1-1-1963

Sedimentary and Structural History of Narragansett Basin

Mutch, Thomas A.

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SUPPLEMENTARY NOTE TO TRIP B

Because of an unusually dry summer certain exposures generally covered by water are now accessible. For this reason it has been decided to add one stop to Trip B. This stop will precede all others and is called STOP 0.

STOP 0 - From intersection of Rtes. 123 and 1 proceed north three miles along Rte. 1. Turn left (west) on Hoppin Hill Ave. and proceed .25 mile to point where road crosses reservoir. Exposures are on north side of road.

This is locality 1 mentioned by Shaler, Woodworth & Foerste (1899, p. 386). Along the west side of the reservoir are exposures of granite. In the middle of the reservoir are several knobs underlain by reddish and gray siltstone and shale interbedded with thin, irregular silty limestone layers several inches thick. On the eastern side of the reservoir in the woods there are exposures of coarse conglomerate containing quartzite pebbles.

The limestone layers contain abundant *Hyolithes*. Collections from here and several nearby localities have also yielded a number of trilobites including *Strenuella* and *Salterella*. The fauna was first recognized as early Cambrian by Shaler (1888). The fossils were re-examined by Shaw (1950) who correlated them with the *Obolella* zone.

The character of the contact between the granite and Cambrian rocks was disputed for many years. Dowse (1950) describes an actual exposure of a sedimentary contact between basal Cambrian beds and coarse-grained granite, establishing this rock as Precambrian.

Conglomerates on the east side of the reservoir are included in the basal Pennsylvanian. Although Wamsutta rocks outcropping nearby are strikingly similar to the Hoppin Hill Cambrian beds, an Allegheny flora clearly establishes their younger age.

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TRIP B

SEDIMENTARY AND STRUCTURAL HISTORY OF NARRAGANSETT BASIN

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Stop 4 by

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General Discussion

During this trip sedimentary and structural features of Pennsylvanian nonmarine rocks within the Narragansett Basin will be observed. As shown in Figure 2 this is a synclinal basin approximately 60 miles long and 20 miles wide, trending north and northeast. Pre-Pennsylvanian sedimentary rocks will be seen near Newport on Aquidneck Island along the southern margin of the basin.

Throughout most of the Narragansett Basin the Pennsylvanian overlies with angular unconformity metamorphic and plutonic rocks. On the western margin the Precambrian(?) Blackstone Series, made up chiefly of quartz-mica schist and quartzite, is intruded by Devonian(?) and Mississippian(?) rocks ranging from quartz diorite to granite. Most of the northern and eastern part of the basin is underlain by the Dedham granodiorite of Precambrian or Paleozoic age. At the southern extremity sedimentary and volcanic rocks of uncertain age are well displayed directly below the Pennsylvanian.

The Pennsylvanian rocks were first described in detail by Shaler, Woodworth and Foerste (1899). A recent and comprehensive discussion of the stratigraphy is provided by Quinn and Oliver (1962). Four formations are commonly recognized: decreasing in age these are Pondville Conglomerate, Wamsutta Formation, Rhode Island Formation, and Dighton Conglomerate. A conglomerate on Aquidneck Island, the Purgatory Conglomerate, is sometimes correlated with the Dighton although it occurs much lower stratigraphically in the Pennsylvanian section.

The Pondville Conglomerate was named by Shaler, Woodworth and Foerste (1899, p. 135-136) for exposures of arkose and quartz pebble conglomerate near Pondville, Massachusetts, in the Norfolk Basin. According to them this zone of arkose extends in discontinuous crops for fifteen miles along the northwestern margin of the basin. Several exposures of fluvial conglomerate along the western margin have been assigned to this formation, but the unit is not present in very limited exposures of rocks along the northern and northeastern margins. Basal units along the southeastern and southern border of the basin are well displayed and, although they are strikingly different from rocks along the western margin, they have been included in the same formation. This southern sequence comprises shale, siltstone and sandstone composed of varying amounts of dark quartz, partially altered feldspar, muscovite metamorphically generated from clay minerals, and carbonaceous material. The quartz commonly is of granule size but coarser-grained conglomerate is lacking.

The Wamsutta Formation includes a sequence of siltstone, sandstone, and conglomerate characterized by reddish color and restricted to the northwestern part of the basin. In the Attleboro area there are two layers of basalt and a single layer of rhyolite. Recent work by Eckelmann and Woods (1961) demonstrated that the rhyolite is extrusive, and the basalt may well have a similar origin. The fine-grained rocks of the Wamsutta Formation display ripple marks, mud cracks, curled mud chips and organic reworking. Detrital volcanic material is abundant in many of the sandstones. Some of the conglomerates are poorly sorted with angular felsite blocks up to several feet in diameter in a silt matrix, suggesting a mud flow origin. Interlayered with these rocks are beds of well-sorted quartz-rich sandstones, apparently fluvial channel sands. The red color of the Wamsutta is partly the consequence of fine-grained interstitial iron oxide pigment and partly the result of large amounts of pink felsite detritus.

The Rhode Island Formation with a stratigraphic thickness of approximately 10,000 feet is the most extensive unit within the Narragansett Basin. Exposed rocks are principally fluvially deposited sandstone and conglomerate with minor amounts of siltstone. An extensive glacial cover is pierced only by topographic highs under-lain by resistant coarse-grained rocks, so shale and siltstone may be more abundant than surface exposures suggest. Fine-grained rocks are apparently more common in the southern part of the basin but this may be a reflection of more complete exposure in shore line cliffs. Rhode Island Formation sandstones are light gray graywackes with quartz, feldspar, mica, and lithic fragments in a clay matrix. Boulders in the conglomerates are chiefly quartzites and granites. Primary structural features are not common but some sandstones contain current cross-bedding. Several coal horizons occur in the lower part of the formation.

The Dighton Conglomerate overlies the Rhode Island Formation and is exposed in three synclinal areas in the northern part of the basin. Although this unit is not composed exclusively of coarse-grained rocks, it contains thick lenses of conglomerate not present in underlying rocks. The general appearance of individual samples is similar to that of the Rhode Island Formation.

The assignment of rocks within the Narragansett Basin to the Pennsylvanian is on the basis of fossil plants. There have been no recent comprehensive descriptions of the flora but Knox (1944) classified a Wamsutta assemblage as early Allegheny. While Pennsylvanian fossils are common in both the Wamsutta and Rhode Island Formations, no plants have been described from the Dighton Conglomerate. This raises the possibility that it is post-Pennsylvanian, although there is no positive evidence supporting this view.

The distribution and character of sedimentary rocks within the basin suggests that the principal direction of sediment transport was north to south. Currents flowing from northeast to southwest are indicated by current cross-bedding and plant alignment at a number of localities within the Rhode Island Formation (Towe, 1959). Along the western margin basal conglomerates and sandstones rest on plutonic and metamorphic rocks which show no development of a pre-Pennsylvanian weathering profile. The mineral constituents of the sedimentary rock correspond in large part to those of immediately adjacent older rocks, indicating local transport of mechanically weathered detritus in a region of active erosion and sedimentation. Along the southeastern margin of the basin the underlying plutonic rocks are deeply weathered and the clay, quartz and partially altered feldspar in basal Pennsylvanian sediments is derived locally from this weathered zone. In contrast to these two areas just described, basal fine-grained well-sorted sandstones in the northern part of the basin have heavy mineral suites unlike those of local pre-Pennsylvanian rocks, indicating that detritus was not derived from a nearby source.

This variation within basal Pennsylvanian rocks indicates a highland to the west and a deeply weathered stable lowland to the east and south. Mature well-sorted sediments in the north were deposited in a flood plain probably associated with the major drainage system leading into the basin.

Problems regarding the source of quartzite boulders common in both the Dighton and Purgatory Conglomerates are raised by fossils which they contain. Walcott (1898) identified several species of Obolus which are confined to Lower Ordovician rocks of Great Belle Island, Newfoundland. More recently Howell (personal communication, 1962) has examined a number of boulders from a collection made some years ago. The specimens are simply labeled "Newport, R.I.", and presumably came from the Purgatory Conglomerate outcropping there although they could be from glacial drift. Howell identified several species of Lingulella characteristic of Upper Cambrian rocks in eastern New York State. He did not observe any specimens of Obolus.

Following their deposition Pennsylvanian rocks were folded and subjected to variable metamorphism. Folds in the northern part of the basin are broad and simple while the compression in the southern part of the basin is much more extreme. Folds here are locally overturned and axial plane cleavage is well developed. This intense compression was accompanied by stretching of pebbles within the Purgatory Conglomerate, a feature not seen in the Dighton Conglomerate in the northern part of the basin.

An increase in intensity of metamorphism toward the south within the Narragansett Basin is very apparent along the western side. This progression is not so marked along the eastern side where there is development of biotite, but not garnet or staurolite.

TRIP B

ITINERARY

STOP B-1 - Southern edge of Attleboro, Mass., just SW of Thacher St. crossing of N.Y., N.H., and H. Railroad, Attleboro quadrangle.

STOP 1 - Rhode Island Formation. Vertical beds show a number of features indicating a fluvial environment of deposition. These include sandstone and conglomerate lenses, cross-bedding, and channeling contemporaneous with deposition. (See Figure B-2). Mottled sandstones and siltstones in the lower part of the section are probably the result of reworking by burrowing animals. The outcrop is polished and striated by glacial action; rocks outcropping 20 yards to the south show the effects of stream erosion related to the glaciation.

Log from Thacher St. locality:

Miles	
0.0	East on Thacher St.
0.5	Turn right (south) on Rte. 152.
8.3	Turn right (south) on Rte. 1A at stop sign.
8.8	Bear right on Rte. 1A.
9.8	Proceed straight through stop light on Rte. 114.
10.2	Proceed straight through stop light on Rte. 114.
10.6	Turn left (east) at stop light on Rte. 6 (Warren Ave.).
11.1	Stop B-2. East Providence quadrangle. To reach outcrop walk 100 yards south, crossing road just south of Rte. 6. Watch out for traffic.

STOP B-2 - A typical exposure of the Rhode Island Formation. Flat-lying beds of sandstone contain discontinuous conglomerate horizons. Plant fragments are abundant along bedding planes. These tend to be oriented in a northeast-southwest direction. (See Figure B-3). A similar alignment of plant fragments and dip directions of cross-beds at other localities within this formation suggest currents flowing from the northeast. (Towe, 1959).

11.1	Proceed east on Rte. 6.
11.5	Bear right on Rte. 6.
16.6	Turn right (south) at stop light on Rte. 136.
18.6	Rhode Island Formation exposed on right (west) side of road. Well developed foliation striking N 40 W and dipping 25 NE obscures the bedding which is nearly horizontal.
19.2	Bear left on Rte. 136, following Newport-Bristol sign.
19.5	Bear right on Rte. 136.
19.6	Proceed straight through stop light on Rte. 136.
23.7	Exposures of Metacom granite gneiss on left (east) side of road. This unit has been interpreted as pre-Pennsylvanian metasediments. (GQ 42) Pennsylvanian rocks crop out several miles north and west of this point but the contact with the Metacom gneiss is not exposed.
25.9	Proceed south across Mt. Hope Bridge to Aquidneck Island (Rhode Island). Excellent view of Narragansett Bay from top of bridge.

Miles

25.9 Prudence Island and west shore of bay to the right, east shore of the bay to the left. Topographic rise less than a mile behind shore on the left marks contact between pre-Pennsylvanian plutonic rocks and less resistant Pennsylvanian rocks.

26.7 Bear right on Rte. 114.

28.1 Proceed straight through stop light.

29.1 Bear right on Rte. 138 at light.

29.9 Bear left on Rte. 138.

30.0 Good view across southern inlet in Narragansett Bay (Sakonnet River) towards Little Compton, R.I.

30.5 Rhode Island Formation exposed on right (west) side of road behind buildings.

32.8 Turn left (east) on Sandy Point Road.

33.3 Turn right (south) on Wapping Road.

35.3 Turn left (east) on Old Mill Lane. Stretched pebble conglomerate is exposed on northeast corner of intersection.

36.1 Turn right (south) on Indian Ave.

37.0 On right and visible from bus are sarcophagus and effigy of Raphael Pumpelly (1837-1923; explored Gobi and Siberia 1863, "Across America and Asia", 1870; Harvard prof. 1866-73; State Geol. Mich. 1869-71, Mo. 1871-73; pres. GSA 1905; published on Mich Cu., Green Mts., mining indust., census, etc.).

38.0 Continue straight on Indian Ave. at intersection.

39.6 "Hanging Rock", large cliff of steeply dipping Pennsylvanian conglomerate on right (west) side of road.

39.7 Turn left (east) along shore road.

40.8 Entrance to U.S. Naval Rifle Range. Entrance without a pass is not permitted. Passes can be obtained at Newport Naval Gate 1. Stop B-3 is located close to southern tip of Sachuest Point within firing range. Sakonnet Point Quadrangle.

<u>STOP B-3</u> - This series of outcrops clearly shows the difference between Pennsylvanian and pre-Pennsylvanian rocks with respect both to original sedimentary character and to style of structural deformation. The geology is shown in Figure B-4.

Pennsylvanian beds overlie older beds with angular unconformity. Rocks are coarse-grained sandstones made up of quartz granules and fine-grained muscovite interbedded with black shales. Basal beds contain detrital feldspar phenocrysts and large fragments of underlying rocks. Pre-Pennsylvanian rocks are poorly sorted siltstones, sandstones, and conglomerates with lenticular bedding, cross-bedding and, locally, graded bedding. Many of the angular boulders in conglomerates are derived from volcanic rocks. Quartzite boulders are extremely rare and boulders of plutonic rocks are not common.

Cross-bedding indicates that pre-Pennsylvanian rocks along the southern part of the point are overturned, dipping to the southeast. As the shoreline is followed north beds become upright, dipping to the northwest. A prominent joint system strikes N10E with movement of several inches along many of the surfaces. Pennsylvanian rocks are tightly folded and faulted, and cleavage is well developed in shales. Faults are accompanied by large quartz veins, especially in the northern part of the point.

40.8 Proceed west on shore road.

42.2 Stop B-4; includes exposures directly east of parking area and south of shore road as well as extensive cliffs extending south from ~~east~~ west end of beach. Newport quadrangle.

STOP B4

PURGATORY

Sam L. Agron

Stop B4. About 1¼ miles east of Newport, at the northeast corner of the triangular peninsula whose southern terminus is Easton Point. A composite cross-section of the peninsula (Fig. B5b) gives some idea of the variable clastic lithology of the Pennsylvanian Rhode Island Formation. Rapid facies changes, pinching, lensing, and interfingering of the conglomerate, schistose sandstones and graywackes, and black slaty beds are common. The major structure of the peninsula is anticlinal, upon which are smaller warps and drag folds, some with vertical to overturned limbs. The extraordinary elongated boulders that appear at numerous places will be inspected along the shoreline north of Purgatory chasm. The boulders range in length from several inches to over four feet (one is 13 feet long). They are mostly quartzite, some containing considerable mica and feldspar; a few are granite and a few are felsite.

In the coarser beds the boulders lie tightly packed; little matrix material is present. They are elongated about N10°E, parallel to the fold axes (b) and a lineation which appears as a faint striation on thin coatings of micaceous material (muscovite and chlorite). This lineation may be seen at the south end of the east side of the isolated outcrop several hundred feet along the beach to the northeast of the main exposure (Location 1, Fig. B5a).

Several thin, dark gray sandy beds indicate bedding dips about 60° to the east. The flat (ab) plane of the triaxial boulders does not lie in the bedding plane, but generally follows a foliation or a cleavage direction which strikes parallel to bedding but dips gentler or steeper in different parts of the structure (Fig. B6). At this stop (Location 1) the plane dips about 60° to the west. Although the boulders show their long axes consistently oriented north-south and horizontal, the flat a-b planes are less uniformly parallel, except where shearing in the a-b plane was very marked.

The tendency of the flat surfaces of the elongated boulders not to be parallel to bedding suggests that the boulders may have been rotated individually about b during folding and also sheared along cleavage planes inclined to bedding. Evidence for such movements occurs in the area.

The axial ratios (b:a:c) of the boulders average approximately 4.1:1.5: 1. Where shearing was more intense it may be 5.7:2.4: 1. The tapered ends commonly consist of intensely crushed material. Some boulders show an elongated rhombic or polygonal outline, in which the straight sides lie along cleavage and shear directions (Fig. B7). Many boulders show indentations or pinching where they were appressed against adjacent boulders; the compressive stress acting east-west but not necessarily horizontally.

One or more sets of fractures may be present in the boulders. Some of these are regional joints transecting many feet of the country rock, but others are small fractures limited to the boulders. Transverse (ac) joints are abundant. They are steep to vertical and trend east-west, essentially perpendicular to the fold axes. These are tension joints; many show a north-south separation. Some are occupied by quartz veins (Fig. B7e). Purgatory chasm has resulted from wave surge and erosion along a prominent cross-joint striking perpendicular to the shore.

Longitudinal fractures (Fig. B7C) may represent a foliation or a cleavage direction, or possibly the original bedding within the boulder. It may be emphasized that faint streaks, apparently bedding, are oriented transversely in some quartzite boulders and yet have not opened up as tension fractures.

Oblique shear fractures striking NE-SW and NW-SE may appear as a single set or as a conjugate system. Slip commonly appears along these joints as a series of stepped offsets producing extension along the major axis, b (Fig. B8). Some oblique fractures, striking at an obtuse angle to b, have opened up because of post-fracturing extension along b (Fig. B7D).

Quartz veins, from one-eighth of an inch to more than a foot thick, follow the several joint directions.

Transverse veins occupying tension fractures tend to be wider than the other sets. Several groups of short en-echelon veins on the flanks of folds, showing an E-W strike of the individual veins, indicate E-W compression and N-S extension. The quartz veins are penetrated by joints and cleavage of the host rock, indicating their syntectonic age. This is also indicated by the folded, contorted, and sheared appearance of some veins. Under the microscope the vein quartz shows strong strain shadows and Boehm lamellae.

Magnetite grains are abundant in some of the sandier beds especially along the western side of the outcrop (Fig. B9). They appear in whisps and layers up to one inch thick, as well as in scattered grains following certain beds.

Miles

42.2 STOP B4 - Proceed west on shore road, bearing left and going up hill.
42.3 Turn right (west) on unmarked road.
42.5 Entrance to St. George's School. Lunch at St. George's School, through the courtesy of Headmaster, Mr. Archer Harman, Jr. and Mr. Lawrence Goldthwait; on the lawn if we have a fine Rhode Island day, in new science building if we have poor NEIGC weather.
43.3 Bear left on Memorial Blvd.
44.7 Turn left (south) on Bellevue Ave. Most mansions along this avenue and Ocean Drive were built during 1890-1910 to serve as summer cottages. See Figure E-1 Field Trip E for a description of some of these houses.
47.7 ~~Bear~~ sharp ~~left~~ right and follow Ocean Avenue.
50.9 Stop B-5. 100 yards east of Brenton Pt. and just east of intersection of Ocean Ave. and Atlantic Ave. Exposures are along shore line south of sea-wall.

STOP B-5 - Pre-Pennsylvanian sedimentary rocks are deformed and metamorphosed but still show original sedimentary features. Prominent foliation surfaces are undulating, striking E-W and ranging in dip between 5°S and 15°N. Sedimentary beds strike SE and dip from 35-50 N. Prominent joints with movement along some surfaces trend slightly east of north. A basic dike was intruded along one of these fractures and has itself been faulted, sheared, and plastically deformed. Sedimentary rocks now contain a quartz-muscovite-chlorite metamorphic assemblage.

Graded bedding within sandstones and siltstones is well developed and consistently shows tops to the north. Several of the thicker graded beds near the southern part of the joint show internal folding and included fragments of underlying rocks.

Geology at Stop B-5 is shown in Figure B-10.

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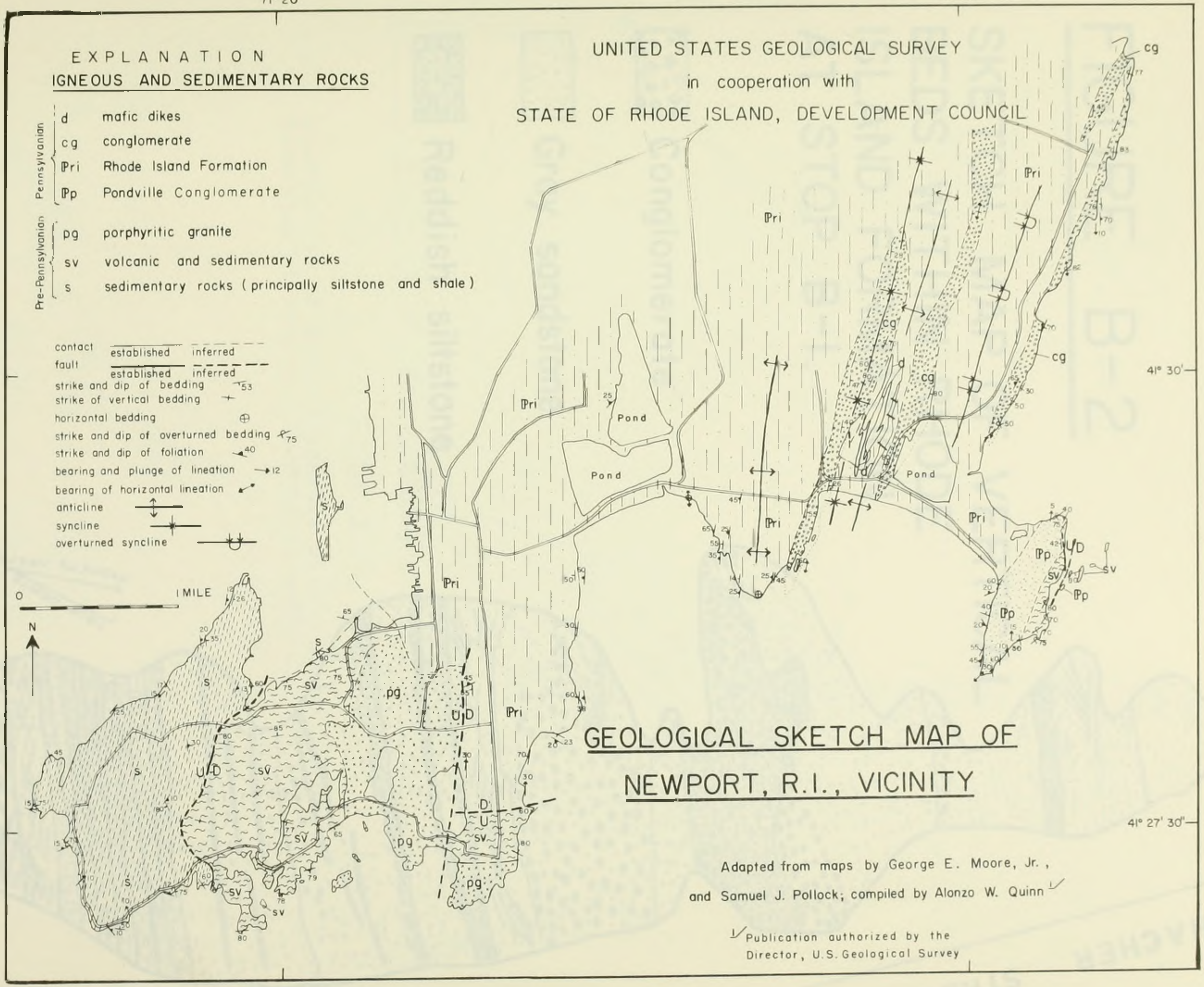

71° 20'
71° 15'
41° 30'
41° 27' 30"
EXPLANATION
IGNEOUS AND SEDIMENTARY ROCKS
Pennsylvanian
d mafic dikes
cg conglomerate
Pri Rhode Island Formation
Pp Pondville Conglomerate
Pre-Pennsylvanian
pg porphyritic granite
sv volcanic and sedimentary rocks
s sedimentary rocks (principally siltstone and shale)
contact established inferred
fault established inferred
strike and dip of bedding
strike of vertical bedding
horizontal bedding
strike and dip of overturned bedding
strike and dip of foliation
bearing and plunge of lineation
bearing of horizontal lineation
anticline
syncline
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UNITED STATES GEOLOGICAL SURVEY
in cooperation with
STATE OF RHODE ISLAND, DEVELOPMENT COUNCIL
Pond
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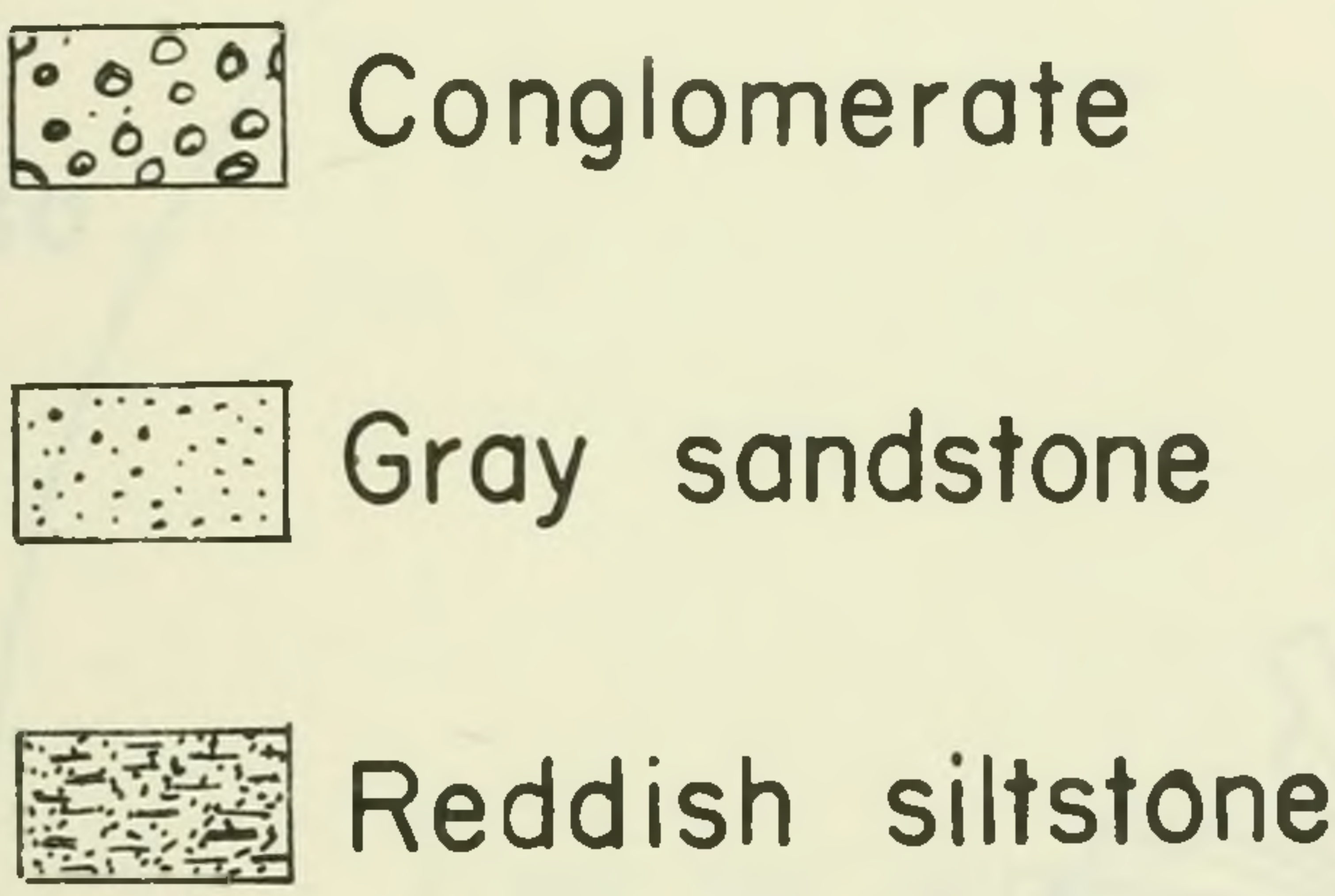
GEOLOGICAL SKETCH MAP OF
NEWPORT, R.I., VICINITY
Adapted from maps by George E. Moore, Jr.,
and Samuel J. Pollock; compiled by Alonzo W. Quinn [1]
[1] Publication authorized by the
Director, U.S. Geological Survey

FIGURE B-2

SKETCH MAP OF VERTICAL BEDS WITHIN RHODE ISLAND FORMATION AT STOP B-1.



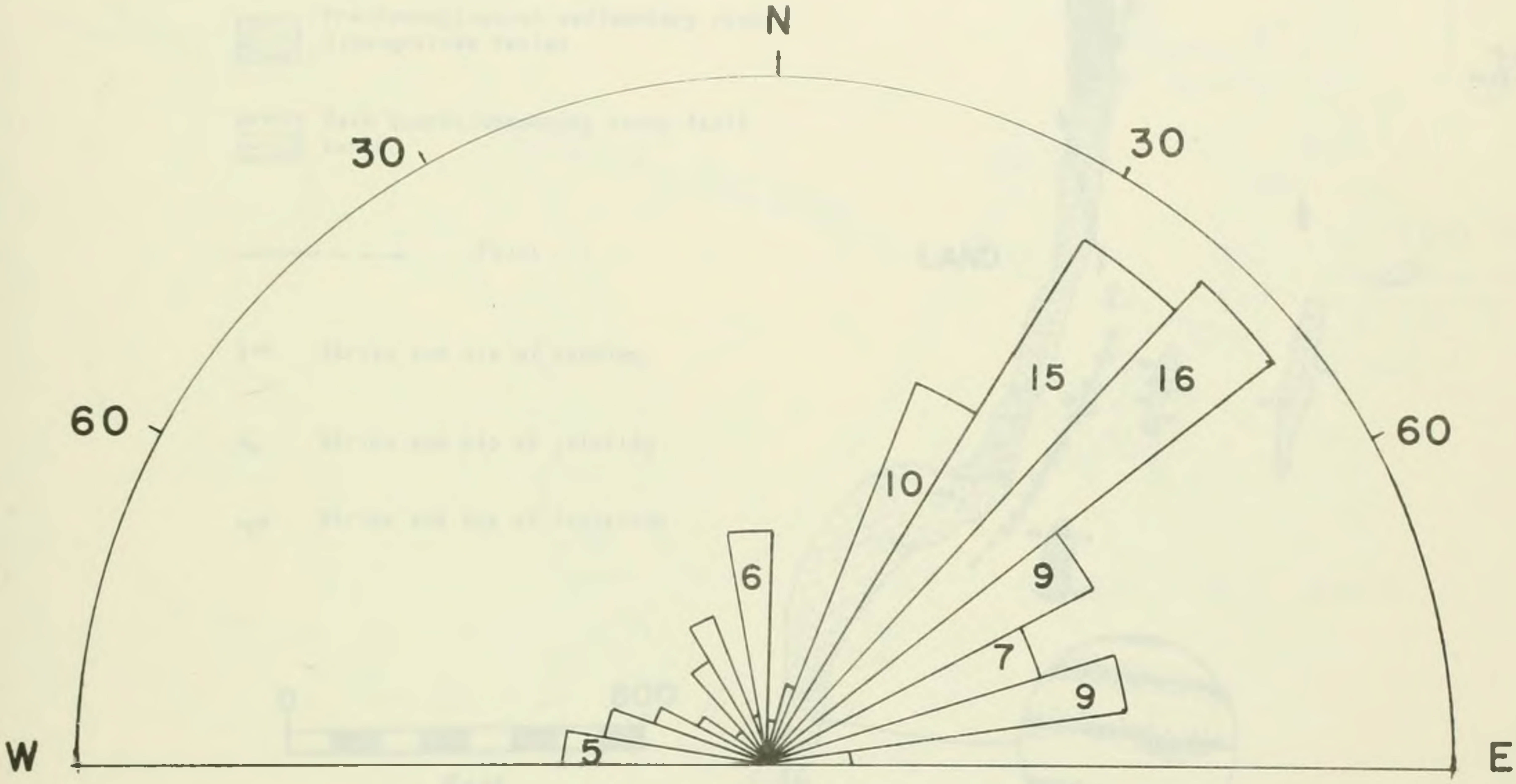


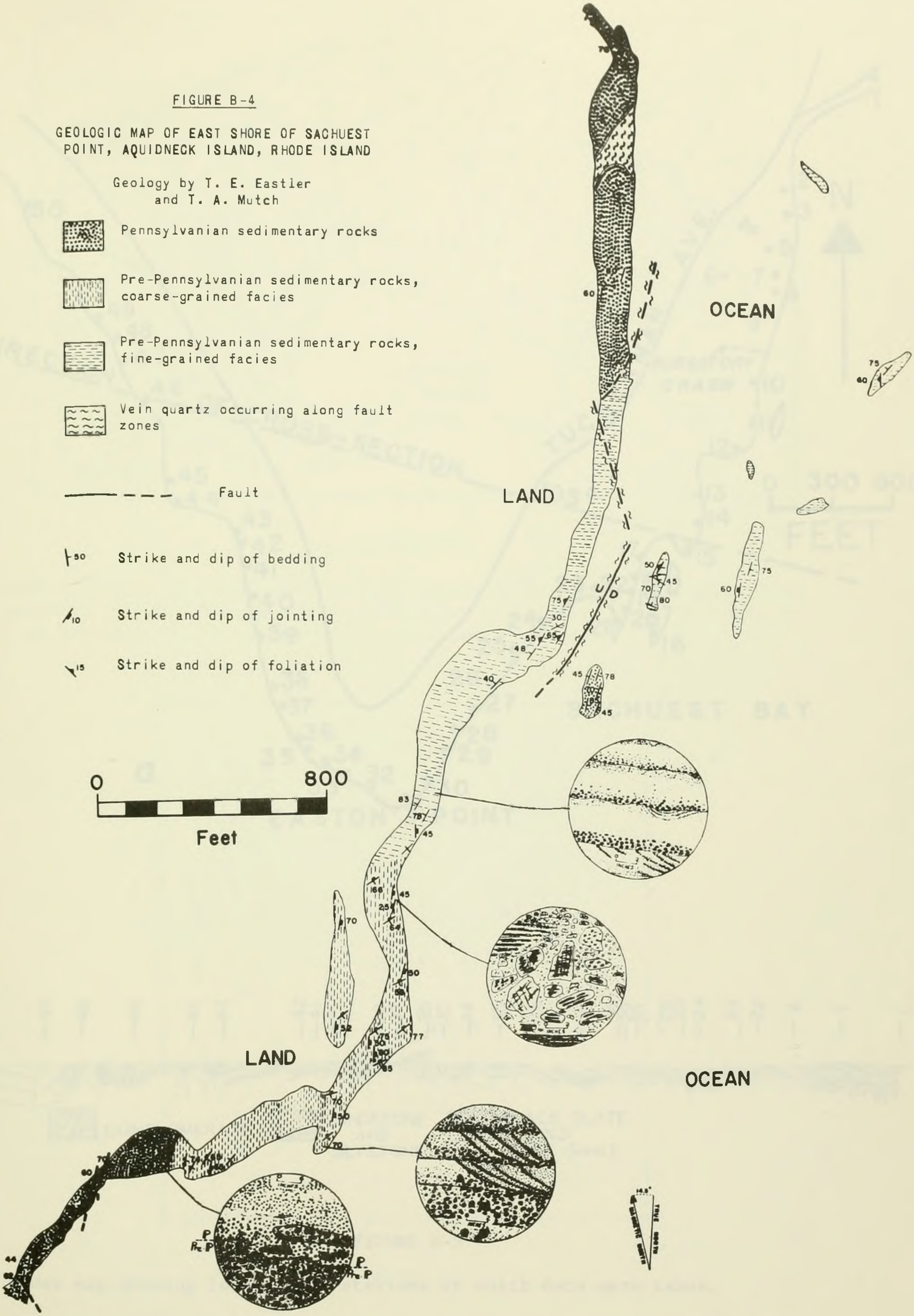
FIGURE B-3

Orientation of plant fragments within Rhode Island Formation at stop B-2 (100 measurements).

FIGURE B-4

GEOLOGIC MAP OF EAST SHORE OF SACHUEST POINT, AQUIDNECK ISLAND, RHODE ISLAND

Geology by T. E. Eastler and T. A. Mutch



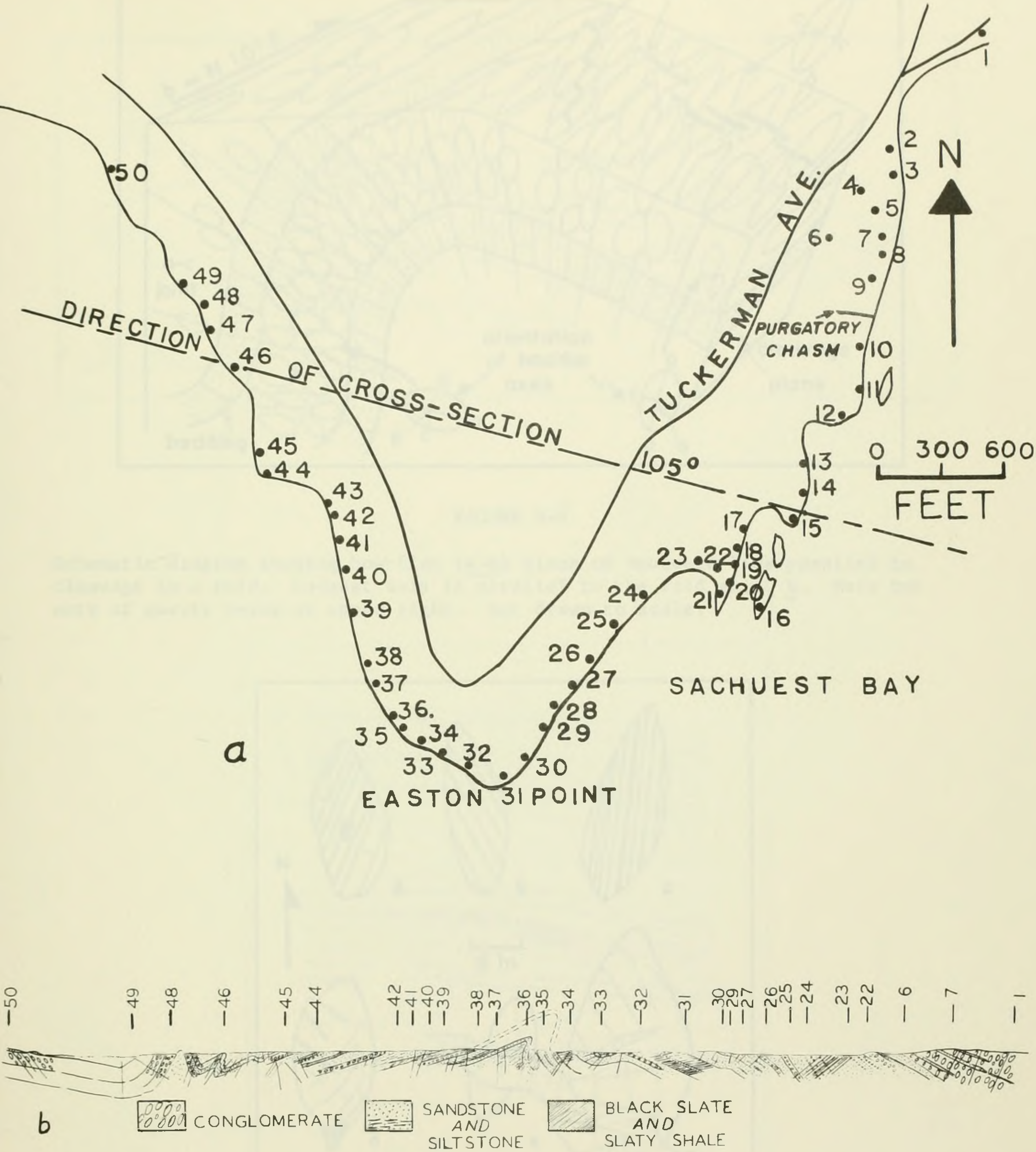


FIGURE B-5

a. Index map showing location of stations at which data were taken.

b. Preliminary composite section across Easton Peninsula along a line bearing 105°. Data projected from stations along perpendiculars to line of section.

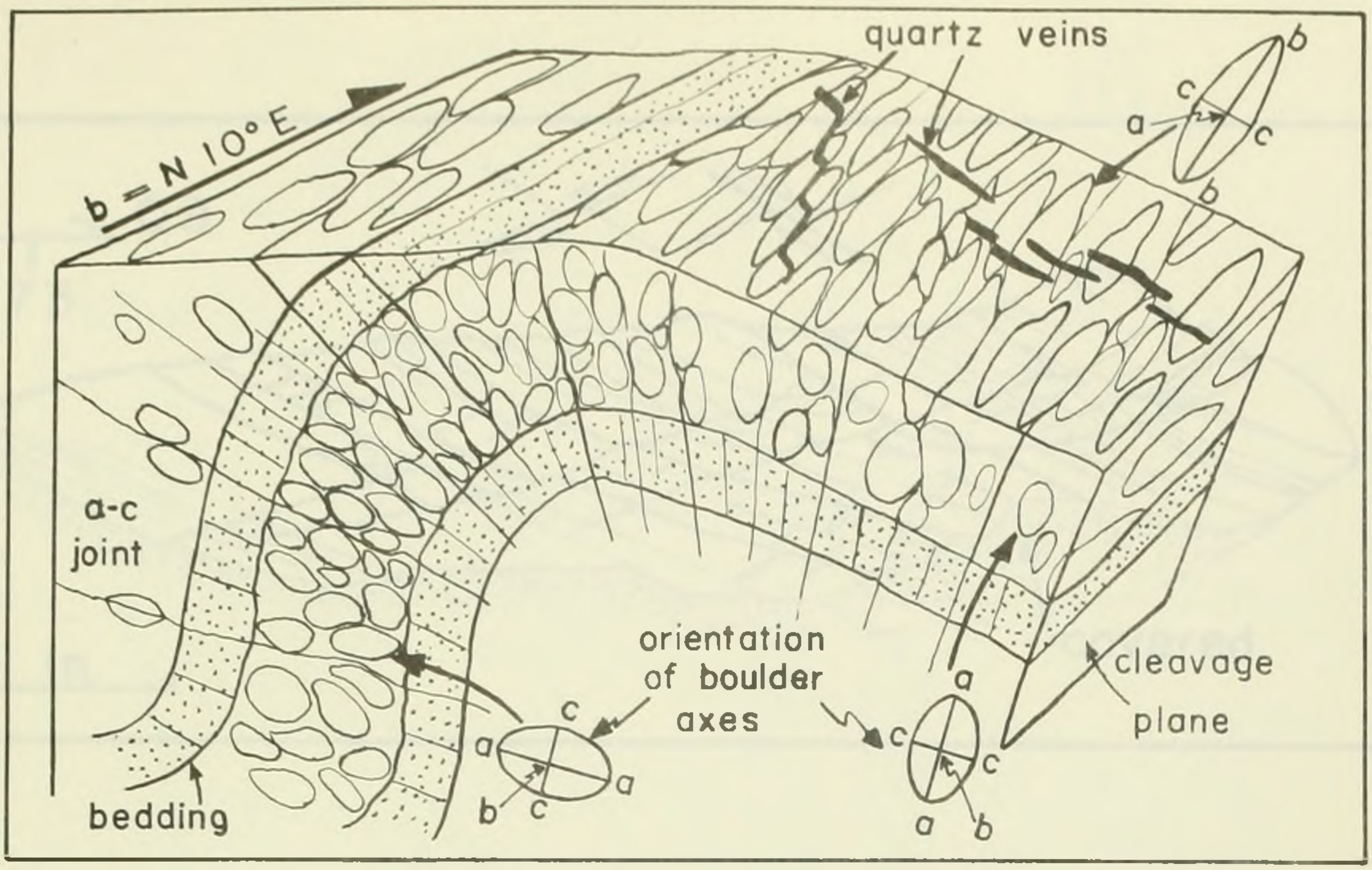


FIGURE B-6

Schematic diagram showing how flat (a-b) plane of boulders lies parallel to cleavage in a fold. Longest axis is parallel to the fold axis, b. Note two sets of quartz veins at upper right. Not drawn to scale.

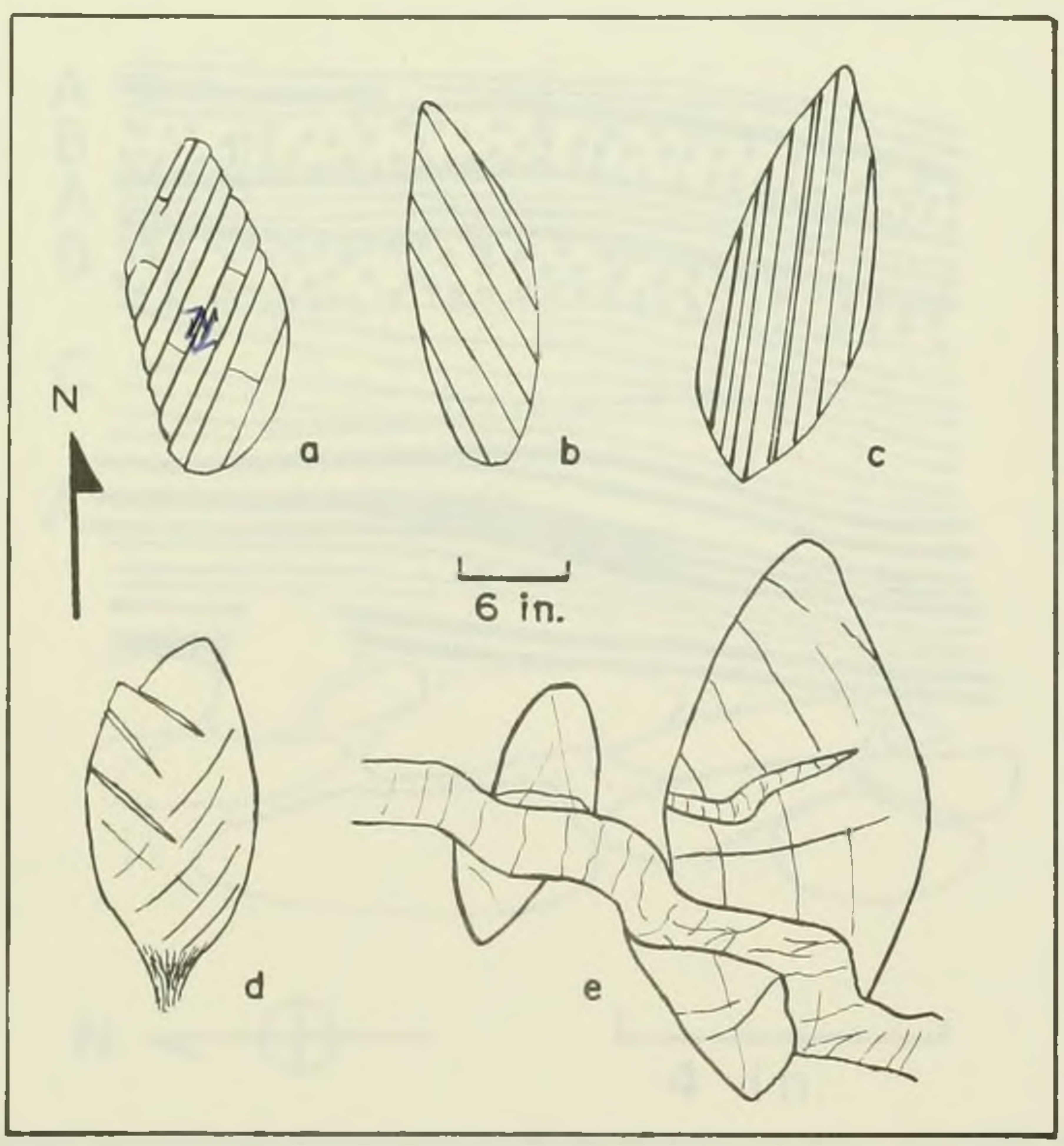


FIGURE B-7

Several elongated boulders showing fracture directions and quartz vein with offset (e).

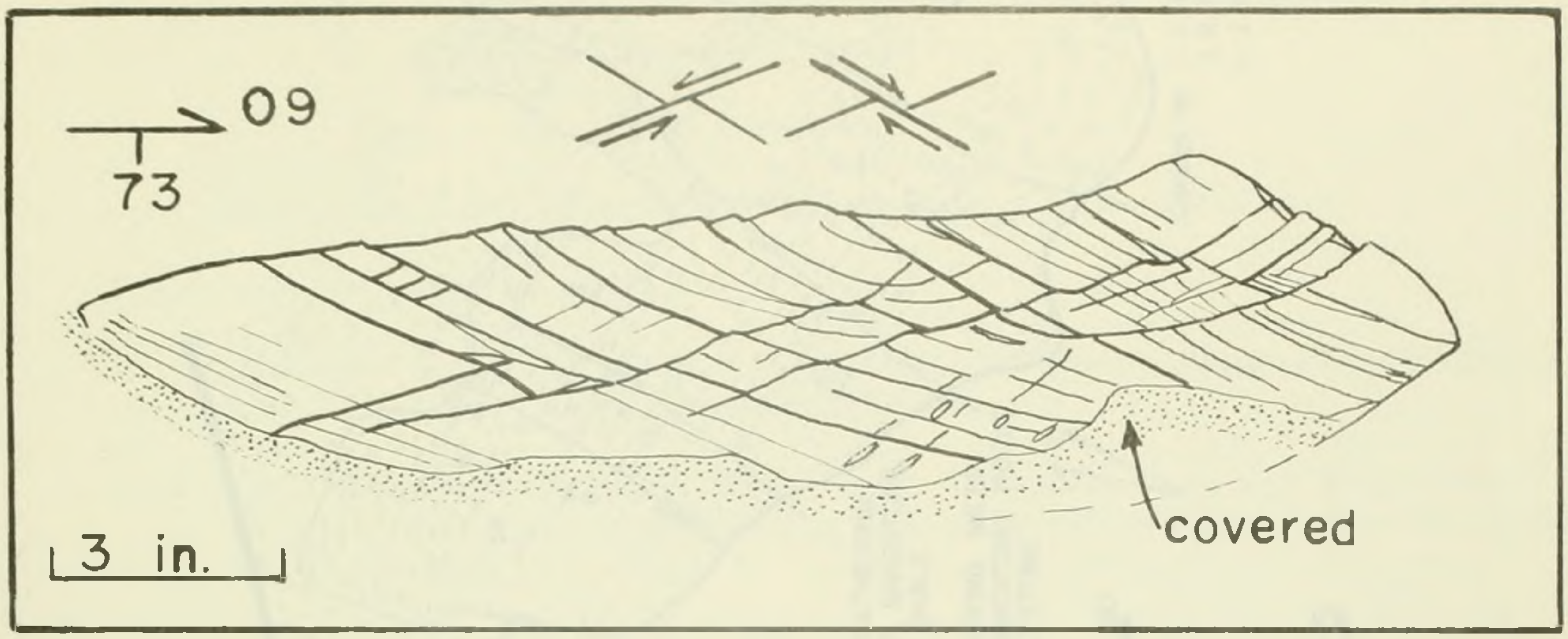


FIGURE B-8

Sheared boulder showing N-S extension and sense of movement along conjugate shears. Location 11.

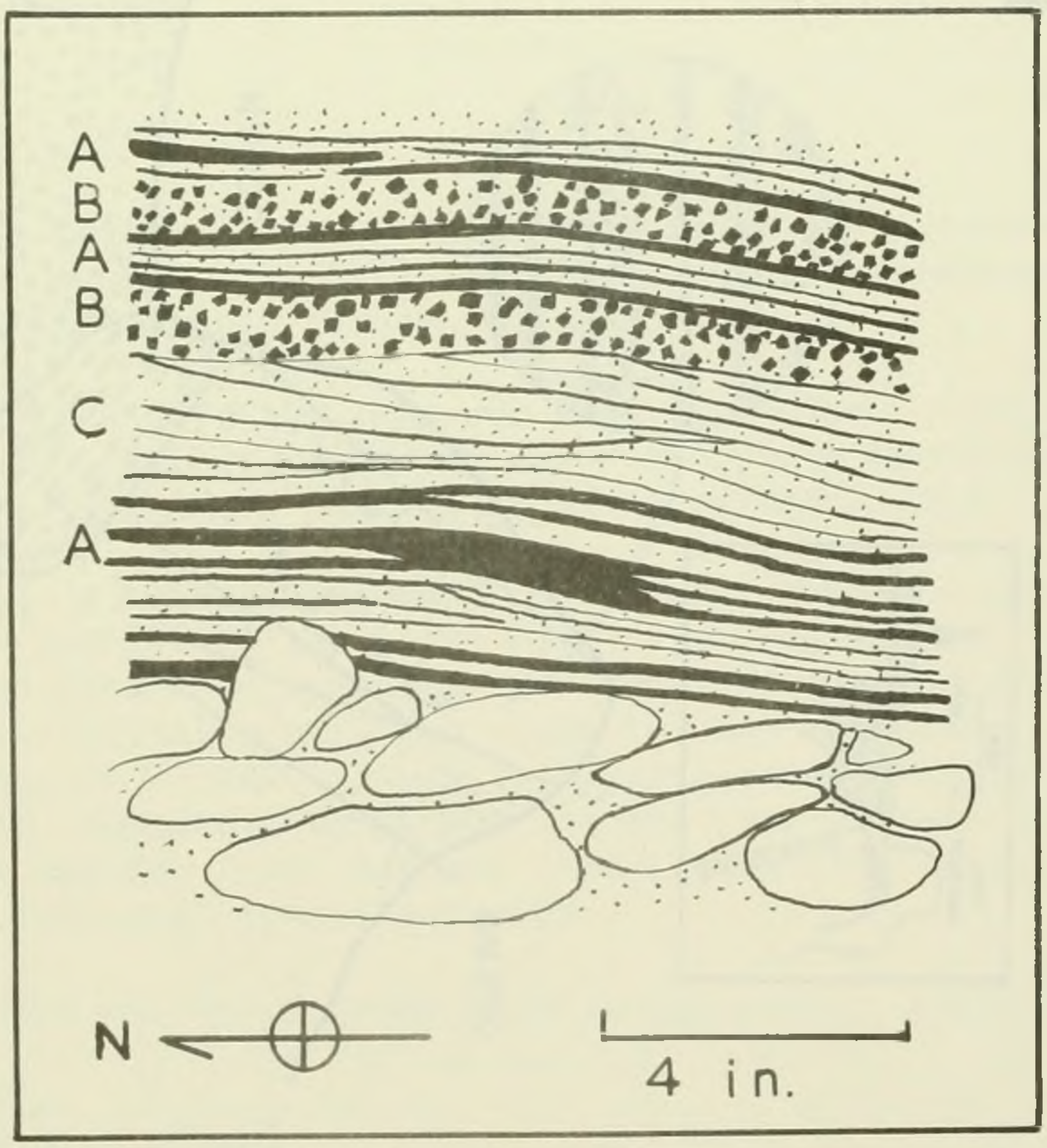


FIGURE B-9

Magnetite occurs in thick bands (A), scattered grains (B), and very thin streaks in silty beds (C). Cross-bedding in layer C indicates top is to the east. Location 4.

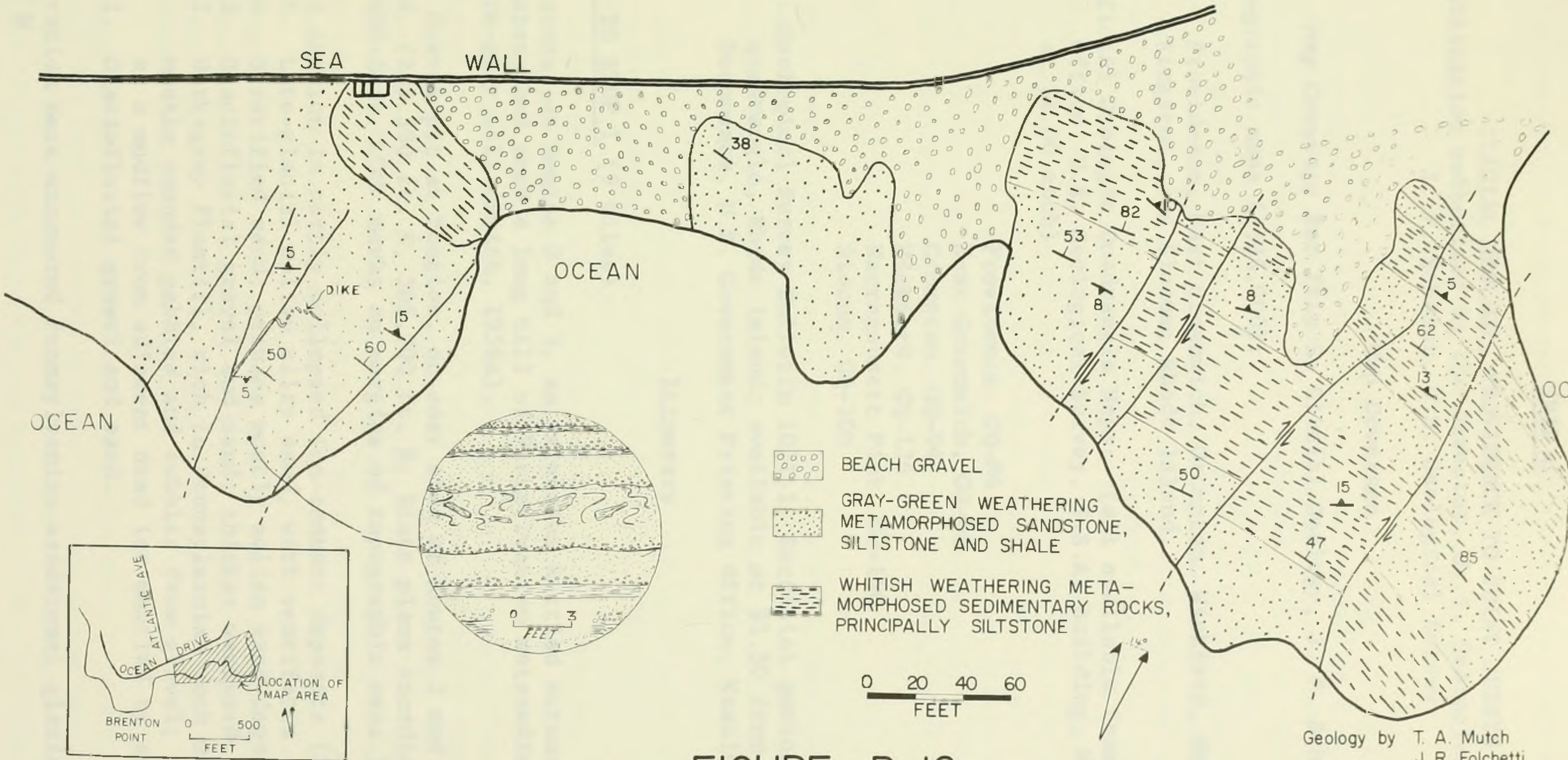


FIGURE B-10

GEOLOGY AT STOP B-5