelite syenite, especially essexite, and were first described from Marblehead Neck near Boston (whence the name). They occur abundantly around Lake Champlain, in the Adirondacks, near Montreal, in New Hampshire, Montana, western Texas, and Brazil. There are many European localities, notably Christiana, Norway; Aina, Sweden; and in Scotland, France, and Portugal; also localities in the East Indies and Madagascar. All of these occurrences and others, have been described in classical petrological works; it may be said that the Sussex County bostonites are representative and typical of a class of rocks of worldwide distribution.

Continue on road NE from Branchville

9.3 Take right fork
10.2 Turn left on dirt road
10.6 STOP 2. Nephelite syenite dike with natrolite-andradite-allanite

This dike, essentially a coarse porphyritic nephelite syenite, extends for about a thousand feet across the road, forming a pronounced topographic ridge, as do many of the alkalic dikes of this region. This feature may reflect not so much the resistance to weathering of the dikes themselves, as induration - generally silicification - of the soft shale and sandstone of the Martinburg formation, which enclose the dikes.

\footnote{Rosenbusch, H., and Osann, A., Elemente der Gesteinslehre, pp. 505-506, Stuttgart, 1923.}
and protect them from erosion. Published literature on this dike includes a brief account by Wolff 2/ in the Franklin Furnace Folio; a study by Parker 3/, with reference to possible economic utilization of the rock as a source of feldspar; and, recently, an account by Milton and Davidson 4/ of the natrolite-andradite-allanite mineralization known only from this one locality.

Wilkerson 5/ refers to this dike as "tinguaite"; he mentions dark brown melanite as present.

A spectrographic analysis (30-12745) of the minor constituents of this rock is given in the discussion of the rocks to be seen at STOP 4/.

The dike is described by Wolff as consisting of phenocrysts of biotite corroded and replaced by aegirite; crystals of augite, red in the center and green on the periphery; and apatite and melanite in a background of orthoclase and nephelite. In some specimens studied by Milton and Davidson abundant cancrinite was found.

The melanite, a dark-brown garnet included by Dana and Ford 6/ as a variety of andradite (calcium-ferric iron garnet) is found here only as a constituent of the nephelite syenite. It thus differs from the andradite of the natrolite-andradite-allanite assemblage, which, furthermore, is green, not brown.

The natrolite, with its associated minerals, is found in loose masses, not over a few inches across, in a crumbly dark-colored gravel resulting from disintegration of the west end of the nephelite syenite dike.

Analyse of the natrolite and andradite are given by Milton and Davidson. 4/ The natrolite sometimes shows good crystal faces but more commonly is massive. At first glance it might be mistaken for quartz, which is only sparingly present. The andradite is well-crystallized, although in very small crystals requiring a hand lens for observation. The dodecahedron is the common form; rarely, by suppression of the whole zone of dodecahedral planes parallel to an axis of trigonal symmetry, a perfect rhombohedron results, a very unusual habit for garnet. The andradite is further remarkable in showing under crossed nicols marked anomalous birefringence in segments whose symmetry is

controlled by the external (dodecahedral) crystallographic development. There is an extensive literature on doubly refracting garnets; a good account is given by Rosenbusch and Mugge. 

Another occurrence of natrolite, without andradite or allanite, has been recently discovered near Hardistonville (STOP 7); however, the dike rock there is a lamprophyre, not a nephelite syenite.

Continue northeast on road towards Beemerville.

11.5
Take right fork.

11.9
Take right fork.

12.2
Left on hard road.

14.0
STOP 3. Ouachitite volcanic plugs.

One major volcanic plug (Rutan Hill, STOP 6), and three minor plugs have been mapped in the Franklin Furnace Folio. Actually, there are a few more. The smaller ones, of which we shall inspect the one on the west side of the road, have a relatively simple lithology, whereas Rutan Hill is extremely complex.

All of the volcanic plugs intrude Martinsburg shale and fragments of the shale are abundant in the igneous matrix (ouachitite). Fragments, often rounded, of quartzite and granite are also present, and pyrite is a common accessory.

Unlike the dikes of the region, which are believed to have flowed into fissures along structural lines of weakness (a relatively gentle process), with magma that chilled in situ, the volcanic plugs show features suggesting a violent explosive emplacement. Instead of magma entering a fissure concurrently with its formation, we may picture a building-up of highly localized gas pressure under a restraining sedimentary cover. Suddenly the cover yielded, with intense shattering, and the magma immediately engulfed the shattered fragments and solidified forthwith. Possibly there was a sequence of explosions, in progressively shallower depths, which would account for the inclusions of granite and other older rocks.

The name ouachitite is derived from the Ouachita Mountains in Arkansas, where there is an alnoite-like rock with no olivine and little or no melilitite; the New Jersey rock has conspicuous black biotite. The Arkansas ouachitite is characterized by low silica (36%) and high magnesia (11.5%); carbon dioxide is also high (4%). The relationships of these alnoite-like rocks are not too clear; it is likely, however, that the composition indicates ingestion of limestone or dolomite in the magma.

14.3
Continue north and turn left at Beemerville.

14.6
Turn right at cemetery.

15.4
Turn right.

---

Park cars at farm, walk up hill west to STOP 4. Nephelite syenite mass.

This is the famous Beemerville nephelite syenite, perhaps the largest body of such rock in the eastern United States. It shows several facies, all with abundant nephelite, but with textures varying from coarsely granular to fine-grained tinguaitie. The tinguaitie occurs as small dike-like bodies cutting the granular and porphyritic types of nephelite syenite.

The characteristic mineral of these rocks, nephelite, can be recognized by its "greasy" luster and its peculiar weathering. On a weathered surface of nephelite-bearing rock, there are rectangular or sometimes hexagonal depressions, usually of a whitish color. These mark where a nephelite crystal has weathered out, in whole or in part (Figure 5).

The most complete account of this nephelite syenite mass is given by Aurousseau and Washington 8/. The following material is quoted from their report: "The formal relationships of the mass are obscure. Both Emerson and Kemp regarded it as a sill, or an irregular, flat, laccolithic mass. Washington visited the locality in 1901 with Kemp and Brogger, and is in agreement with Wolff's opinion. It was examined by Aurousseau in the summer of 1921, with special regard to this point, but no evidence of a decisive nature is obtainable on the ground. As the mass has been studied by a number of competent geologists at intervals over a long period of time, it is improbable that any further evidence will be forthcoming, the outcrops being poor and the contacts obscured by thick soils and drift. In particular, no variations in dip are to be observed in the massive Shawangunk conglomerate which overlies the mass. To our minds the occurrence of the body (which can hardly be younger than early Tertiary and is probably much older) at the junction of the Shawangunk conglomerate and the Martinsburg shale, is critical, and, taken in conjunction with the fact that long, narrow intrusions of nephelite syenite and bostonite lie parallel to the bedding of the Martinsburg shale farther to the east, inclines us to the opinion that the Beemerville mass is a lenticular sill, or a flat laccolith."

Aurousseau and Washington give analyses of the nephelite syenite, nephelite porphyry, and the "leucite" tinguaitie, all of which are found in this mass. (The "leucite" tinguaitie occurs at the south end of the mass, about a mile distant from the STOP; it may be noted that the actual presence of leucite is questionable). The analyses follow:


Note--An unpublished masters' thesis by Edward Sheldon Davidson, "The Geological Relationship and Petrography of a Nephelite Syenite near Beemerville, Sussex County, New Jersey, Rutgers University, New Brunswick; New Jersey, 1948, gives considerable detail concerning this body, with a new map showing revised outlines.
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*Analyses 1 and 2 are supplemented by spectrographic analyses 50-1275S and 50-1276S., for trace elements, which follow.

**Analysis 4 is supplemented by spectrographic analysis 50-1277S, which follows.

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</tbody>
</table>

Not found in any sample: Mo, Pb, Zn, Ni, Au, Pt, W, Ge, Sn, Ag, As, Sb, Bi, Ca, Ti, In, Y, Th, B, Zn

50-1273S Fine-grained syenite dike, 1 mile NE. of Wykertown, N. J.
50-1274S nephelite syenite, 1 mile W. of Wykertown, N. J.
50-1275S nephelite syenite, Davidson locality No. 36, main intrusive, Beemerville, N. J.
50-1276S* nephelite syenite, Davidson locality No. 46, main intrusive, Beemerville, N. J.
50-1277S* nephelite syenite, Wilkerson localities Nos. 4, 5, 6, composite (sill), Sussex, N. J.

The (Ce,Y)\(_2\)O\(_3\) reported by Aurousseau and Washington from the main intrusive (analyses 1 and 2) should probably be amended in view of spectrographic data (analyses 50-1275S and 50-1276S). The rare earths that are present consist in part or wholly of lanthanum, with or without cerium—this element is not detectable spectrographically. Yttrium is certainly not present in detectable quantity.

It should be noted that the chemical analyses 1, 2, 3, and 4 were not made on the same samples as the spectrographic analyses.

Discussion of the analyses. As Aurousseau and Washington point out, the marked chemical similarity of the nephelite syenite, nephelite porphyry, and "leucite" tinguaitae implies that physical conditions of crystallization, rather than original magmatic composition, have caused their differences in appearance.

* These samples were kindly made available for spectrographic study by Dr. J. R. C. Martens, Bureau of Mineral Research, Rutgers University.
The high alkali content—from 13% to 17%—is about double that of most granite, and about four times that of basaltic rocks. Silica is low, much less than that of granitic or basaltic rocks. These imply a fluid, mobile magma. Although the fluorine content is not reported in the first three analyses, most thin sections will show some fluorite, as will many hand specimens.

The fourth analysis, of a smaller dike 3 miles or more east of the main mass, shows the relative constancy of composition of the nephelite syenite.

Wilkerson 2/ mentions that the nephelite syenite from Beemerville contains hackmanite, a variety of sodalite, present in many samples. It fluoresces orange.

18.1 Resume trip and
18.3 Turn right at barn.
18.5 STOP 5. Tinguaite dike.

This is a small dike of tinguaite cutting Martinsburg shale which can be seen only on the south side of the road. Fifteen years ago when the road was opened the exposure was conspicuous, but now it is barely visible. The shale in the vicinity of the dike is crumpled and broken. (If behind schedule, this stop may be omitted).

18.7 Turn left.
19.2 STOP 6. Rutan Hill, a complex volcanic plug.

Rutan Hill is by far the largest of the volcanic plugs of the Beemerville area, being about a quarter of a mile across, and rising some 250 feet above the road at its eastern edge (Figure 2). Much of it is covered with grassy soil, but rocks of various types are exposed in many places. The most common rock is ouachite breccia, as in the smaller plugs; but there is a remarkable variety of coarse syenitic rocks, bostonites, and porphyritic volcanics. One noteworthy rock, outwardly resembling a biotite syenite, has become largely replaced by calcite (description and analyses are given in following paragraphs). The north end of the plug is cut by one or more bostonite dikes.

Carbonate rock, east side of Rutan Hill. This rock crops out over an extent of several yards; no relations to other types on the hill were observable. In the hand specimen it appears to be an ordinary granular igneous rock, with calcite simulating feldspar, and conspicuous biotite flakes. Minute pyrite grains are the only other distinguishable mineral.

Microscopically, the following minerals are seen in the proportions indicated (calculated from the analysis):

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilmenite</td>
<td>4.7</td>
</tr>
<tr>
<td>Magnetite</td>
<td>8.2</td>
</tr>
<tr>
<td>Apatite</td>
<td>5.7</td>
</tr>
<tr>
<td>Pyrite</td>
<td>0.2</td>
</tr>
<tr>
<td>Calcite</td>
<td>48.3</td>
</tr>
<tr>
<td>Albite</td>
<td>10.5</td>
</tr>
<tr>
<td>Biotite</td>
<td>20.3</td>
</tr>
<tr>
<td></td>
<td>97.9</td>
</tr>
</tbody>
</table>

The calcite, which (from the chemical analysis) is very low in MgO, forms a granular mosaic of clear, homogeneous grains, in which the other constituents are embedded. All of these grains show a high degree of twinning, which is probably due to the pressure which existed when the rock was formed. The biotite is fairly fresh, and strongly pleochroic in yellow brown and dark brown. It also shows evidence of mechanical stress, the plates being much bent. It is much frayed and replaced by calcite, with deposition of ilmenite or magnetite peripherally, and development of a small quantity of greenish chlorite. Most of the metallic oxide grains are large and approach isometric forms; they are fissured, with calcite filling the cracks. The large and prominent apatites have similar fissures. In one specimen biotite fills the basal partings of the apatite. The albite is not conspicuous; it is apparently segregated into local areas. It is clear and fresh, and shows fine albite and possibly Carlsbad twinning.

Apparently all orthoclase, nephelite, and pyroxene that may have been present originally have been replaced by calcite and perhaps apatite.

A chemical analysis of this rock follows:

Carbonatite, Rutan Hill, Sussex County, New Jersey.
Charles Milton, analyst

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>14.87</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>6.28</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>5.68</td>
</tr>
<tr>
<td>TiO₂</td>
<td>2.44</td>
</tr>
<tr>
<td>FeO</td>
<td>8.14</td>
</tr>
<tr>
<td>CaO</td>
<td>29.78</td>
</tr>
<tr>
<td>MgO</td>
<td>3.53</td>
</tr>
<tr>
<td>MnO</td>
<td>0.25</td>
</tr>
<tr>
<td>Na₂O</td>
<td>2.40</td>
</tr>
<tr>
<td>K₂O</td>
<td>2.12</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>2.38</td>
</tr>
<tr>
<td>CO₂</td>
<td>21.28</td>
</tr>
<tr>
<td>H₂O⁻</td>
<td>0.07</td>
</tr>
<tr>
<td>H₂O /</td>
<td>1.03</td>
</tr>
<tr>
<td>F</td>
<td>0.20</td>
</tr>
<tr>
<td>Cl /</td>
<td>0.02</td>
</tr>
<tr>
<td>S</td>
<td>0.12</td>
</tr>
<tr>
<td>Oxygen</td>
<td>100.59</td>
</tr>
<tr>
<td></td>
<td>100.46</td>
</tr>
</tbody>
</table>
Leave Rutan Hill and continue north on macadam road to intersection with Route 23.

Turn left and continue through Colesville to

Picnic grounds in High Point State Park. -- Lunch. -- Reverse direction and continue south on Route 23 through Sussex and Hamburg.

Hamburg, N.J., quadrangle

Turn left at Hardistonville.

Take left fork.

Turn left.

Mrs. Marburg's house.

STOP 7. Limestone quarry; Franklin limestone with kugel minette dikes.

This is an excellent example of intelligent conservation; an abandoned limestone quarry has been landscaped into a most attractive setting for a summer home. The Franklin limestone is rich in minerals here, and specimens of chondrodite, graphite, pyrrhotite, diopsidic pyroxene, and scapolite can be found. Cutting the limestone are three lamprophyric dikes; the kugel minettes.

The contact with the limestone is sharp, and there is evidence of shearing in both minette and limestone at the contact.

In 1894 Kemp 10/ published a brief note concerning this dike. He believed that he had identified leucite in the spheroids characteristically present, basing this belief on a microchemical test for potash (fluosilicate), and on leucite twinning exhibited in one of his slides.

In summary he says:

"It would therefore seem to be quite certain that there actually is in Sussex County, New Jersey, a leucite dike rock, associated with the elaeolite syenite, and that the determination of a piece of the earlier described dike by Dr. E. Hussak, as leucite tephrite, although based on altered material and thought by the writer at the time to be premature, really is substantiated by the discovery of satisfactory fresh material. But it is also quite true that

similar spheroids formed entirely of feldspar have developed in the mica-diabase dike at Franklin Furnace, showing thus that instability of the leucite molecule, which has been elsewhere met."

Summarizing Kemp's discussion of these dike rocks we see that, though at first he was somewhat hesitant to adapt Russak's suggestion that the rocks contained leucite, even altered (pseudoleucite), finally in 1894 Kemp believed that leucite was definitely proven to be present. This, however, has never been substantiated. The "leucite" in all likelihood was analcite, which sometimes shows anomalous twinning; and nepheline has been observed in the spheroids which would yield a positive test for potash. Nevertheless, for a long time it was generally accepted that pseudoleucite rocks existed at Beamsville.

These rocks, occurring in dikes up to 20 feet wide, can be traced only short distances. This is due to their extraordinarily rapid weathering. Where exposed, the top of the dike is often broken into rounded, spalling masses a foot or more in diameter. In the course of a very few years the aspect of one of these dikes may change greatly by weathering; indeed, one kugel minette about 1-1/2 miles west of Hamburg, N. J., which is shown on the Franklin Furnace Folio map as several hundred feet long (ca. 1901), had, by 1928, possibly with some "help" from road-grading operations, been reduced by erosion to a visible exposure of only 6 feet. It was at that time exposed over blue limestone which contained cherty bands and quartz-lined vugs. By 1944, further grading had left only a few scattered cobbles to mark the site of the dike. On more recent visits, not a single trace of the dike has been found. This dike contained perovskite, a dark-purple calcium titanate, not noted elsewhere, and abundant sphene, calcium silicotitanate. Figure 16 shows strikingly the combined effects of weathering and human agency resulting in complete disappearance of this dike.

It is interesting to note that this vanished dike is in a line with a fine exposure (recently blasted) of the same rock a mile northwest, and another (not mapped in the Folio) 2-1/2 miles south-east, 1/2 mile northeast of Hardistonville. It is possible that all three are isolated remnants of a single original mass, following the extraordinary propensity of this rock to crumble into soil.

At this locality, fine specimens may be obtained of the kugel minette, as well as the kugeln, themselves, which can be found lying unaltered in the weathered debris of the dike (Figure 20).

Petrographic and chemical data on kugel minettes are given under the description of STOP 10, Buckwheat Pit.

Leave Mrs. Marburg's, and continue on dirt road to Route 23.

Turn left.

34.9 Turn left at Hardistonville.

35.35 STOP 8. Limestone quarry, with scapolite "gabbro" and kugel minette.
This abandoned limestone quarry (Figure 17) has two features of interest. The first, not easily accessible, is seen on the far (north) side of the pond. It is a kugel minette dike, highly weathered, and cut by small, white veinlets of natrolite. No andradite or allanite was noted here, however; and the lamprophyre is quite a different type of rock from the nephelinite aysite seen earlier (STOP 2).

Readily accessible, however, is a "dike" of scapolite "gabbro" ("geflleckter Gabbro" of German writers). In the quarrying operations, the limestone was removed around it, and it now projects a hundred feet or so out into the flooded quarry (Figure 17).

These scapolite "gabbros" are a common feature in the Franklin limestone. Their origin is not clear; the generally held opinion is that they are metamorphosed gabbros that have intruded the limestone. Rosenbusch and Osann 11/ describe a hypersthene-olivine gabbro in the Telemark area of Norway, associated with large masses of chlorapatite. At the contact of these with the gabbro, the latter changes to an aggregate of scapolite-amphibole, with some titanite and rutile. The scapolite sometimes contains unchanged labradorite, and the hornblende sometimes contains pyroxene. Extensive bodies of similar rocks are found in southeastern Canada but these rocks are not always associated with apatite; locally, however, they are associated with fluorapatite --not chlorapatite.

Turner and Verhoogen 12/ give a good account of the general process of scapolitization, of which this rock is an example, as follows:

"Appearance of scapolite in a metamorphic assemblage is possible when chlorine or carbon dioxide are participating components in the metamorphic system*. In some rocks scapolite takes the place of plagioclase, while in others the two minerals are associated. Sundius, in a detailed discussion of the occurrence and origin of scapolites in rocks of the Kiruna region of Sweden, points out that, while scapolitization is usually a metasomatic (pneumatolytic) process, lime scapolites may also develop in limestone during normal regional or contact metamorphism, the necessary volatile components (CO₂, H₂O, SO₃) being supplied in such cases by materials already present in these rocks. Pneumatolytic scapolites are generally of more sodic composition, and correspondingly richer in chlorine, than scapolites formed by normal metamorphism. They occur not only in calcareous rocks, where their presence implies addition of soda as well as of

chlorine, but also in a variety of silicate rocks such as amphibolite and metagabbros. Pneumatolytic origin of scapolite rocks may be clearly demonstrable when they occur associated with skaros in contact aureoles, but there are also instances of widespread metasomatic scapolitization, remote from igneous intrusions, to which the term "regional-pneumatolytic metasomatism" has been applied. Thus throughout much of the Kiruna region, development of scapolite in amphibolites and other feldspathic rocks is in no way related to proximity of outcrops of igneous intrusions but has nevertheless been shown by Sundius to be due to introduction of Cl and CO2 from magmatic gases or solutions, which have also supplied small amounts of such elements as phosphorus, sulfur, titanium, iron, and copper now present in associated apatite, sphenite, and sulfide minerals.

In the Kiruna region, as also in the Norwegian apatite veins, scapolitization is genetically connected with intrusion of basic magma (gabbro, norite, pyroxenite). Sometimes however, scapolite-bearing rocks occur in aureoles surrounding intrusions of acid composition, as in the case of the granite, soda granite, and nordmarkite intrusions of the Oslo district. Again the widespread presence of scapolite in metamorphosed gabbros in the northwestern Adirondacks is attributed by Buddington to the influence of chlorine-bearing emanations from intrusive bodies of granitic magma. Alternately, the general phenomenon of scapolitization of gabbroid rocks has been explained by some writers as a process of autometasomatism analogous to saussuritization."

Weiss 13/ has described a similar scapolite metagabbro from a crystalline marble in southeastern Pennsylvania.

Return to Route 23, and turn left.

Franklin Furnace, N. J., quadrangle

38.1 Turn right (i.e. west) at Sunoco Station adjoining east end of Franklin Pond.

38.7 STOP 9. Limestone quarry with arkosic (?) dike.

Like the scapolite rock just visited, we have here another siliceous rock isolated by quarrying operations in the crystalline Franklin limestone. However, it is a siliceous rock of altogether different sort, and it has been studied and discussed by many geologists in the past 50 years. In 1897 Wolff and Brooks 14/ described it at length, and referred it to the Hardiston quartzite of Cambrian age. Spencer, 15/ however, considered it more likely a siliceous member of the Franklin limestone. Milton 16/ suggested

15/ Spencer, A. C., oral communication.
that it was a granitic pegmatite, shattered and invaded by albitic magma; and his paper gives considerable descriptive data. Finger 17/ questioned the Hardiston quartzite interpretation; Buddington 18/ and Sims, 19/ however, consider this interpretation the most likely. Probably the consensus of present-day opinion would be that we have an arkosic sediment which has been invaded by "granitizing" magmatic solutions.

The occurrence includes three rock types: (1) A gray granitic rock, consisting essentially of rounded and irregularly shaped quartz, microcline, and microperthite grains in a groundmass of carbonate and turbid felsic material. The general appearance is that of an arkose, with a calcareous shaly cement. A noteworthy feature, seen under crossed nicols, is the secondary growth of the quartz in the matrix, in optical continuity with the quartz grains of the "arkose". (2) A dark stony rock, consisting essentially of quartz and albite-oligoclase, with much pyrite. (3) A breccia, composed of limestone and the granitic and stony rocks, with phlogopite, pyrite, fluorite and sphalerite. This rock as been described by Wolff and Brookes (loc. cit.) as a slaty sediment, which it certainly is not. Analyses of the granitic and stony rocks follows:

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>82.00</td>
<td>77.44</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>5.19</td>
<td>8.33</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>.13</td>
<td>1.22</td>
</tr>
<tr>
<td>FeO</td>
<td>trace</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2.05</td>
<td>1.50</td>
</tr>
<tr>
<td>CaO</td>
<td>2.19</td>
<td>1.52</td>
</tr>
<tr>
<td>Na₂O</td>
<td>.28</td>
<td>2.64</td>
</tr>
<tr>
<td>K₂O</td>
<td>3.56</td>
<td>1.58</td>
</tr>
<tr>
<td>H₂O</td>
<td>.05</td>
<td>1.07</td>
</tr>
<tr>
<td>H₂O²⁺</td>
<td>.6</td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>.16</td>
<td>.20</td>
</tr>
<tr>
<td>CO₂</td>
<td>3.25</td>
<td>.51</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>trace</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>.47</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>.43</td>
<td>2.05</td>
</tr>
<tr>
<td>Fe (as pyrite)</td>
<td>.40</td>
<td>1.36</td>
</tr>
<tr>
<td>Zn (as sphalerite)</td>
<td>trace</td>
<td></td>
</tr>
</tbody>
</table>

(0 correction for F) 100.80 99.62

---

17/ Finger, A.; written communication.
18/ Buddington, A. F., written communication.
19/ Sims, P., oral communication.
Mineralogical composition (computed from analyses)

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz</td>
<td>66.5</td>
<td>46.9</td>
</tr>
<tr>
<td>Microcline</td>
<td>18.6</td>
<td>8.9</td>
</tr>
<tr>
<td>Albite</td>
<td>2.6</td>
<td>32.5</td>
</tr>
<tr>
<td>Muscovite</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>Magnesian calcite</td>
<td>6.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Fluorite</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>Fyrite</td>
<td>1.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Rutilé (with sphene)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Chlorite</td>
<td>0.3</td>
<td>5.1</td>
</tr>
<tr>
<td>Sphalerite</td>
<td></td>
<td>trace</td>
</tr>
<tr>
<td></td>
<td>101.1</td>
<td>99.1</td>
</tr>
</tbody>
</table>

I. Gray coarse (granitoid) rock, Franklin Furnace, New Jersey.
II. Dark fine (stony) rock, Franklin Furnace, New Jersey.
   (Charles Milton, Analyst)

Turn north, following guide car, to

STOP 10. Buckwheat Pit, with great dike of kugel minette.

This is the famous open-cut workings at Franklin, where the ore occurred in a northward-plunging syncline whose diagrammatic representation by Spencer 20/ has been a feature of almost every textbook of economic geology. Cutting across the trough is the great dike; largest of the kugel minette dikes of Sussex County. Petrographically, it is in all essential respects like the other minettes of Sussex County, indeed, like kugel minettes from all over the world.

Kugel minettes are lamprophyric dike rocks, characterized by the presence of kugeln, which are small shotlike pellets, usually subspherical, but sometimes elongated, which are always sheathed by a tangential rim of biotite. This biotite rim is one feature that distinguishes the kugeln from ordinary cavity fillings (such as zeolites); another is the apparent similarity, if not identity, of the substance of the kugeln with that of the leucocratic groundmass of the minette. As will be shown, formation of the kugeln appears to have occurred just prior to the final consolidation of the rock. Whereas in ordinary zeolite cavity filling there is a hiatus between crystallization or consolidation of the rock and the subsequent hydrothermal filling of the cavity, in the kugel minettes this hiatus is believed not to have existed; the kugeln developed during the consolidation of the leucocratic fraction of the minette, and consist essentially of the same material.

The petrology of Franklin Furnace minette has been discussed by Iddings, 21/ its geological relations have been discussed by Wolff (in Spencer et al. 20/), and by Ries and Bowen 22/.

20/ Spencer, A. C., et al.; Description of Franklin Furnace quadrangle: U. S. Geol. Survey Folio 161, Fig. 11, p. 24, 1908.
The large dike in the Buckwheat Pit, which in the Franklin Furnace Folio is called a "camptonite," is exposed on both sides of the open cut and sends off numerous offshoots. It weathers into spheroids a foot or more in diameter, the interiors of which appear to be perfectly fresh. In parts of the dark-gray rock, pea-sized whitish pellets are prominent, and where the rock has weathered these have fallen out and may be picked up off the ground. Pellets such as these have been called kugeln (German, Kugel, little ball or sphere, pseudoleucites, and ocelli (Latin, ocellus, little eye). The contact of the dikes with the enclosing Franklin limestone is very sharp, especially for the smaller offshoots. Veinlets of a light-green rock up to 3 inches across cut the smaller dikes. These are evidently a differentiate from the minette magma, but show a much higher proportion of felsic minerals (normative quartz) than the kugeln, which show normative nephelinite with corundum (in analyses A, B, and H, in tabulation, Analyses of kugeln and related structures, and of pseudoleucites).

Wolff (in Spencer et al. 19) gives the following description and analysis of the dike rock:

"The great dike...is 20 feet wide... and can be traced for a long distance. Eighteen small parallel dikes were found near it in the limestone... These dikes belong to the Camptonite family and are of the same general character being dark greenish-black rocks in which the plates of biotite are conspicuous and which vary somewhat in coarseness of grain. Under the microscope the rocks are seen to be holo-crystalline, with large hexagonal plates of deep red biotite, which contains numerous inclusions of apatite and magnetite, prisms of pale red augite, some of which are green toward the periphery and bordered by aegirite, and large prismatic crystals of titanite. These colored minerals are contained in a background composed of irregular areas of albite and orthoclase, partly mixed with analcite. The same minerals in places form radial aggregates or spheroids some of which probably represent the secondary replacement of original leucite. The mineral composition by weight and analysis of the rock are as follows:

**Chemical analysis**

(L. G. Eakins, analyst)

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>40.71</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>19.46</td>
</tr>
<tr>
<td>Fe₂O₃</td>
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<td>FeO</td>
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<tr>
<td>CaO</td>
<td>6.21</td>
</tr>
<tr>
<td>MgO</td>
<td>11.83</td>
</tr>
<tr>
<td>Na₂O</td>
<td>1.80</td>
</tr>
<tr>
<td>K₂O</td>
<td>3.26</td>
</tr>
<tr>
<td>H₂O at 110°C</td>
<td>1.53</td>
</tr>
<tr>
<td>MnO</td>
<td>0.18</td>
</tr>
<tr>
<td>CO₂</td>
<td>0.74</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.01</strong></td>
</tr>
</tbody>
</table>

**Mineral composition**

- Albite: 23.5%
- Orthoclase: 12.5%
- Augite: 40.0%
- Titanite: 5.5%
- Apatite: 1.0%
- Biotite: 8.0%
- Magnetite: 9.5%

(End of material quoted from Wolff).

Iddings 21/ description of the rock follows:
"It is a minette ... that is, a more or less porphyritic holo-crystalline rock, poor in feldspar which is some variety of alkali feldspar, orthoclase or albite, or both, and rich in biotite and monoclinic pyroxene. It is a lamprophyre in Rosenbusch's sense. The rock is dark greyish green and dense, with a small hackly fracture. Abundant small micas are the only mineral constituent which is recognizable megascopically. There are besides occasional lumps of a white mineral that appears to be either feldspathic or zeolitic ... In thin section the rock is seen to be holo-crystalline, with hypidiomorphic granular texture. The ferro-magnesian minerals and iron oxide are idiomorphic with respect to the feldspar. Together they also predominate over the feldspar, which however is more abundant than any other one kind of mineral. Taken in order of their relative abundance, the constituents are feldspar, monoclinic pyroxene, mica, magnetite, epidote, calcite, apatite, pyrite; but this order of abundance varies with the degree of alteration, and in different parts of the rock. The feldspar may be part orthoclase, but some is undoubtedly albite. Minute flakes of epidote, calcite, and chlorite are scattered through the feldspar; also microscopic apatite. Pyroxene of varying abundance more or less altered to epidote and chlorite, is probably augite. Biotite occurs in abundant crystals, which are six-sided plates, comparatively thick. Alteration is in general slight as compared with the pyroxenes, the margins being somewhat chloritized. Sphene is abundant in large idiomorphic crystals. Magnetite and apatite, and abundant pyrite, are found, quite often well crystallized. Epidote, pleochroic in colorless and yellow is secondary. Analcite and also a little secondary quartz and calcite is present."

The analysis by Eakins cited above has been supplemented by one on another specimen of the same rock, here given.

Analysis of kugel minette, Franklin Furnace, New Jersey.
(C. Milton, Analyst)

| SiO₂  | 40.62 |
| Al₂O₃ | 14.16 |
| Fe₂O₃ | 7.06  |
| FeO   | 6.16  |
| MgO   | 5.59  |
| CaO   | 10.19 |
| Na₂O  | 3.67  |
| K₂O   | 3.05  |
| H₂O⁻  | 2.75  |
| H₂O⁺  | 0.00  |
| CO₂   | 0.51  |
| TiO₂  | 4.80  |
| P₂O₅  | 1.04  |
| S     | 0.03  |
| NₐO   | 0.17  |
| BaO   | 0.12  |
| ZrO   | 0.04  |
| Fe    | 0.10  |
| Oxygen| 100.36 |

In the C.I.P.W. classification this gives a norm III 6,2,4, with normative minerals:

Orthoclase 16.7
Albite 6.8
Anorthite 13.3
Nepheline 13.1
Forsterite 2.8
Diopside 23.2
Ilmenite 9.1
Apatite, pyrite, calcite 3.1
Magnetite 5.3
Hematite 3.2
Water 2.8

Total 100.26
Iddings' otherwise detailed description does not mention the kugeln save in his passing reference to "occasional lumps of a white mineral that appears to be either feldspathic or zeolitic." Wolff refers very briefly to "replacement of original leucite,", Kemp, in the papers above cited, was much impressed by these kugeln, and after some doubts, considered them to be replacements of leucite (\(\text{\(:)\}}\) pseudo-leucite.

Composition and structure of kugeln. The characters of the kugeln from New Jersey as determined by the writer, are as follows: The Kugeln are in general spheroidal, of small size, seldom exceeding a few millimeters in diameter; they are sharply differentiated from the surrounding rock, being alkalic instead of ferromagnesian, and therefore light-colored in contrast with their dark matrix; invariably they have a hull or sheath of plates of biotite arranged tangentially. Of the component minerals, albite predominates, followed by zoisite, calcite, and analcide. Orthoclase is rarely present; when it is, it is largely altered to a sericitic mica. Sphene is a common but minor constituent; biotite and the other mafic minerals are as a rule absent from the kugeln.

The term kugeln appears to be the most suitable to these pellets. Pseudoleucites are of a quite different nature, being pseudomorphs after leucite. Oceli, as described by Knopf, \(23/\) appear to be feldspathic crystallizations having a radial structure, and lacking the biotite rim of typical kugeln; however, they may have an origin similar to that of kugeln. A distinction must also be made between kugeln and the variolitic structure as described Pirsson, \(24/\) and seemingly equivalent "feldspar spherulites" as defined by Rosenbusch and Osann \(25/\). Lastly, critical differences exist between kugeln and ordinary amygdaloidal fillings.

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Analyses of kugeln and related structures, and of pseudoleucites.

A. Kugeln from minette, Franklin Furnace, New Jersey. C. Milton, analyst. (composite of 18 kugeln, loose on the ground. Some biotite coating, but no minette matrix).

B. Kugeln; one mile west of Hamburg, N. J., L. M. Dennis, analyst. 26/

C. Kugeln; Weiler bei Weissenburg, Alsace, France. E. Linck, analyst. 27/

D. Kugeln; Serra de Tingua, Brazil. E. Hussak, analyst. 28/

E. Kugeln; Sta. Cruz, Brazil. E. Hussak, analyst. 28/


G. Groundmass of minette, Servance, Vosges Mts., France. M. Delesse, analyst. 28/


I. Pseudoleucite, Spotted Fawn Creek, Yukon Territory, Canada. C. W. Knight, analyst. 30/

J. Pseudoleucite, Magnet Cove, Arkansas. J. F. Williams, analyst. 30/

K. Pseudoleucite, Mt. Vesuvius, Italy. Rammelsberg, analyst. 30/

Cited in C. W. Knight, above.

L. Pseudoleucite, Highwood Mountains, Montana. F. A. Gonyer, analyst. 31/

26/ Kemp, J. E., A basic dike near Hamburg, Sussex County, New Jersey, which had been thought to contain leucite: Am. Jour. Sci., vol. 45, No. 268, pp. 298-305, 1893.


Discussion of analyses of kugeln, etc.

The obvious imperfections of some of the older analyses of kugeln here cited make comparisons of doubtful value. There is also a question of whether the analyses were made on kugeln with or without the closely adhering biotitic hull. Analyses A and B of kugeln from two of the New Jersey localities, by two analysts, are in fair agreement; and together with analysis E, from Brazil, those may be considered the best analyses of kugeln available. Norms computed from these three analyses show nephelite and, in A and B, a little corundum. Analyses F and G appear to support Delease's statement of the similarity in composition between the groundmass of the minette and the materials of the kugeln; however, these analyses cannot be classed as good. Analysis H, of the greenish veinlets cutting the minette, shows normative quartz, thus contrasting with the analyses of the kugeln. In fact, the veinlets actually contain some quartz, with oligoclase, and much zoisite; accompanied by lesser amounts of altered titanite, pyrite, and serpentine. This difference in composition indicates that the veinlets were formed quite late in the magmatic history of the minette; distinctly later than the kugeln, which are similar in composition to the groundmass minerals of the minette. The four analyses of pseudoleucite cited agree well among themselves; they all show excess of potash over soda, absence of carbon dioxide, low lime and magnesia, and low iron oxide; whereby they differentiated from the kugeln. A norm computed for one of the pseudoleucites (analysis K) shows predominant orthoclase which exceeds combined albite and nephelite; whereas in analyses A, B, and E the reverse is true. Such consistent differences in composition between the kugeln and the pseudoleucites indicates a different mode of origin.

Theories of origin of kugel structure. The extensive literature on kugel minettes shows a wide diversity of views as to the nature and origin of the kugeln. These diverse views may be summarized as follows:

Pseudomorphism after leucite (Derby, 32/ Russak, 33/ Kemp, 26/ Wolff, 2/ Sharma, 34/)
Pseudomorphism after garnet (Eigel, 35/)
Pseudomorphism after olivine (Ghose, 36/)
Replacement of glassy amygdules (Rosenbusch, 38/)
Residual "drops" of magma (Flett, 39/)
Immiscible liquid drops (Rinne, 40/)
Filling of amygdaloidal cavities (Linck, 26/ Teall, 41/ Harker, 42/ William, 43/ Rosenbusch and Osann, 1/ Knopf, 44/ and Cannon, 45/)

There are objections to all of these views, and in the opinion of the writer, none of them, in whole or part, are applicable in explaining the kugeln.

The alteration of leucite to pseudoleucite is well known and has been described by numerous writers, among the more recent, Bowen and Ellestad, 46/
and Larsen and Buie.  

It appears from a reading of these papers, however, that the pseudoleucite of these writers is not the same as the kugeln of the minette. The biotite rim is not mentioned in either paper, and leucite either persists or had certainly been present. There can be no question that the pseudoleucite these authors describe results from a more or less complete replacement of a pre-existing crystal, that is, leucite. It is questioned, however, whether their explanation could be extended to the kugeln of the minettes, in which no leucite has been demonstrated. Furthermore, as mentioned


34/ Sharma


41/ Harker, A., Lamprophyre dykes in Long Sleddale, Westmoreland: Naturalist, pp. 266-267, 1912.


by Cannon, 45/ structures having the essential features of kugeln are found in rocks other than minettes, such as diabase, where leucite was unquestionably absent.

Pseudomorphism after garnet, mentioned by Eigl, need not be considered. Replacement of glassy amygdules, as suggested by Rosenbuach, and Rinne's immiscible liquid theory, are both inherently improbably since immiscible liquids are very unlikely to occur in magmatic systems. The filling of amygdaloidal cavities, as proposed by the numerous authors cited above, is open to less obvious objection. Even so, there are difficulties to be considered.

The filling of amygdules is, as a rule, of a different mineral composition from the groundmass of the rock. Quartz, chlorite, calcite, and zeolites are the commonest minerals in amygdules; these minerals are commonly not present in any large proportion in the host rock. Presumably the cooling magma, with its crystallization or solidification nearly complete, disengages gas bubbles, mostly steam; in these openings, a residual mobile fluid percolating through the rock deposits the crystalline fillings of the amygdaloidal cavities.

In the kugeln, however, there is no such marked distinction between the material of the kugeln and the groundmass of the rock. It would seem that a very minor hiatus, at most, existed between the crystallization of the minette groundmass and the formation and filling of the kugeln. At high temperatures and pressures, the alkali-aluminum silicates and carbonates may be considered as dissolved in water-vapor, carbon dioxide, and similar low boiling components, the whole being a single phase. On cooling, with reduced pressure, in this fluid phase (in which such minerals as biotite and augite have already crystallized), a gas phase forms at discrete points forming spheroidal bubbles, which as they grow, force aside the biotite plates; which become "plastered" tangentially. Simultaneously, the silicate-carbonate components of the fluid, no longer held in solution by the gaseous components, crystallize.

A similar mechanism is suggested for ocelli, variolites, and similar leucocratic spheroidal masses, found in diabases, etc., where the biotite rim feature is absent.

This is a radically different process from zeolitic cavity filling, in which deposition occurs from hydrothermal solutions in pre-existing cavities.

It may be asked: can such a fluid exist, which at one set of pressure-temperature conditions behaves as a concentrated solution, and then at not too remotely lowered pressures and temperature breaks up into a gas phase and crystalline material (feldspar, calcite, analcite, etc.)? On this point, Morey and Ingerson 46/ may be cited; after pointing out that magmas as such do not exhibit critical phenomena, they observe, "The emanations, however, considered as a separate system, are probably in the supercritical state when they leave the magma, although the original system (magma and vapor) has at no time exhibited critical phenomena. This fact may be of considerable geological importance, since these highly compressed gases (mostly water) can serve as solvents of non-volatile matter..."
If an emanation leaving the magma can exist in a super-critical state—that is, at such high pressure and temperature that there can be no separate gas and liquid phase—then certainly such conditions will exist before the emanation has physically been separated from the magma; namely, when the emanation is in statu nascendi, a condition which can hardly be conceived except at discrete points in the magma.

The kugeln, then may be interpreted as emanations that never succeeded in leaving their places of origin; without outward movement, the emanations passed through a critical point at which a homogeneous phase, by lowering of pressure and temperature, could (incongruently) assume a gaseous phase, with simultaneous formation of a crystalline phase from the residual material of the previous homogeneous phase.

Pecora and Fisher 47/ have described drusy vugs in a monzonite dike in Montana, which are believed to have formed at least 3,000 feet and possibly 7,000 feet beneath the surface of the earth—that is, under pressures exceeding the critical pressure of water vapor. Their explanation of the formation of the drusy vugs agrees with that suggested for the kugeln in some respects; both theories postulate a gas phase that appeared as crystallization was proceeding with entrainment of gas globules by the rapid consolidation of rock. Pecora and Fisher, however, argue against "condensation of the gaseous fluid in the original rock-walled cavities with concurrent precipitation of dissolved materials". They believe that the vug minerals were deposited by hydrothermal solutions that entered the cavities formed by the (liquified) gas, carrying a constant supply of material dissolved from the adjacent rock. The difference in mineralogical and chemical composition of the monzonite and the minerals forming the contents of the vugs lends weight to their interpretation.

In the kugel minettes, however, there appears to be no such difference; and the gas phase which shaped the kugeln is believed to have been the solvent of the material now forming the kugeln.

Mileage  
39.3 Leave the Buckwheat pit, turn left.
39.35 Turn left.
40.35 Turn right on Route 23; stop sign.
40.60 Take right fork.
42.5 Ogdensburg.

Newton East, N J., quadrangle

46.7 Sparta; turn right on Route 6A.
47.2 At road fork, keep left.
50.0 Turn right; STOP 11. Triassic diabase.
50.1 Leave cars at cornfield, proceed to ridge on east.

This is one of the four dike rocks mapped on the areal geology sheet, of the Franklin Furnace Folio which has been included with the alkalic and lamprophyric dike rocks until shown by Milton 49/ to be diabase, in all probability the westernmost extension of the Triassic igneous rocks of northern New Jersey. The diabase intrudes pegmatitic and quartzitic schists.

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I Average of 28 analyses of tholeitic lavas of Kilauea and Mauna Loa, Hawaii. Tilley, C. E. 48/

II Average of 8 analyses of New Jersey Triassic basalts (H. S. Washington, 1922) (Tilley, C. E. loc. cit.)

III Average of 4 analyses of Sussex County, New Jersey, Triassic diabase. Milton, Charles. 49/

The New Jersey Triassic basalts and associated diabases are tholeitic in character; olivine is rather rare and restricted to certain horizons, for example, the famous "olivine-ledge" in the diabase sill at Weehawken, New Jersey. (Tholeite is one of the two great types of basaltic lava, as distinguished by W. L. Kennedy 50/ consisting essentially of labradorite and monocline pyroxenes, with minor iron ores and little or no olivine, pigeonitic pyroxenes and acid residuum, indicative of late magmatic hydrothermal solutions are common). Tholeite magma, according to Kennedy,


characterizes continental terranes exclusively; olivine basalt magma, on the other hand, occurs both in the continents and the oceanic basins. The implication is that olivine basalt magma represents, in general, the deeper underlying stratum of the earth's crust, whereas tholeiitic magma represents such magma "contaminated" by sialic layer of the crust. From fractional crystallization of such tholeiitic magma, it has been held that granite may arise. There is much to support this view, which to some degree reconciles presently-held controversial views concerning "granitization".

Return to Sparta-Newton road, and turn right to Newton.
Figure 1. Map showing location of Franklin Furnace quadrangle, and distribution of the three major suites of igneous rocks.

Figure 2. Rutan Hill, a complex volcanic plug. Viewed from north.

Figure 3. Photomicrograph x 10.
Basaltite, Branchville, N. J. Shows feldspathic groundmass with much chloritized mafic debris. The large round mass (lower left) is mostly feldspar with calcite; the smaller mass (upper right) is calcite. Note the different appearance of the basaltite from Rutan Hill (Figs. 9 and 10).

Figure 4. Photomicrograph x 10.
Nephelite syenite, near Wyckoff, N. J. The clear areas are orthoclase, the turbid rectangular crystals (at left, etc.) are nephelite. The black areas are brown andradite; near the center is biotite; and large crystals of sphene are to the left and below the biotite. Anhydrite-sugilit and apatite are also present.
Figure 5. Nephelite tingulate porphyry, Beemerville, N. J. Hand specimen x 1. Note shallow cavities caused by weathering of nephelite crystals.

Figure 6. Photomicrograph x 5.
Nephelite tingulate porphyry, Beemerville, N. J. Note hexagonal (basal) and rectangular (prismatic) cross sections of nephelite, also smaller prismatic grains of augite-augite (darker gray). The groundmass, crowded with aegirine crystallites in a feldspathic matrix, is characteristic of tingualites.

Figure 7. Bostonite porphyry, Rutan Hill. Hand specimen x 1. Note orthoclase laths in stony groundmass.

Figure 8. Bostonite porphyry, Rutan Hill. Photomicrograph x 5. Note euhedral orthoclase in turbid groundmass; also mafic relics.

Figure 9. Carbonitized syenite, Rutan Hill. x 1.

Figure 10. Carbonitized syenite, Rutan Hill. Photomicrograph x 10. The brown biotite (basal hexagonal sections black, prismatic with basal cleavage light gray) shows little or no alteration. Almost all of the remaining area is calcite.
Figure 11. Quachitite volcanic breccia
Rutan Hill. Hand specimen, x \(\frac{1}{2}\).
Note the numerous inclusions of Martinsburg shale; the lower center bright area is a fragment of felspathic rock like that shown in Fig. 12. The bright specks are mostly pyrite.

Figure 12. Feldspatic syenite
Rutan Hill. Hand specimen x \(\frac{1}{2}\).

Figure 13. Composite volcanic rock, Rutan Hill. Hand specimen x \(\frac{1}{2}\). Shows abrupt variation in lithology.

Figure 14. Coarsely porphyritic syenite,
Rutan Hill. Hand specimen, x \(\frac{1}{2}\).

Figure 15. Photomicrograph x 5.
Scapolite ("gefleckt") gabbro, Ruttstonville, N. J.
Shows characteristic texture of this rock, an aggregate of scapolite-hornblende-oligoclase andesine-apatite-sphene-calcite. All of these are lume minerals. Some iron-titanium oxide is also present.
Figure 16. This shows dramatically geomorphic changes by human agency. At this site 60 years ago there was a dike of kugel minette, several hundred feet long, which was mapped on the Franklin Furnace geologic folio map. During the last thirty years the writer has observed its progressive obliteration; the last of it disappeared five years ago. 1½ miles west of Hasburg, N. J.

Figure 17. Flooded abandoned quarry in Franklin limestone, Hardistown, N. J. At the left is a dike-like mass of scapolite gabbro, isolated during the quarrying operations. Across the pond with white limestone above and below is a dike of kugel minette.

Figure 18. Kugel minette, Buckwheat Pit, Franklin, N. J. Polished slab, × ½; this shows numerous kugeln; note the complete absence of crystallographic symmetry, such as might characterize “pseudo-leucite.”

Figure 19. Kugel minette, near Hardistown, N. J. (Mrs. Marburg's). This specimen has weathered somewhat, and the kugeln have dropped out of the exposed areas, leaving smooth biotite-lined cavities. × ½.

Figure 20. Kugeln from weathered minette, picked off ground. Near Hardistown, N. J. (Mrs. Marburg's). Where broken, the kugeln show the contrasting white interior and darker biotite coat.

Figure 21. Kugel minette, Jharia Coalfield, India. Photomicrograph × 3. This rock, as is true of kugel-minettes from all over the world, is hardly distinguishable in all essential features from the New Jersey rocks. Note the sharply defined kugeln with the constant tangential biotite rim.
FIELD TRIP B.

SILURIAN & DEVONIAN STRATIGRAPHY

Leader: Henry Herpers

Saturday, May 31, 1952, 8:30 a.m.

NOTE: We will travel over narrow roads with sharp turns and steep hills, the region is sparsely settled, therefore:
1. Double-up wherever you can, in order to keep the number of cars to a minimum.
2. Be sure your brakes are in good working order.
3. There are no places to stop for gas, water or lunch. Be sure to be provided with these items in advance.

ITINERARY

Since Field Trips A & B start at the same time and place and proceed for the first few miles over the same route, our field party will assemble at a point 2.8 miles north of Newton on Route S31. Starting point for mileage is the Cochran House.

Mileage

0.0  Cochran House, Newton. Go west to traffic signal. Right turn on Route S31 and proceed north, following road signs to Culvers Lake and Branchville.

2.8  Assembly Point. R.R. crossing. Just north of the R.R. crossing is a recessional moraine. The morainic surface is especially well-developed west of the highway. It is "banked" against shale hill east of highway.

4.9  Left turn at Ross' Corner.

6.9  Bear left onto divided highway.

7.9  Good exposure of Ordovician Martinsburg slate on left.

9.6  Culvers Lake.

10.6  Culvers Gap. Shawangunk conglomerate, basal Silurian formation forms Kittatinny Mountain, in which gap is cut. Boulders of the formation may be seen to left in woods.
11.7 Entering Stokes State Forest.

15.9 Bear left to Hainesville.

16.0 Note large glacial erratic to right of road. The boulder is of Esopus shale.

16.3 STOP 1. Cole Farm. Poxono Island shale. Lower part of Cayugan Series. Named by I. C. White in 1882 from exposures on right bank of Delaware River opposite Poxono Island about 9 miles above the Delaware Water Gap. Apparently transitional with underlying Bloomsburg red beds and definitely transitional with overlying Bossardville limestone. Thickness in New Jersey unknown. White reported its thickness as 200 feet at the type section. So far the formation has proved unfossiliferous in New Jersey, but ostracods have been found in it in Schuylkill County, Pennsylvania. Correlated with Poxono Island shale of Penna., and lower Tonoloway limestone of Maryland. Apparently pinches out to Northeast and may be a deeper water facies of Binnwater sandstone of New York. In New Jersey typically a greenish shale which weathers buff. Often highly mineralized with calcite. Often contains sandy beds. The formation is not resistant to erosion and therefore exposures are rare. This pit is typical of the formation in New Jersey.

16.7 Left turn.

17.9 Left turn.

17.6 STOP 2. Winters Farm. Coeymans limestone and New Scotland formation. Formerly known as Lower Pentamerus limestone and Delthyris shaly limestone respectively, because of characteristic fossils, Pentamerus galeatus (= Gypidula coeymanensis) and Delthyris perlamellosa. Present names given by Clarke & Schuchert in 1899. Coeymans limestone considered to be basal Devonian formation. Transitional with underlying Manlius limestone. Contact with overlying New Scotland shale has not been observed in N. J., but is probably somewhat transitional. Formation is typically a grey crystalline limestone, generally characterised by Gypidula coeymanensis. In northern part of county a lower "coralline layer" may be distinguished and in southern part, an upper arenaceous member, the Stormville sandstone of authors, is present. Although no full section of the Coeymans limestone is available, a zone characterised by the coral Coenites multiseriata and a cherty limestone zone have been noted in its upper part. Gypidula coeymanensis generally rare in upper zones. Thickness, approximately 40 feet. Correlated with formation of same name in New York and Pennsylvania and with lower part of Haldenber group of central Penna. and Md. Fauna in N.J. totals 47 species. At this exposure we will see Gypidula coeymanensis zone.

The New Scotland is, in general, two-fold in character. The lower portion is a somewhat cherty limestone and the upper portion is a shale. The formation is thruout quite fossiliferous, being especially characterized by Delthyris perlamellosa. The fauna totals 44 species. Thickness in New Jersey is approximately 160 feet. Overlain by Becraft 1s. Correlated with formations of same name in N. Y. & Penna. and with
upper Helderberg group of central Penna. and Md. Lower cherty ls. member may be correlate of Kalkberg limestone of New York State. At this stop we will see the upper shaly member of the formation. Fossils are abundant, especially Delthyris perlamellosa, Leptaena rhomboidealis and Odontochile micrurus.

18.6 Crossing recessional moraine. Note topography.
18.8 Bear left.
19.5 Right turn.
20.5 STOP 3. Roadside exposure of Onondaga limestone. Onondaga limestone in New Jersey is divisible into two members. The lower member (Onondaga ls. of earlier authors) is a grey, fine-grained fossiliferous ls. containing little or no chert. The upper member (Corniferous ls. of earlier authors) is a somewhat darker grey cherty ls. and is the equivalent of the Buttermilk Falls ls. of northeastern Penna. The formation is transitional with the underlying Esopus shale and is overlain by the Marcellus shale. Thickness in New Jersey is unknown, but Shimer estimated its thickness near Port Jervis as 235 feet. Fauna consists of 16 species, none of which actually characterise the formation, but all of which are found in the Onondaga of New York State. Correlated with the Onondaga limestone of New York and with the Buttermilk Falls limestone of northeastern Pennsylvania. In New Jersey the Onondaga limestone and Esopus shale are considered to form the Onondaga group. At this stop we will see a typical exposure of the lower, chert-free member.

20.9 STOP 4. Typical exposure of upper or cherty Onondaga limestone.
21.1 Left turn.
21.3 Left turn.
22.2 Ledges of Esopus shale in fields to left.
22.4 STOP 5. Oriskany formation and Esopus shale. The Esopus shale, the lower member of the Onondaga group, was formerly known as the Gauja-galli grit. It is typically a dark-grey siltstone, and is characterised by an intense cleavage which often obscures the bedding. The formation is underlain conformably by the Oriskany formation and passes transitionally into the overlying Onondaga limestone. The upper part of the Esopus formation is often somewhat massive, often slightly calcareous, and does not possess the striking cleavage of the lower portion. The formation also includes local beds of limey sandstone. The Esopus is approximately 360 feet thick in New Jersey. It is the correlate of the Esopus of New York and of northeastern Pennsylvania and is generally sparingly fossiliferous. The most common fossils are Taonurus caudagalli, Leptosia acutiplicata and L. flabellita. The fauna of the formation consists of 11 species, most of which were found in one of the limey sandstone beds. At this locality we will see the lower shaly portion of the formation.
Mileage

The Oriskany formation in northwestern Sussex County is largely a limestone, but becomes arenaceous to the southwest. Weller divided the formation into three faunal zones; the lower being characterised by "Dalmanites" dentatus (= Coryccephalus dentatus), the middle by Orbiculoidea jervensis, and the upper by "Spirifer" murchisoni (= Acrospirifer murchisoni). The formation is underlain by the Port Ewen shale and is overlain by the Esopus shale. It is approximately 170 feet thick in New Jersey. It is correlated with the Oriskany formation of N. Y. and northeastern Pennsylvania. At this stop we have the siliceous limestone beds of the Acrospirifer murchisoni zone, and this fossil and many others have been found here. An ostracod fauna of 32 species has been collected from the exposure by Earnest H. Horton, while a student at Rutgers University. The fauna of the Oriskany formation as a whole consists of 96 species.

22.8 Right turn.
23.1 Right turn.
24.5 Right turn.
25.2 Right turn.

25.9 STOP 6. Bevans Rock Shelter. Contact between Oriskany formation and Esopus shale. The overhanging rock was once used by the aborigines as a shelter. Archeological excavations have uncovered many artifacts. Again, this is the Acrospirifer murchisoni zone of the Oriskany.

26.8 STOP 7. Cherty Onondaga limestone. Fossiliferous. The following fossils were found here by your leader recently: Coelosipora dichotoma, Leptocelia flagellites, Eodevonaria arcuata, Protoleptostrophia perplana and Schuchertella variabilis.

29.5 Left turn. Steep hill.

30.7 Tillmans Ravine in Stokes State Forest. Lunch Stop. Good exposures of Bloomsburg red beds in ravine. The Bloomsburg red beds had been thought to be unfossiliferous in New Jersey, but fish remains were discovered in the formation near Delaware Water Gap in 1950 by two undergraduate students at Lehigh University. The fossils appear to be representatives of the genus Paleaspis. Specimens of the fish remains are now under study at the Chicago Natural History Museum.

31.8 Left turn. Wallpack Center. Note how valley narrows to southwest.

32.5 STOP 8. Bossardville, Decker, Rondout and Manlius limestones. The Bossardville limestone overlies the Poxono Island shale. It was named by I. C. White in 1882 from exposures near the village of the same name in Monroe County, Pennsylvania. Formerly called the "Ribbon limestone" because of the thin ribbon-like bedding. Passes transitonally into the
underlying Foxono Island shale and is overlain conformably by the Decker limestone. In New Jersey its average thickness is at least 50 feet. Here, 60 to 70 feet of beds referable to the formation are present. The formation is sparingly fossiliferous, only Leperditia sp. having been noted in it in New Jersey. The Rossardville is overlain by the Decker limestone, originally named Decker's Ferry limestone by White in 1882. This formation is abundantly fossiliferous, three faunal zones having been discerned by Weller. The lowest zone is characterised by Chonetes jerseyensis, the middle by Ptilodictya frondosa, and the upper by Stenochisma lamellata.

The Chonetes jerseyensis and Stenochisma lamellata zones are widespread, being found in the Keyser limestone of West Virginia, Maryland and Pennsylvania. In New Jersey the fauna of the Decker consists of 62 species and is marine. The Decker is succeeded by the Rondout limestone into which it passes transitionally. The Rondout, formerly known as the Waterline formation, was given its name by Clarke and Schuchert in 1899 from exposures in the cement quarries at Rondout, New York. It is a dense, fine-grained limestone containing few fossils other than several species of Leperditia and other ostracods, although a few species of brachiopods are known. Two beds composed almost entirely of ostracod remains are included in the formation. The Rondout is approximately 35 feet thick. It was apparently not deposited under typical marine conditions. The entire fauna consists of 16 species. The Rondout grades into the overlying Manlius limestone. The Manlius, formerly called the Tentaculite limestone from the abundance of the pteropod Tentaculites gyracanthus in it, was renamed Manlius by Clarke and Schuchert in 1899. The formation is overlain by the Coeymans limestone into which it grades transitionally. The Manlius is a grey, fine-grained, "knotty" limestone. In New Jersey its thickness is approximately 35 feet. It contains a marine fauna of 31 species. Although the formation is characterised by Tentaculites gyracanthus in New York, this species is not common in the Manlius of New Jersey; but Howellella vanuxemi is fairly common in some beds. Formerly the Manlius was extensively quarried and burned as a source of lime.

The Decker, Rondout, and Manlius limestones constitute a unit formed during a cycle of deposition starting with marine conditions (Decker limestone), changing to non-marine (Rondout), and finally ending with a return of marine conditions in Manlius and Coeymans time. The three formations preserve their distinctive characteristics into New York and northeastern Pennsylvania but lose them southwest of Stroudsburg. Their place in the stratigraphic column is occupied by the Keyser limestone of central Pennsylvania and Maryland. Within the Keyser, Chonetes jerseyensis, Leperditia gigantea and Howellella vanuxemi form definite zones.

Here we will see excellent exposures of all these formations.

33.1 STOP 9. Port Ewen shale, Oriskany formation and Esopus shale. The Port Ewen shale, originally named the Kingston beds by Clarke and Schuchert in 1899, was subsequently renamed by them because the name Kingston was
Mileage

preoccupied. Its type locality is in Ulster County, New York. The formation was not described by Wellen, who was unable to find any exposures of it, although he did state that it was present in New Jersey. It is underlain by the Becraft limestone, and is overlain by the Oriskany formation. It has an estimated thickness of 30 feet. The formation is fossiliferous and in this region is characterised by the presence of two species of Chonetes of small size, Chonetes aroostockensis and an undescribed species. To date, 13 species have been found in the formation in New Jersey. This exposure is the best we have found so far in the state. Intense cleavage makes fossil hunting difficult. Nearby is an exposure of the more or less arenaceous phase of the Oriskany formation containing Acrosibirifer murchisoni, and a good exposure of the Escopus, showing some of the massive beds.

36.3 STOP 10. Onondaga limestone. An exposure in the lower part of the formation. Goldringia aemula, a species characteristic of the Schoharie grit of New York has been found here. These beds may be the time correlatives of the Schoharie.

40.0 STOP 11. Esopus shale. Good exposure of typical Esopus shale. Taonurus caudagalli excellently shown.

40.4 STOP 12. Coeymans limestone. A good exposure of the upper part of the Coeymans limestone proper. Here a cherty crinoidal limestone, The Gyroidula coeymanensis zone is also exposed.

41.2 STOP 13. Rondout limestone. A good exposure of the formation. Laereditia sp. has been found here. In the bank above can be seen the Manlius limestone. Note cemented beds of glacial gravels.

44.0 STOP 14. New Scotland formation. A good exposure of the limey shale. Fossiliferous.

44.4 STOP 15. Haney's Mill. Interesting exposures of Bossardville, Decker, Rondout, Manlius and Stormville member of Coeymans limestones will be seen here.

47.9 Right turn.

48.9 Left turn.

52.8 Right turn onto Route S31.

64.6 Cochran House, Newton.
References


Cook, George H., (1863), The Geology of New Jersey, Newark


TRIP A
CAMBRO-ORDOVICIAN and PRE-CAMBRIAN ROCKS
Leader: Meredith E. Johnson

ITINERARY FOR SUNDAY MORNING, JUNE 1.

Mileage

0.0 Cochran House, Newton. (Cars will assemble on Spring and High Streets, prepared to travel west.)

0.1 Left on High Street (Route 8)

0.4 Left on West End Avenue (sign reads "Windy Brow Farm").

1.0 STOP 1. Abandoned slate quarry. Opened in 1845, it reached a depth of more than 150 feet 1/ As can be observed, the slate produced was hard and gray, and there was much waste of rock because of the presence of sandy "ribbons", considered undesirable in roofing slate although the writer has seen such slate in good condition on roofs more than 100 years old. Tests have shown that the slate has a density of 2.776, a porosity (24 hours) of only 0.177%, and is highly resistant to corrosion. Study of thin sections has shown that it consists of a "medium to fine-grained, thoroughly crystalline aggregate of muscovite and chlorite flakes enclosing numerous grains of quartz and calcite and occasional magnetite crystals". At the entrance to the quarry the cleavage dips 80 SW and strikes N 600 W. The bedding dips 230 NW and strikes N 650 E. Stratigraphically, the slate occurs in the lower part of the Martinsburg formation.

Proceed southwest on the same road for approximately a quarter of a mile where cars may be turned and the direction of travel reversed.

1.7 Turn right on Foster Street.

2.0 Turn 1/2 left across Main Street (Route 31, a "stop" street) and pull to curb just beyond on Maple Avenue.

STOP 2. Jacksonburg limestone. This is a fairly typical exposure of the thin-bedded, fossiliferous, gray limestone of which the lower part of this formation is normally composed. Here, some 10 feet of beds is exposed in several outcrops, these striking N 290 E and dipping 270 NW. Weller 2/ painted out that at Jacksonburg the lowermost 58 feet of beds are characterized by Pionodema /Dalmanella/ subaequata and Lepserditia fabulites, and he regarded these beds as of Black River age. Miller 3/, however, referred them to the Rockland or lowest subdivision of the Trenton. Weller noted a faunal change in the beds above the lowermost 58 feet of the formation at the type locality, the higher beds being characterized by Sowerbyella /Flectambonites/ sericea, "Dalmanella
testudinaria", Zygospira recurvirostris and Calliops (Ptetygometopus) callicephala. Most of the fossils in this exposure are broken and unrecognized, but the stratigraphic position of the beds makes their correlation as Jacksonburg reasonably certain.

Continue north on Maple Avenue to Elm Street.

2.3 Turn left. Re-cross Main Street (Route 31) and continue to High Street (Route 8).

2.5 Turn right on High Street and at

2.6 Spring Street, jog left, then right on Water Street (Route S31). Continue north (n.b. note slate in road cuts and outcrops) to road fork marked "Lafayette 2 miles".

5.2 Turn right and continue past railroad underpass and past concealed horizon of Jacksonburg limestone to the second lefthand road fork.

6.5 Turn left on dirt road and continue past outcrops of Kittatinny limestone, and across tracks of the D. L. & W. Railroad to Route 64.

7.8 Turn right and park cars. STOP 3. Kittatinny limestone. This is the upper part of the formation and it is composed of light-gray, fairly massive beds of dolomitic limestone. No fossils have been noted here, but because of the stratigraphic position of these beds and their lithologic similarity to other sections in which Ordovician fossils have been found, they can be correlated with the Beekmantown (See Waller, p. 15; also Kummel 4). The beds seen here are on the northwestern flank of an anticlinal structure striking about N 40° E from the eastern part of Newton and passing through Lafayette, and as we travel southeast across it you will see many outcrops of the Kittatinny. As is the case in most similar structures, dips are variable, and between this crossroad and the next, a distance of about a quarter of a mile, the dip ranges from a minimum of 7 to a maximum of 32° NW.

Continue southeast through Lafayette to a road intersection.

9.3 Turn left on tarred road. Glacial drift conceals bed-rock, but known exposures indicate that the contact between limestone and slate on the southeast side of the previously mentioned anticline was passed about a third of a mile southeast of the railroad station at Lafayette.

Continue northeast past road-fork to left (note slate in small hill just beyond pond) and over an overpass across the road-bed of a now-abandoned branch line of the Lackawanna. The next outcrops seen will be the light-colored dolomitic limestone of the upper part of the Kittatinny formation, here dipping rather steeply (i.e. 56°) to the northwest.
14.5 At North Church turn right and continue on road to Franklin. Note lobate front of North Church delta on your left.

15.8 Bridge over Wallkill River. Note headframe of Palmer shaft of the Franklin mine, N. J. Zinc Company, on your left. It is anticipated that all of the ore will have been removed from this famous mine by the end of 1953.

Turn right at end of bridge.

16.2 Turn right on Wildcat Road and park just beyond railroad crossing. STOP 4. Walk south through adjoining railroad cut and note limestone beds constituting the lowermost part of the Kittatinny formation; also, the Hardyston formation.

Section in railroad cut at Franklin

<table>
<thead>
<tr>
<th>Description</th>
<th>Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limestone, with thin shaly beds towards the top &quot;thin-bedded, with layers and lenses of flint ranging up to 2&quot; thick</td>
<td>65</td>
</tr>
<tr>
<td>Limestone, massive-bedded, fine-grained, crystalline and dolomitic</td>
<td>10</td>
</tr>
<tr>
<td>Limestone (about 3/4) and interbedded shale (1/4)</td>
<td>30</td>
</tr>
<tr>
<td>Limestone and interbedded shale</td>
<td>16</td>
</tr>
<tr>
<td>Quartzite, with flat, lens-shaped hollows, presumably at one time filled with limestone pebbles</td>
<td>15</td>
</tr>
<tr>
<td>Limestone</td>
<td>6</td>
</tr>
<tr>
<td>Quartzite</td>
<td>2 1/2</td>
</tr>
<tr>
<td>Limestone</td>
<td>4</td>
</tr>
<tr>
<td>Quartzite, argillaceous &amp; limy</td>
<td>4</td>
</tr>
<tr>
<td>&quot;more massive (south end of cut)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>154 1/2 ft.</strong></td>
</tr>
</tbody>
</table>

The interbedding of limestone and quartzite permits some leeway in drawing the contact between Kittatinny and Hardyston, although the writer is inclined to place it at the top of the 6-foot bed of quartzite. The lower contact of the Hardyston cannot be seen in this exposure, but according to Allen Finger, formerly chief geologist of the N.J. Zinc Company, it can be seen within stone's throw of the south end of the railroad cut. The age of the Hardyston is considered to be Lower Cambrian (Weller, pp. 10-11) in view of the contained Olenellus thompsoni.

Here also the sedimentary beds strike northeast (i.e. 53 to 57 1/2°), the quartzite transecting the north end of the eroded Franklin ore-body, the west leg of which had a strike averaging about N 23°E.
Resume trip, and at first cross-road

16.8 Turn left (n.b. good exposure of pre-Cambrian hybrid gneiss). Follow around golf course and at intersection just beyond railroad crossing turn left again.

17.4 Turn right on main road skirting northerly side of Franklin Pond and continue to intersection with Route 23.

18.0 Turn right and at next road fork

18.3 Keep right on road to Sparta.

24.3 At stop-light (Sparta), turn right on Route 6A.

27.1 Turn left at Woodruff's Gap to

29.1 Lime plant and quarry of the Limestone Products Corporation of America.

STOP 5. The Franklin limestone — here a coarse-grained marble — is well exposed, and time will be taken to study it and to collect minerals. The list of those found here includes:

<table>
<thead>
<tr>
<th>Actinolite *</th>
<th>Fluorite</th>
<th>Pyrrhotite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allanite *</td>
<td>Graphite</td>
<td>Quartz</td>
</tr>
<tr>
<td>Augite</td>
<td>Hornblende</td>
<td>Rhodonite *</td>
</tr>
<tr>
<td>Barite</td>
<td>Microcline</td>
<td>Rutile *</td>
</tr>
<tr>
<td>Biotite</td>
<td>Muscovite</td>
<td>Scapclite *</td>
</tr>
<tr>
<td>Calcite</td>
<td>Norbergite</td>
<td>Serpentine</td>
</tr>
<tr>
<td>Chlorite</td>
<td>Oligoclase</td>
<td>Spinel *</td>
</tr>
<tr>
<td>Chondrodite</td>
<td>Orthoclase</td>
<td>Titanite *</td>
</tr>
<tr>
<td>Corundum *</td>
<td>Phlogopite</td>
<td>Tourmaline *</td>
</tr>
<tr>
<td>Diopside</td>
<td>Pyrite</td>
<td>Tremolite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vermiculite *</td>
</tr>
</tbody>
</table>

* Reported by William C. Casperson.

The Franklin limestone was named by Wolff and Brooks /5/ in 1898, the type locality being Franklin, N.J. It is typically a coarsely crystalline white rock, but may be fine-grained or have a light gray color. Graphite in fairly coarse flakes is commonly present and is believed to represent an original organic content, although proof of such derivation is lacking. The Franklin limestone is fairly widespread in its occurrence, extending as discontinuous, small to large masses from New York State to Chester County, Pennsylvania. It has been intruded by pre-Cambrian dikes of both granitic and basic type and is definitely older than the pre-Cambrian Byram and Losee gneisses. Calcite from the Franklin mine can be found in almost every collection of fluorescent minerals because of its beautiful pink color when exposed to short-wave excitation; and in combination with willemite from the same mine, it is transcendingly beautiful.
Mileage
Continue southwest on same road.

30.1 Take right fork to Newton.
34.0 Cochran House, Newton.

REFERENCES


GENERAL REFERENCES


TRIP B
SILURIAN-DEVONIAN SECTION AT
NEARPASS QUARRIES
Leader: Henry Herpers

ITINERARY FOR SUNDAY MORNING, June 1, 8:30 a.m.

Mileage

0.0  Cochran House, Newton. Go west to traffic signal. Right turn on Route S-31 and proceed north, following road signs to Culvers Lake and Branchville.

2.8  Assembly Point, R. R. crossing.

4.9  Left turn at Ross' Corner

10.6  Culvers Gap.

19.3  Right turn on Clove Road.

25.4  STOP 1. Nearpass Quarries. The Nearpass Quarries are located on the ridge a quarter of a mile west of the road. They are two in number, the William Nearpass Quarry, located at the southeast end of the ridge, and the Sanford Nearpass Quarry, at the northeast end. Between the quarries is the Nearpass Bluff, where full and complete sections of the Decker, Rondout and Manlius limestones are exposed.

The section exposed at the quarries and in the bluff is one of the important standard sections of the late Silurian and early Devonian formations in the Northeast. It has been widely quoted in the literature, but because of the vague locations given in the original references, it has probably been more often quoted than visited. The quarries were opened in the Manlius limestone, that being the formation best suited for making lime. They were abandoned in the 1870's and have not been operated since. The sequence of beds was first described by G. H. Cock in 1868 in his "Geology of New Jersey", and he made a rough correlation of the beds with those in the section at the cement quarries at Rondout, New York. The rocks and their included fossils were also the subject of several papers by Dr. Simeon T. Barrett, a dentist of nearby Port Jervis, who was also an amateur geologist. It was not until 1899 that a study of the rocks was made by Stuart Weller. A preliminary report was published in the Annual Report of the State Geologist of New Jersey for 1899, and the final report appeared in 1903 in Report on Paleontology, Volume III, published by the Geological Survey of N. J.
Weller was able to distinguish the Bossardville, Decker, Rondout, Manlius and Coeymans limestones in the Quarry Bluff, and most of the other Devonian formations in the ridges beyond the top of the bluff. He divided the Decker into 3 faunal zones. In 1939, Frank C. Whitmore, then of The Pennsylvania State College, studied the ostracod faunas of the Decker, Rondout and Manlius limestones, and distinguished several faunal zones in the formations. More recently, I was able to distinguish two Leperditia zones in the Rondout. The Faunal divisions made by Weller, Whitmore and me are combined in the following table:

<table>
<thead>
<tr>
<th>Formation</th>
<th>Faunal Zones</th>
<th>Dist, from base of form.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td><strong>Name of Zones</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Name</strong></td>
<td><strong>thick.</strong></td>
<td></td>
</tr>
<tr>
<td>Manlius</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kloedenella bipustulata zone</td>
<td>0 - 30</td>
</tr>
<tr>
<td></td>
<td>Kloedenia nasuta subzone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Middle subzone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Welleria jerseyensis var. pustulosa subzone</td>
<td></td>
</tr>
<tr>
<td>Rondout</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leperditia, spp. zone</td>
<td>114 - 10.4</td>
</tr>
<tr>
<td></td>
<td>Leperditia zone</td>
<td>6.3 - 10.9</td>
</tr>
<tr>
<td>Decker</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stenochisma /Atrypa? lamellata zone</td>
<td>26.5 - 52</td>
</tr>
<tr>
<td></td>
<td>Zygoberyichia nearpassi zone</td>
<td>48 - 52</td>
</tr>
<tr>
<td></td>
<td>Primitiopsis gibosa subzone</td>
<td>49 - 52</td>
</tr>
<tr>
<td></td>
<td>Dizygopleura postangulata subzone</td>
<td>48 - 49</td>
</tr>
<tr>
<td></td>
<td>Ptilodictya frondosa zone</td>
<td>24 - 26.5</td>
</tr>
<tr>
<td></td>
<td>Chonetes jerseyensis zone</td>
<td>0 - 24</td>
</tr>
</tbody>
</table>

The Siluro-Devonian contact may be seen in the two quarries and in the bluff, but it is best exposed in the Wm. Nearpass Quarry. Here the change from the Manlius limestone to the Coeymans limestone takes place in a transition zone approximately 5 feet thick, consisting of alternating, lensing and interlayering beds of coarse-grained, almost coquinal, crinoidal limestone and dense, fine-grained, limestone (calcitlite). The fauna includes Favorites helderbergiae, horn corals and stromatoporoid heads. The underlying Manlius is predominantly a dark bluish-grey calcitlite, containing Howellella vanuxemi, Strophedonta varistriata and Loxonema cf. fitchi as well as stromatoporoid heads. The overlying Coeymans limestone is a gray, coarse-grained, limestone containing the typical index fossil Cypidula coeymanensis.

Return to Newton will be made by same route.
References same as for Silurian-Devonian, stratigraphy field trip of Saturday.