DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Preliminary results of core drilling of Triassic border faults near Riegelsville, Pennsylvania

by

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INTRODUCTION

Two continuously cored vertical drill holes 606 and 200 feet deep were completed in May and June of 1985 near Riegelsville, Pennsylvania. The cores were taken near the intersection of Lehnenberg and Gallows Hill Roads on the hanging-wall block of the Triassic border fault in the Riegelsville quadrangle (Figures 1 and 2). The drill holes, Riegelsville 1 and 2 (R-1 and R-2 respectively), were drilled 289 feet apart in a line normal to the suspected trace of the border fault or faults. Previous seismic reflection profiling along Gallows Hill Road suggested a dip of about 30 degrees for the border fault at this locality (N. M. Ratcliffe and J. K. Costain, unpublished data). R-1 and R-2 were drilled in order to define the dip of the border fault along the seismic line and to determine the mineralogic and cataclastic structures in the hanging and footwall blocks. A water well drilled in 1984 (Fig. 2) on the northeast corner of Lehnenberg and Gallows Hill Roads penetrated through Triassic strata down into gneiss and phyllonite of the footwall at a depth of approximately 190 feet.

Based on the water well data, local geology (Drake and others, 1967) and the seismic data, R-1 was sited to penetrate the border fault at about 250 feet and to sample 500 feet of the footwall block. R-2 was designed to sample the updip projection of the fault in order to confirm the dip and trace of the fault. New data resulting from deepening of the USGS drill hole on Rattlesnake Hill to 900 feet in 1967 is also reported here.

Results of the core drilling are to be used to analyze the cause of the strong reflectors seen on the VIBROSEIS[1] profile coming from beneath the border fault (Ratcliffe and Costain, unpublished data). New field data, geologic data of Drake and others (1967), and the results of the 900-foot Rattlesnake Hill drill hole lead to a reinterpretation of the structure of the Musconetcong fault system as portrayed by Drake and others (1967). For Drake's interpretation see cross section Figure 1.

DESCRIPTION OF DRILL SITES

R-1, located at the southwest corner of Lehnenberg and Gallows Hill Roads, was drilled to a depth of 606 feet. Collar elevation is 399 feet. HQ (2 7/8 in) core was collected to 319 feet, and NQ (2 in core) from 319 to 606 feet. Throughout recovery was greater than 95%, with the only notable omissions occurring in the weathered, upper part of the drill hole above 70 feet. The HQ core was collected using a stainless steel inner liner that allowed removal of the core in continuous ten-foot lengths. By matching structures between runs a continous line for orientation was carried down through the 311 foot depth so that relative orientation is known. From 311 feet to 606 feet the orientation is less certain owing to several instances of lack of continuity in zones of blockage within the slow and difficult-drilling granite gneisses.

Drilling rates ranged between 8 and 10 minutes per foot above 311 feet and between 15 and 30 minutes per foot below 311 feet.

[1]VIBROSEIS is a trademark of Continental Oil Company.

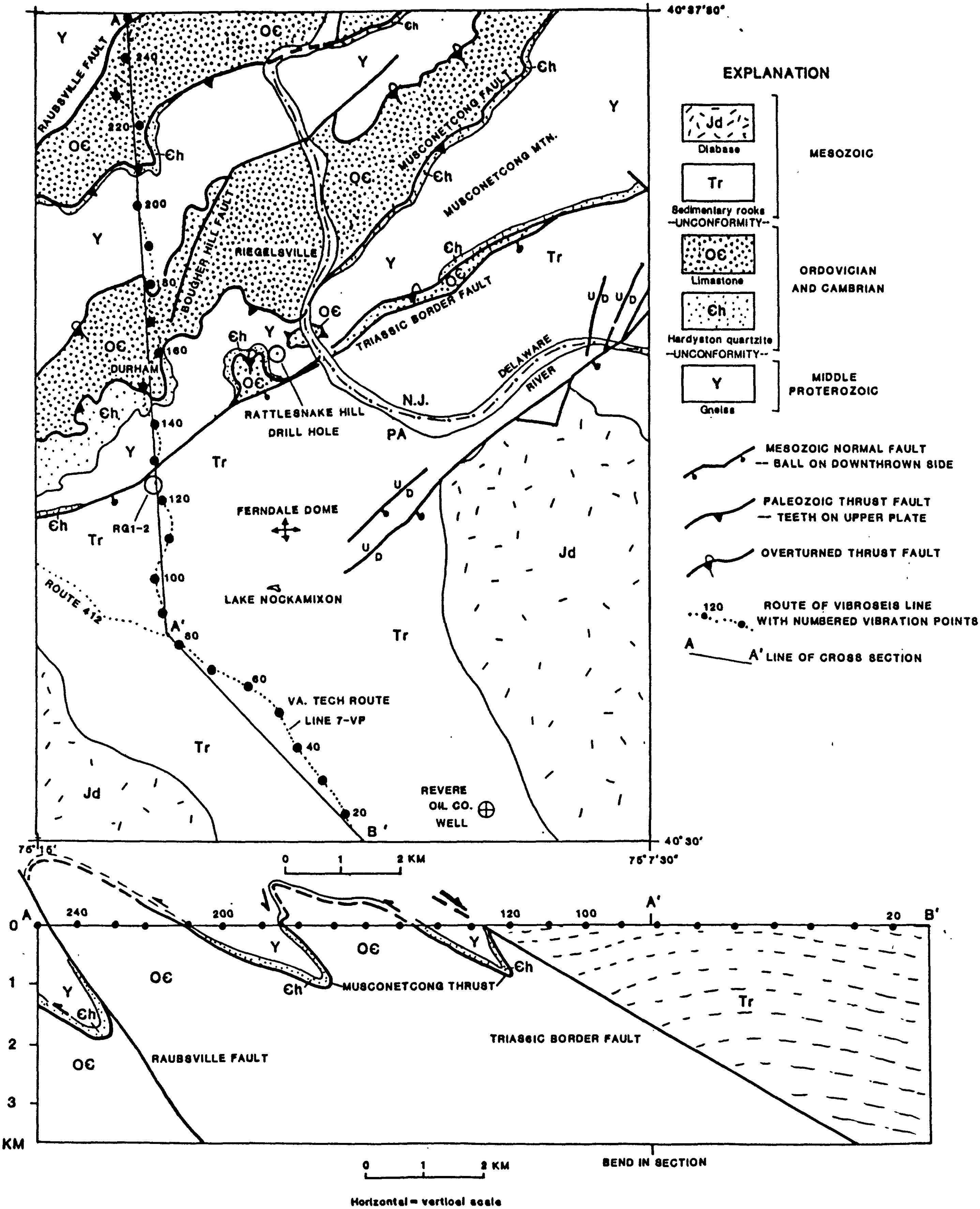

Figure 1. Simplified geologic map of the Riegelsville area after Drake and others (1967) showing location of the Riegelsville and Rattlesnake Hill core holes.

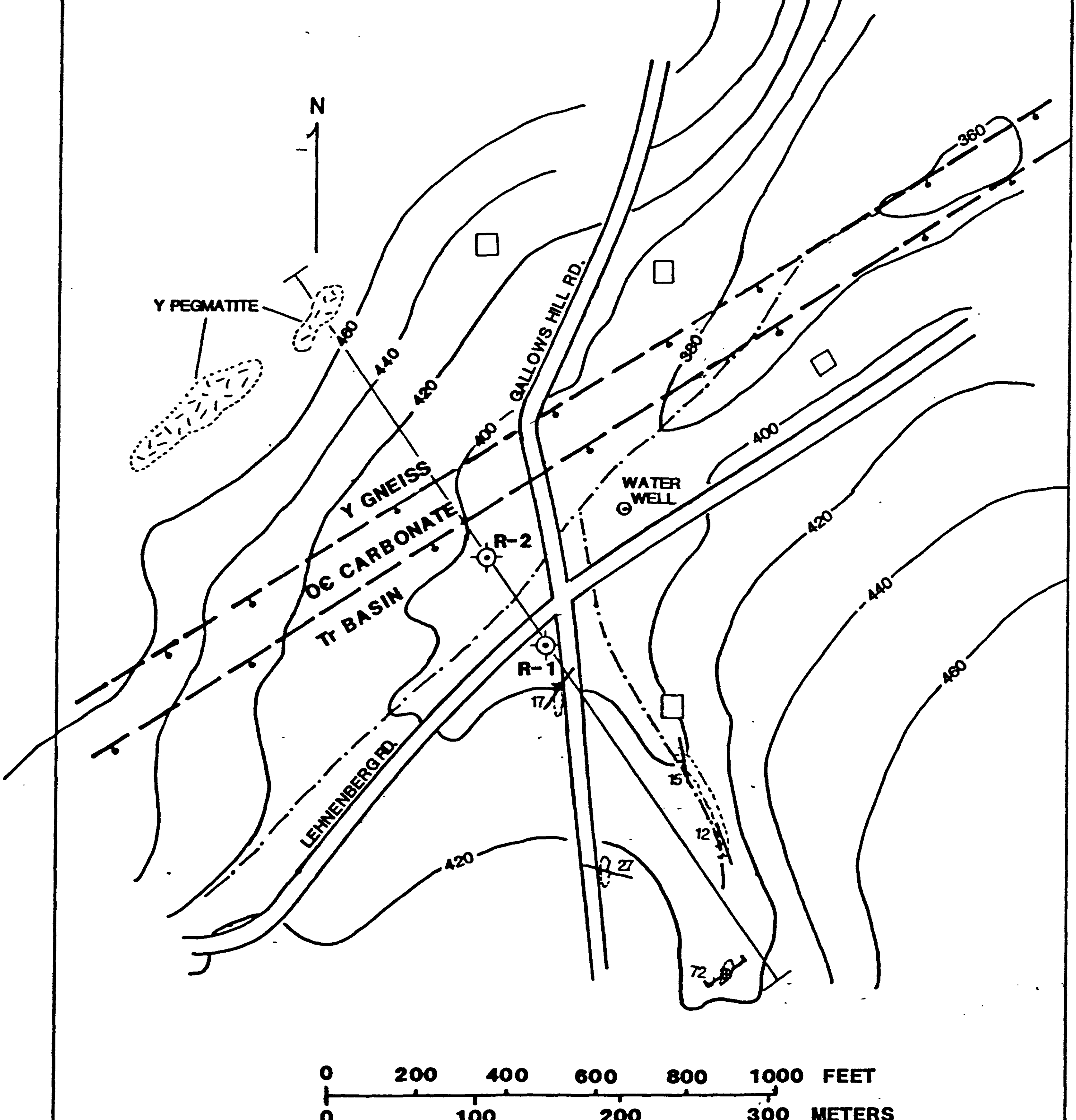

Figure 2. Location map showing site of R-1 and R-2 core holes at margin of Newark basin.

Measurements of verticality, using a spring-loaded compass and inclinometer (Pajari instrument), were made just below the termination of the HQ run at 319 feet and at the bottom of the hole. The results showed the following inclinations and azimuths:

1. at 330 feet: 2° to N31°W; and 1° to N31°W
2. at 596 feet: 2° to N10°E.

These results indicate the hole is substantially vertical.

Following completion of drilling, 50 feet of 4" casing was left in the hole and the hole capped for geophysical logging by Lamont-Doherty in September 1985.

R-2 was drilled 289 feet northwest of R-1. The ground elevation was 398 feet. Because of very deep weathering, solid rock was not encountered above 72 feet, where casing was set. HQ (2 7/8 in) diameter core recovery above 72 feet was poor, but improved below 120 feet. Caving and difficult drilling at about 162 feet necessitated a change to NQ diameter (2 in) and NQ core was collected from 162 feet to 200 feet. Because of the shallow depth, the hole was not surveyed. Following drilling the hole was filled and casing was removed.

Rattlesnake Hill Drill Hole

A drill hole on Rattlesnake Hill in Middle Proterozoic gneiss was drilled in 1967 to a depth of 476 feet. Results of this drilling were reported by Epstein and others (1967). Subsequently in 1967 the hole was deepened to 900 feet for heat flow studies by W. H. Diment of the U.S. Geological Survey. The core from 476 to 900 feet was placed in repository in Washington, D.C., but has not been described previously. The core is 1 5/8-in. diameter. As described by Epstein and others (1967) the contact between highly altered hornblende-plagioclase gneiss and dark-grey dolostone was crossed at a depth of 392 feet. The hole bottomed at 476 feet in dolostone of probable Cambrian age. The results of the core drilling confirmed the structural position of gneiss above Paleozoic limestone proposed by Drake and others (1967).

The hole was deepened from 476 feet to 900 feet later in 1967. From 476 feet to 731 feet highly cataclastic and strongly foliated blue-green, pale-grey and dark-grey dolostone is present. Bedding and cleavage are folded but the structures are shallow-dipping. Between 731 and 736 feet quartz-rich mylonitic rock, possibly pebbly quartzite, is found. Highly cataclastic gneiss begins at about 736 feet. Cataclastic structures die out downwards in the core and from 800 to 900 feet less-sheared biotite and hornblende granite gneiss is present.

RESULTS OF CORING

Riegelsville No. 1

Rocks of the hanging-wall block, (Fig. 3 and Appendix A) above 173 feet consist of interbedded red siltstone and dark-grey dolostone conglomerate of the Brunswick Formation of Upper Triassic age. Locally at 50 and 75 feet

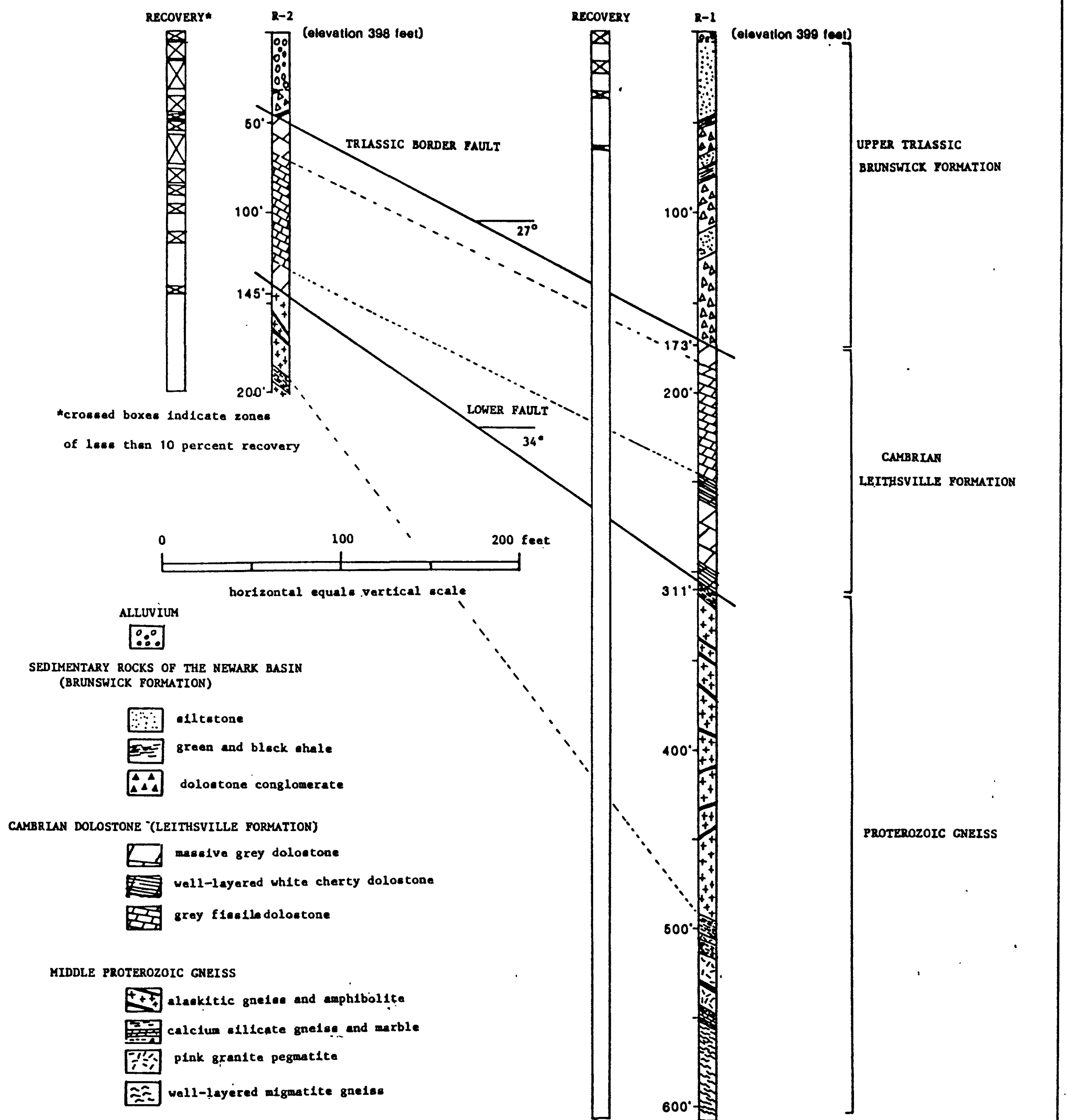

Figure 3. Generalized cross section through USGS core holes R-1 and R-2 showing major faults and rock units.

thin-bedded, dark-grey and green shales are interbedded near the top two prominent layers of conglomerate. A zone 16 feet thick of dark-grey to greenish grey arkose and dark shale is interbedded with the conglomerate at 108 feet. Overall the Upper Triassic rocks dip uniformly at 15° to 30° towards the border fault.

The contact with Lower Cambrian dolostone of the Leithsville Formation was encountered at 173 feet. Details of the fault contact are discussed below. Rocks of the Leithsville Formation consist of two major lithologies; dark, blue-grey, massive, non-siliceous dolostone, and a whitish grey, well-bedded dolostone having 1 to 3 in layers of nodular white chert. Locally the dark dolostone passes into highly carbonaceous, fissile black dolostone. Overall the carbonate rocks are dolomitic, and poor in interbedded siliceous or argillaceous clastic sediments. Metamorphic structures consisting of at least two cleavages are present; one, a penetrative mylonitic sericitic foliation veined with calcite, is present in some zones. The assemblage chlorite-dolomite-quartz appears to be stable, indicating lower greenschist facies metamorphism. A second strain-slip cleavage is also present. Bedding-cleavage relations indicate a right-side-up section.

A second and lower fault was encountered at 300 feet, below which highly cataclastic Middle Proterozoic gneiss was encountered. The upper part of the gneiss is largely light-colored alaskitic gneiss having thin zones of interlayered biotite - hornblende - plagioclase gneiss and amphibolite.

From 494 feet to 555 feet a distinctive hornblende-pyroxene-quartz plagioclase gneiss and interlayered diopside marble is found. This unit is highly intruded by coarse-grained, pinkish biotite and hornblende granite pegmatite.

From 555 to 606 feet a well-layered biotite - plagioclase gneiss with alaskite layers is present.

Rieglesville No. 2

The same general sequence of rocks as in R-1 was encountered in R-2. Dolostone conglomerate forms the footwall above 56 feet. Between 56 and 142 feet dark, blue-grey dolostone and whitish dolostone identical to the sequence of Leithsville in R-1 was recovered.

Alaskitic gneiss of the footwall was encountered from 146 to 188 feet. A prominent zone of hornblende-diopside-plagioclase gneiss similar to that underlying the alaskitic gneiss in R-1 is present at 188 feet. In a simplified section the rock units in the two holes are correlated as shown in Figure 3.

Based on the depth of the major contacts the contact between the Upper Triassic strata and the Leithsville dips 27° to southeast. The contact between Leithsville Formation and the gneiss dips 34° southeast.

Internal structure within the cores is complex but in general fault fabrics dip 20° to 30° to the southeast parallel to the major contacts in Figure 4.

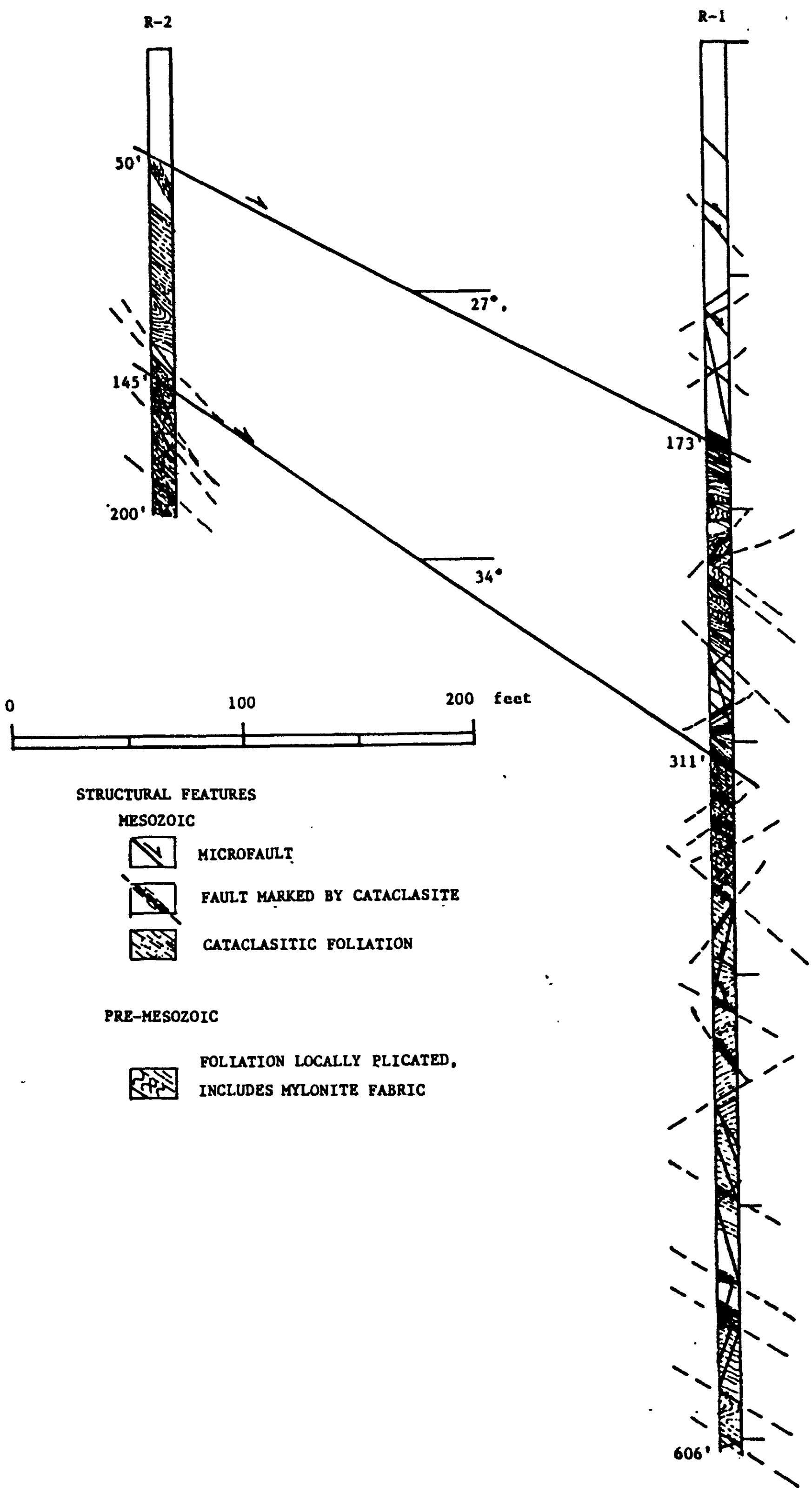

Figure 4. Generalized cross section through USGS core holes R-1 and R-2 showing principal fractures and faults and structural features of pre-Mesozoic and Mesozoic age.

DESCRIPTION OF STRUCTURES

Riegelsville 1 and 2

Cataclastic structures consisting of gouge, cataclasite, microbreccia and calcite-quartz veins are present throughout both cores. The spacing and intensity of the cataclastic structures is used as a key to defining the major zones of faulting that coincide in most cases with the lithologic contacts between Triassic and Cambrian strata and between Cambrian and Middle Proterozoic rocks. Cataclastic rocks are almost entirely coherent except for minor narrow zones of blue-grey gouge and zones of rubble. The major portion of the core near faults is cemented and rebrecciated cataclastic rock showing evidence of multiple cycles of cataclasis, cementation and refracturing. Undeformed zones of foliated, chlorite-rich and slickensided cataclasite commonly dip 20° to 30° to the south-southeast. Redeformed zones of cataclasite and cemented gouge indicate multiple episodes of down-to-the-southeast sense of motion.

Cataclastic structures related to deformation on the hanging-wall block are illustrated by the detailed sketch of the structures above the major fault with the Cambrian Leithsville Formation in Figure 5A. Progressive increase in cataclasis and comminution of dolostone clasts is illustrated in the section from 170 feet down to 171.8 feet. The bottom of this deformed zone is a foliated cataclasite zone that dips 30° to the south. Within the cemented cataclastic rocks, evidence for cycles of faulting, rebrecciation and recementation can be seen.

As the contact with the Leithsville (at 173.4 feet) is approached the dolostone conglomerate is more loosely cemented but still is a coherent brecciated rock bound together by a network of minute calcite veins.

The actual contact, placed at 173.4 feet as recovered, was a slightly clayey breccia without strong cohesion and lacking a strong cataclastic fabric. Cataclasite at the upper surface of the Leithsville was well cemented and locally foliated.

Recovery of this fault in R-2 was not complete enough to allow detailed description, but cataclastic structures near the top of the Leithsville show shallow dips of 20° to 30° and structures similar to those in the Leithsville of R-1.

Cataclastic structures associated with the lower fault encountered in R-1 between Leithsville and underlying Middle Proterozoic gneiss are illustrated in Fig. 5B. Recovery of the contact was complete. A strong cataclastic structure, expressed by weakly coherent chlorite-rich cataclasite and zones of carbonaceous foliated cataclasite, dips 20° to 40° to the south and offsets or deforms older zones of cataclasite. High-angle normal faults dip steeply southeast or northwest and locally pass downwards into shallow-dipping structures. Locally a sliver of pale greenish cataclasite, possibly derived from gneiss, forms a small sliver in dolostone 0.5 foot above the main fault. As in the fault contact described above the minor faults and physical nature of the cataclasite suggest Mesozoic extensional faulting.

Northwest

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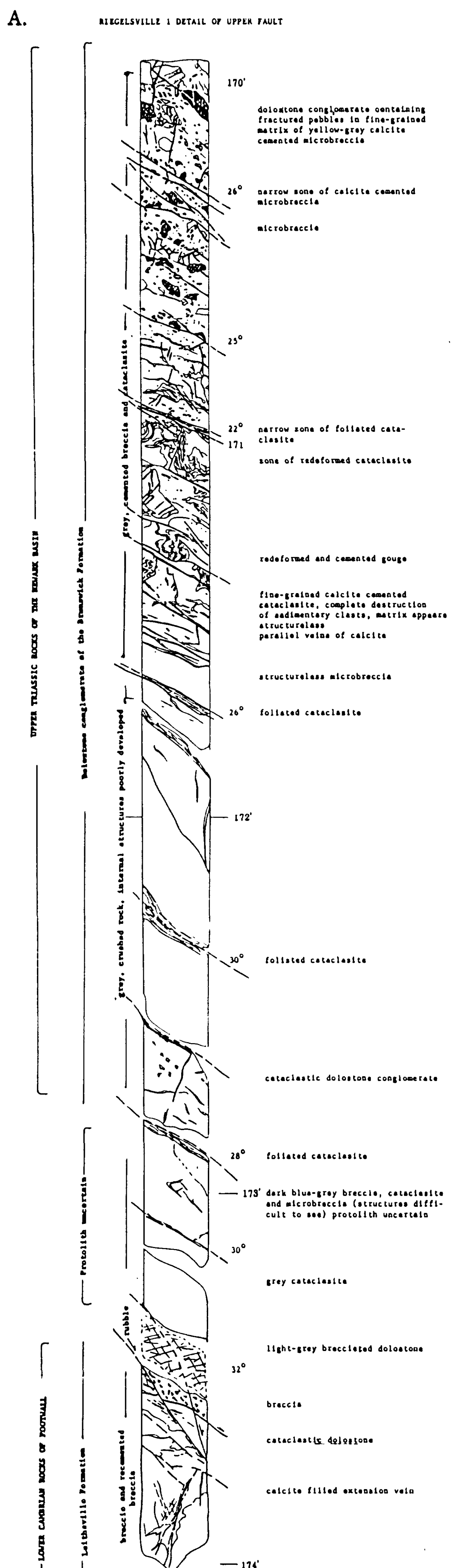
Southeast



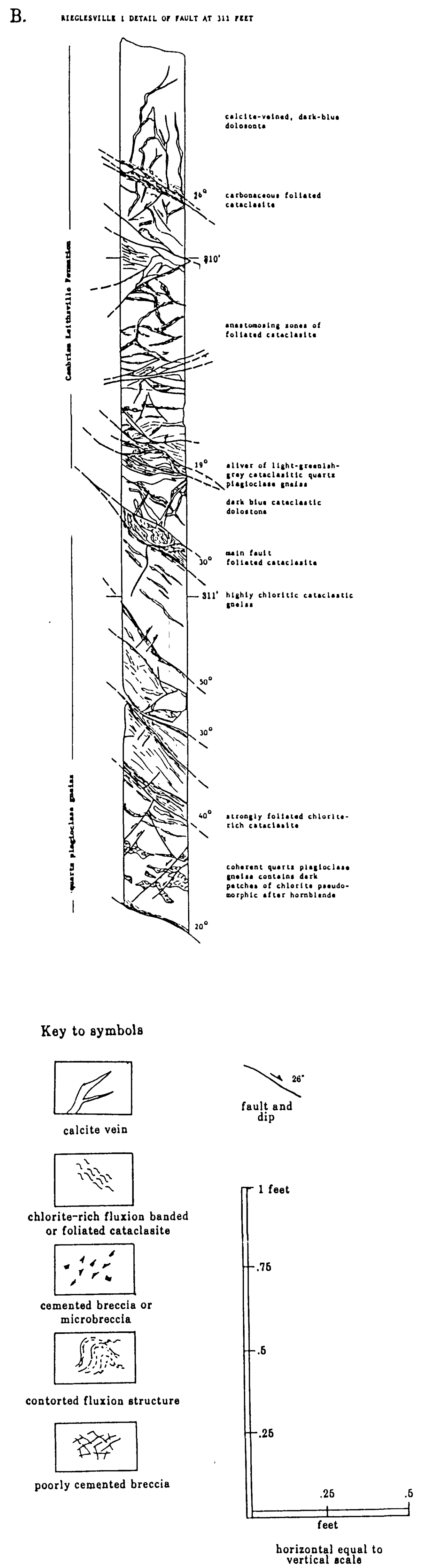


Figure 5. Detailed sketches of core from major fault zones in R-1. A: Upper fault between Triassic dolostone conglomerate and Cambrian Leithsville Formation at 173.4 feet. B: Lower fault between Cambrian Leithsville Formation and Middle Proterozoic gneiss at 311 feet.

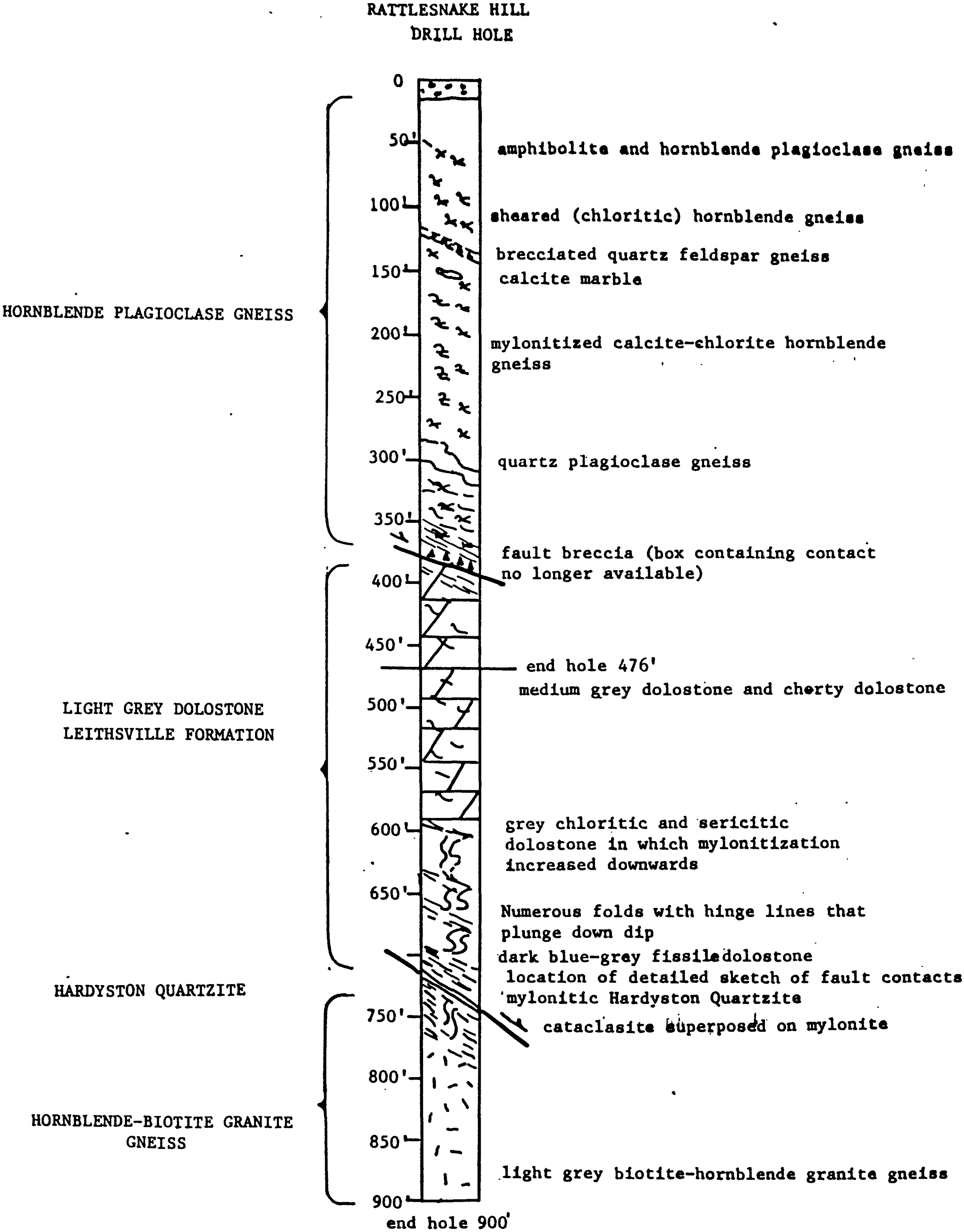


Figure 6. Diagramatic section of Rattlesnake Hill core hole, data above 476 feet from Epstein and others (1967).

Throughout the core cataclastic structures appear to dominate; however, compositional layering within the dolostone is locally expressed by a subparallel foliation resulting from growth of sericite and chlorite. This foliation commonly is highly plicated and folded suggesting deformation of a pre-existing metamorphic structure. Locally folds in the Leithsville have axial planar foliation.

Within the gneiss, zones of mylonite gneiss are present although these zones are difficult to distinguish because of the extreme disruption. Figure 4 is a diagramatic portrayal of the deformation structures seen in the cores. The heavy lines and dark areas represent zones of chlorite-rich cataclastic and breccia assumed to be Mesozoic. The lighter lines in Cambrian and Middle Proterozoic rocks depict structures that predate the clear Mesozoic cataclasis and may be Paleozoic or Middle Proterozoic in age. Attention is called to the central zone of the Leithsville where the white, better-layered dolostone exhibits packages of rock having strongly plicated structures. Many shallow-dipping structures both within the Leithsville and in the gneiss appear to be strongly foliated rocks that have been extensively reactivated by slip on the muscovite surfaces.

The axial regions of the plications appear to lack the strongly chloritic surfaces that are present on the homoclinally dipping surfaces elsewhere in the core, thus supporting the interpretation of older structure. Some zones in the gneiss appear mylonitic and have well-developed quartz elongation fabrics.

Rattlesnake Hill drill core

A simplified log (Fig. 6) of the Rattlesnake Hill core, including the new data from 476 to 900 feet, shows a thick section of amphibolitic gneiss overlying dolostone at 392 feet as described by Epstein and others (1967). Dolostone below the fault becomes increasingly foliated and folded downward in the core as the contact with the underlying Hardyston Quartzite is approached. At the actual contact dolostone is brecciated but not strongly mylonitized. A sketch of this contact at 731.4 feet is shown in Figure 7. The extensional nature of the cataclasis suggests that this fault is a Mesozoic fault. Below this the quartzite is variably mylonitic but locally exhibits reactivation along brittle fracture surfaces as at 734.9 feet.

The quartzite becomes more mylonitic near the contact with the underlying mylonite gneiss at 736.6 feet. The sample of actual contact was removed from the collection prior to my examination of the core and its location is unknown. Gneiss below 737 feet is highly mylonitic and sericite-rich and exhibits abundant minor folds and transposed gneissic layers. This mylonite zone is inferred to be Paleozoic. From 800 feet down in the core the gneiss is relatively non-mylonitic and is a medium to coarse-grained biotite granite gneiss.

Thin section study of selected samples from the contact zone between dolostone, Hardyston Quartzite and gneiss in the depth range 731 to 739.3 feet (Fig. 7) shows composite deformation fabrics. Many thin sections reveal evidence for extensional structures near many of the faults. Carbonate from

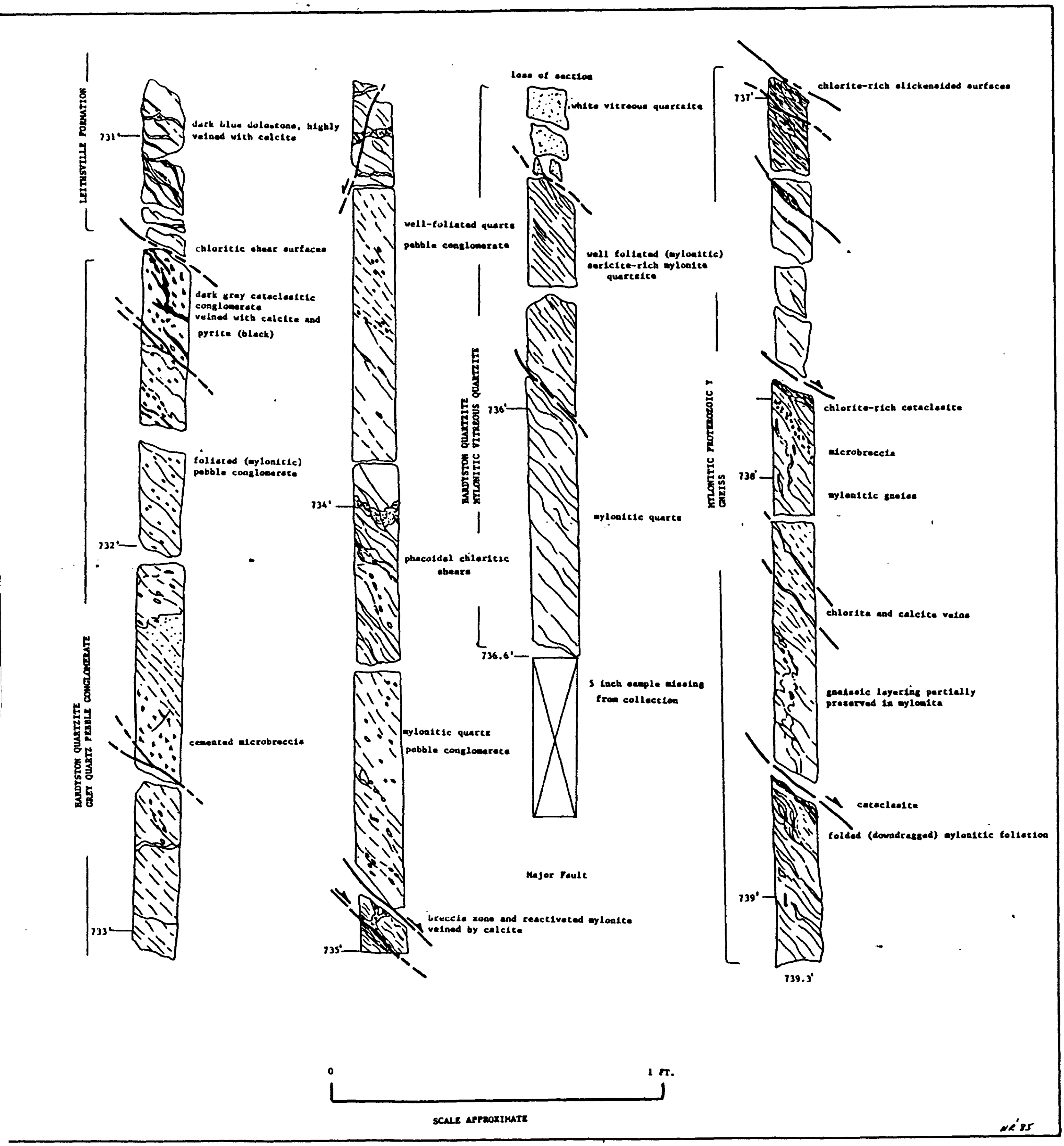


Figure 7. Detailed sketches of major contacts in Rattlesnake Hill core between Leithsville Formation, Hardyston Quartzite and Middle Proterozoic gneiss at 731 to 739 feet. Heavy lines denote faults of probable Mesozoic age superposed on Paleozoic foliation.

just above the Hardyston is micro-veined with hundreds of calcite extension veins 0.5 mm thick showing excellent extension in the horizontal plane.

A strong, older mylonite fabric is present in both the gneiss and the quartzite, but this is widely overprinted by extensional microfaulting.

Extensional structures in outcrops near border fault

Excellent cataclastic structures are locally present in rocks of the footwall block and hanging-wall block. Structure expressed in the footwall block may be seen from the Bloomsbury quadrangle southwest to the drill site at Rieglesville in gneiss outcrops closest to the border fault. Locally, Drake (1967) and Drake and others (1967) mapped or noted such structures.

A sketch of a quarry exposure of the highly cataclastic, chlorite-epidote- and calcite-veined gneiss from the border fault near West Portal (Fig. 8) shows development of a shallow-dipping set of synthetic and antithetic extensional faults. Slickenlines on the chlorite-coated surfaces outlined in the sketch commonly trend S.40°E. or N.40°W. on slip surfaces that are parallel to the overall shallow and undulating dip of the gneissic layering at this and many other localities. As shown by Drake (1967) the zone marked by this deformation is 0.5 km wide in this area.

Overall the deformation structures in the Rattlesnake Hill core suggest the development of Paleozoic thrust-related fabrics (mylonites) and subsequent re-use of the structures in Mesozoic extension.

INTERPRETATION OF GEOLOGIC STRUCTURES

Reconnaissance geologic mapping and detailed examination of exposures near faults lead to an interpretation of the geologic map and cross sections that differs from that of Drake and others (1967). The principal changes (Fig. 9) involve the depiction of the thrust slices as southeast homoclinally dipping imbricate thrusts rather than a single isoclinally refolded thrust.

Critical to the Drake and others (1967) interpretation is the documentation of the refolding of the thrust fault and its inverted cover into a northwest facing synform. Despite poor exposures, mapping of the mylonitic (thrust-related) foliation in the gneiss reveals a gentle southeast dipping structure that is not refolded through the vertical plane as the south margin of the gneiss is approached. The belt of Hardyston Quartzite and Leithsville Formation depicted by Drake and others (1967) southwest of the Rattlesnake Hill drill hole that would lie above the overturned Musconetcong thrust could not be verified. Instead, in exposures along the south border of the gneiss, Hardyston overlies gneiss with northwest dips. Gneiss crops out southwest of the Hardyston in the area shown as Leithsville by Drake and others (1967). These relationships indicate that Hardyston overlies gneiss in right-side-up attitude here and that gneiss extends south to the Triassic border fault. No exposures of Hardyston Quartzite were found along the fault contact with the Leithsville. Drill data from Riegelsville No. 1 show that the contact between Leithsville Formation and the underlying gneiss is a normal fault rather than a thrust fault.

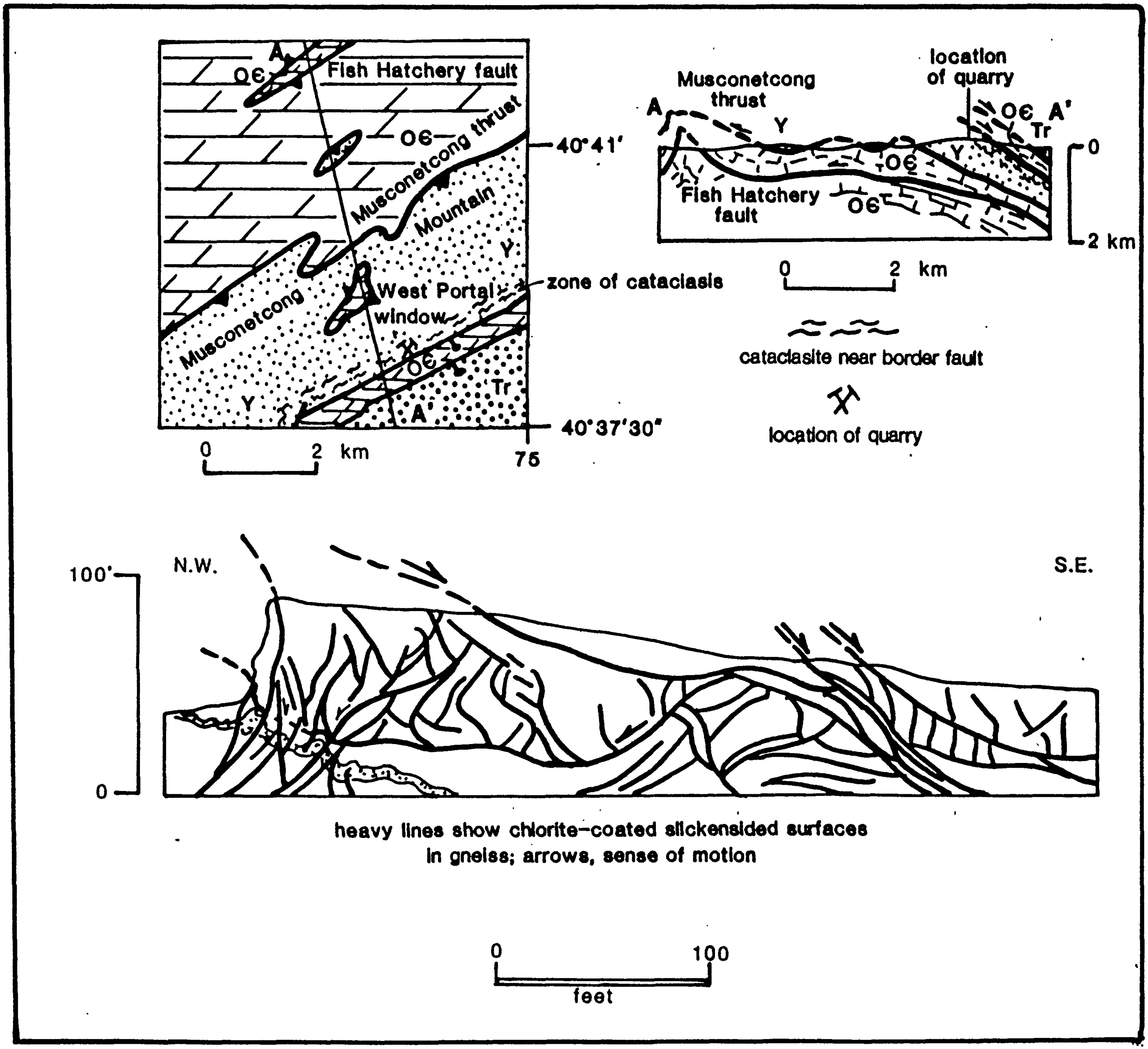


Figure 8. Diagram showing extensional fault fabrics in footwall block of Newark basin exposed in vertical quarry face in cataclasite in the southeast corner of the Bloomsbury Quadrangle, N. J. Index map shows quarry location in relation to geologic map and cross section modified from Drake (1967).

The locality of Hardyston Quartzite shown in the map by Drake and others (1967) along the south side of the gneiss terrane, 2.25 km northeast of the Delaware River, is apparently misidentified. At this locality highly cataclastic well-layered biotite gneiss extends in nearly continuous stream exposure to the east foot of the ridge that marks the contact with Leithsville.

In the present interpretation, Hardyston Quartzite is shown as overlying gneiss in a single east-trending syncline. Bedding-cleavage intersections and bedding measurements support this interpretation, with only local overturning of the quartzite at the overriding thrust as shown in section B-B' (Fig. 9).

No evidence therefore has been found for overturning of the trailing edge of the Musconetcong thrust, and mylonitic fabric internal to the gneiss belt dips homoclinally to the southeast.

The new data from the Rattlesnake Hill core show that Hardyston Quartzite and granitic gneiss underlie the Leithsville Formation. The small window in Leithsville seen along the Delaware River is interpreted as a sliver of carbonate rock above a still lower thrust slice. Outcrops along the west side of the Delaware River at Durham Furnace, just north of the window, lend support for this idea. Inverted Hardyson Quartzite underlies gneiss with an apparent normal sedimentary contact 200 feet south of the first occurrences of Leithsville. Small outcrops of mylonitic granitic gneiss, having shallow southeast dips, intervene between Hardyston and the Leithsville suggesting that two thrust faults may exist as shown in section A-A' (Fig. 9).

In section B-B' three separate fault zones are shown parallel to bands of well-developed mylonite exposed in the gneiss terrane. Still lower thrusts are interpreted to project into the line of section from line A-A'. The area of Hardyston to the southwest of line B-B' may represent a "snake head" above a buried thrust of basement gneiss encountered in the Rattlesnake Hill drill hole. A thrust fault has been drawn showing detachment of the Hardyston from the Leithsville based on strongly developed mylonite structures in the Hardyston near this contact.

Structures associated with faults

Mylonitic textures are common in Middle Proterozoic gneiss above the Musconetcong thrust and in deformation zones internal to the gneiss of Musconetcong Mountain; however the distribution is very sporadic. Locally no obvious structures are present near the trace of the Musconetcong fault and in other cases Mesozoic extensional fabrics dominate or may overprint older structures in a structurally composite zone.

Mylonitic structures consist of the following rock types: augen gneiss, mylonite gneiss and locally ultra-fine-grained phyllonite. Metamorphic mylonitic foliation is penetrative in most samples and a strong rodding exists, consisting of elongate quartz rods sheathed by fine-grained muscovite and chlorite. This rodding is developed throughout the rock rather than just concentrated on shear surfaces. On northeast-striking surfaces this lineation

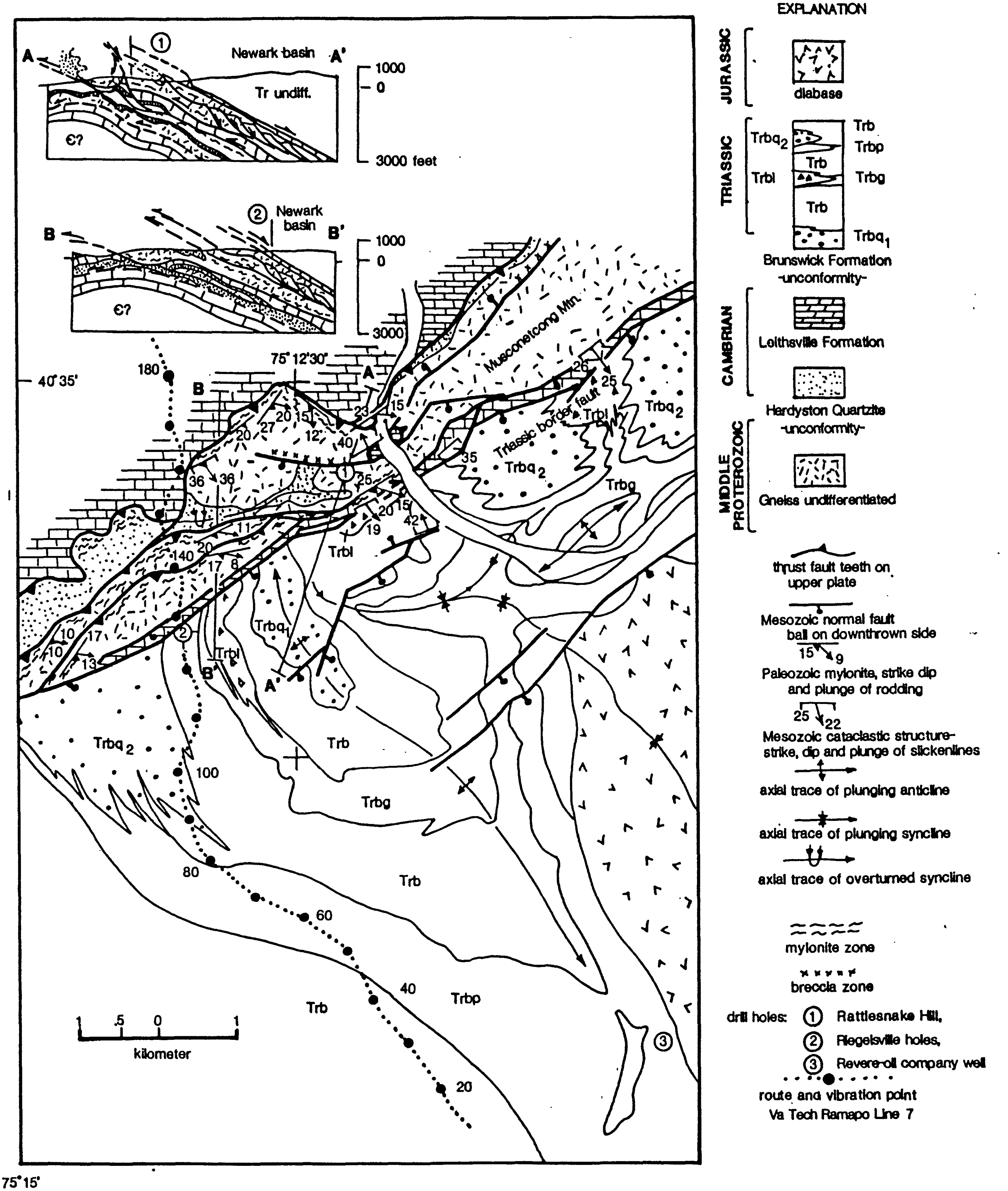


Figure 9. Simplified geologic map and cross sections through the Musconetcong thrust system and Triassic border fault near VIBROSEIS Profile, reinterpreting the fault system as imbricate slices rather than a folded thrust.

plunges about S70°E and is folded to plunge due south on northwest-striking surfaces. In general the thrust direction for the Musconetcong thrust is to the west-northwest.

As reported by Drake and others (1967) mylonitic and cataclastic structures locally overlap in outcrops. The narrow belt of gneiss adjacent to the Leithsville on the footwall block near the Delaware River exhibits both strong mylonitic structure and intense superposed Mesozoic extensional fabric. The features are coplanar and dip southeast at 20° to 30°.

Along the front of the Musconetcong thrust, local outcrops, for example at Durham, exhibit chlorite-coated, reactivated surfaces having Mesozoic extensional directions and structures.

Cataclastic structures associated with Mesozoic faults are distinguishable from mylonites by their more brittle characteristics. Commonly fabrics are spaced zones of cataclasite, expressed by chlorite-rich, carbonate-mineralized zones. Fabrics are non-penetrative and linear structures (slickenlines) are confined to surfaces as wear grooves or quartz or calcite fiber growths. Irregular and complex anastomosing chloritic shear surfaces dominate in zones up to 500 feet west of the border fault in gneiss.

Grooves and slickenlines trend N.40°E. and N.40W. on southeast-dipping faults and northwest-dipping antithetic faults.

Cataclastic zones parallel to the border fault dip 20° to 40° S.E., with dips of 30° most common. Near-vertical extension fractures strike N.60°E. subparallel to the faults, and zones of extensional calcite-filled breccias also trend N. 50-50° E. and dip at high angles to the southeast.

GEOLOGIC SYNTHESIS

Geologic mapping and core drilling in the vicinity of the Triassic border fault near Riegelsville indicates that the border fault consists of two major subparallel shallow southeast-dipping faults, having an average dip of 30° (Fig. 10). A fairly continuous but narrow belt of Paleozoic carbonate rock forms a step into the basin. Reexamination of mylonitic zones in the basement rocks indicates a homoclinal dip of 15° to 25° to the southeast in a broad zone between the Musconetcong thrust and the Triassic border fault. Intensely developed mylonitic structure and phyllonite are present near the sole of the Musconetcong thrust. Locally, extensional structures are present at the sole of the Musconetcong thrust indicating reactivation in the Mesozoic. Examination of the drill cores reveals the dominance of Mesozoic cataclastic structures as would be expected; however, relict mylonitic structures are present in the Middle Proterozoic rocks and in Leithsville Formation rocks in the Rattlesnake Hill core and the Riegelsville No. 1 and No. 2 cores, and in bedrock exposures near the border fault.

The gross geometry, detail of overprint structures and the results of core drilling indicate clearly that the Triassic-Jurassic faulting was localized along the older thrust surfaces, indicating reactivation. This agrees substantially with the similar conclusion of Drake and others (1967)

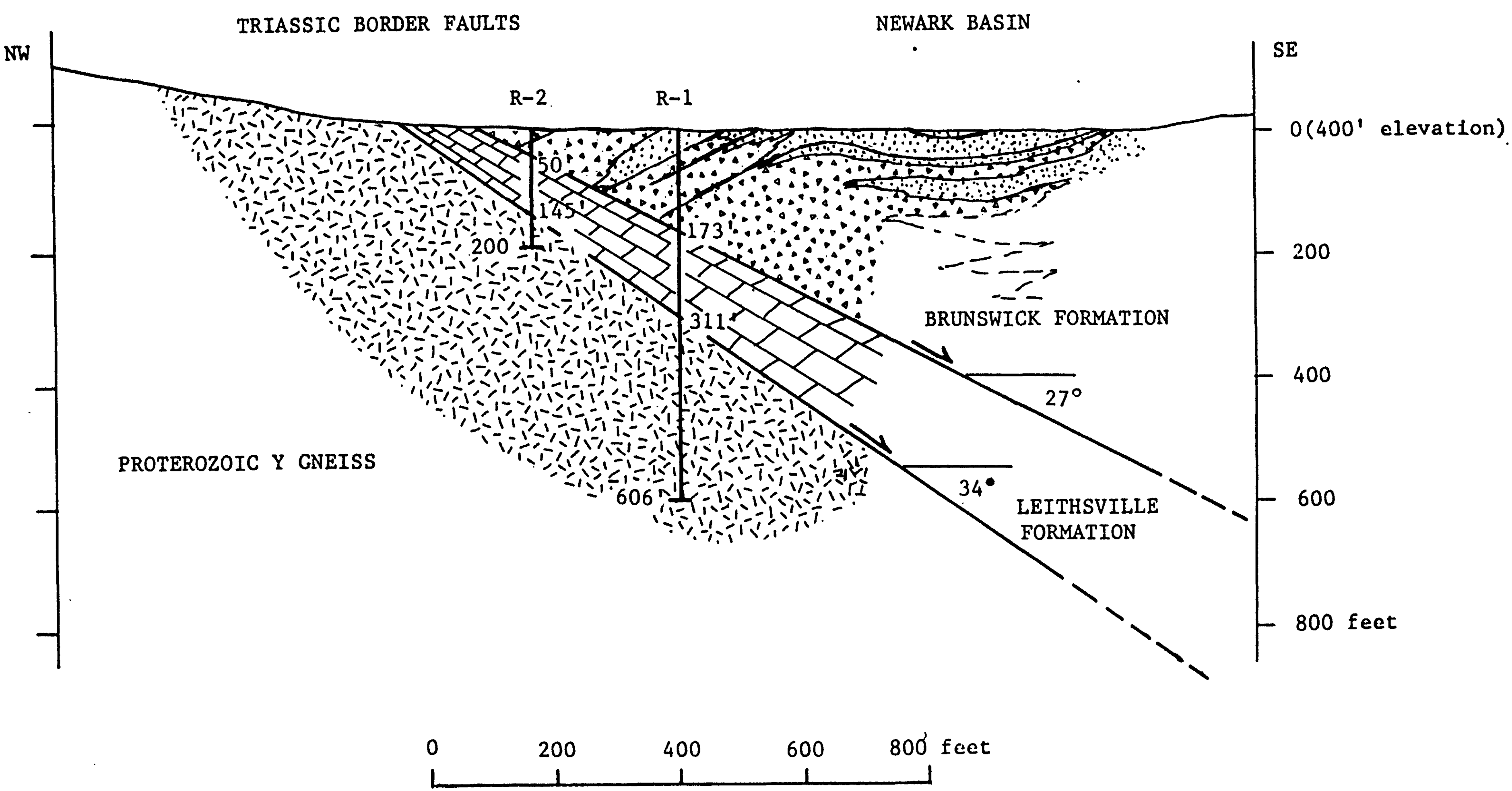


Figure 10. Diagramatic cross section through R-2 and R-1 showing the attitude of the two well-developed Mesozoic faults.

but an imbricate thrust model and shallow- dipping Mesozoic faulting is required.

VIBROSEIS reflection data (N. M. Ratcliffe and J. K. Costain, unpub. data) collected along the route shown in Figure 9 in November 1984 reveals a strong reflection from the Triassic border fault dipping 25° to 30° southeast to the vicinity of the Revere well. Based on our velocity data the floor of the basin at the Revere well would be at 10,500 feet. The core drilling sited here confirms the shallow dip of the border fault.

Strong reflectors are present beneath the floor of the basin as well and project updip to the front of the Musconetcong thrust. Our drill data and field data suggest strongly that this zone of strong reflectors is produced by the imbricated and mylonitic basement rocks of the Musconetcong fault system.

IMPLICATIONS FOR SEISMICITY

The Triassic border fault and ancestral Musconetcong thrust system form a major regional fault system that, at the latitude of eastern Pennsylvania, extends as a near planar fault to a depth of approximately 10,500 feet. Beyond this point, reflectors and structures we describe could extend under the Buckingham Mountain area in the center of the basin. If this geometry is correct the border fault described here probably has undergone about 12 kilometers of horizontal extension during formation of the Mesozoic Newark basin. In this model the fault system and cataclastic structures that are developed in the 0.5 km thick zone beneath the floor of the basin constitute a major regional fault system that extends to depths of 10 or 12 km. Because of the abundance of chlorite-rich gouge and other fault fabrics within the zone, the border fault should be a weak structure capable of localizing earthquakes.

No data seen at the surface or in the drill cores, however, indicate that reactivation in the current or modern stress field has taken place. No modern seismicity has been recorded over the border fault near Riegelsville; however, numerous low magnitude events have been recorded since 1970 in the eastern parts of the basin near Trenton and north of Philadelphia. Recent hydrofracture experiments in the New York area suggest that the principal horizontal compressive stress for the northeastern United States is $N55^{\circ}E\pm10^{\circ}$ (Zoback and others, 1985). If this is true, the Triassic border fault in the Rieglesville area in eastern Pennsylvania is substantially parallel to the principal compressive stress and unlikely to be currently active.

ACKNOWLEDGEMENTS

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Appendix A

Description of lithologies and contacts, Riegelsville Hole No. 1. Collar elevation 399 feet.

	Thickness	Depth
Interbedded red siltstone, mudstone, and sandstone, with weathered-out clayey zones, of Brunswick Fm. (Triassic)	47.5'	0-47.5'
Red and green laminated shale	3'	47.5-50.5'
Dark grey coarse fanglomerate with angular to subrounded clasts of dolostone and minor limestone and quartzite.	17.5'	50.5-68'
Interbedded red siltstone and sandstone with thin fanglomerate beds	6.5'	68-74.5'
Black laminated shale	6'	74.5-80.5'
Coarse grey dolostone fanglomerate	27.5'	80.5-108'
Greenish grey arkose with thin interbeds of dolostone fanglomerate, shale-chip conglomerate, and green and black shale	16'	108-124'
Grey dolostone fanglomerate	46'	124-170'
Cataclastic dolostone fanglomerate of upper fault zone hanging wall	3.3'	170-173.3'
Fault gouge of upper border fault	0.3'	173.3-173.6'
Cataclastic blue-grey dolostone (Paleozoic) of footwall	11.9'	173.6-185.5'
White to grey dolostone with chloritic (mylonitic?) foliation, locally highly folded	76.5'	185.5-262'
Grey massive fractured dolostone	48'	262-310'
Lower border fault zone, containing tectonically interleaved dolostone and gneiss	2'	310-312'
Quartz-plagioclase-microcline gneiss (Middle Proterozoic), locally cataclastic in texture, with thin amphibolite layers (commonly remobilized as chloritic shear zones) and pegmatitic zones	48'	312-360'

Medium to coarse-grained alaskite gneiss with minor remobilized mafic layers	134'	360-494'
Diopside-hornblende-biotite-chlorite-gneiss with cataclastic texture, pegmatite layers	21'	494-515'
Coarse-grained, quartz-microcline-pyroxene pegmatite	31'	515-546'
Calcite-diopside-chlorite gneiss containing cataclastic shear zone	9'	546-555'
Banded alaskitic gneiss and minor amphibolite	51'	555-606'
End hole		606'

Appendix B

Description of lithologies and contacts, Riegelsville Hole No. 2. Collar elevation 398 feet.

	Thickness	Depth
Highly weathered alluvium (stone fragments and clay)	32'	0-32'
Highly weathered bedrock consisting of green shale and grey dolostone fanglomerate (Triassic)	18'	32-50'
Upper border fault between dolostone fanglomerate and dolostone (Paleozoic)		50'
Grey and white cataclastic dolostone	20'	50-70'
White dolostone with chloritic (mylonitic) foliation, locally folded	58'	70-128'
Massive grey dolostone	17'	128-145'
Lower border fault between dolostone and Middle Proterozoic gneiss		145'
Cataclastic quartz-plagioclase-microcline gneiss with thin remobilized (chloritic) mafic layers	43.7'	145-188.7'
Cataclastic hornblende-diopside-biotite gneiss and pegmatite	9.8'	188.7-198.5'
Coarse-grained pink granitic gneiss	1.5'	198.5-200'
End hole		200'