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INTRODUCTION

The geology of Conanicut Island was mapped by Dale (1885a, 1885b). He correctly differentiated the phyllites of southern Conanicut Island from the flora-rich schists of the Pennsylvanian Rhode Island Formation that make up its northern half (Fig. 1). He did not, however, have a basis for age designation but determined that they were lithologically unlike the fluvial metasedimentary rocks of Pennsylvanian age. Subsequent mapping by Nichols (1956) included the phyllites as part of the Rhode Island Formation and these results were incorporated in the geologic map of Rhode Island (Quinn, 1971).

Skehan and others (1976, p. 459) noted that "the structural features at Beavertail suggest that the rocks may have a history of repeated deformation that is more complex than other parts of the Narragansett Basin and may therefore antedate the fossiliferous schist (of Pennsylvanian age) of Northern Conanicut Island near Jamestown." Subsequently trilobites yielded a Middle Cambrian age (A. T. Smith, 1977; Skehan and others, 1978). Field mapping, sedimentational, and structural studies continue.

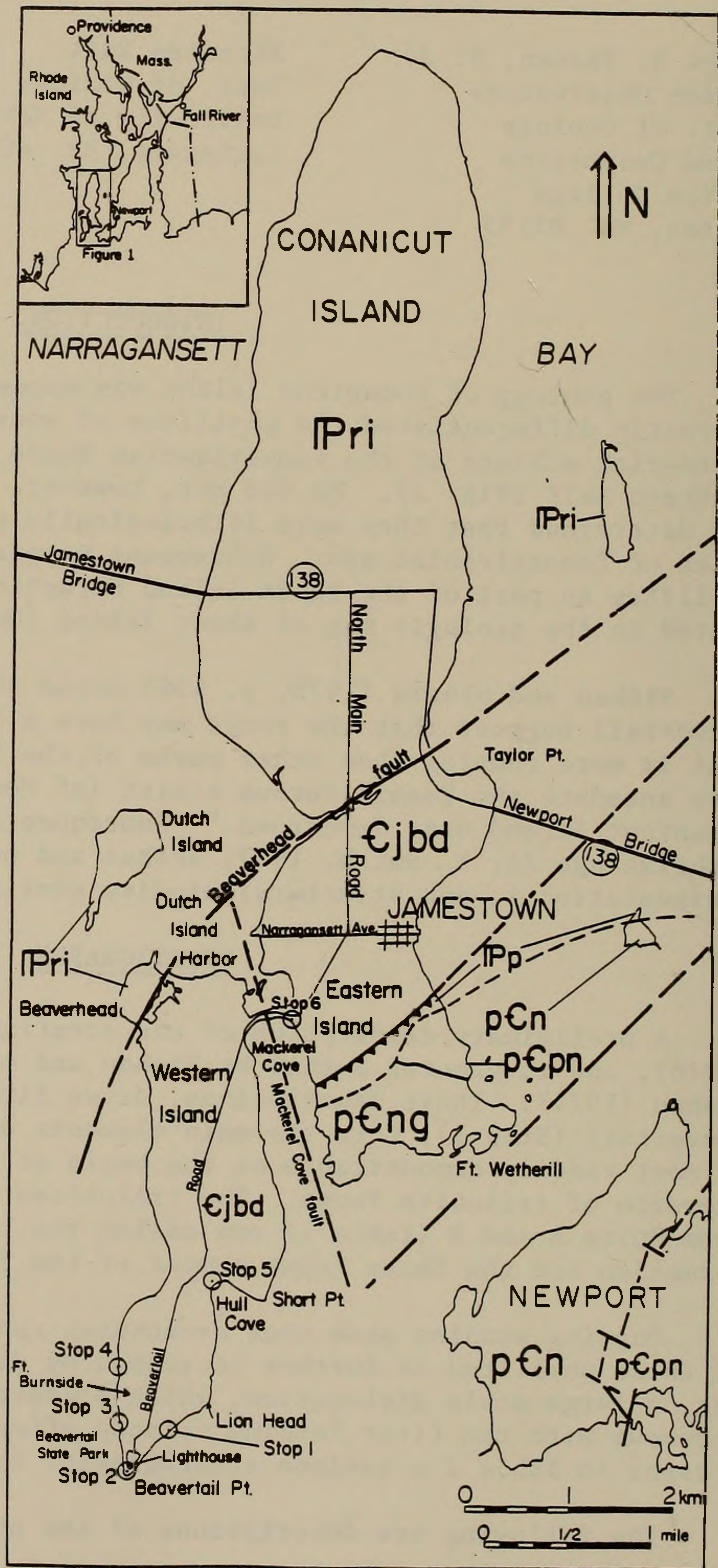
STRATIGRAPHY

A preliminary description of the stratigraphy was given by Skehan and others (1976), and in greater detail by Skehan and others (1978), and by Murray and Skehan (1979). These descriptions, drawn first from the southeastern shore of Beavertail (Stop 1), form the main elements of the stratigraphic succession which is most readily demonstrable on the basis of sedimentary facing criteria and the presence of trilobite fauna. The trilobites diagnostic of age have been derived from Units A and B (Table 1) now called the Lion Head member of the Jamestown formation and the Short Point member of the Fort Burnside formation respectively.

Ongoing studies show that structural complexity due to polyphase folding of these phyllites is further increased by displacements due to tectonic sliding, a large scale dislocation, which predates but may be approximately synchronous with the first folding episode affecting these Cambrian rocks. We present in Table 1 a revised stratigraphic correlation.

The following are descriptions of the stratigraphic units:

Figure 1. Generalized geological and location map showing the distribution of Cambrian rocks of Conanicut Island, Narragansett Bay with respect to Precambrian and Pennsylvanian; showing the location of Stops and type localities of Cambrian units, Ꞓjbd. pꞒn - Newport formation; pꞒpn - Price's Neck formation; pꞒng - Newport granite; Pp - Pondville Formation; Pri - Rhode Island Formation.



Jamestown formation

The Jamestown formation forms the basal part of the Cambrian succession. Nowhere, however, are all three of the members in stratigraphic contact with each other and therefore the stratigraphic position of the Lion Head member, which contains the age diagnostic trilobites, is inferred but not known with certainty. However, on the basis of data from Stop 6 the Hull Cove member is placed below the Lion Head. The Hull Cove may be the facies equivalent of the Beavertail Point member. The Jamestown formation consists of fossiliferous green and gray phyllite with minor amounts of black phyllite, and buff-and white-weathering siltstone. It is estimated to be about 200 m thick.

Beavertail Point member. This unit consists of 80 to 90 percent green phyllite comprised of the assemblage quartz-chlorite-muscovite-feldspar $\pm$ siderite $\pm$ paragonite. Buff-and white-siltstone makes up about 8 to 15 percent of the member; white siltstone beds (< 1 percent of the siltstone), rarely exceed 2 cm in thickness). The buff siltstone, 2 mm to 30 cm thick is micaceous (approximately 10 percent muscovite), internal laminae are generally 1 mm thick, and may contain up to 40 percent dolomite. When siltstone beds are present the bedding is recognized as cyclical. Black phyllite, comprising about 5 percent of the member, has the same mineral assemblages as the green phyllite; the black color may be due to graphite. Dolomite concretions, 6 to 40 cm, are present but are not as abundant as in the Dutch Island Harbor formation. Ichnofossils, present in this member, will be seen at Stop 2 and will be discussed further under Paleontology.

Skehan and others (1976)	Skehan and others (1978) and Murray and Skehan (1979)	This Paper
Unit a	Unit E	
Unit b	Unit D	Dutch Island Harbor formation
Unit c	Unit C	Fort Burnside formation Taylor Point member
Unit d	Unit B	Short Point member
Unit e	Unit A	Jamestown formation Lion Head member Hull Cove member Beavertail Point mem.

Table 1. Correlation of Cambrian Stratigraphic Units of Conanicut Island.

Hull Cove member. This member consists dominantly of green phyllite on the western island (Fig. 1) and of gray phyllite on the eastern island. White siltstone is the dominant coarse clastic on both islands but buff siltstone is rare. The white siltstone beds, rarely exceedingly 9 cm, consist of the assemblage quartz-chlorite-muscovite-carbonate; carbonate, however is substantially less than in the buff siltstone. On the eastern island the phyllite is gray and the bedding cyclical with cycles being up to 45 cm in thickness and

PALEONTOLOGY AND AGE OF ROCKS

Three different trilobite forms have been recovered from the sequence just described (Skehan and others, 1978). The most useful for age dating is Badulesia tenera (Harrt) (Fig. 2a through 2c), a widespread species of medial Middle Cambrian age. This species is known from New Brunswick, Eastern Newfoundland, southern Germany, northern Spain and eastern Turkey. Closely related species are also known from southern France. Close stratigraphic control is provided by Sdzuy (1967) for northern Spain, where he shows that this species characterizes a subzone within the Middle Cambrian Badulesia zone and that it correlates approximately with the lower part of the Paradoxides paradoxissimus zone of northern Europe. The next most abundant trilobite is an indeterminate species of Paradoxides (s.l.). The most complete specimen (Fig. 2d) consists of half of a thorax and the anterior part of a cranidium that has been separated and rotated 90% from the thorax. These fragments suggest that the individual was at least 45 cm long.

A third species not figured is represented by an unidentifiable fragment with a strong granular orientation (Skehan and others, 1978).

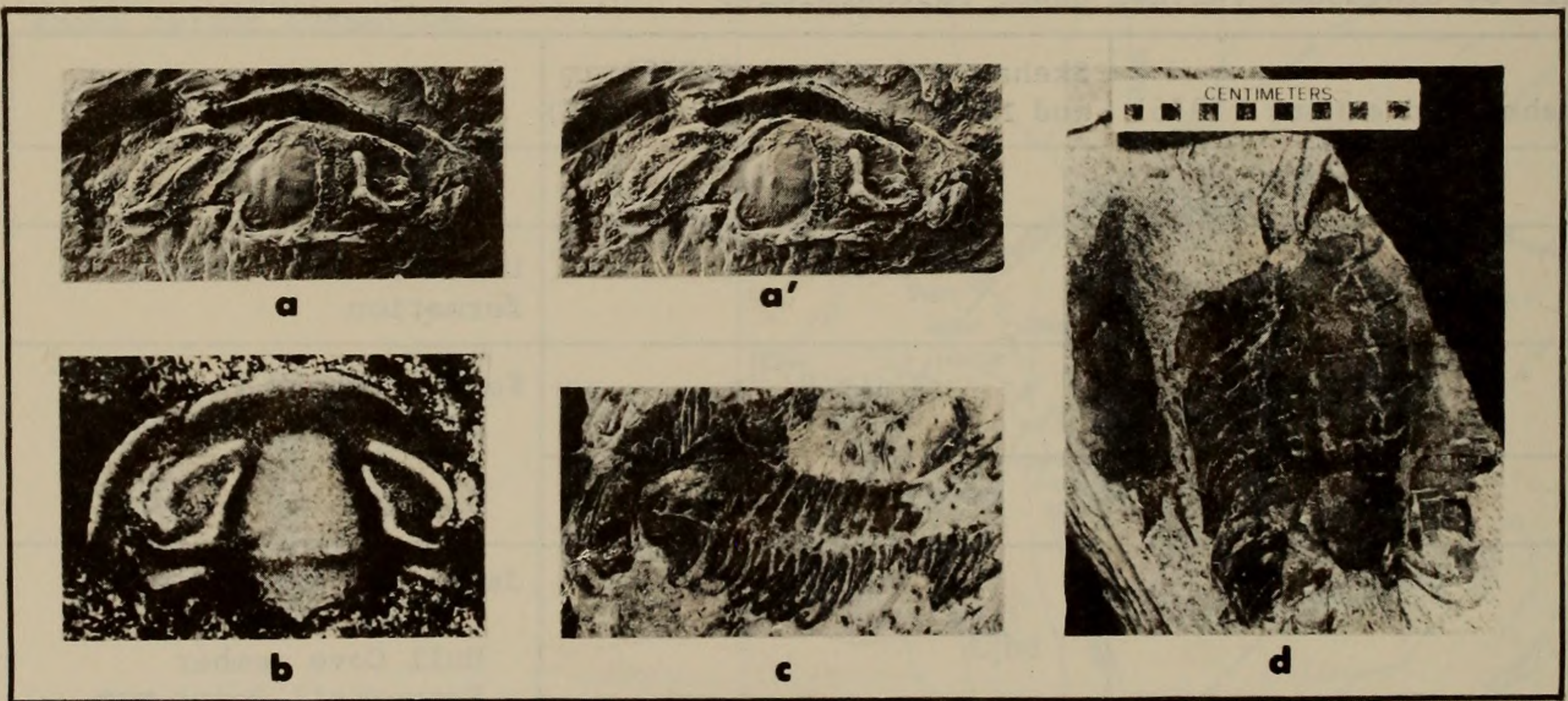


Figure 2. Middle Cambrian trilobites, (a,a') Stereopair of cranidium of Badulesia tenera (Hartt), Conanicut Island, Rhode Island, x 1 (horizontal dimension of photo, 48 mm); (b) cranidium of Badulesia tenera (Hartt) (Sdzuy, 1967, Pl. 6, Fig. 3) from Eastern Asturias, Spain, x 0.6 (horizontal dimension, 75 mm); (c) left side view of laterally compressed, partially complete specimen of Badulesia Tenera (Hartt), x 1 (horizontal dimension, 48 mm); (d) thorax and anterior cranidial margin (to left) of Paradoxides sp., x 0.2 (horizontal dimension, 240 mm) (Skehan and others, 1978).

progressing upward from white siltstone to black phyllite to gray phyllite. Other than in respect to carbonate there is no major difference in lithology. Trilobite fragments, as well as minor ichnofossils, have been observed at Hull Cove.

Lion Head member. This gray phyllite consists of the same mineral assemblages as the corresponding parts of the other two members of the Jamestown formation but differs from them in the absence of coarser clastics and in the presence of fluorapatite nodules and abundant trilobites and trilobite fragments. The unit is massive without conspicuous bedding; the bedding, however, is seen as a minor color variation in the phyllite and is on the order of 3 to 8 cm.

Fort Burnside formation

The Fort Burnside formation here is named for the U.S. Harbor Command Control Post formerly occupying part of the property now being developed as the Bay Islands Park system. It consists of two members and is a distinctive, cyclically bedded unit of buff- and white-weathering coarse siltstone overlain by black and gray phyllites. This formation is approximately 50 m thick.

Short Point member. The cyclical sedimentational units of this member consist of buff siltstone and black and gray phyllite. The development of the cycles is such as to produce an interlayering of siltstone laminae and black phyllite which gradually gives way to black phyllite without siltstone. The siltstone beds are micaceous, calcareous, and have abundant ripples, cross lamination, and truncation surfaces. Both phyllites appear to be structureless except that fluidization structures are common in the lower 20 m of the unit. This member has a conspicuous development of soft sediment fault offsets.

Taylor Point member. This member is thin, approximately 10 m, and differs from the Short Point member by the absence of gray phyllite from the sedimentary cycles. South of Lion Head chasm (Fig. 1) the siltstone tends to be buff in color and micaceous as well as calcareous. Elsewhere, as north of Lion Head and at Taylor Point the phyllites are white and cleaner, containing less than 5 percent carbonate and less than 10 percent mica. This unit tends to be broken up either by soft sediment deformation, as is more likely, and/or by tectonic dislocations. Going up section in the Taylor Point member there is a gradual increase in the amount of unoxidized shaley material and a decrease in the amount of sand, a feature which reaches maximum development in the overlying Dutch Harbor Island formation into which the Fort Burnside formation grades.

Dutch Island Harbor formation

The Dutch Island Harbor formation is a black rhythmically bedded phyllite consisting of beds 1 to 4 cm in thickness, commonly containing 1 cm-deep scour channels. There is an abundance of carbonate concretions which have a shaley inner core and cone-in-cone structures in the outer core. The Dutch Island Harbor formation is about 100 m thick.

These fossils have been derived from the Lion Head and from the basal part of the Short Point member. Most of the more than a dozen fossils collected for use in the study by Palmer (Skehan and others, 1978) came from Lion Head, north of Lion Head chasm, and from just south of it as well. The Lion Head member, wherever it is found, is typically rich in fossil hash, as are also parts of the Beavertail Point and Hull Cove members. Logue found an approximately 6 cm long complete individual trilobite identified by Palmer (pers. comm. to Skehan, 1980), as an infantile form of Paradoxides. That trilobite was found at the top of the Hull Cove member adjacent to the contact with the Lion Head north of Short Point of Stop 5 (Figs. 1 and 5).

Ichnofossils or worm burrows from the Beavertail Point member of Stop 2 (Fig. 6) have been identified by Ronald K. Pickerell (written comm. to D. F. Logue, 1981). Three ichnogenera were identified as Palaeophycus (= Buthrotrephis), Planolites, and Helminthopsis. Logue has also found ichnofossils in the Hull Cove member (Stop 5).

In summary, diagnostic trilobites have been found in the Lion Head and Short Point members; trilobite hash, in abundance not only in the Lion Head but also in the Beavertail Point members. An isolated trilobite and fragments have been found in the Hull Cove member of the Jamestown formation, and additionally ichnofossils have been found in the Beavertail Point and Hull Cove members of the Jamestown formation. Thus the members of Jamestown formation have yielded variably abundant fossil material as also has the base of the Short Point member of the Fort Burnside formation. To date, however, no fossils have been reported from the Taylor Point member or the Dutch Island Harbor formation at the top of this succession of Middle Cambrian rocks.

The sedimentological characteristics of these rocks, discussed below, suggest that these formations are a unified package of sediments having an uninterrupted history of deposition. Thus the age, even of the upper part, in which as yet no fossils have been found, is probably limited to Middle Cambrian.

ENVIRONMENT OF DEPOSITION

The same mineral assemblages are present in the gray, green, and black phyllites of the Lion Head and Hull Cove members of the Jamestown formation, of the Fort Burnside formation, and of the Dutch Island Harbor formation. The lower two formations represent a coarsening upward sequence but the rhythmically layered Dutch Island Harbor formation represents a trend towards a quieter environment of sedimentation (Skehan and others, 1978).

Geologic mapping by one of us (D.F.L.) of the entire Cambrian outcrop area (Fig. 1), a representative portion of which is shown as Figures 4, 7, and 9, has led to the conclusion that at least the Beavertail Point and Hull Cove members may be lateral equivalents of each other. Additionally the Lion Head member overlies the Hull Cove member (Stops 5 and 6).

Pickerell (written comm. to Logue, 1981) having examined the ichnofossils advanced the opinion that since deep-water Cambrian rocks are poor in trace fossil density and diversity, a more shallow water regime would be favorable to their development. Other characteristics of the sediments are consistent with a relatively shallow water, relatively near shore shelf environment. These include the green coloration, due to chlorite, of the Beavertail Point and part of the Hull Cove members. Additionally, these rocks are rich in other minerals possibly in large part derived from a volcanic source terrain. The gray to black phyllites may have been deposited on the outer contenental shelf, possibly in a depression which was subject to high organic and phosphate productivity due to upwelling, giving the dark coloration and forming nodules, beds, and lenses of phosphate.

STRUCTURE

General. This Cambrian terrain is replete with a wide variety of structures of various relative ages. An objective of the field stops and traverses will be to demonstrate the relative and, as possible, the absolute timing of structural events. Some structures were developed as pre- and syn-lithification features, others probably developed as synorgenic structures, and still others were developed as late brittle rock features.

Tectonic slides and F_1 folds. Tectonic slides have been defined by Bailey (1910) as fold-faults or, in modern language, synkinematic fracture discontinuities, commonly lacking signs of cataclastic disturbance. They have recently been reviewed by Hatton (1979) and form an important element of tectonic deformation in metamorphic rocks of all grades of metamorphism. The term tectonic slide is preferred to thrust because often the original movement on these discontinuities is indeterminate and they may have had a distensional, rather than compressional origin.

Features, such as opposing sedimentary topping directions and/or breccias near contacts, pre-cleavage ramp faults, and others associated with tectonic slides are extraordinarily well displayed in these rocks and provided the basis for recognizing these structures. Tectonic slides here antedate structures associated with F_1 folds but probably the two are nearly contemporaneous and possibly are an integral part of the same tectonic activity.

Thus the age of tectonic sliding and F_1 folding may be as early as late Middle or Late Cambrian time. The tectonic sliding may have been in response to uplift and consequent instability of the outer shelf or upper continental slope causing large blocks of the entire Middle Cambrian succession to be transported on top of other parts of the same succession but deposited in a recognizably different sedimentary environment within the same basin. Some folding identified as F_1 may be essentially contemporaneous with sliding and other F_1 folds may represent a continuing deformation of the autochthonous, together with the allochthonous successions.

The most readily recognized F_1 folds are those with upright northerly-striking axial planes. A fabric interpreted as S_1 cleavage is axial planar to early folds and may be examined at Stop 1 (Fig. 5), and this and other F_1 folds will be examined at Stops 1, 2 and 3.

Structures Associated with F_2 folds. F_2 folds in Cambrian rocks of Conanicut Island and associated axial plane cleavage are probably the most conspicuous of structural features. Typically F_2 fold axes trend approximately N-S.

On eastern Conanicut axial plane cleavage ranges from horizontal to gently dipping to the west; on western Conanicut it dips on average more steeply to the west. Lenticular carbonate porphyroblasts elongate in the plane of S_2 may record the movement direction of thrust sheets or nappes which may have been responsible for the F_2 folds and gently dipping cleavage.

Post F_2 Structures. Such features include thrust faults associated with the Alleghanian orogeny; late normal faults, kink band folds, and a trans-current fault. Although Alleghanian thrust faults may be widespread, at present they have been proven in this Cambrian terrain only on the eastern shore of Mackerel Cove where the Jamestown thrust, a name newly proposed here, thrusts Pennsylvanian Pondville formation, lying non-conformably on the Precambrian Newport granite (Fig. 1), as a unit on Cambrian phyllites (Stop 6). The Newport granite and older, Late Precambrian rocks of the Price's Neck formation near Fort Wetherill (Fig. 1), are cut by easterly-dipping faults which we tentatively interpret as Alleghanian as well.

Late normal faults are widespread in this terrain. Kink bands are well developed in many places and are typically associated with late extensional faults.

A possible transcurrent fault is the Beaverhead fault which separates the Cambrian phyllites in the lower greenschist facies of metamorphism of southern Conanicut Island from the higher grade Pennsylvanian schists of northern Conanicut Island. The former fault and the rocks which it separates have been described by Murray and others (1979), Murray and Skehan (1979), and Burks and Mosher (1980 and this volume). The Mackerel Cove fault, newly proposed here, offsets the Jamestown thrust as well as the rocks transported by it. It is not yet known whether the Beavertail fault is offset by the Mackerel Cove fault which is probably dextral, or whether the Mackerel Cove is a branch of the Beavertail system and essentially contemporaneous with it.

METAMORPHISM

The phyllites of the eastern island have been mapped in the chlorite zone of metamorphism and those of the western island in the biotite zone (Nichols, 1956; Quinn, 1971). We now recognize that the Cambrian phyllites of neither island record metamorphism higher than chlorite zone. The only megascopically identifiable minerals in these phyllites are pyrite and siderite, the latter showing an overgrowth of siderite on a similar ferroan carbonate. The Beaver-tail fault may displace metamorphic isograds in Pennsylvanian schists of northern Conanicut Island. Quinn (1971, Plate 1) shows the northwesterly-trending metamorphic isograds of northwestern Narragansett Bay as curving to the south and southwest. Accepting this trend in the north, and although the isograd locations on northern Conanicut have been in part remapped, the trend remains as Quinn portrays it as far south as the trace of the Beavertail fault (Gill, pers. comm., 1981). Thus one may conclude on the basis of the curvature of isograds, that the Beavertail fault is dextral, a con-clusion supported by evidence from offsets of magnetic lineations (Miller and Frohlich, 1981).

ROAD LOG GUIDE

The locations of field stops for this excursion are shown on Figure 1; certain features will be illustrated in greater detail in subsequent figures. The directions in this guide are designed for smaller self-led groups, and therefore, differ slightly from the route which we will actually follow due to easier access to certain stops as a result of special permission of land-owners.

Mileage

0.0 Start trip at the junction of Route 138 with North Main Road marked by a traffic light in a valley at a four way intersection. Those coming from the west will arrive by taking Route 138 east across the Jamestown Bridge (no toll) proceeding east for an additional 0.7 miles. Those coming from the east will arrive by taking Route 138 west across the Newport Bridge (toll $2.00) and continuing west for 1.6 miles. Bypass the center of Jamestown (unless you are familiar with the route to Beavertail).

Proceed south on North Main Road.

0.7 Jamestown Historical Society windmill (1787) on left (east) side of North Main Road.

1.3 Trace of the Beaverhead fault (covered), separating the Cambrian from Pennsylvanian rocks, passes across the island under this tidewater lowland. Beaverhead Point may be seen to the right (southwest) in the middle distance.

2.0 Cross Narragansett Avenue in Jamestown and proceed south, at which intersection the name becomes Southwest Avenue.

2.6 Bear right and continue across the sand bar which ties the eastern island to the western island. Mackerel Cove on left (south), Dutch Island, and Dutch Island Harbor (type locality) are seen to right (north). Here the name of the road we are travelling becomes Beavertail Road, the only road leading to the parking area from which you will walk to the start of the traverse of Stop 1 (Fig. 3.).

5.3 Turn left (east) off Beavertail Road into Beavertail State Park; 100 m ahead on right may be seen a remnant of Fort Burnside, once a submarine communications center but now a part of the Bay Islands Park System.

5.4 Parking for Stop 1, overlooking the rockbound shore of the south-eastern coast of Beavertail. Walk immediately northeasterly along the shore a distance of about 500 m (or about 1500+ ft) to Lion Head Chasm (Fig. 4). To reach Lion Head stay left near the upper shoreline exposures and walk carefully around the head of the Chasm, along the only path there, to the beginning of the traverse immediately N of the Chasm.

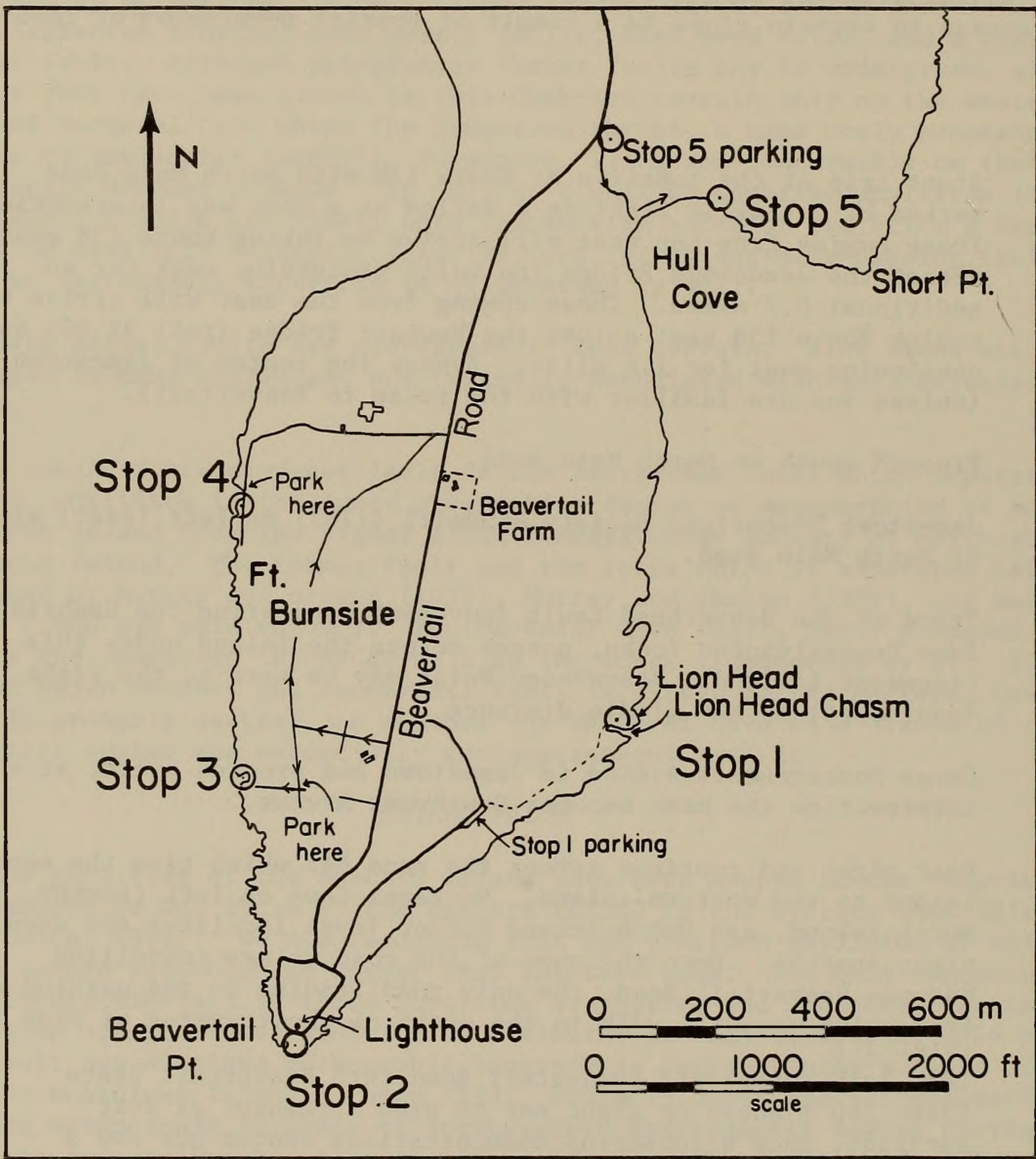


Figure 3. Location map for Stops 1-5, Beavertail and Hull Cove, Jamestown.

Stop 1. Cambrian succession, structures, and trilobite locality. Traverse from Lion Head SW to parking area. NO HAMMERS PLEASE; State of Rhode Island requires a permit to remove any rock specimens from the outcrop in this park.

Features to be observed here include:

A. The inverted stratigraphic succession. Along this traverse the entire Cambrian sequence with the exception of one member may be seen. From NE to SW one may examine the inverted sequence which from the base upward consists of: the Lion Head member of the Jamestown formation, the Short Point and Taylor Point members of the Fort Burnside formation, and the Dutch Island Harbor formation. At the southwestern end of the traverse the Beavertail Point member, in tectonic slide contact with the Dutch Island Harbor formation, will be examined. These informal stratigraphic names are introduced in this paper and their equivalence to unnamed, lettered stratigraphic divisions by Skehan and others (1976) and Skehan and others (1978) is given in Table 1.

B. The trilobite locality in the Lion Head member from which fossils diagnostic of a medial Middle Cambrian age were recovered (Fig. 2).

C. Structures associated with intraformational and interformational tectonic slides, as at 1-7 and 1-9; a variety of soft sediment deformation features possibly associated with slides and related instability of the sedimentational basin as between 1-4 and 1-5.

D. Folds and associated features. The dominant folds of this stop are F_2 folds and associated gently dipping S_2 cleavage. It is the latter that is chiefly responsible for this coastline being so different from that of the steep coastal cliffs of part of the west side of Beavertail (Stops 3 and 4). The F_1 folds of 1-6 and 1-8, with their associated S_1 cleavage, are apparently localized phenomena related to intraformational slides. F_1 folds on the other hand at Stop 3 (below) appear to be part of the larger F_1 structure deformed by the F_2 flattening event.

E. Late brittle faults and kink bands. A number of relatively late brittle deformation features may be seen, as at 1-4 and 1-10 along the well exposed trace of the Beavertail fault and its branches. Many of these contain slickensided vein quartz in the plane of the fault, as at 1-7, while others may be without quartz veins but truncate earlier veins.

Throughout many parts of this Cambrian outcrop area on Conanicut Island kink bands are well developed, as between 1-2 and 1-4 along the higher parts of the outcrop. These kink bands appear to be closely associated with the Beavertail fault and some of its branches.

Although the movement of these branch faults may not be great, it appears responsible for local offsets and rotation of blocks which produces changes in strike and dip of S_2 cleavage from block to block along this shore.

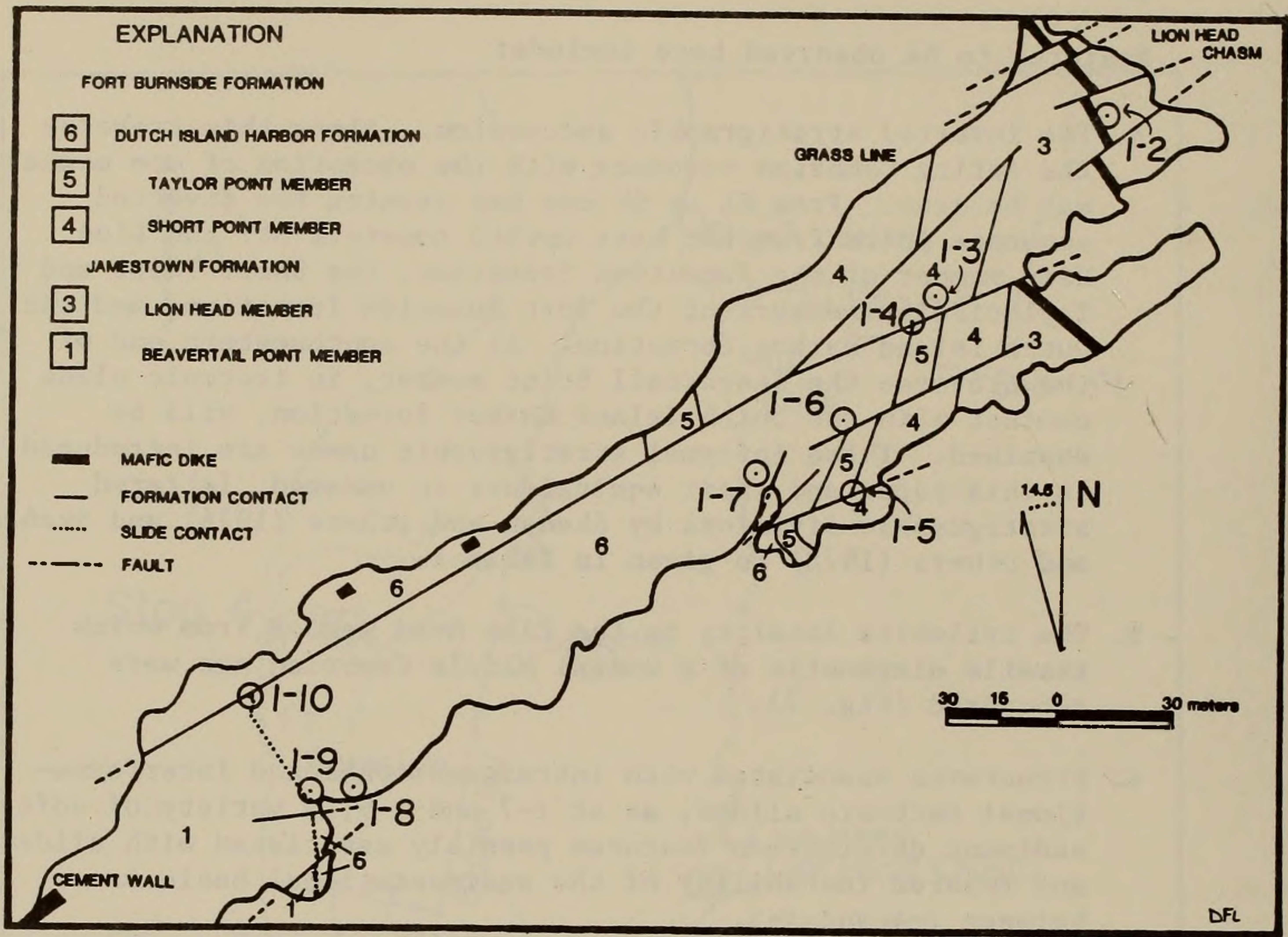


Figure 4. Geological sketch map showing location of stations on the Stop 1 traverse from Lion Head southwest to the parking lot (Fig. 3), eastern shore of Beavertail, Conanicut Island.

Specific features are noted at the following points along the traverse:

1-1. From this point Hull Cove and Short Point (type localities, Fig. 1) may be seen in the near distance to the north. In the middle distance are the cliff exposures of Newport granite of the eastern island near Fort Wetherill. Across Narragansett Bay to the northeast is Newport, the site of a field trip by Rast and Skehan (this volume). The lighthouse at the end of the Castle Hill traverse (1-15 of Stop 3) may be seen on the rock cliffs on a bearing N. 65° E. from here.

This outcrop at Lion Head is about 40 X 40 m and forms the northern margin of Lion Head Chasm. Together with the cliff exposures just north of a second, smaller chasm, as well as the cliffs along the southern margin of Lion Head Chasm near 1-2, they are the source of the original fossils diagnostic of age recovered in 1976 (A.T. Smith, 1977; Skehan and others, 1978; Murray and Skehan, 1979).

This is the type locality of this member (description above in text). Note its characteristic massive, relatively uniform appearance except for the scattered, small, dark phosphatic lenses and chip-like masses (mudchips of Skehan and others, 1978). Note also the siderite porphyroblasts, elongate (N. 65°W. at 15°) in the S_2 plane.

A partial specimen of Paradoxides 18 cm long remains in the outcrop. Its nearly horizontal orientation, marking the bedding, forms an acute angle with the S_2 cleavage (N. 40°E.; 13°NW). Fourteen trilobites or substantial fragments have been collected from this locality and 1-2. Fragments of trilobites are abundant on the surface exposures of the Lion Head member wherever it is seen.

We urge that those who must collect something collect from the fossil hash which is abundant outside the State Park. The Paradoxides at this station cannot be collected intact because of the cleavage. Moreover it should not be collected because of its wide usefulness to classes of geology students and for public education field trips by the park naturalist. Therefore, we urge the continued preservation of this remnant of the Middle Cambrian for the enjoyment and education of present and future generations.

In passing along the head of the chasm rim to 1-2 note that the massive beds of the Lion Head are underlain by upturned beds of alternating gray and black phyllite with buff-siltstones of the Fort Burnside formation.

1-2. South side of Lion Head Chasm. A metamorphosed minette dike consists of the assemblage zoisite + quartz + biotite + plagioclase + calcite + accessories (Skehan and others, 1976). The dike (N. 25°W.; 25°SW) cuts the Lion Head member, has a chilled margin, is folded by F_2 folds and is cut by S_2 cleavage. The carbonate porphyroblasts near the dike are notably larger than the average elsewhere (elongation lineation - N. 30°W. at 0-15°). The fragments of this faulted dike form excellent markers for recording the apparent movement on the Beavertail fault and its branches.

A partial Paradoxides individual 10 m S. of this station has been left on the outcrop for the same purposes as noted above for 1-1.

1-3. Just north of the gully formed in the Beavertail fault zone. Characteristic lithology and bedding features of the Short Point member are well illustrated here in F_2 folds to which the dominant S_2 cleavage is axial planar. These have been figured in Murray and Skehan (1979, Fig. 12). Stratigraphic tops are to the NW as indicated by the upward-fining graded beds.

1-4. A gully between 3 m high cliffs of rock exposes the Beavertail fault (N. 60°E.; 60°NW), a post-F_2 structure (F_2 axis - N. 28°E. horizontal). Antithetic faults and branches of the Beavertail fault offset the stratigraphic units and the meta-minette dike of 1-2. The contact of the top of the Fort Burnside formation with the base of the Dutch Island Harbor formation is exposed in the cliff face southeast of the fault.

In passing from 1-4 to 1-5 the magnificently exposed section of the Short Point and Taylor Point members of the Fort Burnside formation may be observed. Here are displayed a wide range of sedimentational, soft sediment and tectonic structures. F_2 folds, whose axes (S. 10°W. at 15°), are well defined by thick buff-weathering siltstone beds, are easily observed.

1-5. This location near the high tide level can be recognized by the presence of the main development of a 0.3 m thick, buff-weathering quartz vein along a fault. Standing near the vein and looking north at a small cliff 5 m distant are seen F_1 folds, showing closure of beds again folded by F_2 movements and both limbs of F_1 cut by the dominant S_2 cleavage. These folds have been described and figured by Murray and Skehan (1979, Figs. 14A and 14B).

Follow the quartz vein SW to the contact with the base of the inverted Dutch Island Harbor formation. Here the truncation of the cross laminated ripples indicates that the Taylor Point member, faces into the Dutch Island Harbor beds.

1-6. Ten m WNW of the contact just described. Here may be seen F_1 folds with S_1 cleavage referred to above (Fig. 5).

1-7. Near a prominent steep cliff face covered with vein quartz 25 m due W of contact between Fort Burnside and Dutch Island Harbor formations noted above. A ramp fault may be seen in typical, rhythmically layered phyllites of the Dutch Island Harbor formation containing carbonate concretions, and phosphatic beds and lenses. The slide plane of this intraformational tectonic slide is marked by carbonate-bearing quartz veins deformed by F_2 folds which can be traced up the face of this cliff. The beds on either side of the slide plane become parallel to the north of the cliff face, whereas to the south they are at angles up to 25 degrees. This structure was figured by Skehan and others (1976, p. 465).

These earlier formed structures are cut by a quartz vein-filled normal fault (N. 60°E.; 55°SE.) the quartz preserving approximately down-dip slickensides. In passing to 1-8 one may walk along the lower "platforms" near the high tide mark to observe sedimentational features and the F_2 folds (N. 5°W.; axis horizontal) which are well exposed in cross section as well as on nearly horizontal S_2 cleavage surfaces.

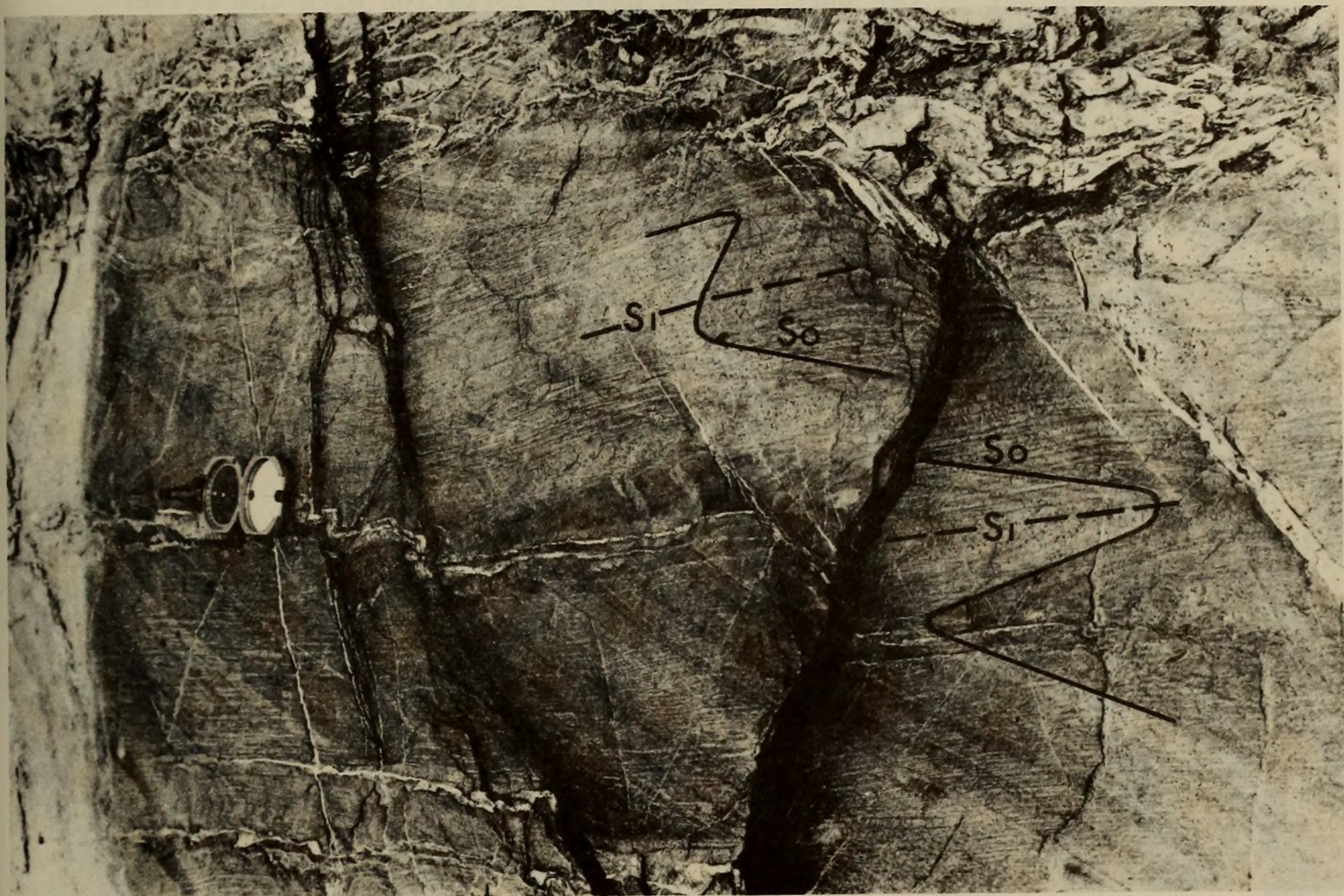


Figure 5. Structural elements in the Dutch Island Harbor formation. S_2 is the flat surface on which the north pointing compass rests, (Murray and Skehan, 1979).

1-8. Here is the first of a series of nearly flat S_2 platforms just N. of a fault gully 15 m N. of the conspicuous contact between the dark phyllites of the Dutch Island Harbor formation and the pale green phyllites of the Beavertail Point member of the Jamestown formation. Here pre-F_2 folds, produced by slippage on quartz-filled intraformational faults, are seen between these faults. The same type of S_1 cleavage as was noted at 1-6 is developed here subparallel to the associated quartz-filled slide planes.

Carbonate concretions, associated with phosphatic and carbonate siltstone beds, record well developed F_2 folds.

1-9. At contact of the Dutch Island Harbor formation with the Beavertail Point member of the Jamestown formation. Here are well exposed F_1 and F_2 folds (Skehan and others, 1976), the former having axial planes which are upright and the latter parallel to the S_2 cleavage. We regard this contact as a tectonic slide which antedated the F_1 folding, although in a general sense, the F_1 folding may have been essentially contemporaneous. Siltstone beds in the Beavertail Point phyllites near this contact have truncated cross-laminated ripples which indicate that it is facing north into the contact with the Dutch Island Harbor formation which is itself facing south into the contact. There are tiny, lenticular fragments of green phyllite breccia strung out in the dark phyllite within a few inches of this folded tectonic slide contact.

Follow the folded contact north to Station 1-10.

1-10. This station is at the junction of the slide contact with the Beavertail fault. Here in addition to relationships of 1-9, the Dutch Island Harbor formation is brought into contact with the Beavertail Point formation by movements along this well exposed post-F_2 fault along which the S_2 cleavage is offset.

Return to parking area and proceed S. to Stop 2 at Beavertail Point Lighthouse, Beavertail State Park Headquarters and Visitor Center.

Mileage

5.9 Park as near as possible to the Lighthouse, and to the historical marker at the foundation of the old Beavertail Lighthouse (Fig. 3).

Stop 2. Beavertail Point member, Dutch Island Harbor member, tectonic slide, and Beavertail fault. At Beavertail Point.

Features of general geological interest at this locality include:

A. Lithology and sedimentological features of the Beavertail Point member at the type locality, as described above in the text.

B. The tectonic slide at the contact of the Dutch Island Harbor formation and the Beavertail Point member noted above is well exposed here. This is essentially the same type of slide contact on the north side of the Beavertail fault as was observed at Stop 1, Station 1-10 on its south side. A well developed mylonite zone within the Dutch Island Harbor formation near but not at the contact may be seen.

C. Ichnofossils or "worm trails" are well developed here.

D. An F_1 fold may be observed as well as an excellent development of F_2 folds especially at the slide contact where the color contrast enhances the recognition of S_2 fold patterns.

E. Late faults showing several kinds of features or relationships.

A series of specific features may be examined at the following field stations (Fig. 6):

2-1. Well developed sedimentological features of the Beavertail Point member should be examined so that similarities and differences may be noted between that member and the Lion Head member, possibly a facies variant of the Beavertail Point member. These features are exposed in cross sections of F_2 folds to which the dominant S_2 cleavage is axial planar.

2-2. Southeast side of Beavertail fault. Gray and black phyllite beds within the Beavertail Point member are exposed.

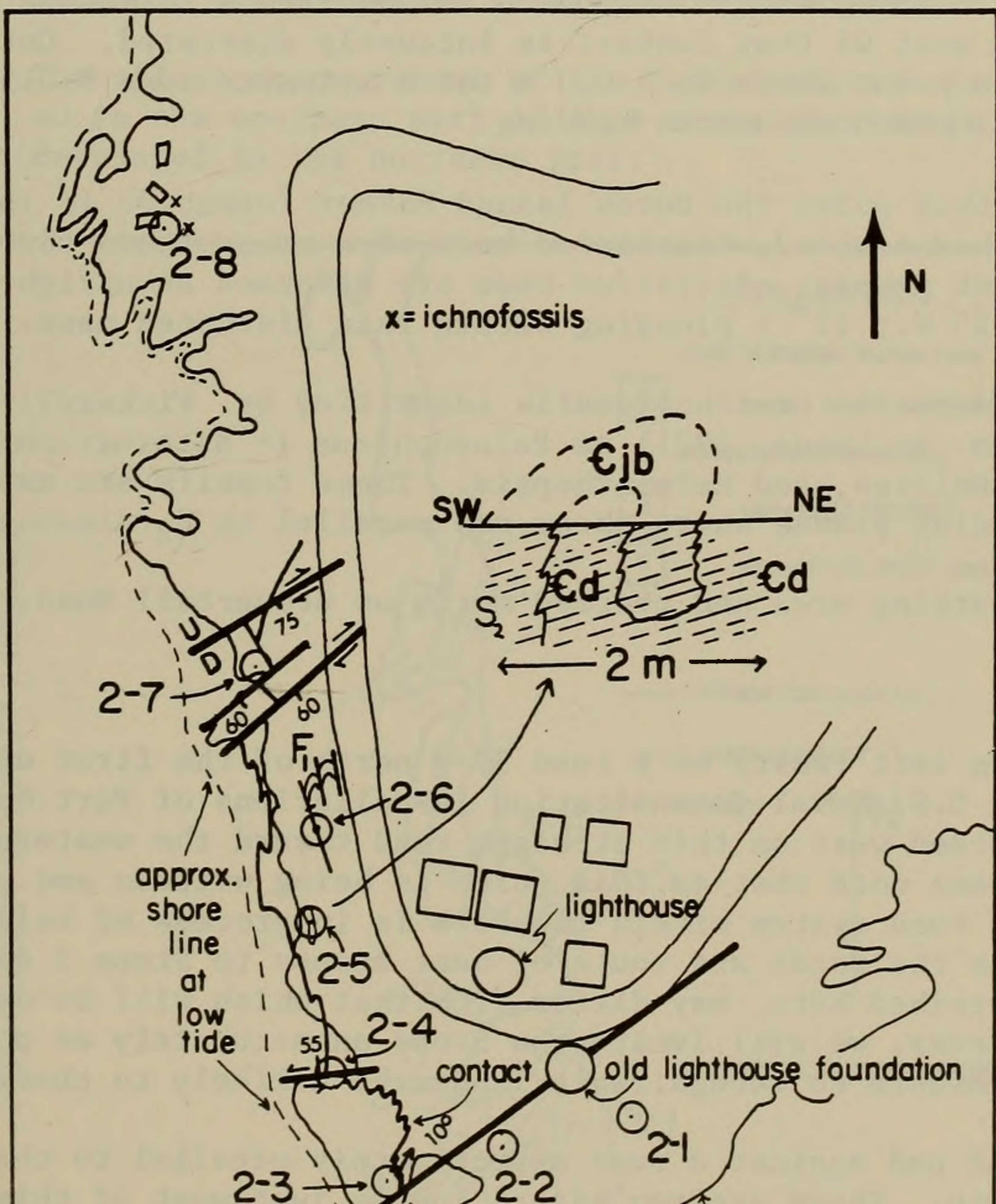


Figure 6. Location map for Stop 2 showing Beavertail fault, and slide contact, offset along late faults, and ichnofossil locality. Insert is a cross section of F_1 fold at 2-5. (Modified from Skehan and others, 1976).

2-3. The contact between the Dutch Island Harbor formation and the Beavertail Point member is well deformed by F_2 folds. This contact and the units on either side are offset by the adjacent Beavertail fault, a late post-F_2 fault. If interested in observing the folded contact walk it out as it climbs up and over a cliff (Fig. 6) looking for micro-breccia, truncated beds and other slide associated features which, however, are not as well developed here as at Stops 3, 4 and 5.

2-4. Late quartz-breccia filled fault (N. 87°E.; 55°NW) offsets the tectonic slide contact about 7 m in a sinistral sense.

2-5. An upright F_1 fold, which deforms the tectonic slide contact as indicated in Figure 6.

2-6. The bedding within the Dutch Island Harbor formation about 7 m east of that contact is intensely disrupted. Cutting through this point there is a 0.3 m thick mylonite zone N. 15°W.; vertical) which truncates bedding.

2-7. At this point the Dutch Island Harbor formation is in contact with disrupted, brecciated beds of a mass within the Beavertail Point member. Siltstone beds are deformed as upright F_1 folds N. 25°W.; 12°) plunging within this disrupted mass.

2-8. Worm trails or ichnofossils identified by Pickerell (written comm. to Logue, 1981) as Palaeophycus (= Buthrotrephis), Planolites, and Helminthopsis. These fossils are exposed on bedding planes where these are parallel to S_2 cleavage.

Return to parking area and proceed north on Beavertail Road.

Mileage

6.4 Turn left (west) on a road 30 m north of the first of two remaining U.S. Naval Communication installations of Fort Burnside (Fig. 3). Proceed west on this straight road toward the western shore. Please note that as this guide is being written and published the road system within the Park is in process of being developed. Thus the roads and route of best access to Stops 3 and 4, as described here, may differ from that which will be developed. However, we will locate the Stops as accurately as possible with reference to recognizable landmarks unlikely to change rapidly.

6.55 Dead end against a road approximately parallel to the shore. Go south. There are two signal towers just west of this road.

6.6 Park close to the second (more southerly) of these two towers. Follow the blocked-off road to the right (west). Two 10 inch posts stick above the brush. Stop 3 is located at the post at the clifftop.

Stop 3. Lion Head and Short Point members in slide contact with Beavertail Point member. Western shore of Beavertail at southern property limit of Fort Burnside.

Features of general geological interest include (Fig. 7):

A. The lower stratigraphic units seen at Stop 1, except for the Taylor Point member and a small section of phyllite interpreted as Beavertail Point member.

B. Excellent display of F_2 as well as some small F_1 folds. Axial planar S_2 cleavage is well developed here.

C. Truncation of beds of the Short Point member against chaotically broken rocks at the south end of this stop represents a tectonic slide feature that is well developed.

D. The siltstone component of the bedded section is well developed in the southern part of this stop; whereas it is poorly developed in the northern part.

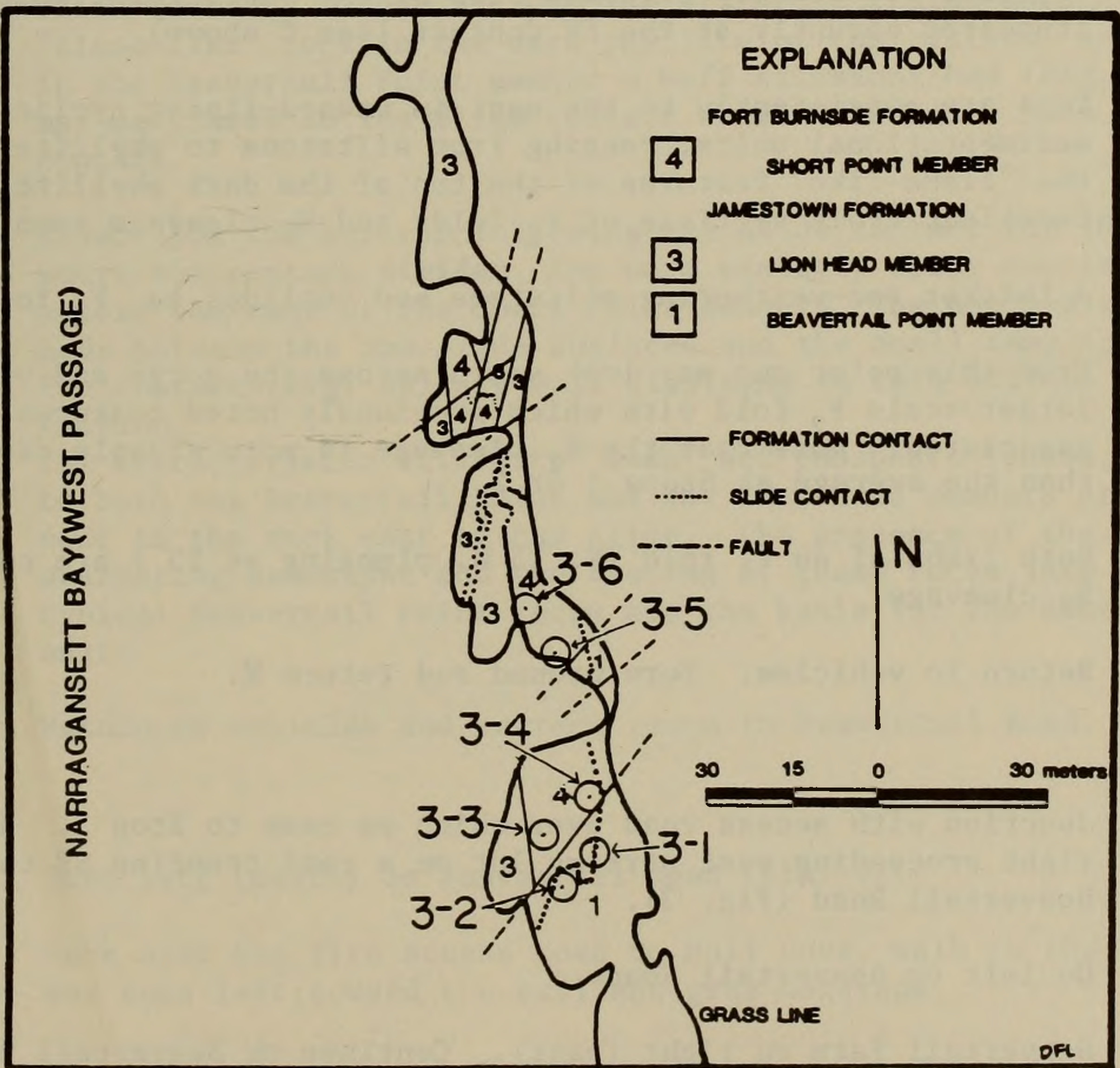


Figure 7. Geologic sketch map showing location of stations of Stop 3, western shore of Beavertail (Fig. 3).

Specific features may be noted at these stations (Fig. 7).

3-1. The phyllite has the dark gray color, massive appearance, trilobite fragments, and phosphate lenses typically associated with the Lion Head member. Although features diagnostic of differences between the Lion Head and Beavertail Point member are absent at this stop, these rocks are traced south into undoubted Beavertail Point member.

Along the northerly-trending steeply-dipping slide, there is a feature that appears to be characteristic of the slide contact in a number of locations. The phyllite near the contact weathers to a more finely divided phyllitic residue than is typically the case elsewhere, due possibly to a residual fabric produced in the sliding process.

3-2. The chaotic breccia is composed of Beavertail Point phyllite blocks and is especially well developed near its contact with adjacent chaotically deformed beds of the Short Point which are truncated abruptly at the EW contact (see C above).

3-3. Tops are consistently to the east in upward-fining cyclic sedimentational units, ranging from siltstone to phyllite, and on the "flame-like" features of the top of the dark phyllite units. Excellent cross sections of F_2 folds and S_2 cleavage seen here.

3-4. A thicker red-weathering siltstone bed outlines an F_2 fold.

3-5. From this point one may look south across the gorge and view the larger-scale F_2 fold with which previously noted features are associated. Note that the S_2 cleavage is more steeply dipping than the average at Stops 1 or 2.

3-6. Both limbs of an F_1 fold (N. 15° W. plunging at 25°) are cut by S_2 cleavage.

Return to vehicles. Turn around and return N.

Mileage

6.7 Junction with access road over which we came to Stop 3. Bear right proceeding past parking lot on a road trending NE to meet Beavertail Road (Fig. 3).

6.9 Go left on Beavertail Road.

7.1 Beavertail Farm on right (east). Continue on Beavertail Road.

7.15 Turn to left (west). Pass second of the remaining buildings of Fort Burnside on north side of road, continuing on an unpaved road which trends generally W. toward the shore.

7.4 Road turns south just east of the brush-covered clifftop.

7.45 Parking on left. Access path to Stop 4 is 0.05 miles to the south.

Stop 4. Tectonic slide contact. West side of the western island, Beavertail State Park (Fig. 3).

Access is best accomplished near low tide when important relations at the south end can be most readily seen. This important outcrop is isolated by a rock-bound gully on the south and a secluded sandy beach and fairly steep seacliffs on the north, made so by the west-dipping 50° cleavage surfaces.

4-1. At the south end of the outcrop there is a well displayed cross section (Fig. 8A) of an F_2 fold. The lower slopes consist of Lion Head, the prominent fold is outlined by the Short Point member, and the upper slope is formed of Beavertail Point member. The Short Point member has tops indicators facing east into the slide contact. These include the siltstone fining upward and "flame-like" tops in the dark phyllite of the cyclical sequence. In the Beavertail Point member a buff siltstone bed (Fig. 8A) may be traced to the slide contact where it strikes into the contact.

4-2. Climb upon the outcrop following the slide contact for 10 m where the contact divides, the more westerly splay cutting across the beds of the Short Point member. The north-striking beds between the two slide surfaces and the small ramp folds at the contact (Fig. 8B) are well displayed in this oblique cross section.
The characteristic trilobite "hash" and phosphate lenses, common to both the Beavertail Point and the Lion Head members are present in the rock east of the slide. The presence of the red-weathering sandstone and the tracing of these rocks into more typical Beavertail Point rocks are the basis for the name of the unit.

Return to vehicles and retrace route to Beavertail Road.

Mileage

7.8 Turn left (north) on Beavertail Road (Fig. 3).

8.3 Park near the fire access road to Hull Cove, walk to the beach and turn left toward the brillant gray outcrops.

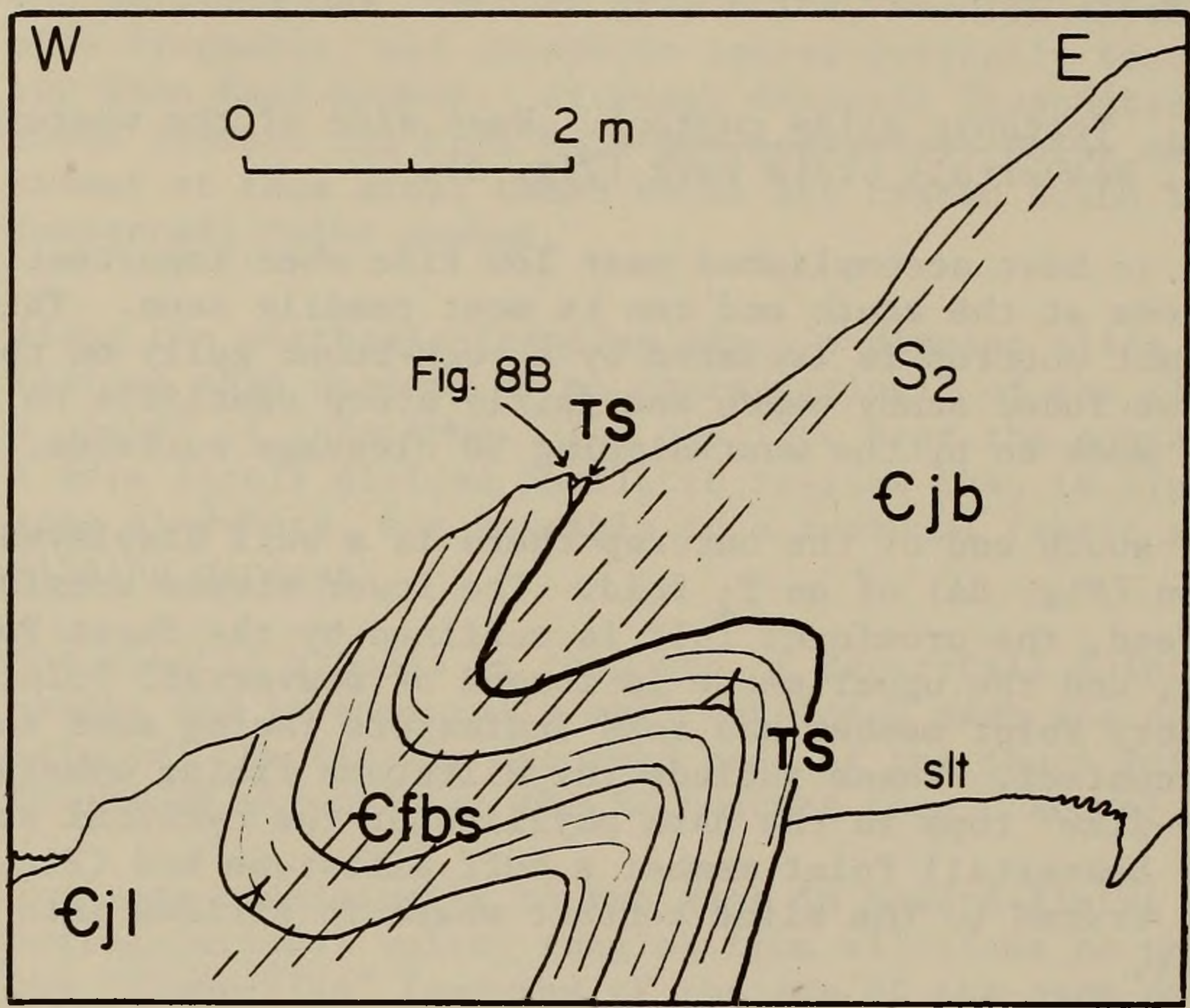


Figure 8A. Schematic cross section at south end of Stop 4 (Fig. 3) showing the tectonic slide contact (TS) between the Beavertail Point member (Єjb) and the Short Point (Єfbs) and the Lion Head (Єjl) members. These are deformed by the F_2 fold and cleavage. Siltstone bed (slt) in Beavertail Point member is truncated at slide contact, and facing direction in the Short Point is toward the slide contact.

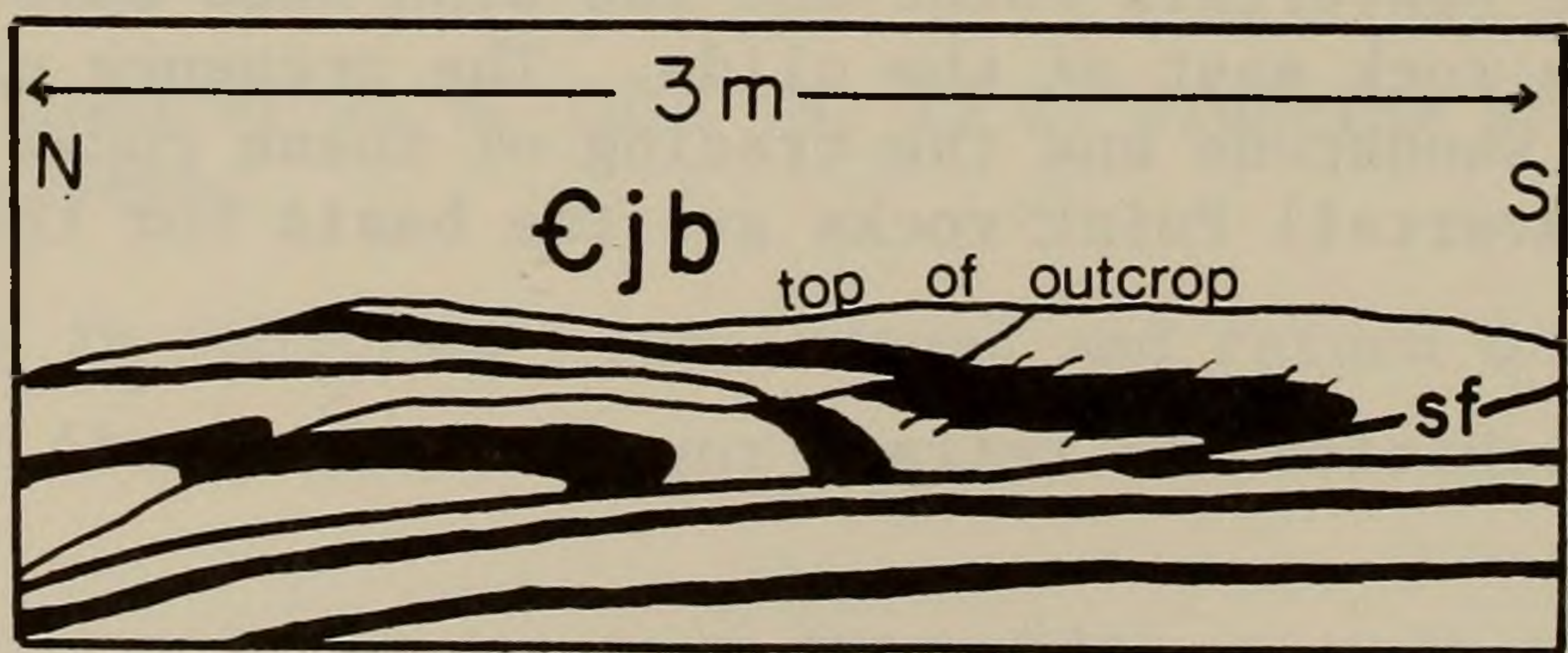


Figure 8B. Cross section sketch looking ENE at a splay of the main tectonic slide as exposed on the S_2 cleavage dipping toward the viewer and approximately 10° from the strike of the beds, illustrating apparent angular relations of beds at the plane of the slide. sf - splay fault; black - dark phyllite; white - gray phyllite except for Єjb in background.

Stop 5. Hull Cove member at type locality in tectonic slide contact with other units including Short Point member at type locality. Hull Cove and Short Point (Fig. 9).

Features of general geological interest here include:

A. The Hull Cove and Short Point members of the Jamestown and Fort Burnside formations respectively at their type localities.

B. The tectonic slide breccia is very well displayed and it was here that it was first recognized as a pre-F_2 fault related feature.

C. The Dutch Island Harbor formation and other distinctive units are strongly deformed by late faulting.

Specific features may be observed at these stations:

5-1. The shoreline exposures of this distinctive unit display progressively the changes in lithology that are characteristic. Chalky white siltstone lenses and red-weathering siltstone beds are nearly flat-lying except where the dip locally is recognized as steepening in an F_2 fold. Tops indicators are few and difficult to recognize as diagnostic. S_2 cleavage strikes E and dips an average 10°N. Logue (Fig. 9) has found ichnofossils at this station.

5-2. West of the brown-weathering meta-minette dike. White phyllites contain red siltstones with cross lamination ripples; within 10 m of the dike the white siltstones increase in number and thickness; they are nearly flat-lying, north-dipping beds.

5-3. The minette dike (N. 60°W.; 50°NE) cuts the Hull Cove member, the brecciated slide contact and the adjacent Dutch Island Harbor formation, but is cut by the S_2 cleavage. There is well developed trilobite hash near the west end of the dike.

5-4. 30 m east of the western exposure of the dike the polymictic mylonitic breccia in a black matrix is well exposed 1 m above the dike's upper contact. Here it is clear that the breccia is exposed in tight S_2 folds and attains its greatest development of 0.3 m although the true thickness may be variable. You may trace the breccia discontinuously along the folded contact which, together with the dike, is cut by late normal faults with small (1.5 m) dextral displacement (Fig. 9). The breccia zone on average appears to strike N. 10°W. and is vertical. The Dutch Island Harbor formation is cut by numerous late faults which may be observed en route to 5.5.

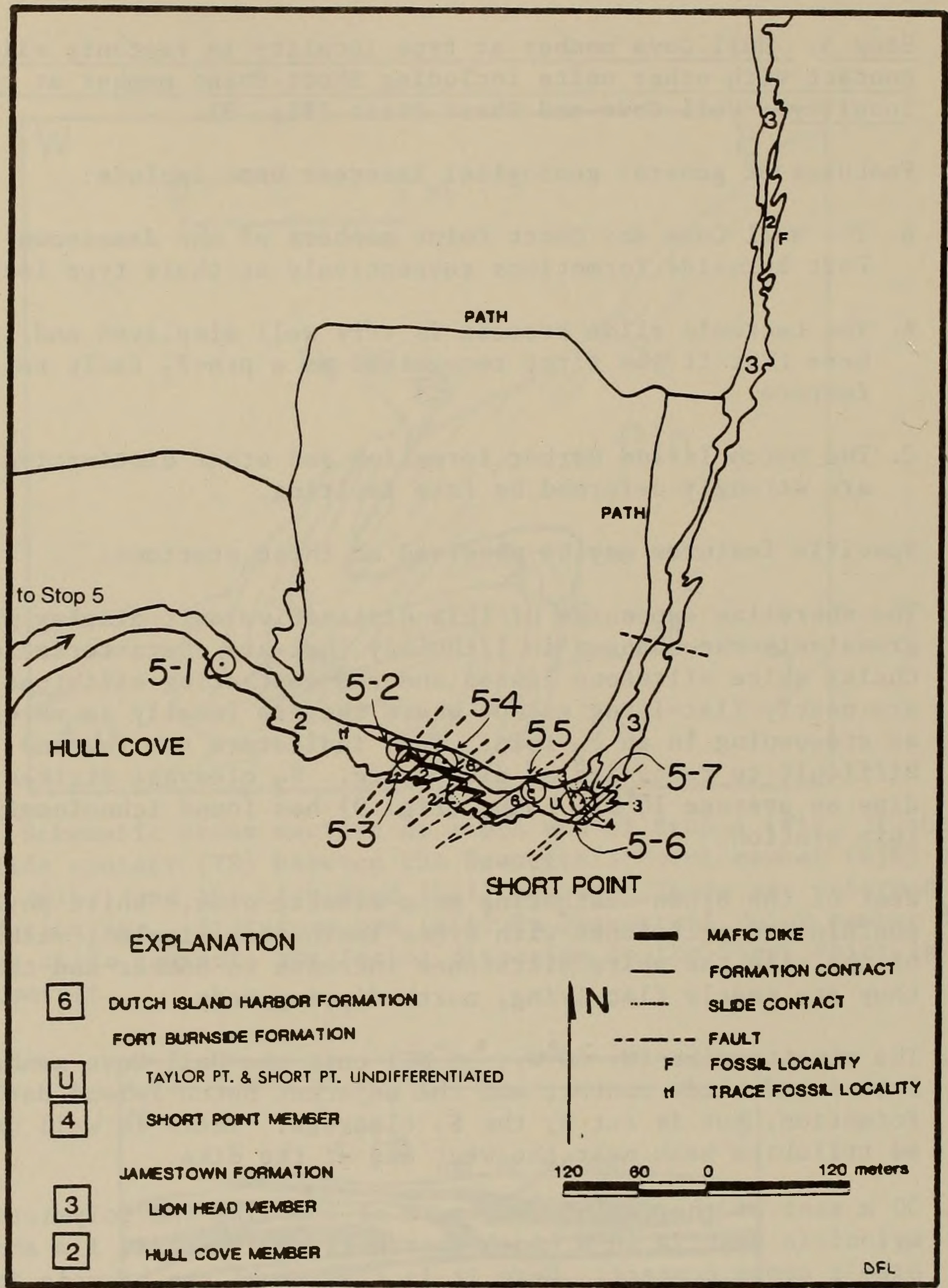


Figure 9. Geologic sketch map showing location of stations on traverse at Stop 5, Hull Cove and Short Point (Fig. 3).

5-5. The contact of the Dutch Island Harbor formation with the complexly deformed, in part undifferentiated Fort Burnside formation is well exposed at the type locality along the south facing cliffs of Short Point. The sequence is very well displayed as F_2 folds in an inverted succession which tops to the west into the slide contact. The tops indicators are upward fining graded beds, "flame-like" structure in the dark phyllite, and the cyclical sedimentation units. A variety of F_2 fold shapes and faulted folds may be observed in the sea cliff cross sections which are quite accessible.

5-6. Trilobite "hash" beds of the Lion Head member are seen on the south facing part of the Point.

5-7. Rounding the eastern side of the point blocks of Short Point member are exposed in several locations, the present exposure resulting from complex polyphase faulting, in part at least, late. Near the shore two blocks have moved relatively 10 m in a dextral sense along slickensided quartz-filled faults (N. 35°E.; 40°SE).

We will not proceed further north from Short Point but note that an infantile form of Paradoxides was found by one of us (D.F.L.) adjacent to the contact of the Hull Cove with the Lion Head member of the Jamestown formation (Fig. 9).

Return to vehicles and go N. on Beavertail Road.

Mileage

10.0 Park at the east end of Mackerel Cove Beach (Fig. 10). Walk southeast along the eastern shore of Mackerel Cove. Low tide conditions are helpful for best viewing of the succession. They are essential to shoreline access to the contact of the Cambrian beds with the Pennsylvanian Pondville formation at the southern end of the traverse.

Stop 6. Relationships of Lion Head and Hull Cove members; thrust fault relations of Pennsylvanian Pondville formation on Hull Cove. Eastern shore of Mackerel Cove.

Features of general geological interest include:

A. Relationships between the Hull Cove and the Lion Head suggest that the former is stratigraphically below the latter and therefore forms the base of the exposed Cambrian strata.

B. The dominant structure is a westward-facing F_2 fold. At the southern end of the traverse the Hull Cove member (Fig. 10) is cut by numerous NE-striking, SE-dipping thrust faults. The Newport granite and the overlying basal Pennsylvanian Pondville formation have been thrust as a unit onto Cambrian rocks. Kay and Chapple (1976, p. 438) identified this fault but considered it as within the Pennsylvanian as rocks to the north (Hull Cove member) were then considered to belong to the Rhode Island formation.

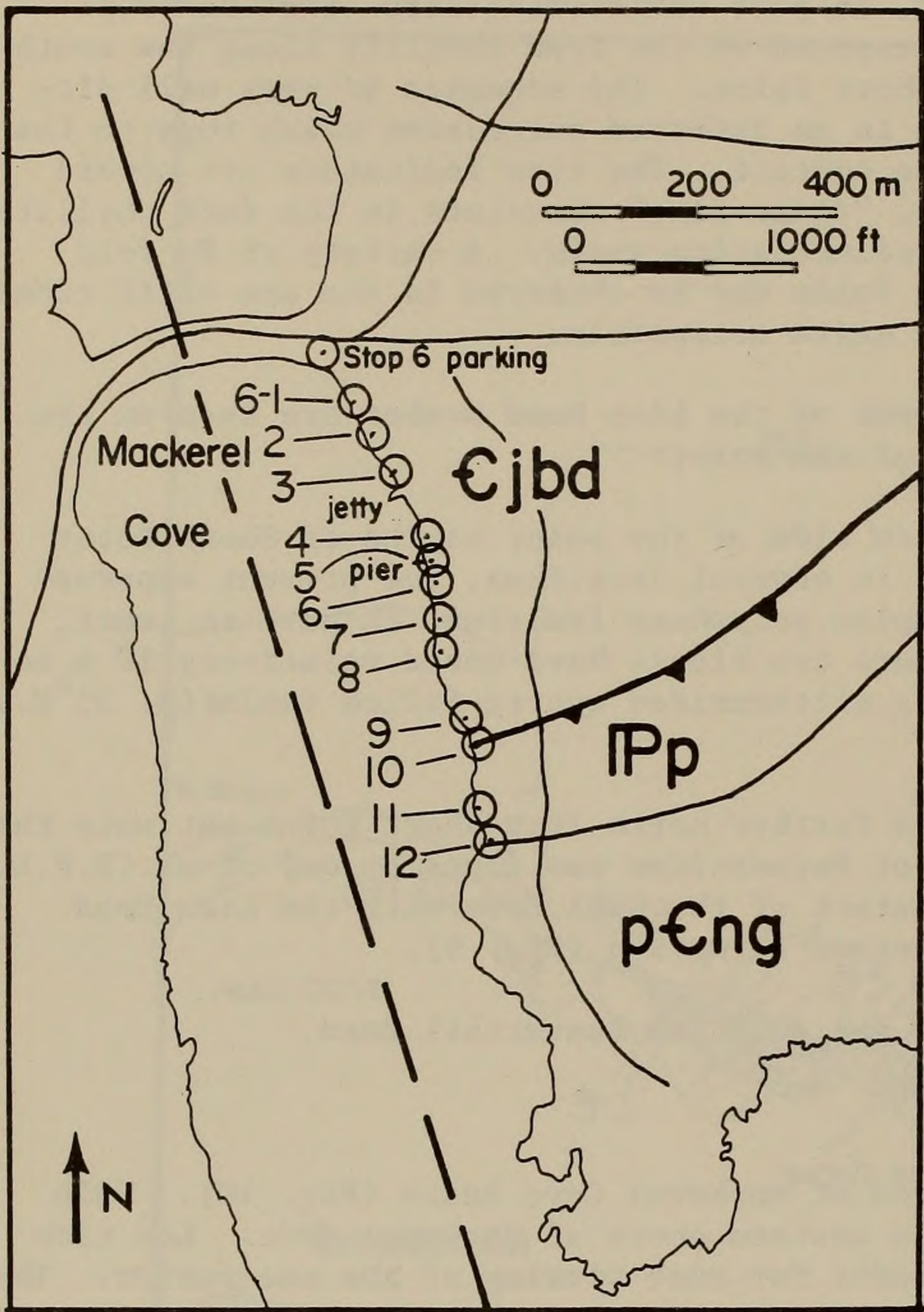


Figure 10. Location map for traverse south (Stop 6) along the eastern shore of Mackerel Cove, Conanicut Island.

Specific features may be seen at the following stations (Fig. 10):

6-1. About 150 m S. of Mackerel Cove Beach are outcrops of inverted Short Point member (N-S; 45°E) which face to the W in an F_2 fold (S_2 cleavage - E-W; 25°- 45°N.)

6-2. Contact of Short Point with Lion Head which is non-porphyroblastic. F_2 fold plunges 10° toward N. 12°W. The folded contact is well exposed north of a former jetty now consisting of a line of rock blocks and metal pipes.

6-3. Lion Head, coarsely porphyroblastic and lineated (N. 65°W.; variable plunge) on S_2 cleavage, is cut by late fault consisting of a 0.5 m thick gouge and vein-quartz.

6-4. About 80 m south of the jetty (6-2) is the covered contact between the Lion Head and the Hull Cove members, both well exposed nearby. The Hull Cove beds, as was the case with the units to the north, strike in a northerly direction, dip gently E, and are inverted in an F_2 fold whose beds face to the west.

6-5. North of and at the boat pier are exposures of fossiliferous Hull Cove member. S_2 cleavage is warped by kink bands (N. 35°E.; 80°SE.) whose short limbs step down to the SE.

6-6. 70 m S. of the pier (6-5). Reverse fault (N. 50°E.; 60°SE) brings Hull Cove beds south of the fault against Lion Head beds.

6-7. 70 m further S. is the contact between the inverted west-facing Hull Cove beds (NS; 20°E) which go up into the massive dark phyllite of the Lion Head member. Thus it appears that the stratigraphic relations of these two members of the Jamestown formation are established.

6-8. Southward from this station at a fault (N. 80°E.; 50°SE), the Hull Cove beds are cut by numerous high angle reverse faults. The cleavage orientations are disrupted and irregular quartz veins are abundant.

6-9. Several NE- and ENE-striking thrust and high angle reverse faults indicate that the influence of the Jamestown thrust fault is more intense (Fig. 10). A meta-minette dike, rusty weathering, is involved in faulted folds which are overturned to the NW. At its northern exposure, about 40 m N. of the main thrust fault the dike contact with Hull Cove beds is N. 55°E.; 60°SE.

6-10. The Jamestown thrust fault (Fig. 10) has transported the Pennsylvanian Pondville conglomerate and its underlying Newport granite northwesterly onto the Middle Cambrian. These relationships, which persist to the eastern shore south of the village of Jamestown, however, are not present on the western island. Thus we infer the presence of the Mackerel Cove fault, having sinistral motion, and interpret that it is responsible for transporting this mass of rocks of the southern part of the eastern island to their present positions relative to the Cambrian of the western island.

Retrace steps to vehicles. End of field trip for this year!

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