VERMONT GEOLOGICAL SOCIETY

ANNUAL FALL FIELD TRIP

TOPICS: THE GILE MOUNTAIN/WAITS RIVER STRATIGRAPHIC SEQUENCE QUESTION.

THE POMFRET DOME--ORIGIN OF THE CLEAVAGE DOME STRUCTURE AND ASSOCIATED ORE MINERALIZATION.

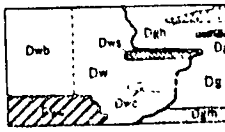
OCTOBER 23, 1982

FIELD TRIP LEADER: CHARLES A. RATTE'

From Doll et al (1961) Centennial Geologic Map of Vermont

EASTERN VERMONT

DEVONIAN — Lower Devonian



Waits River formation

Gray quartzose and micaceous crystalline limestone weathered to distinctive brown earthy crust, interbedded and intergradational with gray quartz muscovite phyllite or schist. Where more metamorphosed the limestones contain actinolite, hornblende, zoisite, diopside, wollastonite, and garnet, and the phyllite and schist, biotite, garnet, and locally andalusite, kyanite or sillimanite

Dws Standing Pond volcanic member amphibolite, garnet amphibolite, coarse garnet schist with fasciculitic hornblende, and hornblende maculite contains pillow lavas near St. Johnsbury and passes eastward into actinolitic greenstone and greenstone south of Windsor

Dwc, Crow Hill member tough gray quartzite near St Johnsbury is distinctive similar rock (not shown on map) occurs at several other places

Dwb Barton River member interbedded siliceous crystalline limestone and sericite quartz chlorite phyllite in northern Vermont diopsidic limestone and cordierite hornfels at contacts with granitic dikes and sills

Dwa Ayers Cliff limestone member siliceous crystalline limestone containing thin beds of slate and phyllite north of the Lamoille River

Gile Mountain formation

Gray quartz muscovite phyllite or schist, interbedded and intergradational with gray micaceous quartzite (graywacke northeast of Nulhegan River), calcareous mica schist, and, locally, quartzose and micaceous crystalline limestone like that of the Waits River formation. The phyllite and schist commonly contain porphyroblasts of biotite, garnet, or staurolite, and locally kyanite, andalusite, or sillimanite

Dgh Hall Stream member highly feldspathic grit, probably meta-, feldspathic chlorite-ankerite schist and amphibolite all northeast of Nulhegan River

Dga amphibolite hornblende-quartz-biotite-chlorite rock

Dgm Meetinghouse slate member chiefly gray slate or phyllite characterized by beds of gray schistose quartzite ¼ inch to 2 inches thick

Dl

Littleton formation

Gray slate and phyllite containing interbeds of gray schistose quartzite ¼ inch to 3 inches thick. West of Guildhall are lustrous, light to dark gray biotite-garnet phyllite and schist, some slate, and subordinate quartzite and impure quartzite. South of Bellows Falls gray phyllite passes eastward into gray mica schist containing porphyroblasts of biotite, garnet, and staurolite

SILURIAN — Middle and Upper Silurian

DSn

Northfield formation

Dark gray to black quartz sericite slate or phyllite with fairly widely spaced interbeds a few inches thick of siltstone and silty crystalline limestone like that of the Waits River formation calcareous slate north of Lamoille River, phyllite passes into gray quartz-sericite schist containing abundant porphyroblasts of biotite and garnet in southern Vermont

Sf

Fitch formation

NORTHEASTERN VERMONT

Bluish gray, white weathered sandy limestone

SOUTHEASTERN VERMONT

Quartz plagioclase-biotite granulite, actinolite-diopside granulite impure limestone and dolomite, mica schist, the carbonate-rich beds are typically an inch or two thick and segmented so as to give the weathered outcrop a characteristic pitted appearance

Lower Silurian

Shaw Mountain formation

NORTHERN VERMONT

Chiefly tan to brown weathered quartzose limestone and calcareous quartzite characterized by specks of limonite after ankerite locally underlain by quartz conglomerate and overlain by blue fossiliferous crystalline limestone greenstone and quartz-sericite schist

SOUTHERN VERMONT

Quartzite, quartz conglomerate, cummingtonite schist amphibolite, and quartz sericite schist with porphyroblasts of biotite and garnet

Clough formation

NORTHEASTERN VERMONT

Boulders, cobbles, pebbles and angular fragments of quartzite micaceous quartzite, and gray mica schist in matrix of dark gray quartz mica schist or quartzite schist commonly contains porphyroblasts of biotite, less commonly garnet

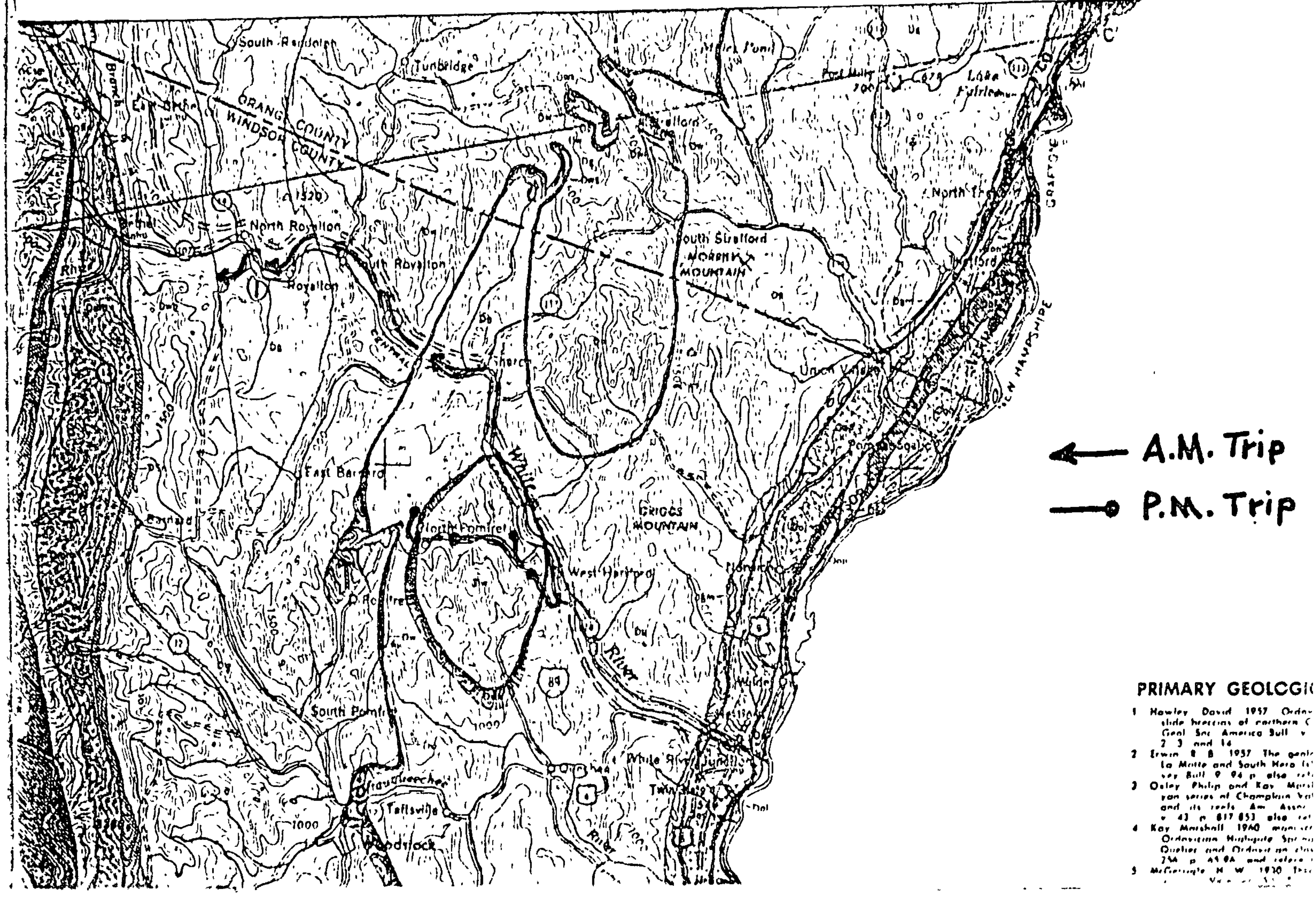
SOUTHEASTERN VERMONT

Quartzite quartz conglomerate, and mica schist lenses of fossiliferous calcareous quartzite in upper part

UNCONFORMITY

UNCONFORMITY

OUNTAINS



PRIMARY GEOLOGI...

1 Hawley David 1957 Ordo... slide breccias of northern ... Geol Soc America Bull v ... 2 3 and 14
2 Erwin R B 1957 The geol... La Motte and South Hero Is... vey Bull 9 94 p also ...
3 Oxley Philip and Kay Marsh... von series of Champlain Val... and its rocks Am Assoc ... v 43 p 817 853 also ...
4 Kay Marshall 1940 ... Ordovician Highgate Sp... Quebec and Ordovici... 734 p 49 9A and ...
5 McGerrigle H W 1930 ...

References

Lyons, J. B., 1955, Geology of the Hanover Quadrangle, New Hampshire-Vermont: Geol. Soc. Am., Bull., v. 66, p. 106-146.

Thresher, J. E., Jr., 1972, Geochemical investigation of Pomfret Dome, Vermont: Vermont Geological Survey, Economic Geology, no. 8, 31 p.

White, W. S., 1949, Cleavage in east-central Vermont: American Geophysical Union, Transactions, v. 30, p. 587-594.

White, W. S. and Jahns, R. H., 1950, Structure of central and east-central Vermont: Journal of Geology, v. 58, p. 179-220.

The following U.S.G.S. 7½ minute topographic maps can be used to locate the field trip stops:

Quechee, Vermont
South Royalton, Vermont

ABSTRACT

The stratigraphic sequence of the Gile Mountain and Waits River Formations, two major Silurian-Devonian lithostratigraphic units in eastern Vermont, has long been controversial. This uncertainty has given rise to numerous difficulties in interpreting the regional structure of eastern Vermont. Extensive sequences of compositionally graded beds at 19 localities across the Gile Mountain belt near Royalton, Vermont, show that the Gile Mountain Formation is younger than the Waits River Formation, indicating that the belt is a syncline.

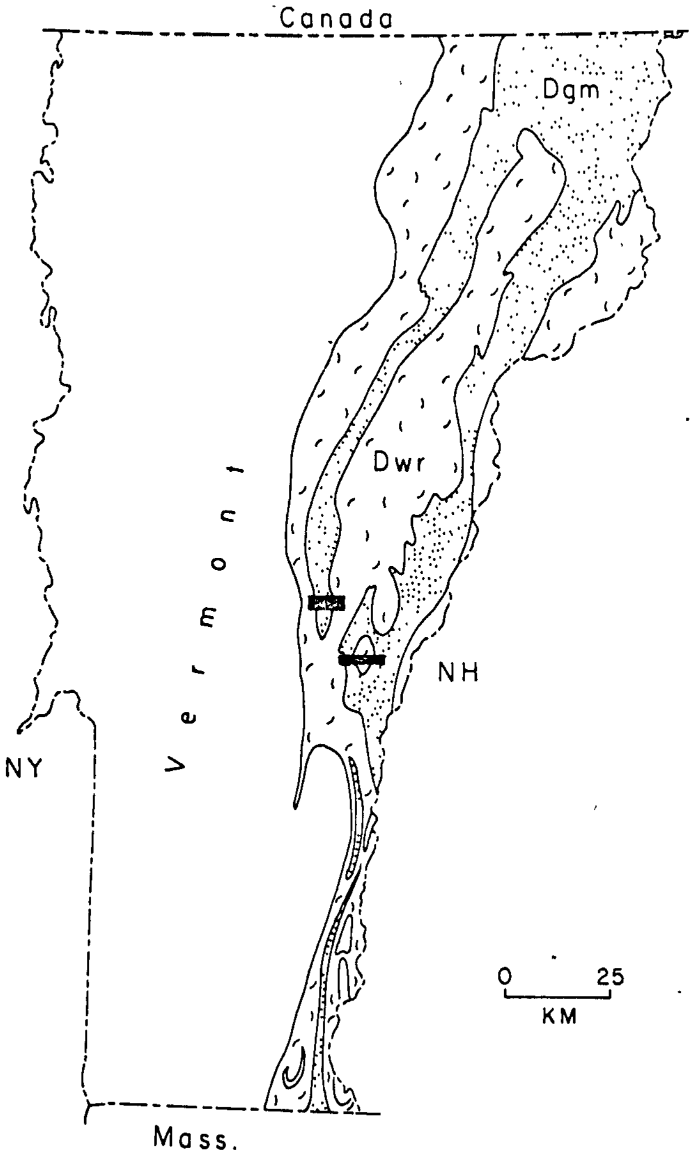


Figure 1. Extent of Gile Mountain (Dgm) and Waits River (Dwr) Formations in eastern Vermont, adapted from Doll and others (1961); rectangle indicates area shown in Figure 7, at Royalton, Vermont.

Figure 2. Compositionally graded beds of micaceous quartzite rhythmically interbedded with garnet-mica schist in Gile Mountain Formation, 50 m east of contact with Waits River Formation in a pasture 2.8 km west of Royalton, Vermont (loc. A, Fig. 7). View is looking north; grading indicates tops to east, toward Gile Mountain Formation. S_1 is parallel to bedding; S_2 is parallel to pen. Pen is 16 cm long.

Geological Society of America Bulletin, Part I, v. 91, p. 282–286, 7 figs., May 1980, Doc. no. 00506.

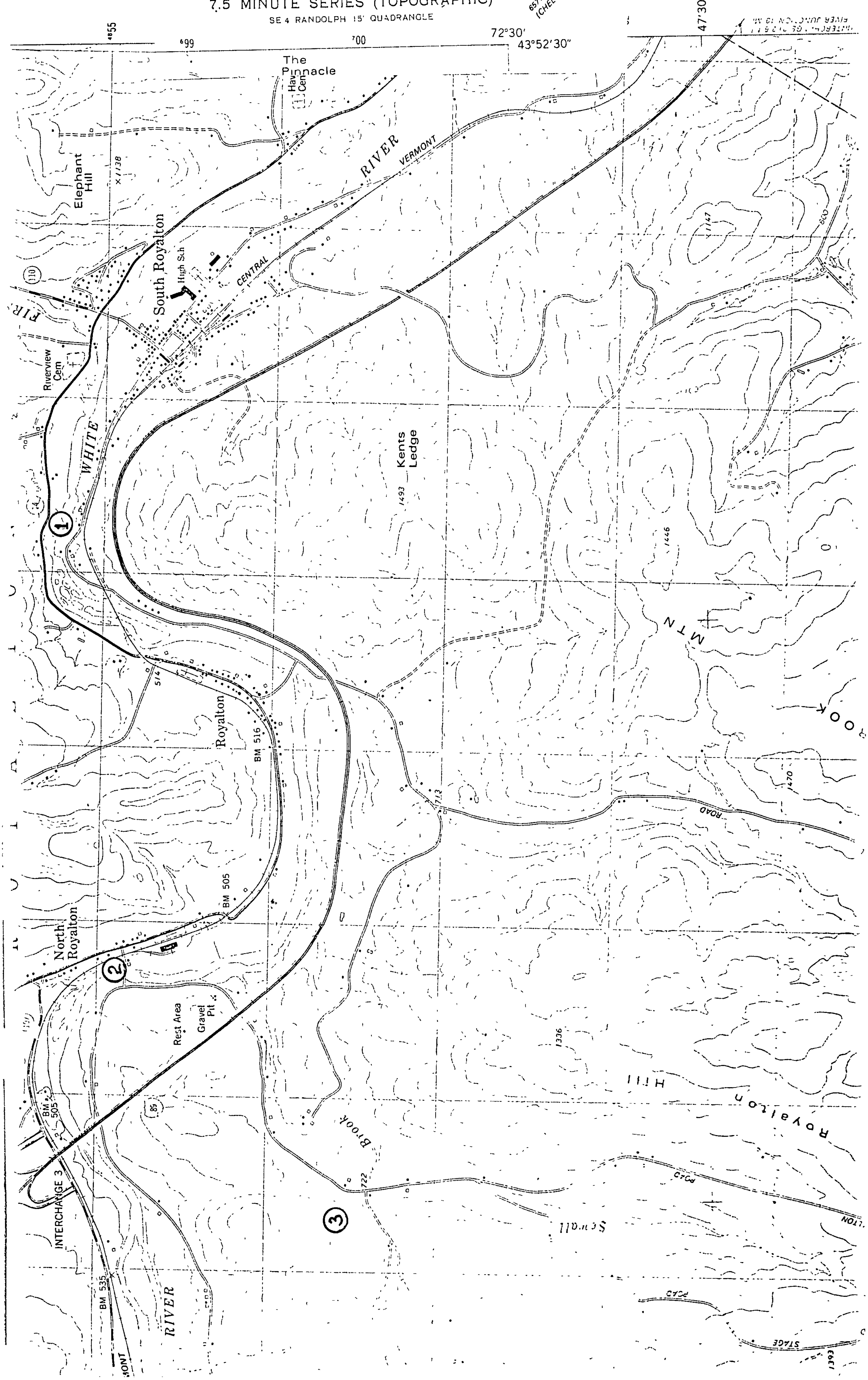
From Fisher and Karabinos (1980)

SOUTH ROYALTON QUADRANGLE

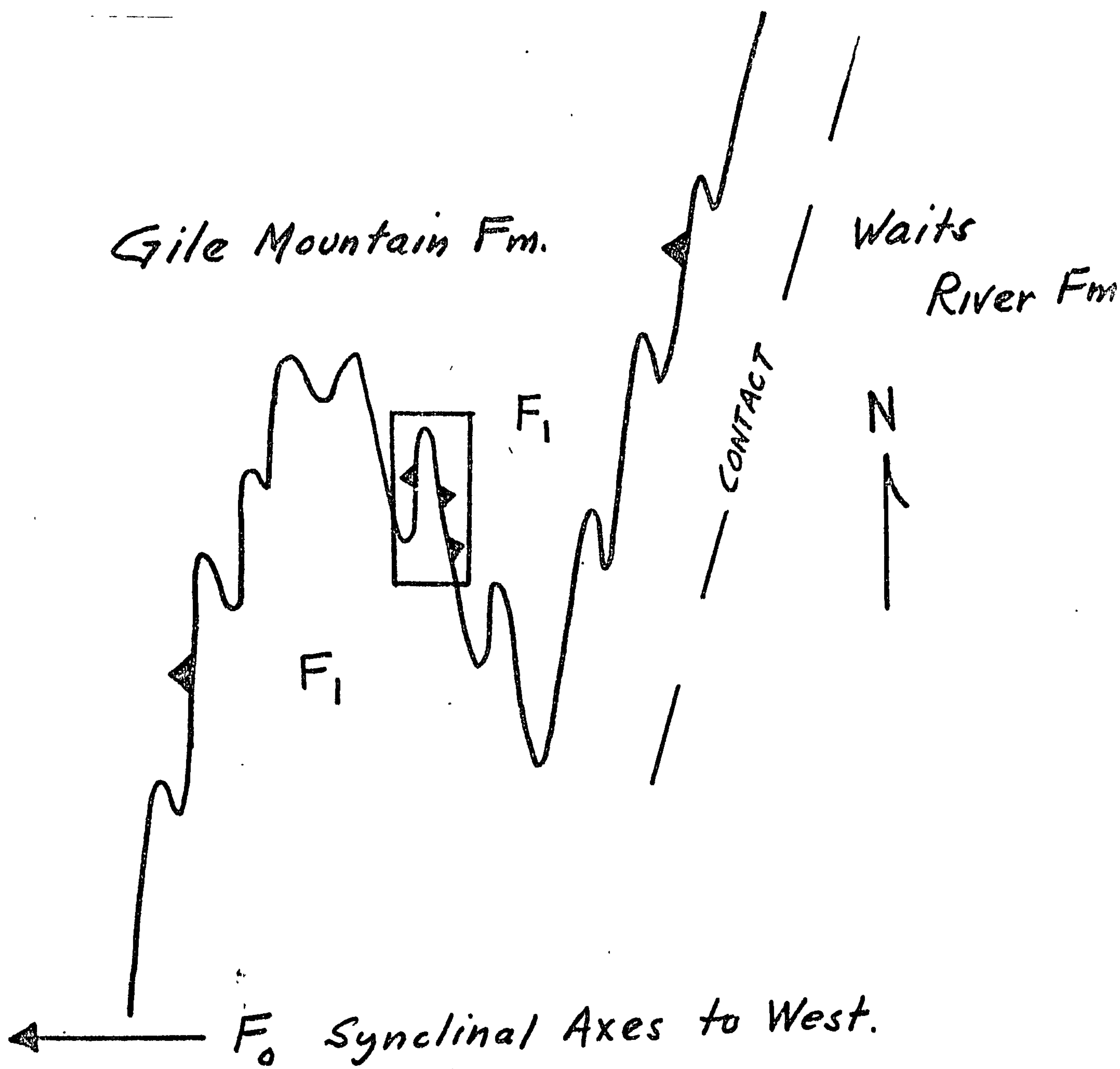
VERMONT

7.5 MINUTE SERIES (TOPOGRAPHIC)

SE 4 RANDOLPH 15' QUADRANGLE



STOP 1. This outcropping of the Gile Mountain Formation displays excellent examples of compositionally graded beds. The beds here are very complexly folded and topping sense as inferred from the graded beds is contradictory. Fisher and Karabinos (1980) suggest this location represents a series of minor folds (drags) associated with the western limb of a larger F_1 synform. The location of this outcrop may be situated as shown in the diagram below with facing directions showing both a westerly and easterly sense.



From Fisher & Karabinos (1980)

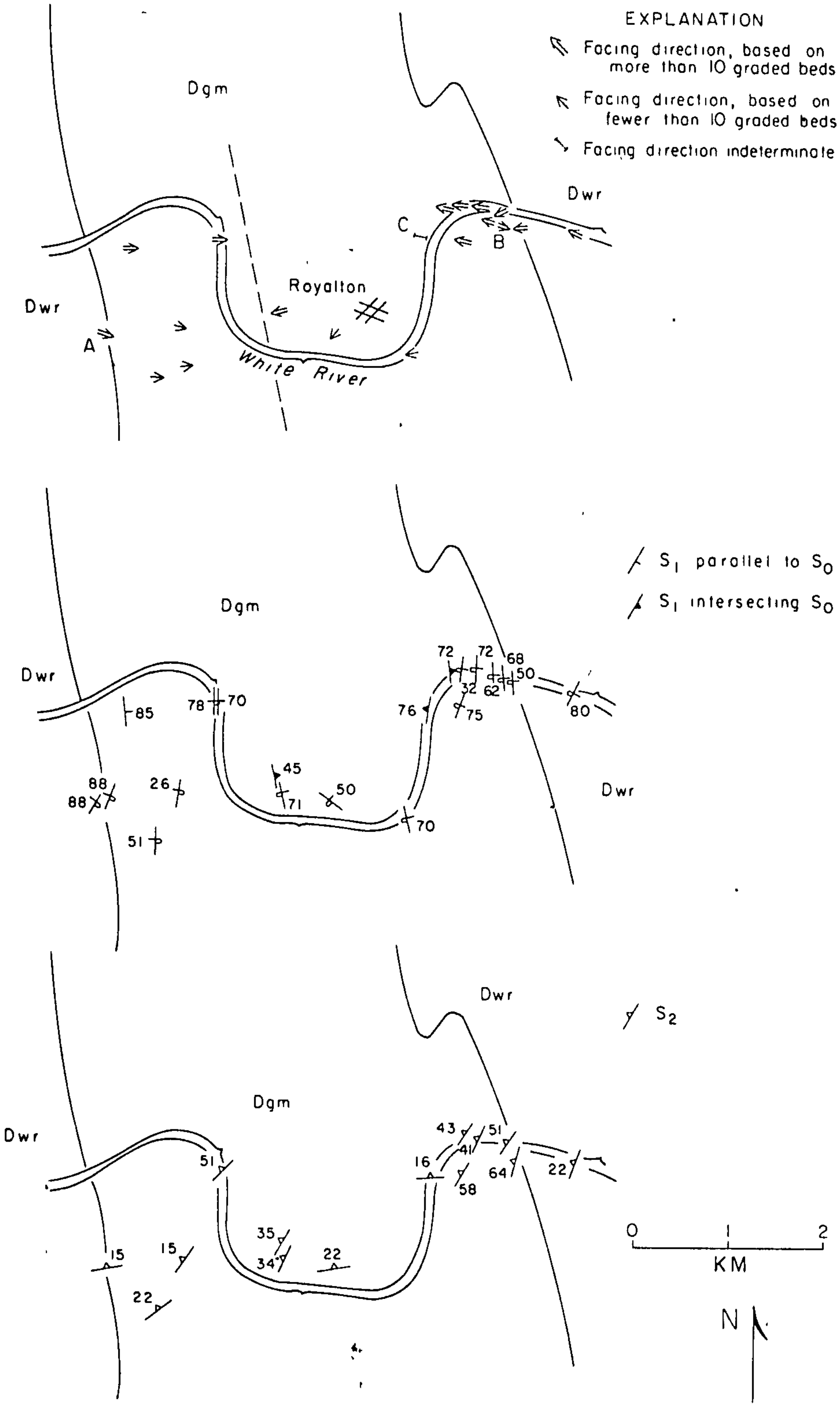


Figure 7. Stratigraphic sense inferred from graded beds near Royalton, Vermont, in Gile Mountain (Dgm) and Waits River (Dwr) Formations, together with orientation of bedding (S_0) and schistosity (S_1 and S_2). A, B, and C denote localities referred to in text. For location of area shown, see Figure 1.

Formation, but some in the Waits River Formation — show tops toward the Gile Mountain Formation (Figs. 2, 3). Only three beds, presumably on the short limbs of minor F_1 folds, show tops in the reverse direction.

At only one locality (B in Fig. 7) does the inferred facing direction appear to conflict with a synclinal interpretation of the Gile Mountain belt. The western part of the outcrop displays only a few graded beds, all topping to the west, whereas the eastern part displays many beds, nearly all facing east, which give an eastward-facing sense to the outcrop as a whole. These east-facing beds are affected by a minor F_1 fold with a left-handed sense viewed parallel to its north-plunging axis, suggesting that these beds are on the western limb of a larger F_1 synform. By contrast, the many nearby outcrops, which are dominated by west-facing beds (Figs. 4, 5), consistently contain right-handed F_1 folds (Fig. 6), suggesting that they lie on the eastern limb of a major F_1 synform. Because outcrops with west-facing beds and right-handed F_1 folds greatly predominate in this area (Fig. 7), it seems likely that locality B is on the short limb of a local F_1 fold and that the regional F_1 synclinal axis lies to the west, near the center of the Gile Mountain belt, as shown in Figure 7.

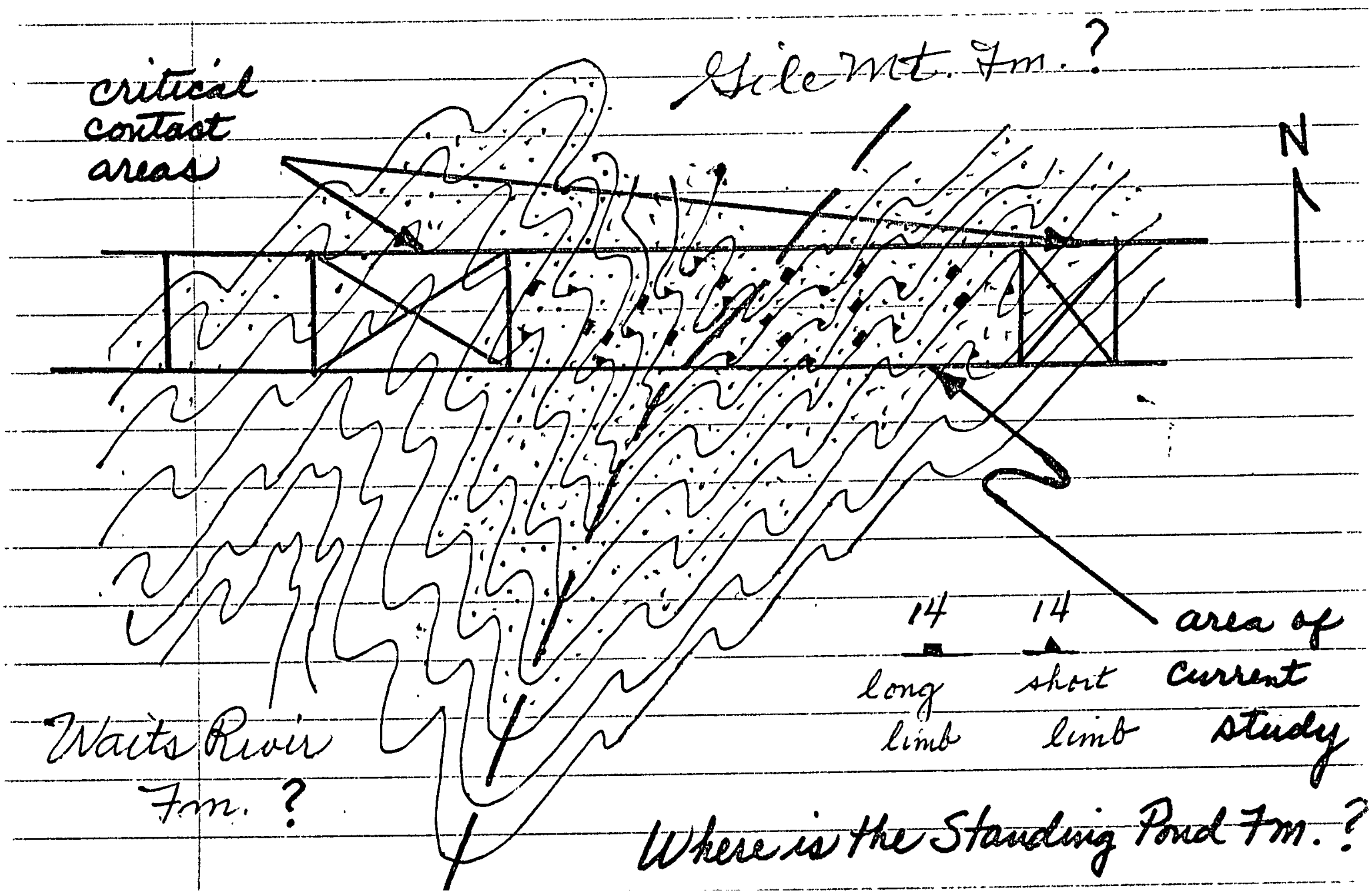
At one locality (C in Fig. 7) minor F_1 folds are so numerous that no overall facing direction could be determined. However, the graded beds show that the downward-closing minor folds are all synclines, and the upward-closing folds are all anticlines, confirming that the regional F_1 syncline is a normal upright structure.

DISCUSSION AND REGIONAL SIGNIFICANCE

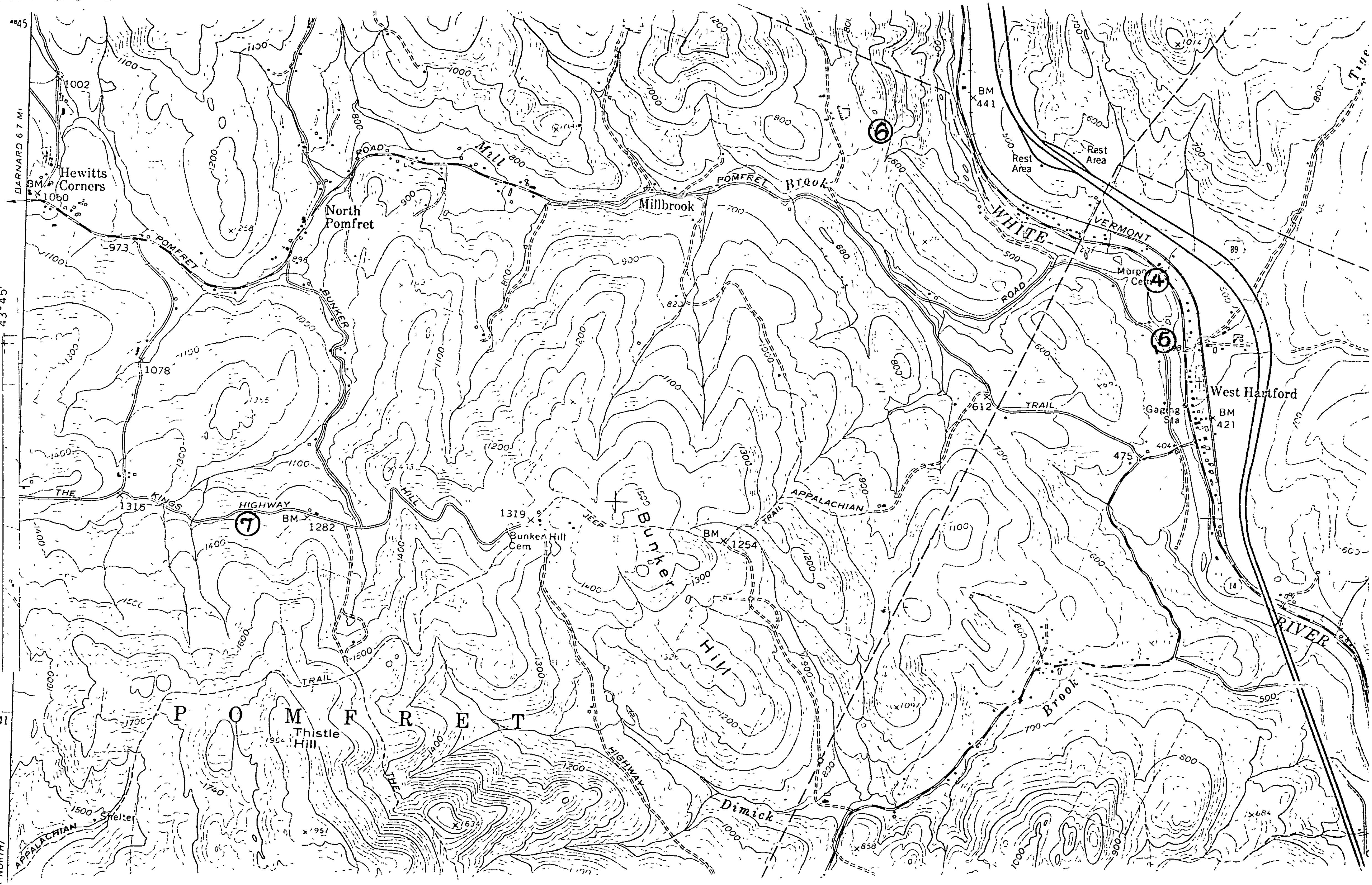
Because of the gradational nature of the contact between the Waits River and Gile Mountain Formations, the consistent direction of tops indicated by graded bedding in both units, and the absence of any indication of tectonic disruption near the contact, we assume that the two formations are in normal stratigraphic contact. Our observations of graded beds suggest a stratigraphic sequence opposite to that inferred by Ern (1963, p. 70–71) from observations of minor folds and bedding-cleavage relations, locally combined with graded bedding. However, Ern did not show his

STOP 2. Compositionally graded beds showing a topping direction to the east. These graded beds are within the Gile Mountain Formation. The synclinal axis lies between Stop 1 and Stop 2.

STOP 3. Numerous outcroppings of the Gile Mountain Formations display cross-sectional views of compositionally graded beds most with an easterly topping sense. Exposures of the Waits River Formation (supposedly older than the Gile Mountain Formation) may be seen at the western edge of the pasture, however, no actual topping directions can be observed at the actual contact of the two formations. Such deficiency of field evidence in highly folded rock leaves the question of age relationship still begging an answer. Two possible interpretations (for the evidence here presented) are described in the plan view drawing below. Synform could be interpreted as overturned anticline if statistical count happened to involve mostly short limb measurements.



QUECHEE QUADRANGLE
VERMONT–WINDSOR CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



STOP 4.

Standing Pond Amphibolite.

This outcropping illustrates the structural attitude of the strata on the eastern flank of the Pomfret Dome (the strike is north, the dip is east).

The rock banded and laminated rather than massive, there are no pillows; contacts, although not seen here, are not baked. Boudinage structures are evident. Mineral content is primarily hornblende and plagioclase.

Origin: 1. Mafic tuff?
2. Metamorphosed impure limestone?

STOP 5.
(location R on geologic map)

Standing Pond/Gile Mountain contact here is gradational, interbedded. Sulfidic, iron oxide staining. Contains "coticule," accumulations of manganiferous garnet and quartz. Mineral resource potential, may have some relation to South Strafford area to the north (see Thresher, 1972).

Origin: a. Chemical sediments
b. Stratabound sulfides
c. Hydrothermal ore fluid mineralization

STOP 6.

Interior of Pomfret Dome.

Complexly folded cleavage dome structures in the Waits River Formation. Primarily calcareous rocks.

See the associated diagrams from White and Jahns (1950) for discussion of nappe development and later stage doming.

STOP 7.

Standing Pond Formation on west flank of Pomfret Dome. At this location the strike is northerly and the dip westerly. This is the "right side up" limb of the quaquaversally dipping beds encircling the dome. Overturned limbs of the overlying recumbent fold lie to the west and north of the dome (see Figures 10 and 11 of White and Jahns, 1950, for the Strafford Village area).

From Thresher (1972)

Figure 2. Traverse and geologic map. Geologic information taken from Lyons (1955)

LEGEND
Og-Gile Mountain Formation
Oga- Amphibolite
Ows-Standing Pond Amphibolite
Ow-Waits River Formation

approximate formation boundary

traverse with station indicated

NOTE
Following Lyons, the formations were assigned by the author to the Ordovician. They are now considered to be Devonian.

From Thresher (1972)

COMPARISON OF THE MINERALIZATION OF THE POMFRET DOME TO THAT OF THE ELIZABETH MINE, STRAFFORD QUADRANGLE

The minor sulfide mineralization noted in the Pomfred Dome is similar in composition and in relationship to structure to that of the other deposits of the Vermont Copper Belt, and in particular to that of the Elizabeth Mine at South Strafford. The major sulfide has been found to be pyrrhotite, but varying amounts of other sulfides, notably chalcopyrite, have been found and mined at South Strafford, Vershire, Corinth and other localities in the Copper Belt. Most of the mineralization found in eastern Vermont is along the eastern flanks of the domal and related structures. Table 1 shows a comparison between the Pomfret mineralization and that at the Elizabeth Mine.

As can be seen in Table 1, the mineralization is very similar in the two areas, with the notable exception that the mineralization at the Elizabeth Mine is more extensive than that in the Pomfret Dome. The mineralization at the Elizabeth Mine is considered to be hydrothermal in orign (Howard, 1969) and because of the textural, structural, and mineralogical similarities between the two areas, the mineralization in the Pomfret Dome is also considered to be of hydrothermal origin.

RECOMMENDATIONS

As a result of this work and the comparison of its findings to those of other related areas, the following recommendations are made:

1. Since minor mineralization is present in the amphibolite at "S" on Figure 2, drilling should be carried out on the amphibolite in order to establish the economic feasibility of opening a mine in that area. Although it appears that a deposit of the magnitude of the Elizabeth Mine has not been found in the Pomfret Area, the possibility exists that since the ore body at the Elizabeth Mine is plunging, this also may be the case in the Pomfret Dome, so that only a small part of the body was seen. Only drilling will give a reasonable estimate of the depth and quality of the deposit.

2. It is also recommended that a program of exploration be carried out in the dome-like areas to the south of the Pomfret Dome in order to determine if they too contain sulfide deposits.

3. The deposit of rutile and ilmenite is considered to be too small and the titanium concentration too low to be of economic significance by today's standards. Therefore, no further work is recommended with respect to this deposit.

Feature	Pomfret Dome	Elizabeth Mine
1. Ore minerals	Pyrrhotite, chalcopyrite	Pyrrhotite, chalcopyrite
2. Mineral occurrence	Disseminated grains in amphibolite	Massive sulfide bands, disseminated grains in schists and coarse-grained aggregates filling narrow veins and fractures.
3. Location of ore in dome	Southeastern part	Northeastern part
4. Lithologic association	Amphibolite in the Gile Mountain Formation	With amphibolite but mostly in the schists of the Gile Mountain Formation
5. Background copper from cold acid method	1-5 ppm Cu, in soil	1-5 ppm Cu, in soil
6 Anomalous copper from cold acid method	25 ppm Cu maximum in soil	200 + ppm Cu in soil
7. Alteration associated with mineralization	Sericitization of feldspar, chloritization of hornblende	Sericitization of fled-spar, formation of biotite from hornblende

Table 1. Comparison of the Pomfret Dome and Elizabeth Mine Minealization.

From White and Jahns (1950)

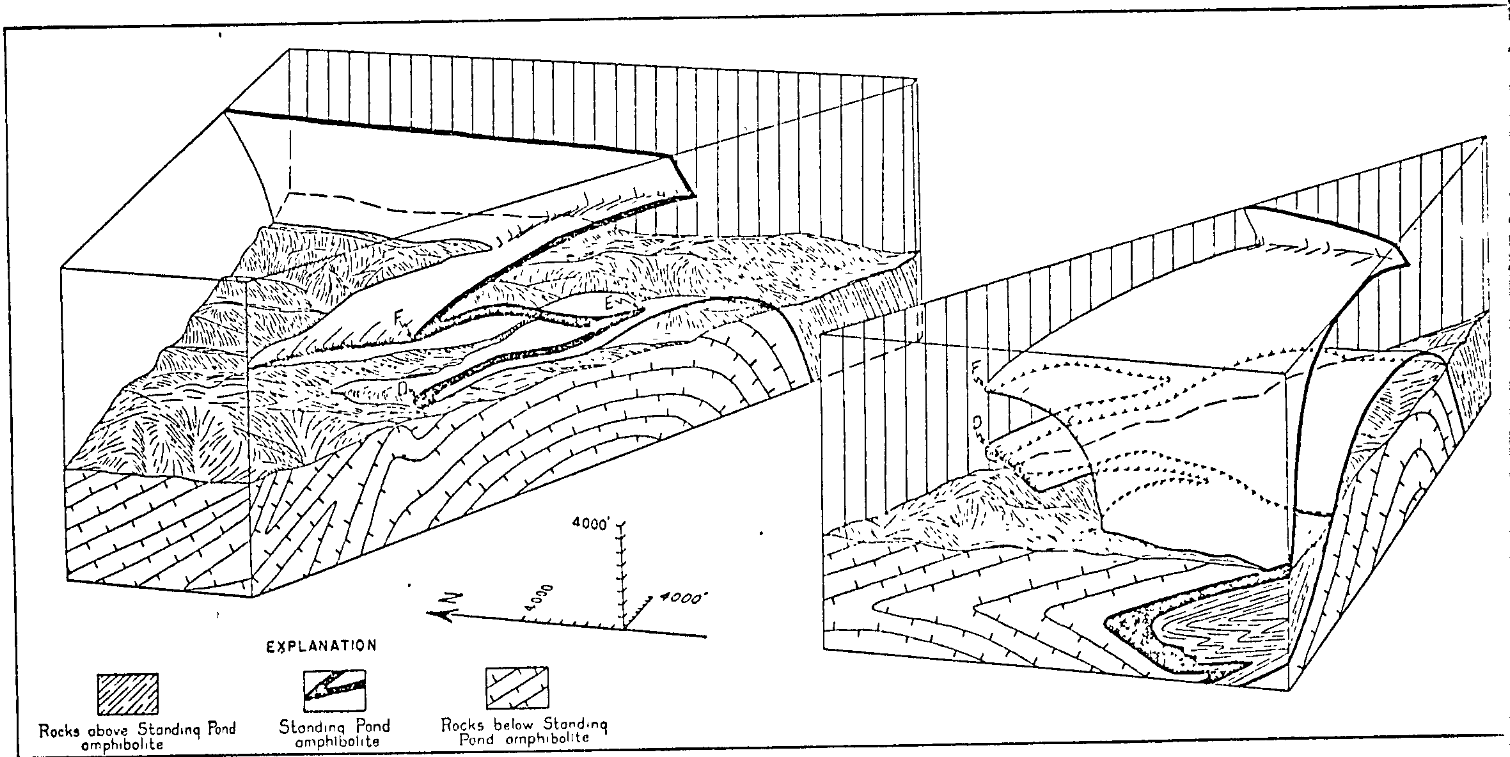


FIG. 11.—Block diagram of the Strafford Village area (see figs. 9 and 10), showing folds restored above present land surface. Original block is cut and p[ulled] apart to indicate appearance of folds in section. Fold axes are identified by same letters as in fig. 10

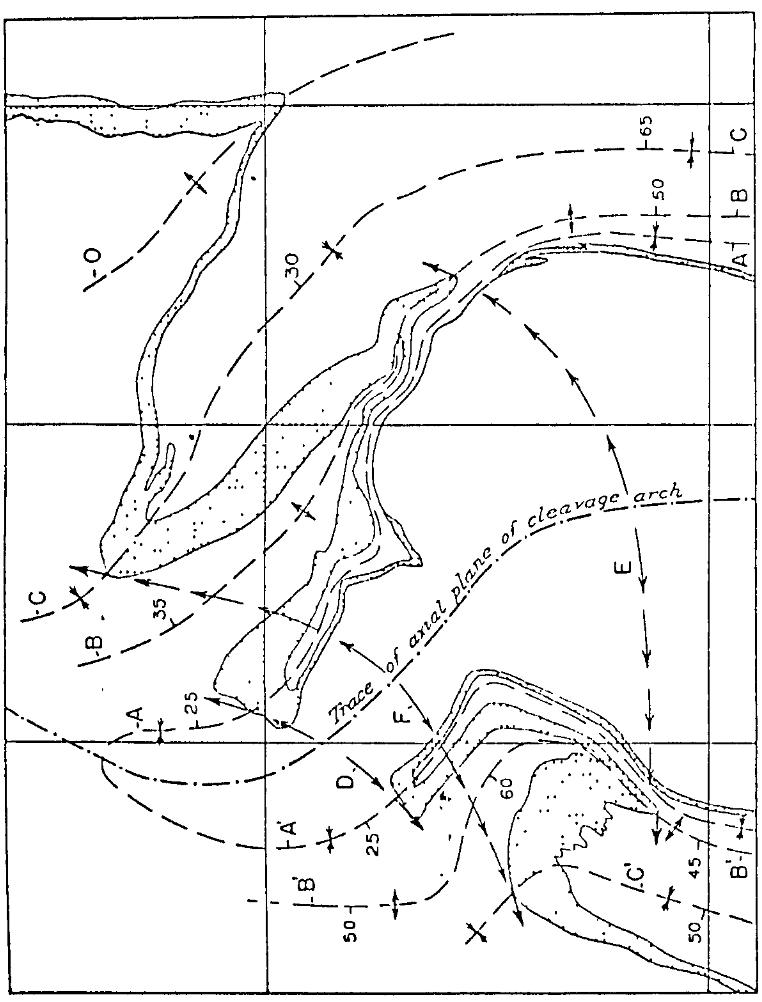


FIG 10.—Tectonic map of the Strafford Village area (see fig 9). Folds are shown by distribution of Standing Pond amphibolite of Doll (*stippled*). *A*, *A'*, *B*, *B'*, *C*, *C'*, and *O* are traces of axial planes of folds, with dips also indicated, and *D*, *E*, and *F* are horizontal projections of fold axes. *A*, *A'*, *D*, Strafford Village syncline, *B*, *B'*, *E*, Granny hand anticline; *C*, *C'*, *F*, Old City syncline, *O*, Orange anticline

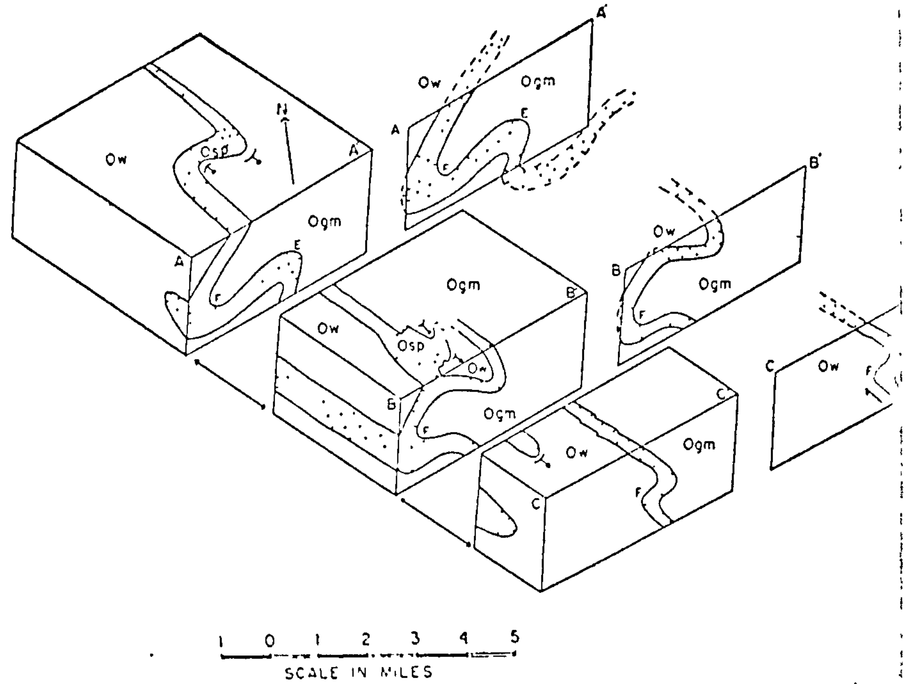
From Lyons (1955)

LEGEND

STRUCTURAL SYMBOLS

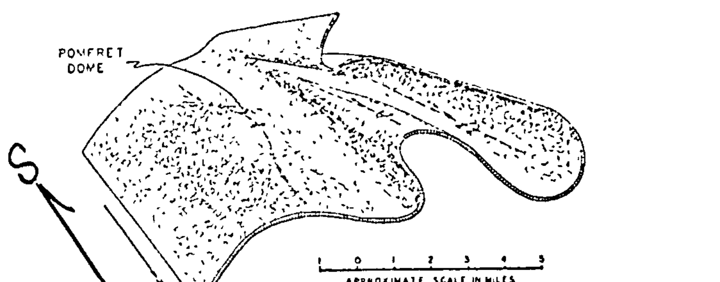
- Strike and dip of beds
- Strike and dip of overturned beds
- Strike and dip of foliation or schistosity
- Strike of vertical foliation or schistosity
- Horizontal schistosity
- Strike and plunge of linear element
- Strike of horizontal lineation
- Strike and dip of axial plane of minor fold
- Strike and dip of axial plane of minor fold, with strike and plunge of fold axis
- Strike and dip of axial plane of minor fold, with horizontal fold axis
- Top of formation as deduced from
  - b - primary bedding features
  - c - cleavage - bedding relations
  - d - drag folds
  - p - pillow structure
- Anticline, showing trace of axial plane and bearing and plunge of axis
- Syncline
- Overturned anticline, showing trace of axial plane, direction of dip of limbs, and bearing and plunge of axis
- Overturned syncline
- Strike and dip of joints
- Fault

Formation symbols as on geologic map (Plate 1)



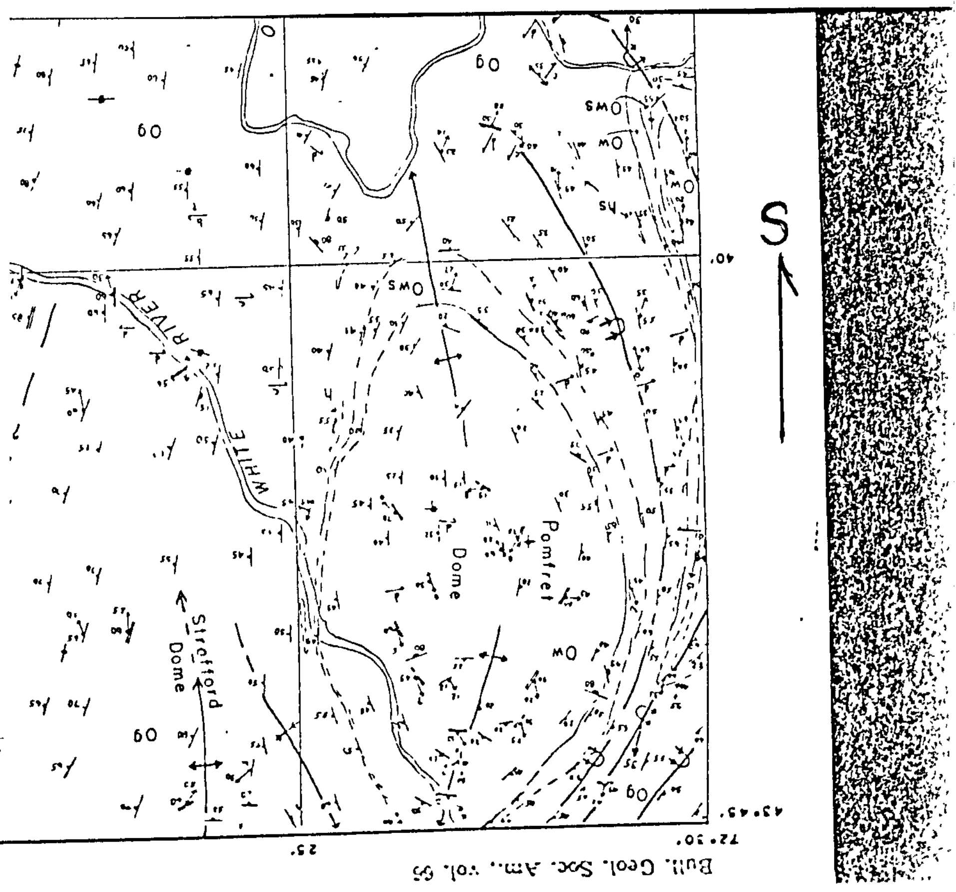
(a) Block diagram showing fold pattern of Standing Pond amphibolite in western portion of quadrangle.

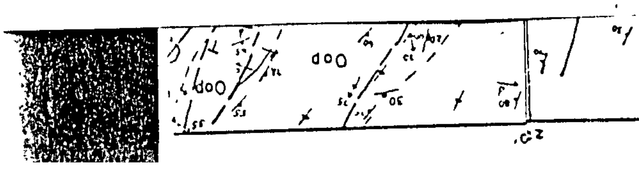
Og = Gile Mountain formation
Ows = Standing Pond amphibolite
Ow = Waits River formation



(b) Sketch, looking south, of fold pattern in Standing Pond amphibolite in western portion of quadrangle. Drawing by J. L. Snyder.

FIGURE 6.—RECUMBENT FOLDS





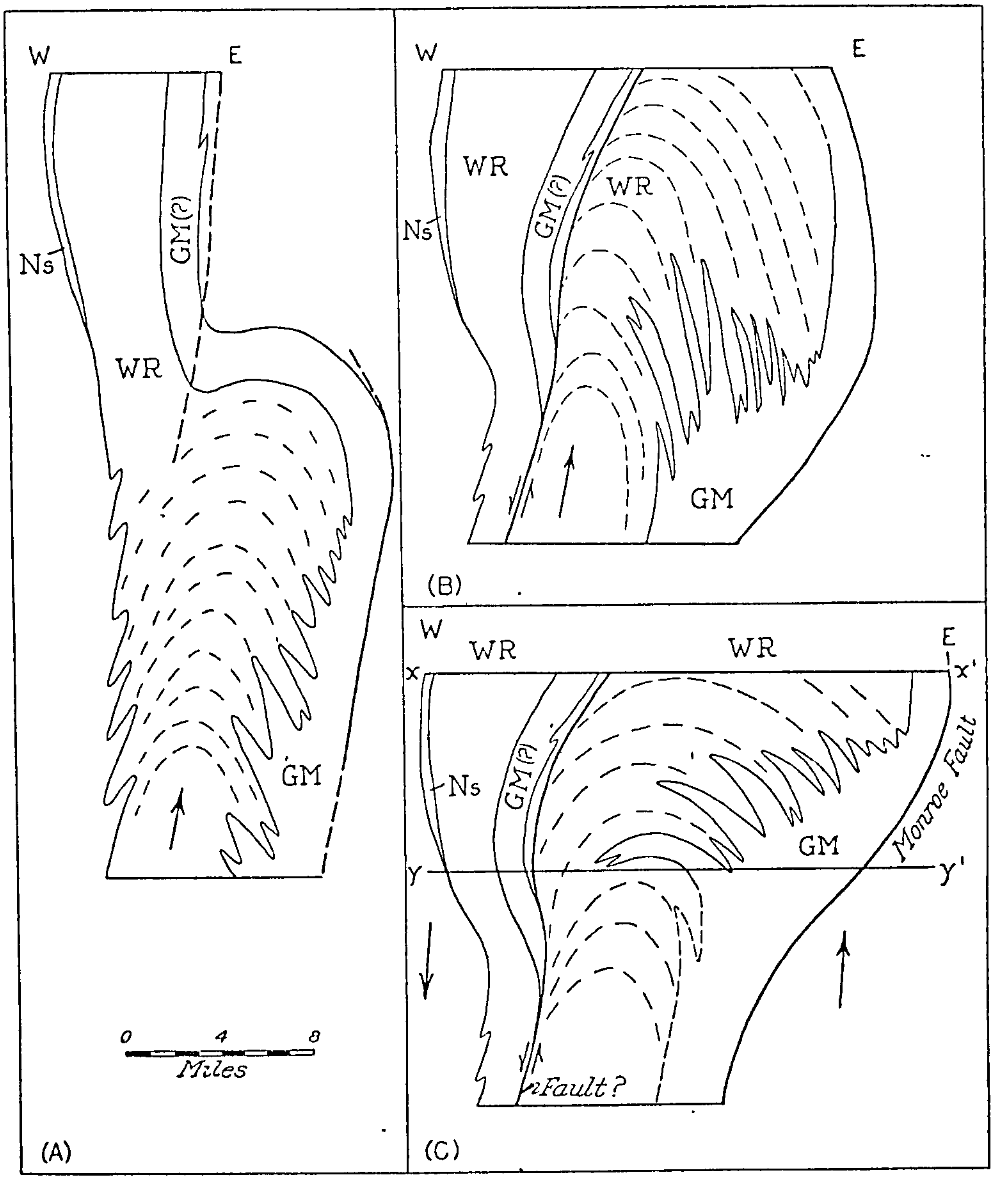


FIG 13.—Diagrammatic east-west vertical sections showing possible evolution of structure in the central tectonic belt Letter symbols are same as in fig 12. Meetinghouse slate, next to Monroe fault, omitted from diagram *A*, cleavage arch (suggested by dashed lines representing schistosity and axial planes of minor folds) begins to form, owing to upward flowage *B*, folds in eastern boundary of Waits River formation become elongate and almost isoclinal as they are brought together by continued upward transport; faulting along west side of arch *C*, eastern side of area rises with respect to western, and isoclinal folds are rotated into cleavage arch *B* and *C* may have occurred simultaneously, that is, *C* may have developed directly from *A* by a combination of the movements of *B* and *C*, but without any intervening stage *B* distinct as such Cause of upward push, *A* and *B*, may be subjacent igneous rocks, extreme flowage of calcareous rocks, or a combination of factors

From White and Jahns (1950)

Field Trip #4 Evidence of Glacial Erosion and Deposition.

Stop #1. Glacial TILL deposited as ground moraine.

This stop is on the college campus behind the construction sight of the new language-classroom building. This type of glacial deposit (till) is a mixture of many different sizes of glacially eroded debris. Note the fine, grey clay and silt, the pebbles and large boulders all mixed together. Such a mixture has simply melted out of the glacial ice and remained in one area totally unaffected by meltwater and, therefore, completely unsorte Where this type of glacial debris, called till, is spread over an extensive area it is called ground moraine. The entire college campus is covered with this clay-rich glacial till. Contrast this type of deposition with that which you will see at stop #4a.

Stop #2. Glacially scoured bedrock surface on exposure just west of the campus on River Road.

Note the following features produced by the scouring (sand pape action of a moving mass of glacial ice. The rock debris (sand, pebbles, etc.) frozen in the sole of the glacier scour the bedrock surfaces over which they move producing:

a. a smooth polished surface
b. elongated scratches (striations)
c. elongated grooves and ridges.

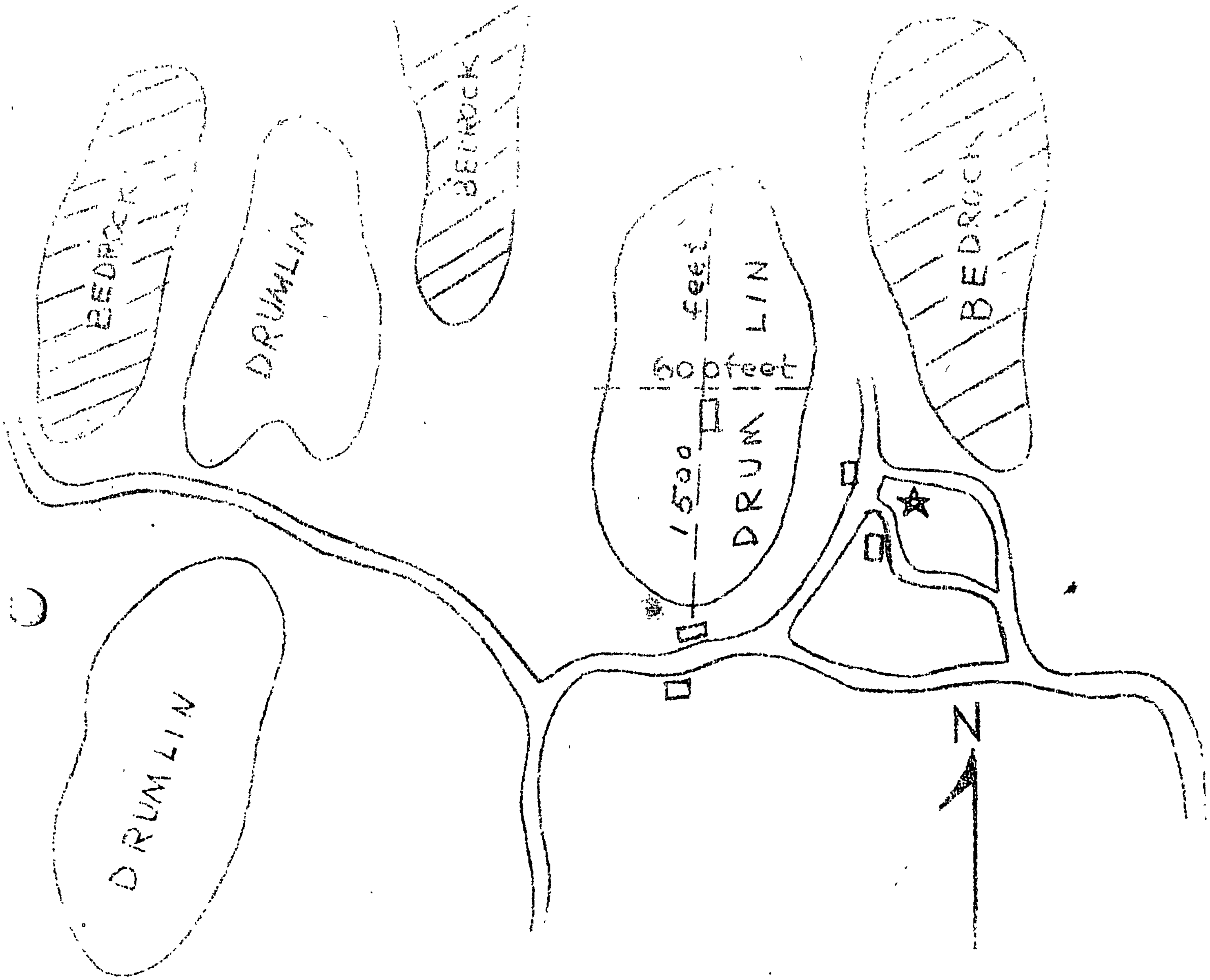
Note the direction of elongation of the striations and grooves. In what direction did the glacial ice move?

Compare this with the elongate features you will see at stop #3.

Stop #3. Drumlins

This stop is in the Black Mountain Drumlin Field near Sandanona (Experiment in International Living) on the Black Mountain Road, Brattleboro, Vermont.

Note the rounded, turtle-back shaped hill. This hill is about 1500 feet long and 600 feet wide. There are several hills of similar dimensions in the immediate area. The long dimension of each hill is aligned in a north-south direction.

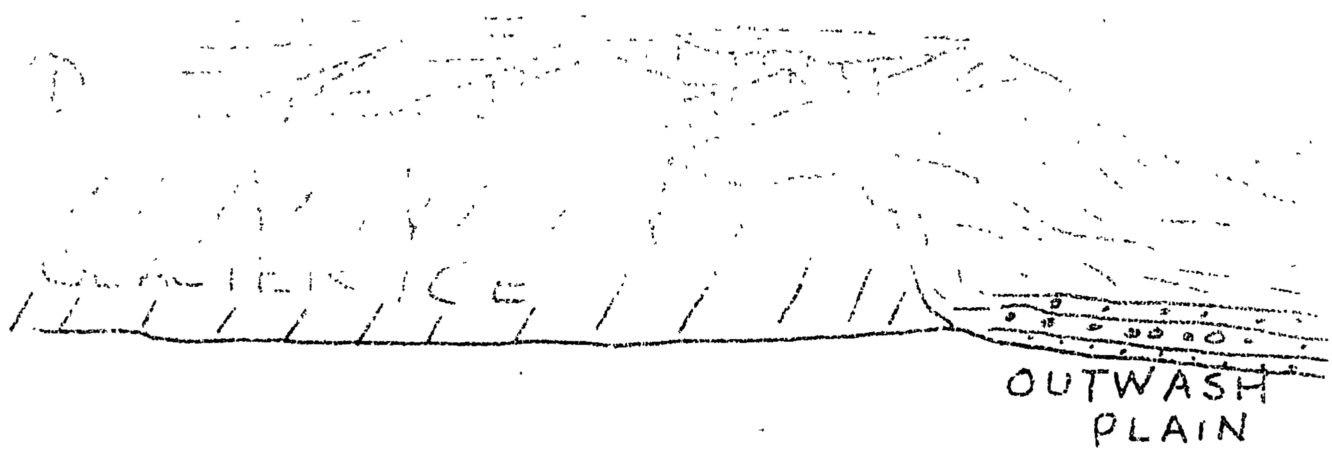


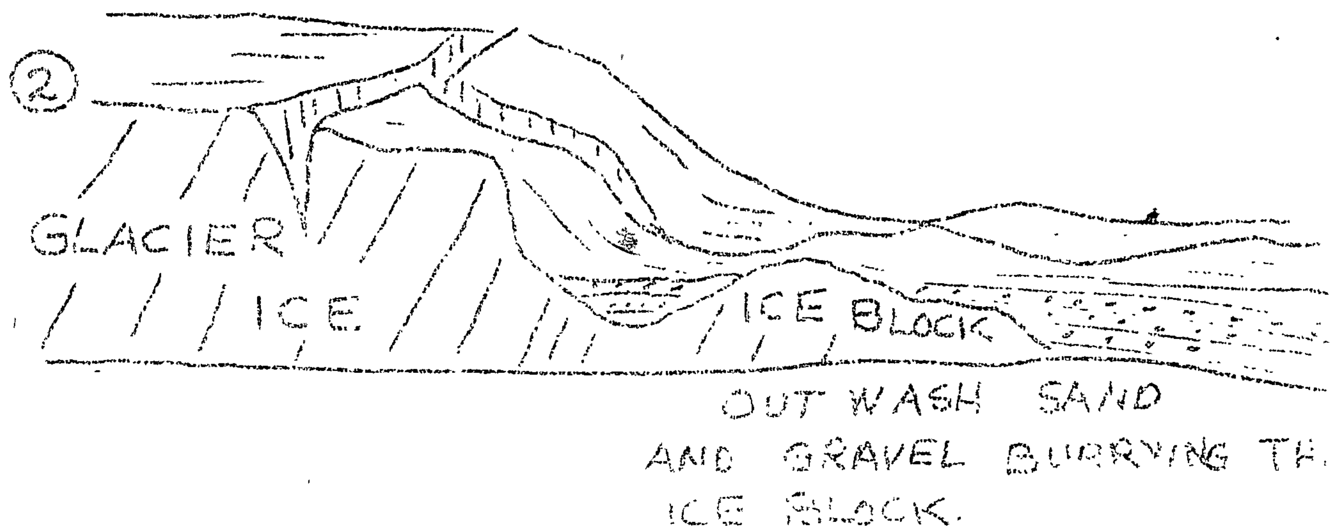
A water well drilled into this hill penetrated 300 feet of glacial till, However, the hill stands only 75-80' above the level of the parking lot (where the bus is parked).

Stop #4. Glacial Outwash sands and gravels, and a Kettle Hole depression in the outwash plain.

a. Note the stratified sand and gravel in the bank behind the Whitcomb Concrete Block Company, South Main Street, Brattleboro. These sands and gravels represent a portion of an extensive outwash plain formed by coalescing alluvial fans that spread out in front of a melting glacier as the eroded debris was carried and sorted by numerous meltwater streams. These are called GLACIO-FLUVIAL deposits.

b. Note large, circular depression in the outwash plain near the Brattleboro Union High School. There are no streams feeding into or draining out of this depression. The water represents the level of the water table in the area This depression is called a KETTLE HOLE. A kettle hole is formed when a large block of ice breaks off the front of a melting glacier and is subsequently burried by rapidly accumulating sands and gravels that form the surrounding outwash plain. As the block of ice melts, the overlying sediment slowly slumps into the void. Thus a circular depression is all that remains where the ice block once stood (see cross-sectional diagram below).


GLACIER ICE
OUTWASH PLAIN


2
GLACIER ICE
ICE BLOCK
OUT WASH SAND AND GRAVEL BURRYING TH ICE BLOCK.


3