

University of New Hampshire

University of New Hampshire Scholars' Repository

NEIGC Trips

New England Intercollegiate Geological
Excursion Collection

1-1-1987

Stratigraphy and Structure of the Sutton Area, Southern Quebec: Construction and Destruction of the Western Margin of the Late Precambrian Iapetus

Colpron, Maurice

Dowling, William M.

Doolan, Barry

Follow this and additional works at: https://scholars.unh.edu/neigc_trips

Recommended Citation

Colpron, Maurice; Dowling, William M.; and Doolan, Barry, "Stratigraphy and Structure of the Sutton Area, Southern Quebec: Construction and Destruction of the Western Margin of the Late Precambrian Iapetus" (1987). *NEIGC Trips*. 426.

https://scholars.unh.edu/neigc_trips/426

This Text is brought to you for free and open access by the New England Intercollegiate Geological Excursion Collection at University of New Hampshire Scholars' Repository. It has been accepted for inclusion in NEIGC Trips by an authorized administrator of University of New Hampshire Scholars' Repository. For more information, please contact nicole.hentz@unh.edu.

STRATIGRAPHY AND STRUCTURE OF THE SUTTON AREA, SOUTHERN QUEBEC:
CONSTRUCTION AND DESTRUCTION OF THE WESTERN MARGIN
OF THE LATE PRECAMBRIAN IAPETUS.

Maurice Colpron¹, William M. Dowling and Barry L. Doolan
Department of Geology, University of Vermont
Burlington, Vermont, 05405

Introduction:

The purpose of this excursion is to introduce the reader to the Late Precambrian/Early Cambrian stratigraphy of the Oak Hill Group in southern Québec, and to evaluate the effects of the Taconic orogeny west of the Green/Sutton Mountains anticlinorial axis (GSMA).

The Sutton area has been subject to numerous studies between 1930 and 1960 (Clark, 1934 and 1936, Eakins, 1963, Osberg, 1965, and Rickard, unpubl.). These works, particularly those of Clark (1936), established the stratigraphy of the Oak Hill Group west of the Enosburg Falls/Pinnacle Mountain anticline (EFPMA, fig.1). Fossils found within the intermediate formations of the Oak Hill Group indicate a Lower Cambrian age (Clark, 1936). These authors also mentioned the structural complexities that arise east of the EFPMA. Sudden change in the structural and thermal history occurs as one crosses the "Mansville Phase" (Clark, 1934). Rocks to the east, known as the Sutton Schists, have tentatively been correlated to the Oak Hill Group (Table I), although no real evidence is yet proposed.

The goals of current studies, north and south of the international border, are to re-evaluate the tectonic evolution along the southern arm of the Québec reentrant, to provide better constraints on possible stratigraphic link across the Sutton/Richford syncline (SRS) and to document the structural/thermal evolution west of the GSMA.

Stratigraphy:

The Oak Hill Group, as defined by Charbonneau (1980), includes 8 formations (fig.2). Because this excursion will primarily emphasize on the lower Oak Hill stratigraphy (rift-related volcanic/sedimentary facies), only five (5) formations will be describe below. The reader is refered to Clark (1936) and Charbonneau (1980) for descriptions of the upper Oak Hill formations.

¹: with permission of le ministère de l'Énergie et des Ressources, Québec.

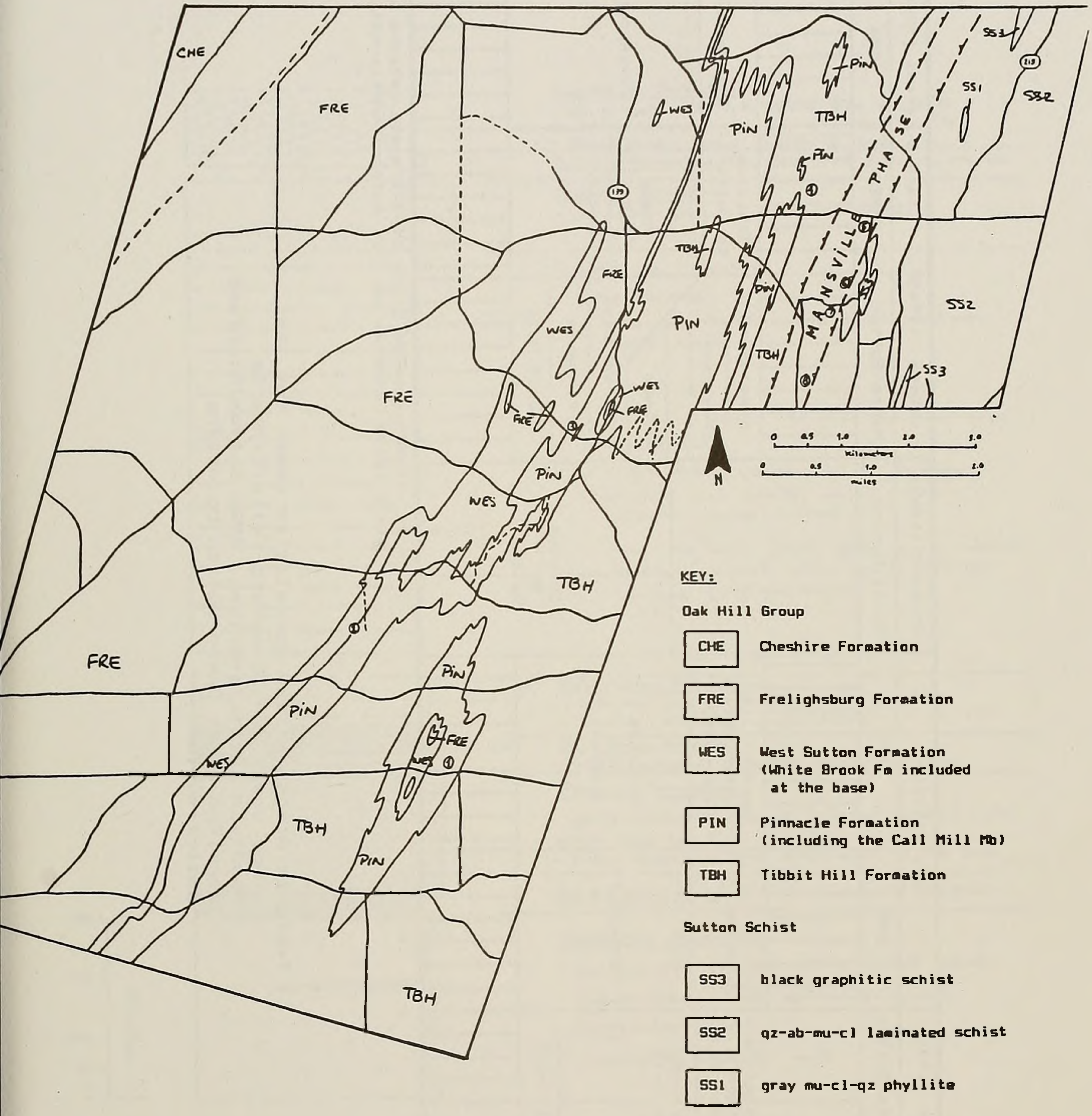


Figure 1: Geologic map of the Sutton area, southern Québec (modified after Colpron, in progress, Dowling, in progress, and Eakins, 1963).

Clark (1934)*	Clark (1934)	Cady (1960)	Rickard (1965)	Osberg (1965)	Clark & Eakins (1968)
PMA	Monts Sutton	SRS	Monts Sutton	Monts Sutton	SRS
Vail	Schistes de Sutton incluant la Phase Mansville du Groupe des Oak Hill	SMA	Schistes de Sutton	Sweetsburg incluant Scottsmore et Dunham	SMA
Sweetsburg					
Scottsmore	Sweetsburg	Mansonville inférieur (~Ottauquechee)			
Oak Hill	"Bonsecours"	Schistes de Sutton		Gilman	Schistes de Sutton
Dunham				Bonsecours	Phase Mansville (en bordure ouest)
Gilman				Pinnacle	
West Sutton				Tibbit Hill	
White Brook					Bonsecours
Pinnacle					
Call Mill					
Tibbit Hill	Tibbit Hill				

* la nomenclature de Clark (1934) a été retenue ici, étant celle adoptée par les auteurs mentionnés.

Table 1: Across strike correlation chart for the study area; PMA: Enosburg Falls/Pinnacle Mountain anticlinorium, SRS: Sutton/Richford syncline, SMA: Green/Sutton Mountains anticlinorium.

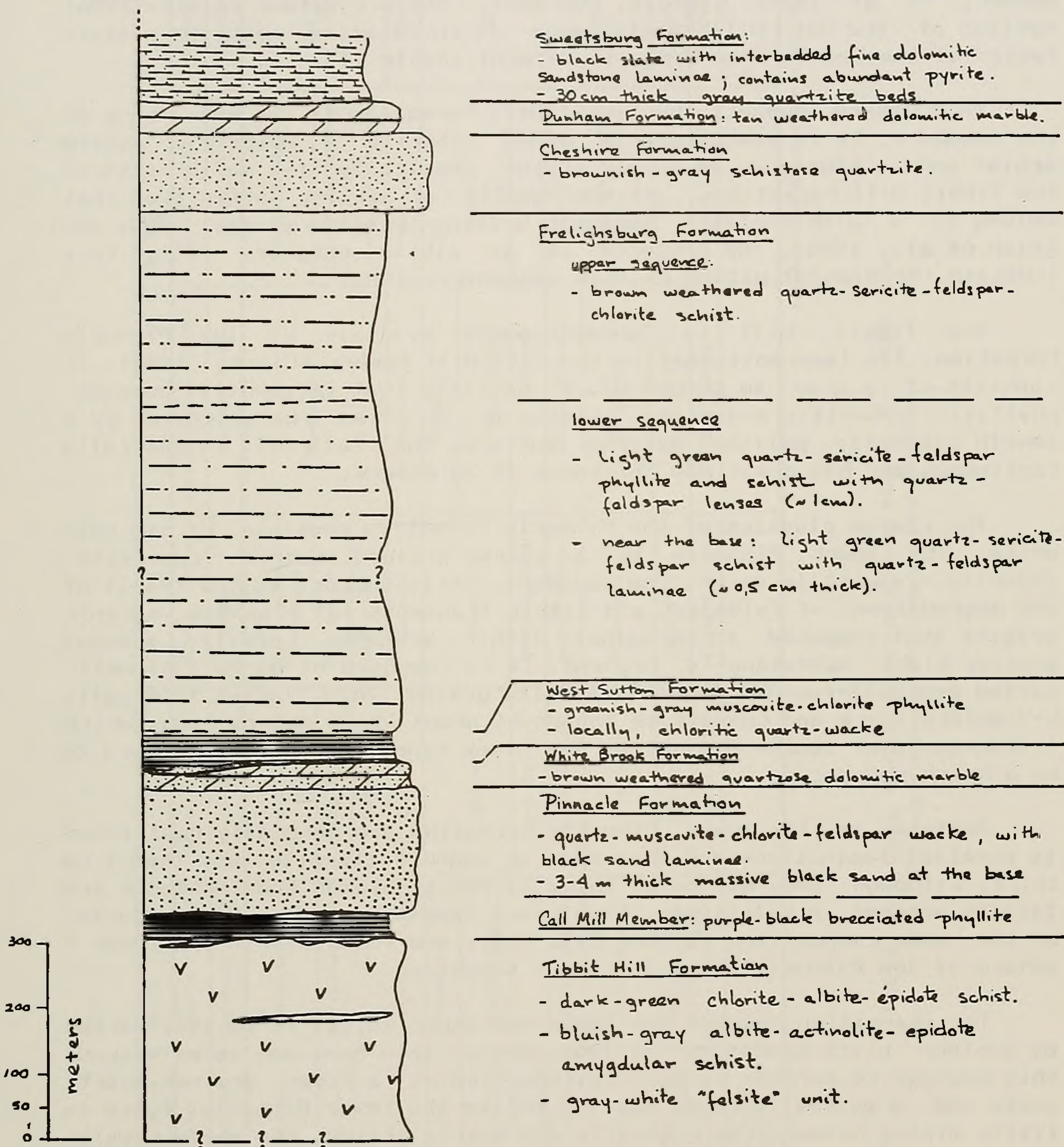


Figure 2: Stratigraphic column for the Oak Hill Group in southern Québec.

Rocks of the Oak Hill Group occupy a 15-25 kilometer wide belt that trends N20E. They lie on the western limb of the GSMA from Danville, Québec, to at least Lincoln, Vermont. The pre-Gilman (Clark, 1936) section of the Oak Hill stratigraphy is correlative with the eastern facies of the Camels Hump Group in Vermont (Table II).

In southern Québec, the Tibbit Hill Formation is the known base of the sequence. It is essentially a green chlorite - epidote - albite schist and a blue-gray amygdular schist. Chemically, the mafic rocks of the Tibbit Hill Formations are metabasalts of alkalic affinities that belong to a "within-plate" tectonic setting (Pintson *et al.*, 1985, and Coish *et al.*, 1985). The presence of an albite porphyry felsic rock indicate the bimodal nature of this volcanic suite.

The Tibbit Hill is unconformably overlain by the Pinnacle Formation. Its lowermost unit is the Call Mill Member (Clark, 1936). It consists of a gray to purple-black phyllite that frequently contains phyllitic, chloritic and slaty clasts. It is often characterized by a smooth glacially polished outcrop surface. The Call Mill is laterally continuous and has a maximum thickness of 30 meters.

The coarse clastics of the Pinnacle Formation consists of two main units. The lower Pinnacle is a coarse-grained quartz - muscovite-chlorite - magnetite wacke. The abundant matrix support is the result of the degradation of feldspars and lithic fragments (of probable volcanic origin) that composed an original lithic arenite. Locally, a basal massive black sandstone is present. It is composed of 80-90 % of well-sorted and well-rounded magneto-ilmenite grains. This facies is usually 4-7 meters thick and constitute lenses of about 25-30 meters long, which transgress over coarse graywacke. The black sandstone is interpreted to be a beach sequence.

Bedforms in the lower Pinnacle Formation are generally restricted to parallel laminations and thin beds of magneto-ilmenite less than 1 cm thick, although they may be as thick as 10 cm. Slumps and loadcasts are locally present in relatively thick black sandstone beds. Slate clasts, of the same composition as the Call Mill, are found within the lower 5 meters of the Pinnacle wacke and black sandstone.

The transition between the lower and upper units is locally marked by another black sandstone horizon. Where this horizon is not found, this passage is marked by the introduction of a finer grained quartz wacke and a muscovite-rich matrix. Unlike the lower Pinnacle, there is little mixing between the magnetite and quartz grains. The above results in better defined black sandstone beds and "cleaner" quartz wacke.

Bedforms are more abundant and varied in the upper Pinnacle. Load casts and slumps develop in magnetite beds greater than 2 cm. The crest of symmetrical ripples are rarely higher than 2 cm. Larger mega-ripples are truncated by tabular cross beds which indicate a unidirectional flow. Parallel beds and laminations are numerous. Laminations can be as thin as one grain, attesting to the remarkable sorting in this unit. The above bedforms do not correspond to any stratigraphic horizon. However, channels and dolomitic lenses are restricted to the upper 7 meters of

		V E R M O N T					Q U E B E C				
	Tauvers (1982)	Doll (1961)	Dennis (1964)	Booth (1950)	Clark (1934)	Charbonneau (1980)*	Cooke (1962)	Marquis (1985)			
Q1?	Lincoln	Centre-Sud	Sweetsburg	Nord-Ouest	Sutton	Sutton (W)	Shefford	Richmond			
			Skeel Corners		Vall						
Q2	Dunham	Clarendon Springs	Sweetsburg		Sweetsburg	Sweetsburg	Sweetsburg	Sweetsburg			
		Denby Winneeki	Bridgeman Hill	Rugg Brook	Scottsmore	Upper Mansville Phase	Upper Mansville Phase				
		Monkton	Rugg Brook Parker Dunham	Parker	Oak Hill	Scottsmore Oak Hill Dunham	Scottsmore Oak Hill Dunham				
E1	Cheshire	Dunham		Dunham	Dunham	Dunham	Dunham	Dunham			
		Cheshire	Cheshire	Cheshire	Gilman	Gilman	Cheshire	Gilman	Gilman		
HADRYNIEN	Fairfield Pond	Fairfield Pond	Fairfield Pond	Gilman	Gilman	Frelighsburg	Gilman	Gilman			
		Forestdale	White Brook	West Sutton	West Sutton	West Sutton	Lower Mansville Phase				
		Pinnacle	Pinnacle	White Brook	White Brook	White Brook	White Brook	West Sutton White Brook Pinnacle Call Mill	Pinnacle		
PE	Mount Holly Complex	Tibbit Hill	Tibbit Hill	Call Mill	Call Mill	Call Mill	Call Mill	Call Mill			
		Mount Holly Complex	?	Tibbit Hill	Tibbit Hill	Tibbit Hill	Tibbit Hill	Tibbit Hill	Tibbit Hill		

* nomenclature adoptée pour ce rapport

Table 2: Along strike correlation chart for the Oak Hill Group between Vermont and Québec.

the Pinnacle Formation. The Pinnacle Formation is 150-190 meters thick.

The Pinnacle Formation is overlain by the White Brook Formation. This unit is a brown-weathering sandy dolomitic marble. Detrital magnetite is never present. The White Brook is one of the best stratigraphic markers because of its high resistance to erosion. Locally, a basal dolomitic sandstone is present in the White Brook Formation. In some place, a black hematiferous slate is abundant. The White Brook has a maximum thickness of 30 meters, but is highly variable and becomes discontinuous near the international border.

Another hematiferous slate horizon (30 cm thick) is locally present at the base of the West Sutton Formation. However, the West Sutton is typically a silver- to greenish-gray phyllite. A chloritic wacke is also associated with the West Sutton Formation. This formation has a maximum thickness of 30-40 meters.

The West Sutton pass into the Frelighsburg Formation. In the course of this excursion, only the lower Frelighsburg will be observed. It is a pale green phyllite that weathers orange. The lower Frelighsburg is characterized by the presence of millimetric to centimetric quartzo-feldspathic lenses. Fine euhedral crystals of magnetite or pyrite are abundant. Larger pyrite cubes are replaced by limonite, conferring a "spotty" aspect to this rock. The quartzo-feldspathic lenses are the result of two successive transposition of thin silty beds.

The presence of pillow structures in the Tibbit Hill Formation indicates that at least part of the volcanic pile was extruded in a subaqueous environment. Whether the entire Tibbit Hill was subaqueous is problematical. The chemical affinity of these rocks, their bimodal nature, and the geometric distribution and thickness indicates that the Sutton area was the focal point of rifting in the Québec re-entrant during late-Hadrynian time (Kumarapeli *et al.*, 1981, Williams, 1978, and Rankin, 1976). In such an environment high heat flow will prohibit the initial subsidence of surrounding terrane. Evidence for slow subsidence is seen in the overlying clastic sequence.

The lateral continuity of the Call Mill Member indicates that volcanic activity ceased prior to Call Mill time. The upper contact is interpreted to be erosional because of its sharp nature and the presence of slate clasts in the lowermost Pinnacle Formation. The Pinnacle time represents the beginning of clastic sedimentation. The abundance of chlorite matrix in the lower Pinnacle section suggests the subaerial exposure and erosion of volcanic terranes (Tibbit Hill Formation). The peneplanation of the volcanic terranes occurred during middle Pinnacle time, as indicated by the scarcity of matrix in the upper unit.

Several lines of evidence suggest a static, shallow water, high energy environment through Pinnacle time. The presence of heavy minerals and the deposition of these as beach placers is found throughout the Pinnacle Formation, indicating the proximity to a shoreline. A shallow water environment is further suggested by the appearance of dolomitic lenses in the uppermost Pinnacle. The absence of "shale" horizons and the bedforms in the upper Pinnacle implies constant reworking and

winnowing of sediments.

The calcareous cement of the uppermost Pinnacle and the occurrence of dolomitic lenses indicates that there is no time gap between the reworking of the last Pinnacle sediment and the deposition of White Brook lithologies. The presence of hematiferous slate within and on top of the White Brook suggest a deeper environment. Passage into the West Sutton "shale" agree with this interpretation. The chloritic wacke associated with the West Sutton Formation probably results from storm generated reworking of Pinnacle sediments deposited in a more distal environment, attesting for the paucity of heavy minerals.

We believe that a "rapid" episode of subsidence began during White Brook time. Subsequent units record a deeper or more distal environment. In this context, the Frelighsburg Formation is interpreted as a distal turbidite, where thin silty horizons are interbedded in a shaly matrix. Transition from initial to thermal subsidence occurred during middle Frelighsburg time as indicated by the coarsening upward sequence of this formation.

The same stratigraphy is preserved within the "Mansville Phase", east of the EFPMA. However, the units are considerably thinner there (table III). Only the Pinnacle Formation presents a different aspect. It is a dark gray dirty sandstone with millimetric clean quartzite laminae. On the east side, the "Mansville Phase" is bordered by a rusty weathering black graphitic phyllite. This phyllite often contains millimetric to centimetric quartzo-feldspathic beds. Pyrite molds are common.

East of the "Mansville Phase", the rock assemblage is known as the Sutton Schist. This "group" includes some black graphitic schist (similar to those of the "Mansville Phase"), a quartzo-feldspathic gneiss (?), a quartz - albite - tourmaline meta-arkose, an albite porphyroblasts greenstone, a silver-gray muscovite - quartz schist, some laminated quartzite and a quartz - feldspar - muscovite - chlorite laminated schist (similar to the Frelighsburg). No stratigraphy of the Sutton Schist have been established yet. However, current work indicate that some of these units are continuous and may eventually lead to the definition of a stratigraphy. The aim of such work is to compare a possible stratigraphy of the Sutton Schist with the well established series of the Oak Hill Group.

Historically, correlations with the Oak Hill Group (Table I) have been supported by the low chemical maturity of metaclastics and the presence of metavolcanic and some marble horizons (Clark, 1934). The chemistry of greenstones indicates that they were extruded through a thinner continental crust than the Tibbit Hill (Coish et al., 1985). Therefore, the Sutton Schist may record a later stage of rifting and should not be envisaged as time correlative with the Oak Hill, at least for the pre-drift section. However, some distal equivalent of the drift facies of the Oak Hill Group might be present in the Sutton Schist (e.g. black graphitic schist \approx Sweetsburg Formation; qz-fd-mu-cl laminated schist \approx Frelighsburg Formation ?). Constraints on environment may be provided by the presence of tourmalinite laminae in several lithologies.

TABLE 3: Comparison of thicknesses between the "normal" sequence of the Dak Hill Group (e.g. west of the EFPMA) and the "Mansville Phase". Thickness in meters.

Normal	Lithology	Mansville Phase
606 +	Frelighsburg Fm	?
10-40	West Sutton Fm	?
6-30	White Brook Fm	< 17
150-190	Pinnacle Fm	< 10
0.3-30	Call Mill Mb	0-6
?	Tibbit Hill Fm	?

Chown (1987) reports tourmalinite from environment subjected to partial evaporation. A similar origin for the tourmalinites of the Sutton Schist is compatible with a rift environment.

Structural geology:

The Sutton area has undergone three phases of deformation. The first one is represented by the S_1 schistosity. S_1 is best developed in phyllitic rocks. In the "Mansville Phase", the early schistosity is ubiquitous. Although F_1 folds are rarely observed, the map pattern suggest the presence of an early folding event. The transposition of S_1 along the S_2 cleavage is probably responsible for the obliteration of the early folds at mesoscopic scale.

The dominant cleavage, S_2 , is a crenulation cleavage axial planar to tight to isoclinal folds. F_2 folds dominate the map pattern. Muscovite recrystallization along the S_2 plane increases eastward. S_2 defines a cleavage fan centered on the EFPMA (fig.3). This anticline is a second phase structure. In the "Mansville Phase" important slip along S_2 results in the shearing of the limbs of F_2 folds.

A late "fracture cleavage" (S_3) is sparsely developed west of the EFPMA. To the east, F_3 open folds and undulations deform anterior structures. The third phase is responsible for the formation of the GSMA. The last two phases of deformation are dated to be Taconic in age (Rickard, 1965).

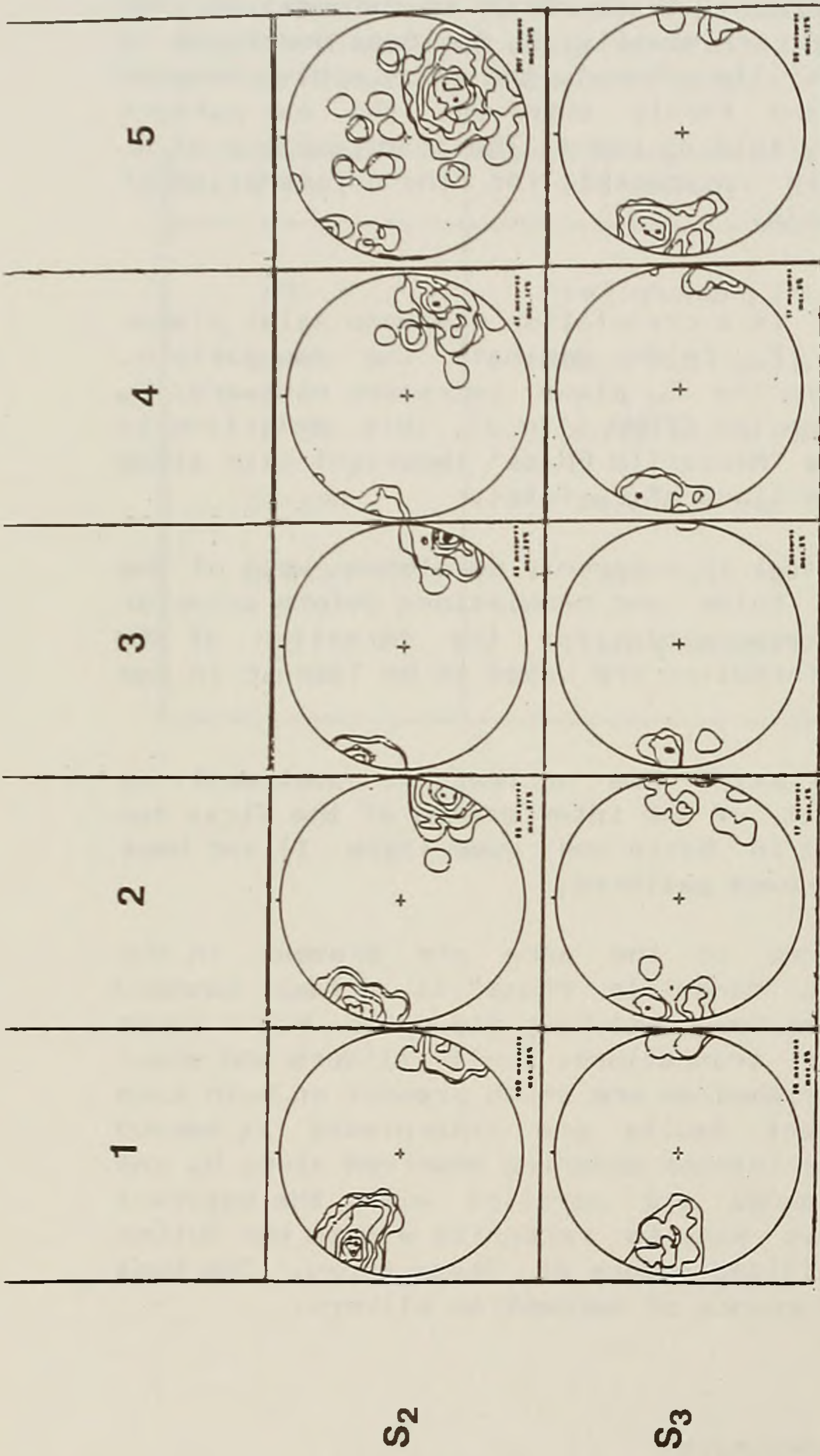
The change in plunge of F_2 axis, from northeast to southwest, is interpreted here as the result of the interference of the first two phases of deformation. This issue in basin and dome (type 1) and hook (type 2, Thiessen, 1986) interference patterns.

The main brittle structures in the area are present in the "Mansville Phase". In fact, this "Mansville Phase" is a fault-bounded zone within which intense shearing and stretching did occur. Fault zones are illustrated by stratigraphic truncations, fault slivers and shear fabrics (C/S). Small magnetite octahedron are often present on both side of the fault contact. The dominant faults are interpreted as second phase structure, because of the intense shearing observed along S_2 and the fact that sides of shear bands are parallel with the dominant cleavage. Fault zones are not as easy to recognize within the Sutton Schist, due to the more recrystallized nature of these rocks. The best indicator of fault zone is the presence of serpentine slivers.

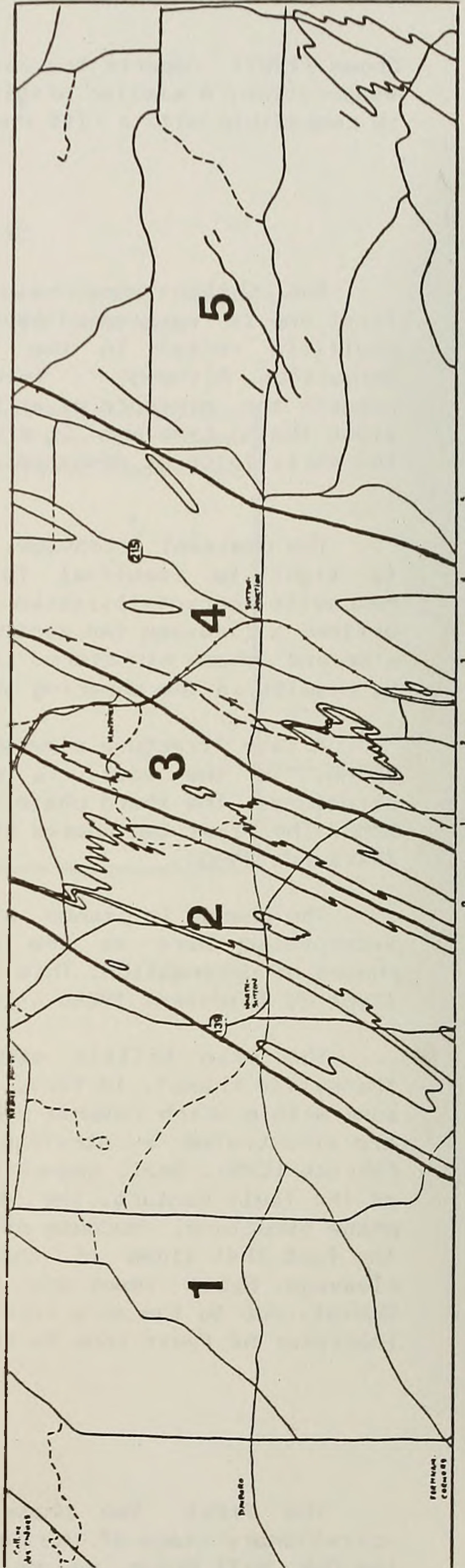
Discussion:

The first two phases of deformation are related with the accretionary stage of the Taconic orogen. Geophysical data suggest that the Oak Hill Group may still be rooted (St-Julien *et al.*, 1983), being

Figure 3: Equal-area stereonet of poles of S_2 and S_3 for the different structural domains. Contours are of 1, 2, 5, 9, 15, 20 and 30 percent per 1 percent area.



DOMAINES STRUCTURAUX



transported on a basement slice in a later stage of accretion.

Although few indications of the first phase (D_1) are observed in the field, we believe that F_1 folds and S_1 schistosity are related with the emplacement of nappes. Relative timing of the D_1 episode with respect to the external domain is constrained by the fact that the D_1 stage Stanbridge nappe is thrust over by the Oak Hill Group along a second phase fault (Charbonneau, 1980).

S_2 fanning developed contemporaneously with folds and thrusts of second generation (D_2). This is indicated by parallelism of this cleavage with fault structures. Backthrusting along the "Mansville Phase" is interpreted to be coeval with westward thrusting at the toe of the Oak Hill "slice". Conjugate fault system appears to develop preferentially in the surficial part of the orogen. Away from the master décollement (e.g. the sole of the Oak Hill slice), the backward component becomes more important. The Sutton area is considered to lie at intermediate crustal level, where both types of structure are developed. In this context, the "Mansville Phase" is a 500 meter-wide shear zone where deformation took place by intense shearing and stretching.

Preliminary work on metamorphism supports this evolution. Rocks of the Oak Hill Group were first subject to higher metamorphic grade (upper greenschist ?) during D_1 thrusting, being buried beneath the allochthons. D_2 deformation brought up the Oak Hill Group in a "pop-up" fashion along the conjugate fault system, as attested by the chlorite grade, lower greenschist metamorphism. More intense recrystallization of the Sutton Schist results from deeper environment during D_1 as well as D_2 underthrusting.

The last phase (D_3) records the final collision of the island-arc with the continental margin. Broad arching, in the Sutton area, exposed biotite grade rocks in the core of the GSMA.

Conclusion:

The lower Oak Hill Group records the early stage of rifting during the late Precambrian opening of Iapetus. Sedimentology of the Pinnacle Formation indicates a static shallow water and high energy environment, attesting to a low rate of initial subsidence. This contrasts with the sedimentology of the Pinnacle sequence in central Vermont (Dowling *et al.*, 1987). Such contrast is explained by the relative position of the basin to the focal point of rifting, where a thermal bulge is expected to form. The Sutton area is then interpreted to be in proximity to the paleo-position of the triple junction that generated the Québec reentrant.

These rocks were later involved in the three phases of deformation of the Taconic orogeny. The dominant structural features of the area result from the second phase. Deformation was concentrated within specific zone of high strain like the "Mansville Phase".

Bibliography:

- Charbonneau, J.-M., 1980 - **Région de Sutton**. Ministère de l'Énergie et des Ressources, Québec, DPV-681, 89 pages.
- Chown, E.H., 1987 - **Tourmalinites in the Achebian Mistassini Group, Quebec**. Canadian Journal of Earth Science, v.24, n.4, p. 826-830.
- Clark, T.H., 1934 - **Structure and stratigraphy of southern Quebec**. Geological Society of America Bulletin, v.45, p. 1-20.
- _____, 1936 - **A Lower Cambrian Series from southern Quebec**. Transaction of the Royal Canadian Institute, n.45, v.21, part I, p. 135-151.
- Coish, R.A.- Fleming, F.S.- Larsen, M.- Poynes, R.- Seibert, J., 1985- **Early rift history of the Proto-Atlantic ocean: geochemical evidence from metavolcanic rocks in Vermont**. American Journal of Science, v.285, p. 351-378.
- Dowling, W.M.- Colpron, M.- Doolan, B.L., 1987 - **The Oak Hill Group, southern Quebec and Vermont: along strike variations across a late-Precambrian rift margin**. Geological Society of America, Abstract with Program, v.19, n.1, p. 11.
- Eakins, P.R., 1963 - **Sutton map-area, Quebec**. Geological Survey of Canada, Study 63-34, 3 pages.
- Kumarapeli, P.S.- Goodarce, A.K.- Thomas, M.D., 1981 - **Gravity and magnetic anomalies of the Sutton Mountains region, Quebec and Vermont: expressions of rift volcanics related to the opening of Iapetus**. Canadian Journal of Earth Science, v.18, no.4, p. 680-692.
- Osberg, P.H., 1965 - **Structural geology of the Knowlton-Richmond area, Quebec**. Geological Society of America Bulletin, v.76, p. 223-250.
- Pintson, H.- Kumarapeli, P.S.- Morency, M., 1985 - **Tectonic significance of the Tibbit Hill Volcanics, geochemical evidence from Richford area, Quebec**. Current Research, Part A, Geological Survey of Canada, paper 85-1A, p. 123-130.
- Rankin, D.W., 1976 - **Appalachian salients and recesses: late Precambrian continental breakup and the opening of the Iapetus ocean**. Journal of Geophysical Research, v.81, n.32, p. 5605-5619.
- Rickard, M.J., 1965 - **Taconic orogeny in the western Appalachians: experimental application of microtextural studies to isotopic dating**. Geological Society of America Bulletin, v.76, p. 523-536.
- St-Julien, P.- Slivitsky, A.- Feininger, T., 1983 - **A deep structural profile across the Appalachians of southern Quebec**. in Contribution to the tectonics and geophysics of mountain chains, ed. by R.D. Hatcher Jr, H. Williams and I. Zietz, Geological Society of America, Memoir 158, p. 103-111.

Thiessen, R., 1986 - **Two-dimensional refold interference patterns.**
Journal of Structural Geology, v.8, n.5, p. 563-573.

Williams, H., 1978 - **Tectonic lithofacies map of the Appalachian orogen.**
Memorial University of Newfoundland, map no.1a, scale 1:2 000 000.

Itinerary:

Assembly point is the restaurant Chez Camil, Sutton, Québec, on route 139, 10.8 km north of the Richford custom station. Parking space is available in the commuter lot, few meters to the northeast of the restaurant (fig.4). Starting time is 9:00 AM. Topographic map: Cowansville 30' quadrangle (NTS 31H/2; 1:50 000).

kilometers

- 0.0 From the parking lot in Sutton, take left on route 139 (south).
- 4.4 Take right on Alderbrook road.
- 5.1 Turn left on Perkins road.
- 9.3 STOP 1: 50 m after the junction of Perkins and Three Parish roads (to the left) park cars on the side of the road near the driveway that lead to the Ross farm. Take driveway to the farm house and ask permission to get in the woods in back of the farm.
- The hill back to the farm display the complete stratigraphy of the lower Oak Hill Group exposed on the overturned limb of a basin. Climb the hill from the eastern side; refer to text for details on the stratigraphy and sedimentology of the lower Oak Hill Group.
- At the end of the traverse, return to cars and continue westward on Perkins (at this point, Grande Ligne) road.
- 13.6 Take left on Russel road.
- 14.8 At the intersection of Russel and Jordan roads, turn right and then left on Dymond road (50 m).
- 17.0 Turn right on McCullough road.
- 19.6 Take right on Strobl road. Drive up to the end of this road.
- 20.2 STOP 2: Park cars off the road near the house of Kara and Gail Chaplin-Szathmary. Ask permission to get at the outcrop located in the backyard. **HAMMERS ARE PROHIBITED ON THIS OUTCROP.**

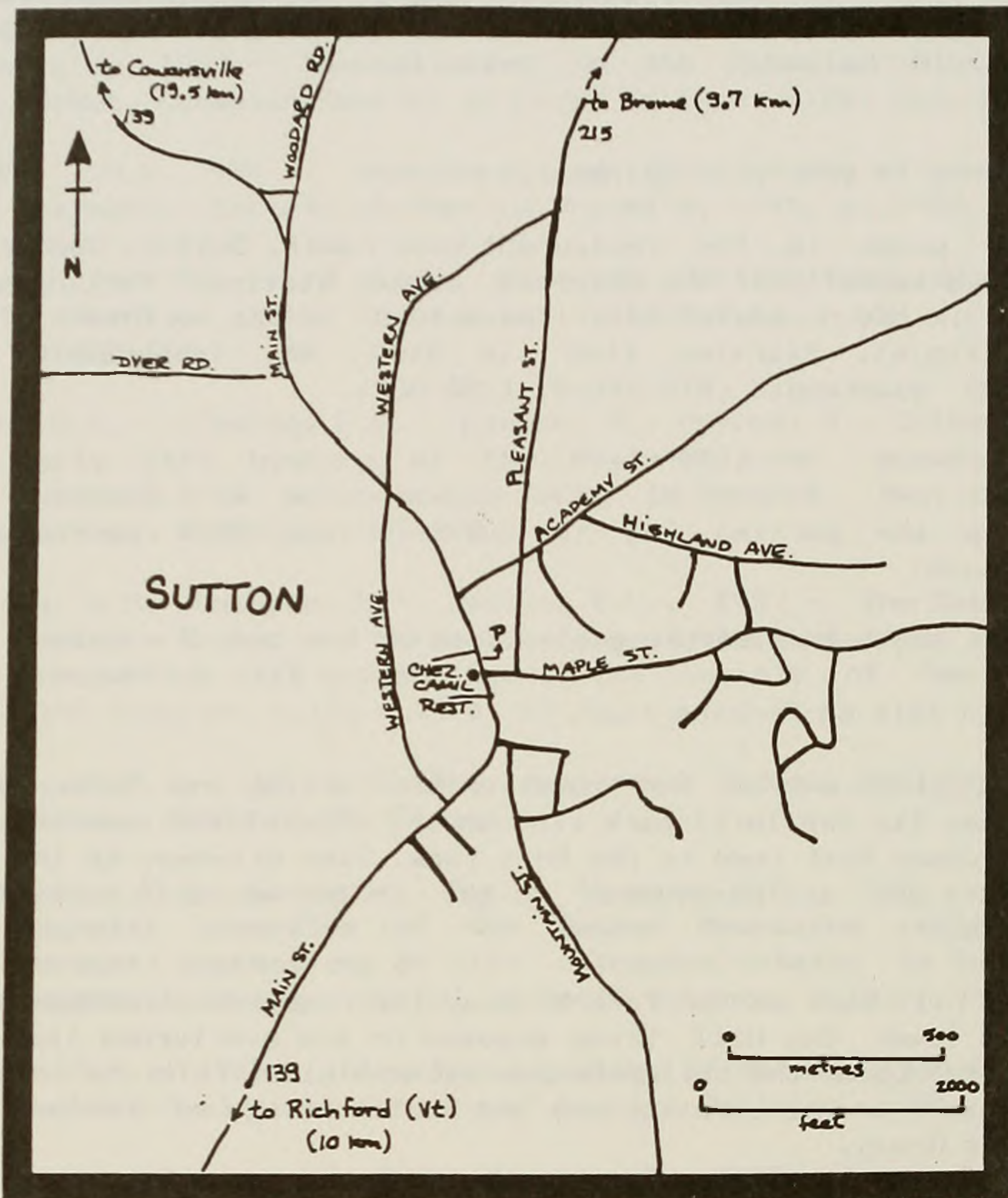


Figure 4: Detail map of the town of Sutton, Québec. The commuter parking lot is indicated by a "P".

This locality exhibits the numerous sedimentary features encountered in the upper Pinnacle Formation. Contact with the White Brook Formation is exposed at the northwest end of the yard. Note the abundance of black sandstone, the presence of dolomitic sandstone lenses in the Pinnacle and the transitional clean sandstone near the contact.

We will eat lunch at this locality. After lunch drive back Strobl road and take right on McCullough.

25.1 At the T intersection, turn left on Alderbrook road.

27.8 Take left on Macey road at the road crossing at West Sutton.

28.1 STOP 3: Park cars in front of the outcrop located on Mr. Hamel's property. This is only a short stop to illustrate the style of folding associated with D_2 structures of the western limb of the EFPMA. Folds are defined by black sandstone beds of the upper Pinnacle Formation. At this locality, a small basin is cored by the White Brook and West Sutton Formations.

Going southeatward from the Pinnacle exposure, get in the White Brook Formation. Note the presence of thin "seams" of hematiferous slate and the numerous quartz veins. Then, going northeastward, get in a small open pit. The floor of the dugged area is composed of chloritoid-bearing West Sotton phyllite.

From this locality continue westward on Macey road.

31.0 Take right on North Sutton road.

33.9 Cross the intersection at North Sutton and get on route 139 eastward.

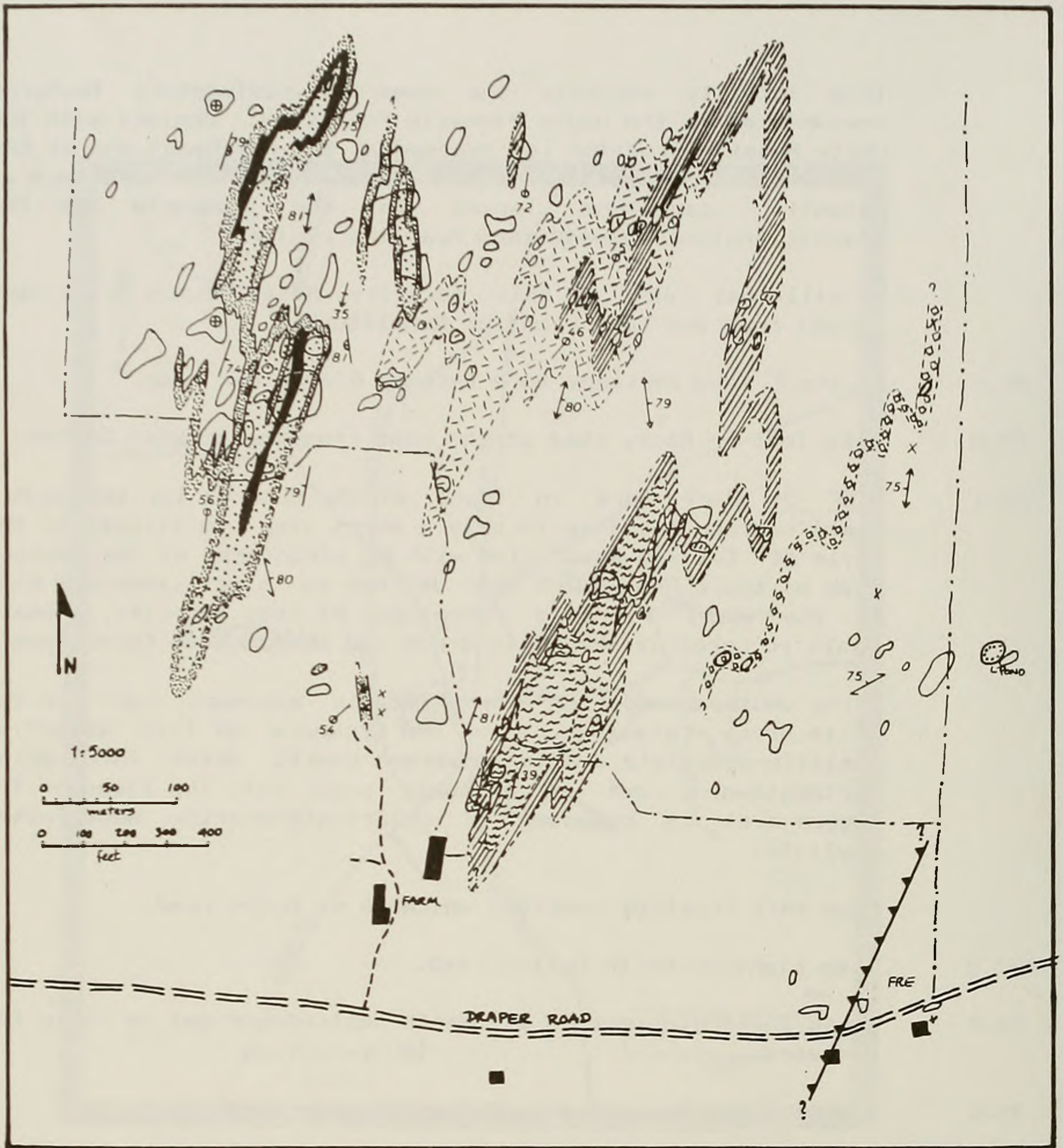
35.0 Take left on Draper road at the "Y" intersection.

36.4 STOP 4: After the end of paved road, take left on the second driveway (Hathaway Farm). Park cars on the left side of the barn. Ask permission to get in the pasture.

This locality display the various facies of the Tibbit Hill Formation. See figure 5 for the location of the different facies and particular features. The western end of the pasture exhibits a small double basin cored by the lower Pinnacle Formation.

From the Hathaway Farm, take left on Draper road. The next four stops will illustrate the structural features of the "Mansville Phase".

37.4 Turn left on Woodard road.



KEY:

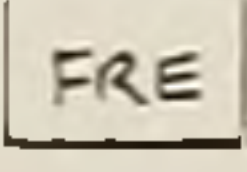
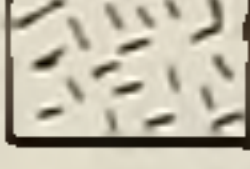

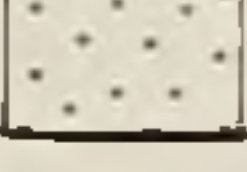
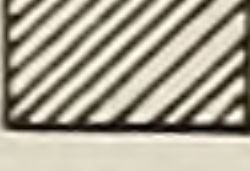
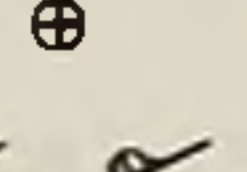

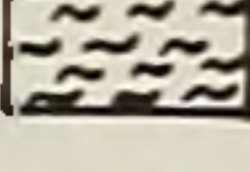
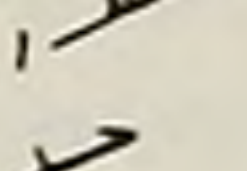

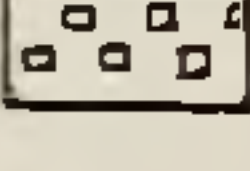
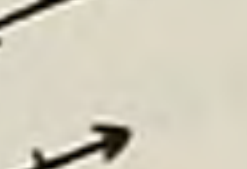

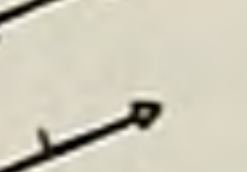

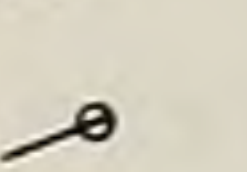

- | | | | | | |
|---|---|--|---|---|--|
|  FRE | FREIGHTSBURG Fm. |  | gray amygdalar schist
(TIBBIT HILL Fm.) |  x | outcrop. |
|  | Qa-Cl-Mt wacke
(lower PINNACLE Fm.) |  | blue amygdalar schist
(TIBBIT HILL Fm.) |  ⊕ | pillows location. |
|  | massive black sandstone
(lower PINNACLE Fm.) |  | laminated Cl-Ab schist
(TIBBIT HILL Fm.) |  | bedding plane, with top. |
|  | black phyllite
(CALL HILL Mb.) |  | felsic rock
(TIBBIT HILL Fm.) |  | early schistosity (S ₁) |
|  | massive Cl-Ab schist
(TIBBIT HILL Fm.) | | |  | slip cleavage (S ₂) |
| | | | |  | late cleavage (S ₃) |
| | | | |  | S ₁ /S ₂ intersection lineation
(L ₂) |
| | | | |  | stretching lineation |

Figure 5: Detail geologic map of the pasture at the Hathaway Farm (STOP 4).

- 37.6 STOP 5: Park cars on the right side of the road at the end of the first field. Walk up to the second field, then, along the northern edge, reach the corner of the field. Follow the red flags up to the trail. Refer to figure 6 for outcrop location.

This locality present a small fault-bounded refolded syncline that exhibits the stratigraphy of the Oak Hill Group within the "Mansville Phase". Note the thickness of the different units.

After this stop, continue southward on Woodard road.

- 38.6 Take right on Hivernon road, then left on Godue street (38.7). Climb up the hill and turn left on Harvey street (39.1). Park cars on side of the street.

STOP 6: Walk back to the intersection of Godue and Harvey. A black graphitic schist containing centimetric quartzofeldspathic laminations is exposed in the right-side ditch. S_1 , S_2 and S_3 are observed in this outcrop. The same rock is exposed on both side of the house facing Godue street. On the left side, at the end of the driveway, the same structures are present. From this outcrop westward, go to the end of the yard. A few greenstone outcrops are visible. Regional mapping indicates that they are the exposed part of a fault sliver of the Tibbit Hill Formation. Here the Tibbit Hill is bounded by the Frelighsburg Formation and the black graphitic schist (a possible correlative of the Sweetsburg Formation).

From this locality, continue westward on Harvey street.

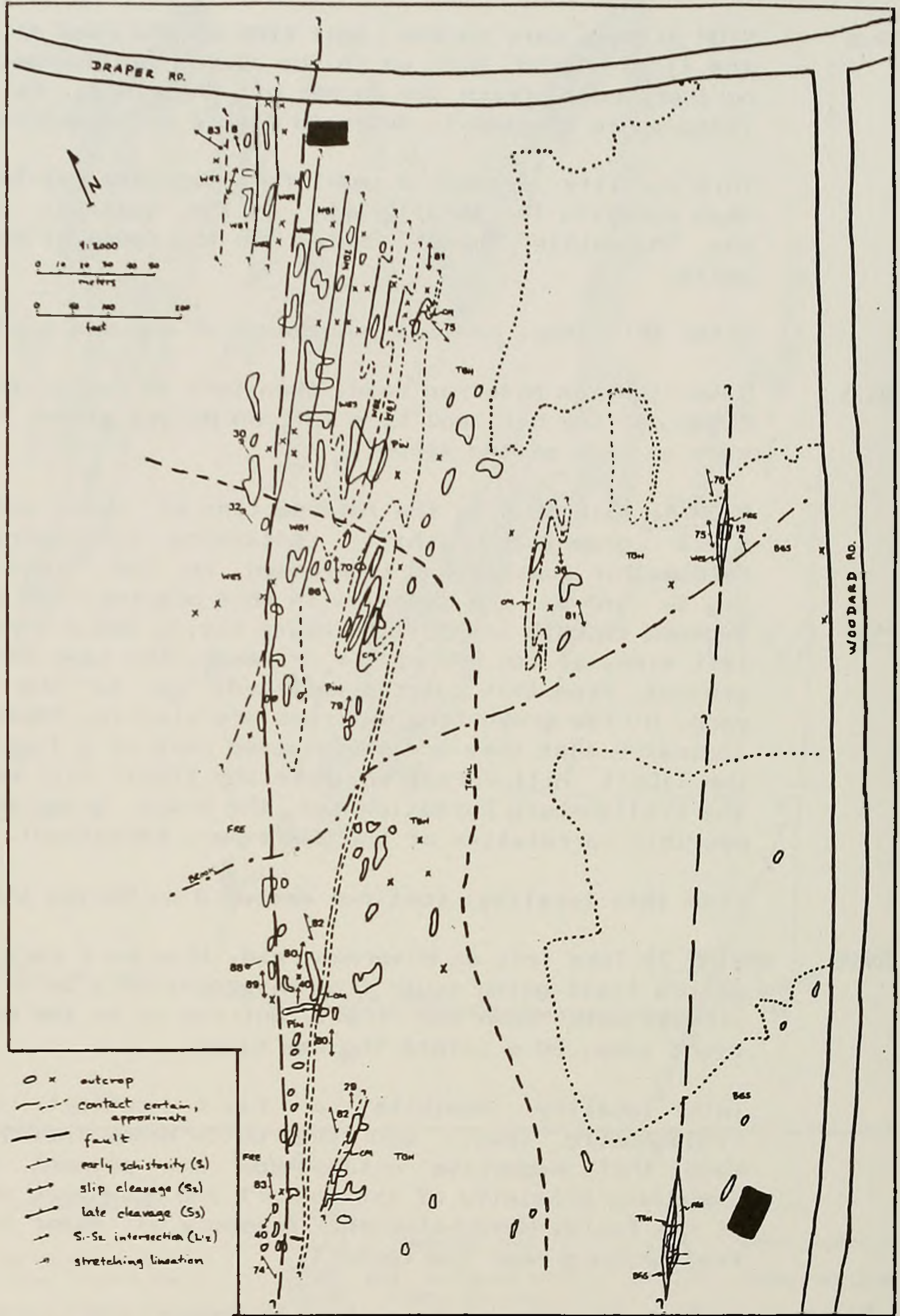
- 39.7 STOP 7: Take left on Hivernon road, then park cars on the side near a trail going south from Hivernon, 30 m before Asa Frary street. Walk down the trail. Outcrop is in the woods, on the right side, 20 m before the bee hives.

This locality exhibits a fault contact between the Frelighsburg (east) and the White Brook (west) Formations. Note that magnetite octahedrons are present only in the immediate proximity of the contact and developed on both sides of the fault. Note also the presence of shear bands in the Frelighsburg near the contact.

Go back to cars and drive back Hivernon road to Harvey street, and take left toward route 139. Go southward on route 139.

- 41.2 STOP 8: Turn left in the parking lot at the Rocher Bleu golf course. Park cars.

The lawn in back of the parking lot exhibits several small outcrops of White Brook dolomite. At the eastern edge, it is possible to follow the same contact between the White Brook and the Frelighsburg as observed at locality 7. Note again the presence of magnetite octahedrons in both lithologies.



KEY

BGS black graphitic schist	WB1 dolomitic sandstone (WHITE BROOK Fm.)
FRE FRELINGSBURG Fm.	PIN PINNACLE Fm.
WES WEST SUTTON Fm.	CM Call Mill Mb.
WB2 dolomitic marble (WHITE BROOK Fm.)	TBM TIBBIT Fm.

Figure 6: Detail geologic map for part of the "Mansville Phase" (STOP 5). Approximate scale: 1:2500.

Going down the hill, along the southern side of the fairway, the first outcrop present is a highly sheared lithology that may belong to either the West Sutton or Frelighsburg. Note the nose of small F_2 folds preserved between two S_2 -slip planes.

From the golf course, take route 139 south to Sutton.

44.0 Return to the commuter parking lot in Sutton.

The itinerary for Trip C-6 starts on page 314. The introductory article for this trip, the itinerary for Trip B-8, and the articles by Laird and Coish are all assembled as a package.