The Bedrock Geology

of the

Hartford South Quadrangle

WITH MAP AND CROSS SECTIONS

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STATE GEOLOGICAL AND NATURAL HISTORY SURVEY OF CONNECTICUT

Department of Energy and Environmental Protection

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STATE GEOLOGICAL AND NATURAL HISTORY SURVEY OF CONNECTICUT

DEPARTMENT OF ENERGY AND ENVIRONMENTAL PROTECTION

The Honorable Dannel P. Malloy, Governor
State of Connecticut

Daniel C. Esty, Commissioner
Department of Energy and Environmental Protection

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State Geological and Natural History Survey of Connecticut

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Abstract

A bedrock geological map was constructed for the Hartford South quadrangle in the central Hartford Basin, Connecticut. The Hartford Basin fill consists of four sedimentary units (of which the Shuttle Meadow, East Berlin, and Portland Formations are interpreted to occur in the Hartford South quadrangle) separated by three volcanic units (of which the Holyoke and Hampden Basalts are known to occur in the quadrangle). Mapping was conducted by locating and investigating as many outcrops as possible in the highly urbanized south Hartford area. These data were combined with observations and interpretations from previous mapping efforts. Because of extensive construction in the area over the past few decades, each generation of mapping had a different set of outcrops available for investigation.

The lithologies that occur in the Hartford South quadrangle include black and gray shale, reddish-brown siltstone, reddish-brown sandstone, conglomerate, and basalt. In general, sedimentary units are poorly exposed, and similar lithologies occur in all the formations present within the quadrangle. Thus, it is difficult to identify the sedimentary formations at any isolated outcrop with certainty. The basalt units are better exposed, and are used as the basis for stratigraphic and structural interpretations. It is difficult to distinguish between the Holyoke and Hampden Basalts on the basis of macroscopic mineralogy and textures, so elemental geochemistry data were collected for 23 representative basalt samples. Major element, trace element, and Rare Earth Element compositional data all produced unique results that permitted the Holyoke and Hampden to be distinguished. These data were used to interpret and test our structural model.

The Hartford Basin formed during the Triassic and Jurassic Periods during incipient rifting that ultimately lead to the opening of the North Atlantic Ocean. The basin is a major half-graben, bounded on the east by a border fault system. Sedimentary and volcanic units dip 10-20° to the east across most of the basin. The Hartford South quadrangle is located in the central portion of the basin. It contains a N110°E trending anticline that has been dissected by at least 2 separate generations of normal faults. The older generation is oriented approximately N10°E, and consists of a few laterally extensive faults that dip to the west and are synthetic to the major

basin bounding fault system (the Eastern Border Fault system is located to the east of the mapping area). The second generation of faults appears to be less laterally extensive, are oriented approximately N50°E, and are both synthetic and antithetic to the westward dipping major basin bounding faults. Most fault surfaces show slickenside evidence of later strike-slip movement.

Introduction

Geological bedrock mapping of the Hartford South quadrangle in central Connecticut (Figure 1) was funded by the United States Geological Survey EDMAP Program, and was conducted jointly by faculty and undergraduate students from Eastern Connecticut State University and geoscientists of the State Geological and Natural History Survey of Connecticut. It has been decades since previous geological mapping in the quadrangle (Gray, 1978), and extensive suburban development, coupled with the recent discovery of dinosaur trackways in the southern part of the quadrangle (Steinen et al., 2007), revealed the need to better understand the regional geology in order to balance societal needs with the preservation of Connecticut's natural geological heritage.

Location and Earlier Mapping

The Hartford South quadrangle is situated between longitude 72°45'00" W and 72°37'30" W and latitude 41°37'30" N and 41°45'00" N, and is located completely within the sedimentary and volcanic formations of the Hartford Basin in central Connecticut. It contains the southern parts of Hartford, West Hartford, and East Hartford along its northern edge, and extends south into the towns of Berlin and Cromwell. All or parts of the towns of Newington, Wethersfield, Glastonbury, Rocky Hill, and Portland are also found within the mapping region. The Connecticut River runs along the eastern side of the quadrangle.

Most of the surrounding quadrangles have geological bedrock maps that were published in the 1950's and 1960's, but there is no formally published bedrock map of the Hartford South quadrangle. Deane (1967) published a surficial map and report for the Hartford South quadrangle. In the late 1960's and early 1970's, Weitz (1972; Appendix 1) and Byrnes (1973) collected orientation data for over 400 fractures and bedding planes. Norman Gray (University of Connecticut) constructed a preliminary map of the quadrangle (Gray, 1978; Appendix 2). Finally, in 1985, John Rodgers (Yale University) compiled a Bedrock Geological Map of the entire State of Connecticut, including the area covered by the Hartford South quadrangle (Rodgers, 1985). These maps were utilized in constructing the bedrock map of the Hartford South quadrangle included with this report. Bedrock outcrops were located by referring to the surficial geology map of Deane (1967) and Gray's 1978 unpublished map. The maps by Weitz and Gray contain formational, structural, and bed orientation data that were incorporated into the current bedrock map. Intense suburban development in the mapping area that began in the

1980's and continues today has resulted in significant changes in outcrops available to study. Many outcrops labeled on the earlier maps could not be located, whereas several new outcrops (associated with new construction) were identified. The Bedrock Geological Map of Connecticut (Rodgers, 1985) was consulted to be sure that the details in the Hartford South quadrangle bedrock map conform to the regional geology of the state. However, the state map does not contain enough detail to precisely match the quadrangle map. Bedrock maps from quadrangles surrounding the Hartford South quadrangle were also consulted to be sure that the geology of the current map matched that of the surrounding quadrangles. However, these maps were constructed individually with no coherent structural framework model, so precise geological continuity among the regional quadrangle maps was not possible.

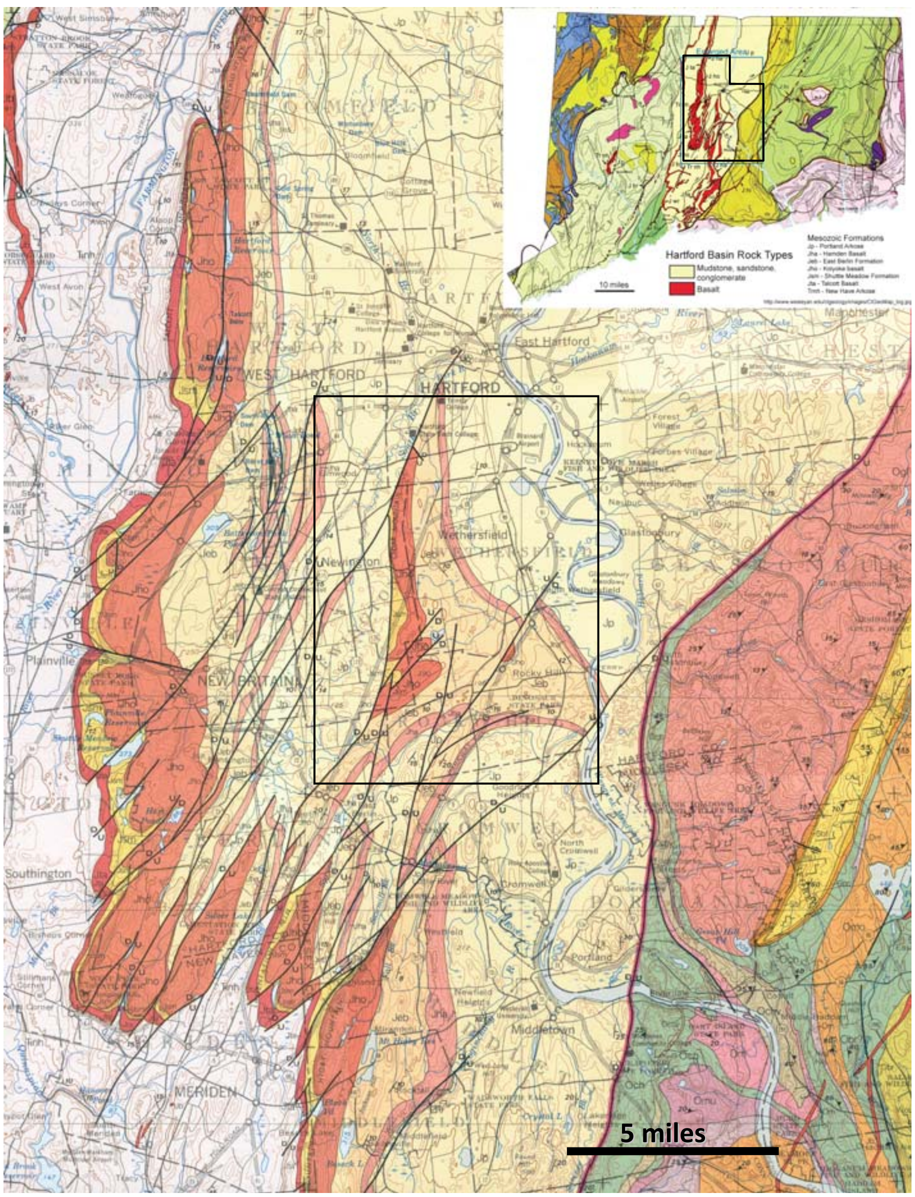


Figure 1. Location of the Hartford South quadrangle. The inset of the geological map of Connecticut is from the Connecticut Geological and Natural History Survey, and shows the location of the more detailed geological map of central Connecticut. The larger map comes from Rodgers (1985). The location of the Hartford South quadrangle is identified as the black rectangle in the larger map.

Methods

Reconnaissance mapping was conducted early in the summer of 2007 by the entire mapping team in order to become familiar with the lithologies and nature of the outcrops. For the majority of the summer smaller teams went out to locate all possible outcrops. Areas that were intensely developed since the mapping in the 1970's were examined street by street to identify any new outcrops exposed through construction. In all, data were collected from over 80 new and previously known outcrops (Figure 2), and include GPS locations, bedding attitudes, lithology, and fault/fracture orientations. These data were transferred onto a base map using ArcGIS.

Intense weathering and vegetation of areas overlying sedimentary rocks result in poor exposures. When sedimentary outcrops were located, the lithologic similarities among the Shuttle Meadow, East Berlin, and lower Portland Formations, and paucity of age discriminating fossils made identification of the particular formation impossible. The volcanic rocks in the Hartford South quadrangle are better exposed. As a result, mapping was conducted primarily through the proper identification of basalt layers. This is petrographically difficult, so the compositions of 23 basalt samples were analyzed to chemically "fingerprint" the basalt outcrops. The sedimentary units were mapped based on their stratigraphic position relative to the basalt flows. Overall, outcrop density (Figure 2) is relatively high in the central portion of the quadrangle, along the basalt ridges. It is low along the western and eastern edges of the quadrangle which are dominated by buried sedimentary units. Outcrops are virtually absent in the northeastern corner of the quadrangle where bedrock has been buried by Quaternary glacial lake deposits and alluvium associated with the Connecticut River.

Geological structure was better inferred by reference to the basalts than to the sedimentary units. Orientations of bedding planes and joint surfaces were obtained whenever possible. Only a few faults were directly observed in the Hartford South quadrangle. Most of these occurred within the volcanic rocks, but one juxtaposed volcanic rocks against sedimentary rocks. All other faults were recognized by displacements along basalt ridges, or as terminations of basalt ridges. No faults could be directly traced through regions underlain by sedimentary rocks. Structural folds were identified based on changes in bed orientations and flexures within basalt ridges. Structural data were located using GPS, and transferred onto a base map through the use of ArcGIS. The structural framework used while constructing the map conforms well to the large-scale structure on the published state geological bedrock map (Rodgers, 1985).

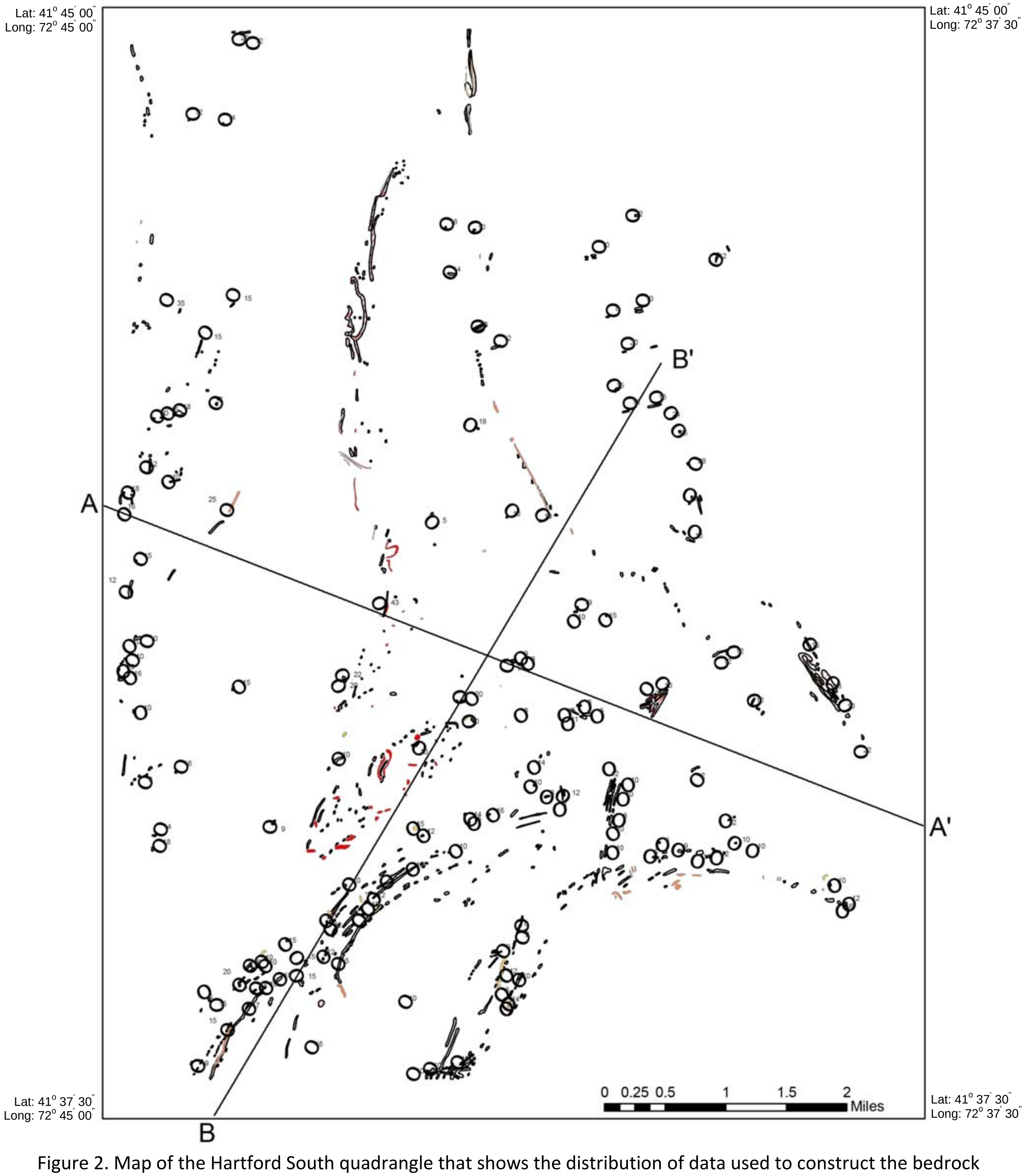


Figure 2. Map of the Hartford South quadrangle that shows the distribution of data used to construct the bedrock map. The circles are locations of GPS control points. The irregular shapes represent outcrops from both this mapping effort (colored) and from the work of Gray (1978) (black). Line A-A' and B-B' are the location of structural cross-sections (figure 29).

Geological Setting

Hartford Basin

The Hartford Basin is one of a series of rift basins that formed along the eastern margin of North America in association with the rifting of Pangaea and the opening of the Atlantic Ocean during the late Triassic and early Jurassic Periods (Figure 3; Schlische, 1993; 2003). The basin (about 120 km long and 30 km wide) is a half-graben bounded on the east by a series of normal

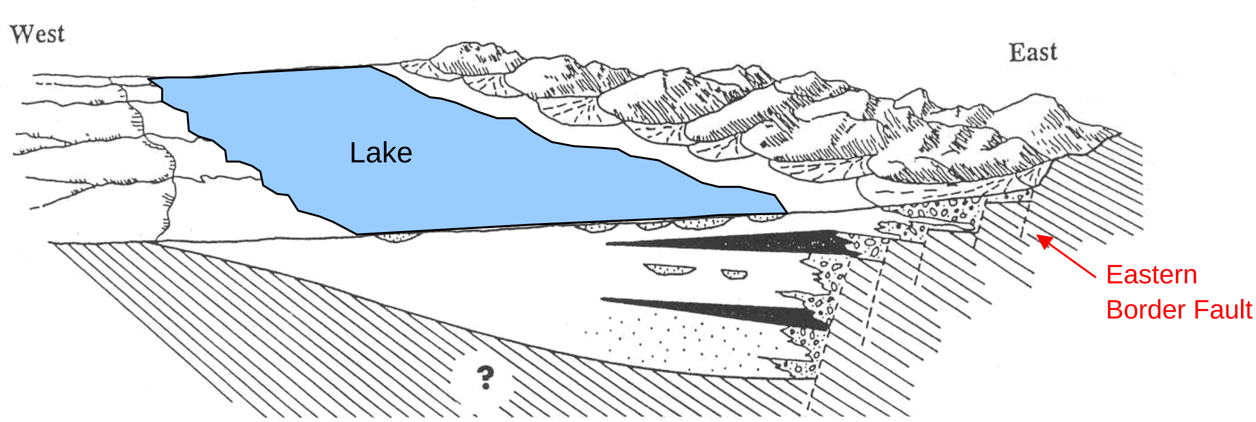


Figure 3. Schematic cross-section through the Hartford rift basin during the early Jurassic Period. The basin is a half-graben, with numerous intrabasinal faults exposed in the central portion of the basin. The thickest sediments occur on the eastern side of the basin, adjacent to the Eastern Border Fault (modified from: Horne et al., 1995).

faults collectively known as the Eastern Border Fault (Figure 3). The basin is filled with 5 to 7 km of continental strata divided into four sedimentary formations separated by three nearly basin-wide basalt flows (Figure 4; Hubert et al., 1992) that collectively dip 15˚-20˚ to the east.

The Hartford South quadrangle contains the youngest formations in the Hartford Basin (Figure 4), including (from oldest to youngest) the Shuttle Meadow Formation, Holyoke Basalt, East Berlin Formation, Hampden Basalt, and lower Portland Formation (all early Jurassic in age). The sedimentary Shuttle Meadow, East Berlin, and lower Portland Formations are composed of red mudstone, sandstone and conglomerate, interpreted as playa-related facies, alternating with black shale interpreted as perennial lake facies (Hubert et al., 1978; Gierlowski-Kordesch and Rust, 1994; Drzewiecki and Zuidema, 2007). The East Berlin Formation within the Hartford South quadrangle contains strata with spectacular trackways of *Eubrontes and other* therapod dinosaur footprints that occurs in Jurassic strata of the Eastern United States (Farlow and Galton, 2003; Smith and Farlow, 2003).

The best age control for units within the basin (Figure 4) comes from radiometric dating of the basalt layers, and some biostratigraphic data. McHone (2000) and McHone and Puffer (2003) suggest an age of about 201 million years for the basalt flows, placing them within the Lower Jurassic (Hettangian), an age supported by continental biostratigraphy (Lucas and Huber, 2003; Olsen et al., 2005). The New Haven Arkose, not present in the mapping area, is Late Triassic in age (Hubert et al., 1992).

The sedimentary and volcanic units are repeated several times across the Hartford South quadrangle by numerous intra-basin normal faults. The largest faults strike generally NE-SW, but their dips and offsets are very poorly constrained. Fault displacements are commonly inferred from offsets in basalt ridges. In addition, mapped locations of the poorly exposed sedimentary units on the Bedrock Geological Map of Connecticut (Rodgers, 1985) are inferred based on assumed fault displacement and their spatial relationships to exposed basalt flows. Although some of the basalt outcrops in the Hartford Basin have been chemically fingerprinted (Puffer et al., 1981; Philpotts and Reichenbach, 1985), in many cases they have not been positively identified. Proper chemical identification of basalt outcrops was critical for accurate mapping of the Hartford South quadrangle.

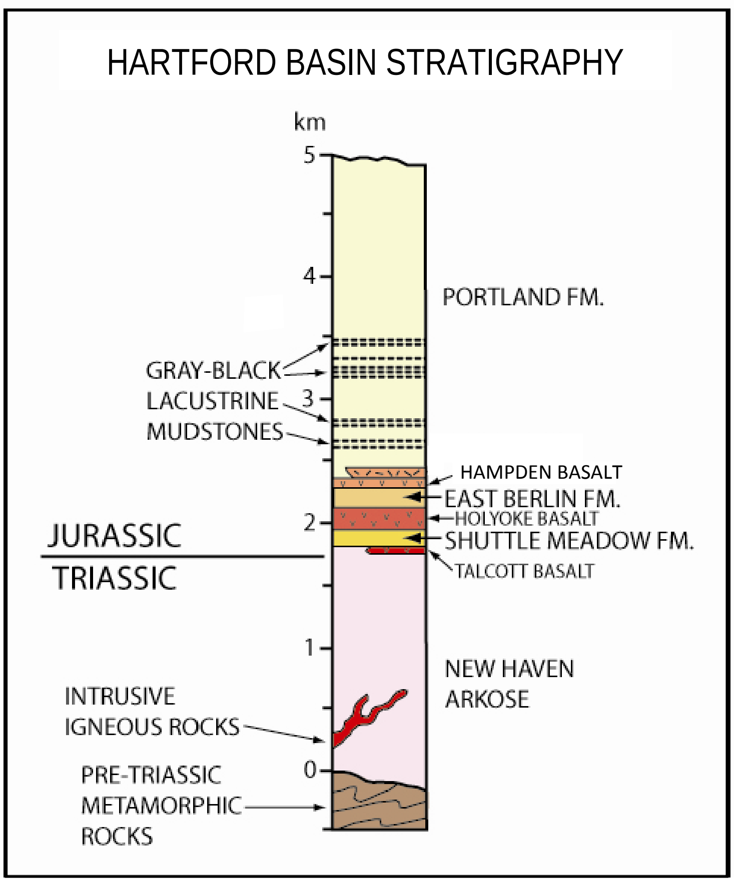


Figure 4. Stratigraphic column of the Hartford Basin, showing the vertical stratigraphic positions, relative thicknesses, and ages of the various sedimentary and volcanic formations (modified from Hubert et al. 1992).

Sedimentary Geology

The sedimentary and volcanic rocks in the Hartford South quadrangle are part of the Hartford Group (Newark Supergroup) that fills the Hartford Basin (Fig. 4). The Hartford Group is composed of the Late Triassic New Haven Arkose at its base, overlain by the Early Jurassic Meriden Group (composed of the Talcott Basalt, Shuttle Meadow Formation, Holyoke Basalt, East Berlin Formation, and Hampden Basalt), and capped by the early Jurassic Portland Formation (Krynine, 1950; Rodgers, 1985; Weems and Olsen, 1997). The Hartford South quadrangle contains all these formations, except the basal two, the Talcott Basalt and the New Haven Arkose.

The Shuttle Meadow, East Berlin, and lower Portland Formations consist of about 2000 meters of lacustrine and alluvial strata (Hubert et al., 1992). They were deposited when high rates of fault-related subsidence resulted in a closed drainage basin in which either perennial lakes or playas developed, depending on prevailing climatic conditions.

Sedimentary Facies

All three Lower Jurassic sedimentary units in the Hartford Basin are exposed in the Hartford South quadrangle. Only the Upper Triassic New Haven Arkose is not exposed. No complete stratigraphic exposures exist for any of the formations within the quadrangle, but reasonable sections of the East Berlin Formation occur in Cromwell and East Berlin, along the southern boundary of the mapping region. The Shuttle Meadow Formation and the lower part of the Portland Formation are poorly exposed throughout the Hartford Basin. However, approximately 600 meters of the lower Portland Formation are preserved in a series of cores (Park River Tunnel cores) taken approximately 1 km north of the Hartford South quadrangle boundary.

The oldest formation exposed in the Hartford South quadrangle is the Shuttle Meadow Formation. It is poorly exposed in only a limited number of outcrops in the western portion of the quadrangle, immediately west of (below) the Holyoke Basalt. Outcrops are limited in both lateral extent and in stratigraphic thickness. All exposures of the Shuttle Meadow are interpreted to be from the uppermost portion of the formation based on their occurrence immediately below the Holyoke Basalt, but a direct contact with the overlying Holyoke was not observed. Gray (1978) mapped an outcrop (now gone) preserving this relationship in the Cedar Mountain region of the quadrangle (NW part of mapping region). Where exposed, the Shuttle Meadow Formation is dominantly reddish-brown mudstone, with thin reddish brown to gray, fine-grained arkose beds.

The East Berlin Formation overlies the Holyoke basalt and underlies the Hampden Basalt. Except for the highway outcrops (notably the intersection of Route 9 and highways I-91) most exposures of the East Berlin in the Hartford South quadrangle are limited in vertical and lateral extent. However, the entire thickness of the formation is interpreted to lie beneath the vegetation and alluvium covering the bedrock in portions of the mapping unit. Mapping efforts suggest it is consistent in thickness with the published values of 150 to 200 meters (Gielowski-Kordesch and Rust, 1994; Olsen et al., 2005). The basal contact with the Holyoke Basalt has not been directly observed, but the upper contact with the Hampden basalt was recognized in a number of locations, particularly in the southern portion of the Hartford South quadrangle. Exposures of the East Berlin Formation occur in the southern portion of the Hartford South quadrangle, and in an outcrop belt that runs north through the center of the quadrangle (Figure 1).

Only the lowest part of the Portland Formation (younger than the Hampden Basalt) occurs in the Hartford South quadrangle. The very limited number of small, isolated outcrops make a lithologic description difficult. However, cores taken through the lowest 600 meters of the formation immediately north of the Hartford South quadrangle show it is lithologically very similar to the East Berlin Formation. The Portland Formation is interpreted to occur along the western quarter of the Hartford South quadrangle, along the southern boundary of the map, and in the northeast quarter of the map. It is important to note that rocks from this formation were not directly observed in the southernmost part of the map, or in the northeastern portion, although Gray (1978) did report some in the northeast portion.

The East Berlin Formation and the lower Portland Formation (and perhaps the Shuttle Meadow Formation) can be divided into a number of distinct facies within the mapping region. These facies are similar to those of Demicco and Gierlowski-Kordesch (1986), Gierlowski-Kordesch and Rust (1994), Gierlowski-Kordesch and Huber (1995), and Drzewiecki and Zuidema (2007), and include:

Laminated Black Shale- This facies (Figure 5) is composed of thin-bedded and laminated fissile black shale with thin persistent gray siltstone and discontinuous carbonate laminae. There are some burrows and pyrite crystals evident within the laminated black shale. Laminae are frequently deformed by post-depositional processes. The depositional environment is interpreted to have been an oxygen-poor, deep perennial lake.

Structureless Black Shale- This facies (Figure 5) is similar to the laminated black shale, but typically lacks laminations. It is interpreted to represent perennial lakes that contain enough oxygen to permit thorough bioturbation.

Thin-bedded Gray Shale- This facies (Figure 6) is structureless, very thin-bedded, or laminated shale and siltstone. The color is distinctively gray and there are some occasional disruptions within the laminae caused by mudcracks, burrows, or soft-sediment deformation. The depositional environment is interpreted to have been a shallow perennial lake margin that experienced occasional exposure.

Figure 5. Perennial lake facies include laminated black shale (left), and structureless black shale (right). These samples are the Jurassic Portland Formation from the Park River Tunnel Core FD 30-T, Hartford, CT.

Figure 6. An example of a lake margin facies composed of thin-bedded gray shale. Note the mudcracks and burrows in the shale. This sample is from lower Portland Formation in the Park River Tunnel Core FD 30-T, Hartford, CT.

Crinkly-laminated Siltstone- This facies is made up of thinly interbedded reddish-brown mudstone, siltstone and very fine-grained sandstone (Figure 7). The laminae are highly convoluted and crinkly. Sand-filled mudcracks are abundant throughout this facies. The depositional environment is interpreted to have been shallow ephemeral lakes in a playa environment. The crinkly laminations are interpreted to be microbial in origin.

Figure 7. Crinkly-laminated siltstone with abundant sand-filled mudcracks and disrupted fabrics, interpreted to be a playa lake environment. This sample is from the lower Portland Formation in the Park River Tunnel Core FD 30-T, Hartford, CT.

Cross-bedded Sandstone- This lithofacies is white to light brown, medium- to coarse-grained arkosic sandstone with trough cross-bedding and some planar bedding (Figure 8). Individual sandstone beds are between 10 and 50 cm thick with erosional bases overlain by red siltstone and mudstone rip-up clasts. This facies may represent sheet flood deposits (Gierlowski-Kordesch and Rust, 1994), sheet deltas, and/or small, poorly confined braided streams.

Rippled Siltstone- This facies is composed of red siltstone, very fine-grained sandstone and/or medium-grained sandstone that contain current and/or wave ripples (Figure 8). It is equivalent to the interbedded sandstone and mudstone facies and ripple cross-laminated siltstone facies of Gierlowski-Kordesch and Rust (1994) and Gierlowski-Kordesch and Huber (1995). Asymmetric current ripples, symmetric wave ripples and some flaser bedding are pervasive throughout this facies, and mudcracks are very common. This lithofacies was deposited by ephemeral flowing water on playa mudflats and sandflats, occasionally reworked by waves after deposition.

Figure 8. Evidence of ephemeral flowing water is found in the cross-bedded sandstone facies with distinct trough cross-bedding (left) and rippled siltstone facies (right, with sand-filled mudcracks). These samples are from the lower Portland Formation found in Park River Tunnel Core FD 30-T, Hartford, CT.

Mud-cracked Siltstone- This facies is composed of red mudstone to very fine-grained sandstone that is typically structureless but can contain obscure laminae or ripple cross-laminae (Figure 9). Sand-filled mudcracks and burrows are abundant. The depositional environment is interpreted to have been playa mudflats and/or sandflats.

Figure 9. Mud-cracked red siltstone. This sample is from the lower Portland Formation from Park River Tunnel Core FD 30-T, Hartford, CT.

Pedogenically-altered Siltstone- This lithofacies is reddish-brown siltstone to very fine-grained sandstone with evidence of pedogenic alterations (Figure 10). Some diagnostic characteristics include carbonate nodules and homogenized (burrowed) sandstone and mudstone. There is also a very high concentration of mudcracks throughout the facies. This facies represents exposure of playa mudflats and sandflats, and subsequent incipient soil development.

Conglomerate- Conglomerate and conglomeratic arkose (Figure 11) have been identified in the East Berlin Formation, in the southeastern corner of the Hartford South quadrangle, near the Connecticut State Veterans Hospital. Conglomerate clast composition is primarily phyllite. This facies is restricted to outcrops in close proximity to the eastern edge of the Hartford Basin, and may represent fluvial or fan delta deposits at the basin margin.

Figure 10. Examples of pedogenically altered siltstone facies from the lower Portland Formation. The siltstone displays intense mudcracks, dolomite nodules (right) and highly disrupted fabric (above). These samples are from the Park River Tunnel Core FD 30-T, Hartford, CT.

Figure 11. a. Porous medium-grained feldspathic arenite. Pore spaces filled with black vitreous material interpreted to be pyrobitumen. Pyrobitumen is found in most of the porous sandstone beds in the area associated with the Rocky Hill Anticline. b. Phyllite clast conglomerate that is inferred to be part of fan delta. Some clasts contain small (0.5 mm) garnet crystals. This is similar to Littleton Schist in the eastern highlands. Interestingly, Glastonbury Gneiss clasts are extremely rare in this layer suggesting complex source area geology. c. Scour marks on surface of sandstone bed filled with mud-drape.

The three black and gray shale facies typically occur together, and are used to recognize depositional cycles within the East Berlin and lower Portland Formations. Natural outcrops tend to preferentially reveal sandstone and conglomerate facies, followed by the various siltstone facies. The black and gray shale facies are rarely observed in natural outcrops in the Hartford South quadrangle.

Sedimentary Formations in the Hartford South Quadrangle

Portland Formation. The Portland formation crops out poorly in the quadrangle. It is found most often in stream valleys and as artificial cuts associated with road and building construction. Natural outcrops consist of reddish-brown to grayish-red interbedded fine- to medium-grained sandstone and siltstone (Figure 12). Coarse-grained, pebbly sandstone may be found in some of the eastern outcrops, closer to the Basin margin.

Cores recovered through the lower Portland formation reveal that the predominant red-beds are punctuated by several cycles of gray and black shale (see previous facies discussion and Olsen et al, 2005). Depositional environments alternated between semiarid alluvial plain and playas to humid perennial lakes and mud-flats.

Figure 12. Typical low outcrop of Portland Formation at Wethersfield Cove boat launch area consisting of interbedded reddish gray fine grained sandstone and mudstone. Sandstone may be ripple laminated or contain tabular cross-beds (see figure 8 above). Upper parts of the mudstone beds are desiccated and have been disrupted by pedogenic alteration. Some contain small carbonate (caliche?) nodules. a. Overall outcrop. b. Close-up of the upper portion of the outcrop. The picnic tables in the background of both photos provide a sense of scale.

East Berlin Formation. The East Berlin Formation consists of reddish-brown and reddish-gray sandstone and mudstone (shale/siltstone) alternating with gray and black sandstone, mudstone and shale. The reddish sediments are inferred to result from deposition on alluvial plains and playa lakes during semi-arid climate cycles. The gray sandstone, mudstone and shale were formed by deposition in and adjacent to perennial lakes during humid climate cycles. The cyclic nature of Mesozoic stratigraphy in the Newark Supergroup is interpreted to have been caused by Milankovitch climate forcing (Olsen et al., 1995). The East Berlin Formation contains an abundance of preserved dinosaur footprints (Figure 13) and, in the black shale layers, fossil fish (Ostrum and Quarrier,1968; Colbert, 1970; McDonald, 1982; Farlow and Galton, 2003; Steinen et al, 2007; McDonald, 2010).

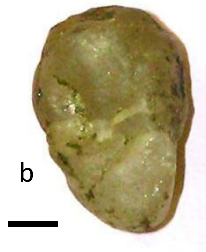
Figure 13. Large slab of dinosaur footprint-bearing sandstone recovered during excavation associated with subdivision across street from Dinosaur State Park. This sandstone layer may correlate to the track bearing layer at the park. Notice that footprints are preserved on the underside of the slab, i.e. they are raised structures (negative tracks) formed when sand filled in the actual footprints. The positive footprints were probably made in a thin shale bed that was destroyed during the excavation. The hammer is approximately 30 cm.

The East Berlin Formation is approximately 170m thick (Lehmann, 1959), but only the upper 120m are well described (Hubert et al, 1978; Gierlowski-Kordesch and Rust, 1994; Olsen et al., 2005). The formation is poorly exposed in most of the Hartford South quadrangle because it is covered by thin glacial soils. Construction routinely exposes rocks of this formation briefly, and in some cases, for instance along major highways, creates long standing exposures (Figure 14). A series of low linear ridges in the southern and southwestern part of the quadrangle are underlain by East Berlin Formation and expose slightly more resistant reddish-brown sandstone beds. The best exposures within the quadrangle, however, are along the north-bound lane of Route 9 at the interchange with Interstate-91 South (Klein, 1968; Hubert et. al, 1978) where excavation during construction of the Route 9 highway cut through several of the low ridges. There three gray and black lacustrine cycles are interbedded with reddish-brown alluvial/playa cycles. This is about 3 kilometers east of the type section of the East Berlin Formation, where 6 major lacustrine cycles are exposed in road cuts at the Routes 9/15 interchange (Olsen et al, 1989). Gierlowski-Kordesch and Rust (1994) recognize additional minor [thin] cycles within the major ones.

Figure 14. Outcrop exposed in the center median along Interstate-91 just to north of exit 23. Here the East Berlin Formation consists of interbedded fine-grained cross-bedded sandstone and ripple-laminated siltstone. Height of road-cut outcrop is about 7m.

Mapping (Steinen et al., 2008) at construction sites adjacent to Dinosaur State Park (DSP) revealed a variety of sandstone, conglomerate, and mudstone lithologies (Figures 11, 15). It exposed three black shale layers that are difficult to correlate with the known type section. These may be older cycles. The construction adjacent to DSP and at sites to the east exposed conglomerate (figure 11) suggesting that the formation coarsens somewhat toward the east (recognized by Krynine, 1950, in southern Connecticut).

Shuttle Meadow Formation. The Shuttle Meadow Formation may be exposed in the western portion of the Hartford South Quadrangle. If it is, it is lithologically similar to the East Berlin Formation, and the two formations are difficult to distinguish due to the poor outcrop quality.



b

Figure 15. a. Gray shale layer temporarily exposed during excavation of a utility trench at State Veterans' Home in Rocky Hill. The view shows about 1 meter of sedimentary layers. Overlying fine-grained sandstone beds contain abundant dinosaur tracks and portions of this layer are bioturbated (track-bearing?). Correlation of this shale (and two additional black shale layers below it) is uncertain, but this may be the 7^{th} major lacustrine cycle below the Hampden Basalt. This shale overlies the phyllite-clast conglomerate (Fig. 11b) and contains dropstones (Fig. 15b). b. Dropstone recovered from shale layer in Fig. 15a. The smooth polished surface of the stone suggests it is a gastrolith. Scale bar is about 5 mm.

Volcanic Rocks

Three distinct basalt flow units occur within the Hartford Basin (Figures 1 and 4). From oldest to youngest, they are the Talcott, Holyoke, and Hampden Basalts. All three units are stratigraphically significant, in that they are used to subdivide the lithologically similar sedimentary rocks into four distinct stratigraphic entities. Thus, field mapping in the basin relies on recognizing the resistant, well-exposed basalt formations, and using them to interpret geologic structures and the poorly-exposed sedimentary units between basalt outcrops.

Basalt Formations in the Hartford South Quadrangle

Holyoke Basalt. The Holyoke Basalt is the thickest (up to 200 m) and most laterally persistent of the three flood-basalts in the Hartford Basin. It forms the main traprock ridge through the Connecticut Valley (LeTourneau, 2008) with local relief of more than 30 m and cliffs of 5 to >10 m height being common (it is a local rock climbing attraction in many parts of the state). The Holyoke is a quartz-normative tholeiite with relatively high iron concentration (Weigand and Ragland, 1970; Philpotts and Reichenbach, 1985; see basalt geochemistry section below). It has a remarkably even texture throughout the flow. Except for segregation sheets, no differences in grain size or composition were apparent during macroscopic observation. The Holyoke contains 0.5 mm laths of plagioclase feldspar, slightly smaller stubby crystals of pyroxene and a gray groundmass. Phenocrysts were not observed.

In places colonnade and entablature cooling fracture patterns are well developed. The most complete exposure of the Holyoke that is readily accessible in the Hartford South Quadrangle is along the roadcut outcrops on Connecticut Route 175 just south of Cedar Mountain. There only the colonnade is easily observed in the lower third of the outcrop (Figure 16a). The upper portions of the flow have less well developed columnar joints. The entire outcrop, however, contains abundant well-developed tectonic joints that parallel NW-SE faults in the immediate vicinity. Several of the tectonic joints are mineralized mainly by quartz with traces of barite. Segregation sheets (Figure 16b) are easily observed in the lower third of the flow at Route 175 but were not seen in the upper portions of the roadcut. The segregation sheets are composed of coarse grained rock, presumably gabbroic in composition (ferrodiorite according to Philpotts et al, 1996). An interesting cooling history, involving compaction of an early-formed crystal-mush and incompatible element enrichment of the residual liquids has been inferred (Philpotts et al., 1996; Philpotts and McHone, 2004).

Figure 16. a. Jointing in the Holyoke Basalt exposed on south side of CT Route 175 in Newington. Joints are composed of both the colonnade cooling-joints and tectonic joints that parallel the NW-SE faults that cut the basalt. This outcrop is about 10m high. b. Top of a segregation sheet in lower third of Holyoke Basalt on north side of CT Route 175. Contact between coarse-grained segregation below and fine-grained basalt above is just below pencil eraser and dips toward the east at about same angle as local bedding. The pencil is about 15 cm.

Hampden Basalt. The Hampden basalt is found in two outcrop belts running roughly north-south through the quadrangle. The eastern outcrop belt extends from the northern edge of the map to the southern edge, and outlines the Rocky Hill Anticline. A western outcrop belt crops out in the northwest corner of the quadrangle. The Hampden Basalt forms a low ridge with local cliffs. The maximum relief along the ridges is only about 25m and cliffs rarely exceed 5m in height within the quadrangle (Fig. 17).

The Hampden Basalt is a quartz-normative tholeiitic basalt with relatively high titanium and iron contents (compared to the other basalt flows in the Hartford Basin; Weigand and Ragland, 1970; Philpotts and Reichenbach, 1985). It is fine to medium-grained basalt that may contain decimeter thick coarse-grained sheets (Fig. 18a) that are gabbroic or dioritic composition. The

Hampden is composed of plagioclase feldspar laths with stubby pyroxene crystals set in a gray groundmass. The flow has a chilled base. It baked the upper few centimeters of the underlying mudstone and resulted in considerable steam generation. The steam escaped upward through the lava and formed numerous pipe-stem vesicles at the base and vesicle cylinders higher in the flow (Fig. 18b, 18c). Gray (1982) found the pipe-stem vesicles extended upward into the basalt up to 2 m and the vesicle cylinders up to 6 m. Our observations suggest that the vesicle cylinders may extend to near the surface of the flow. Pipe-stem vesicles are tilted toward the northeast which has been interpreted to indicate northeasterly flow of the basalt during the time the steam bubbles were escaping upward (Gray, 1982, Ellefson and Rydel, 1985). Local, poorly developed pillow-like structures are seen at the base in some locations (Fig. 19a, 19b).

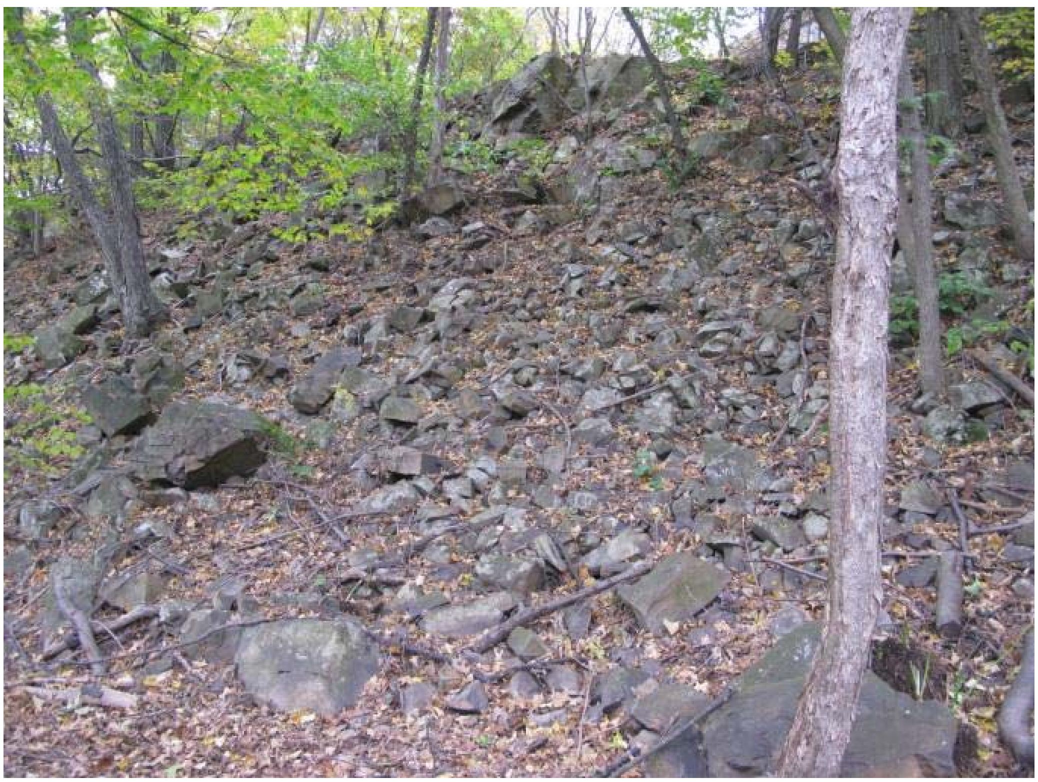


Figure 17. Typical outcrop of Hampden Basalt, forming a ridge with talus, but rarely forming a significant cliff. Here, at Century Village (near the Rocky Hill-Cromwell town boundary), the cliff is only about 1-2 m in height.

Figure 18. Segregation sheets and vesicles at the base of the Hampden Basalt. a. Segregation sheet in Hampden Basalt at outcrop just a few meters into the Hartford North Quadrangle. The lower boundary is just below hammer head. The upper boundary about 5 cm above the end of the handle. b. Base of Hampden Basalt showing scattered vesicles formed by escaping steam generated by hot lava overlying wet sedimentary layers. The steam escaped upward from the top of the sediment into the basalt forming vesicles as the lava congealed. Vesicles are small black areas (holes) in image. The head of the hammer is about 10 cm long. c. Unusually wide-diameter vesicle-cylinders at Rock Ridge Park in the northern part of quadrangle.

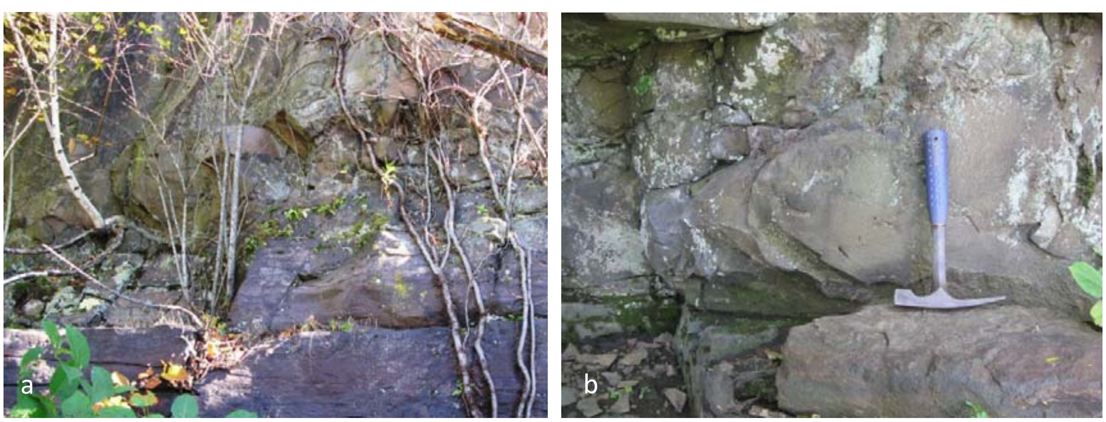


Figure 19. Pillow-like structures locally at base of Hampden Basalt in Rock Ridge Park, Hartford. “Pillows” up to 30 cm thick and .5 m in length occur at the contact with the underlying East Berlin Formation. Vesicles in “pillows” occur at unusual angles to “pillow” surface. Birch tree on left of image in a. is 4 cm in diameter; hammer in b. is about 30 cm. in length.

Most of the Hampden is massive. Columnar joints are present but well-developed colonnade or entablature structures are not. Most of the prominent joints appear to be tectonic in origin, paralleling known or reliably interpreted faults. The upper few meters contain abundant vesicles (Figure 20) and/or amygdales with calcite and/or prehnite fillings. In some places gabbro-filled dikes or sills cut the flow Figure 18 a). These may be segregation sheets that are so common in the underlying Holyoke Basalt (Philpotts et al., 1996). The surface has a preserved flow-top breccia in some locations (Figure 21a, 21b), but in other locations the top of the flow was eroded prior to deposition of the overlying basal Portland sediments (Hoffman et al., 1994). In some locations Pleistocene glacial erosion may have removed some of the top (Fig 21 c). The Hampden appears to consist of only one flow unit in the Hartford South quadrangle (Gray, 1982).

Figure 20. a. Vesicles at top of outcrop in Rock Ridge Park suggest that this exposure is near top of flow. The hammer head is about 18 cm long. b. Large vugs formed by steam in uppermost sediment layer (baked) beneath Hampden Basalt. The irregular vugs are about 2 centimeters in diameter. The width of hammer handle is about 3 cm.

Figure 21. a., b. Breccia at top of Hampden Basalt on campus of Trinity College. c. Shallow glacial furrows (filled with leaves) at top of outcrop of eastward dipping Hampden Basalt.

Basalt Geochemistry

The three basalts of the Hartford Basin are not distinct enough in their macroscopic petrography to permit accurate field identification in hand sample. They do have slightly differing mineralogy, but they can appear very similar (Puffer et al., 1981; Philpotts and Reichenbach, 1985; Philpotts and Martello, 1986; Puffer and Philpotts, 1988). Variations within each basalt unit also complicate identification. To aid field mapping and structural interpretation, 23 samples from basalt outcrops were collected and analyzed for elemental composition with XRF and ICP procedures at the Washington State Geoanalytical Laboratory.

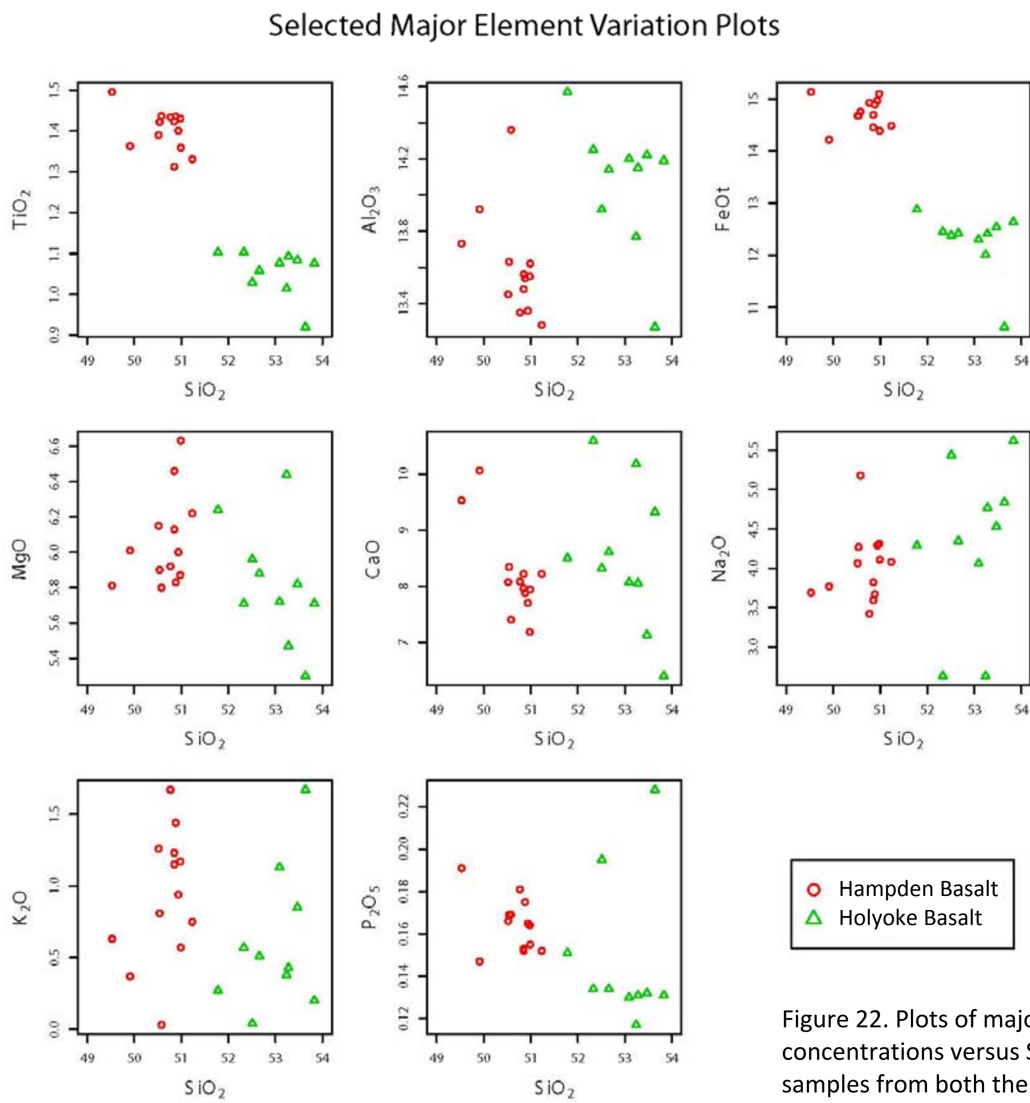


Figure 22. Plots of major element concentrations versus SiO_2 for samples from both the Hampden and Holyoke Basalts.

Significant effort was taken to collect samples with the minimum possible alteration. All three basalts have significantly different chemical compositions (Philpotts and Reichenbach, 1985). Two basalts, the Holyoke and Hampden occur in the Hartford South quadrangle. The geochemical results significantly aided outcrop correlations, sedimentary and volcanic formation identification, and structural interpretation, particularly in areas of complex faulting.

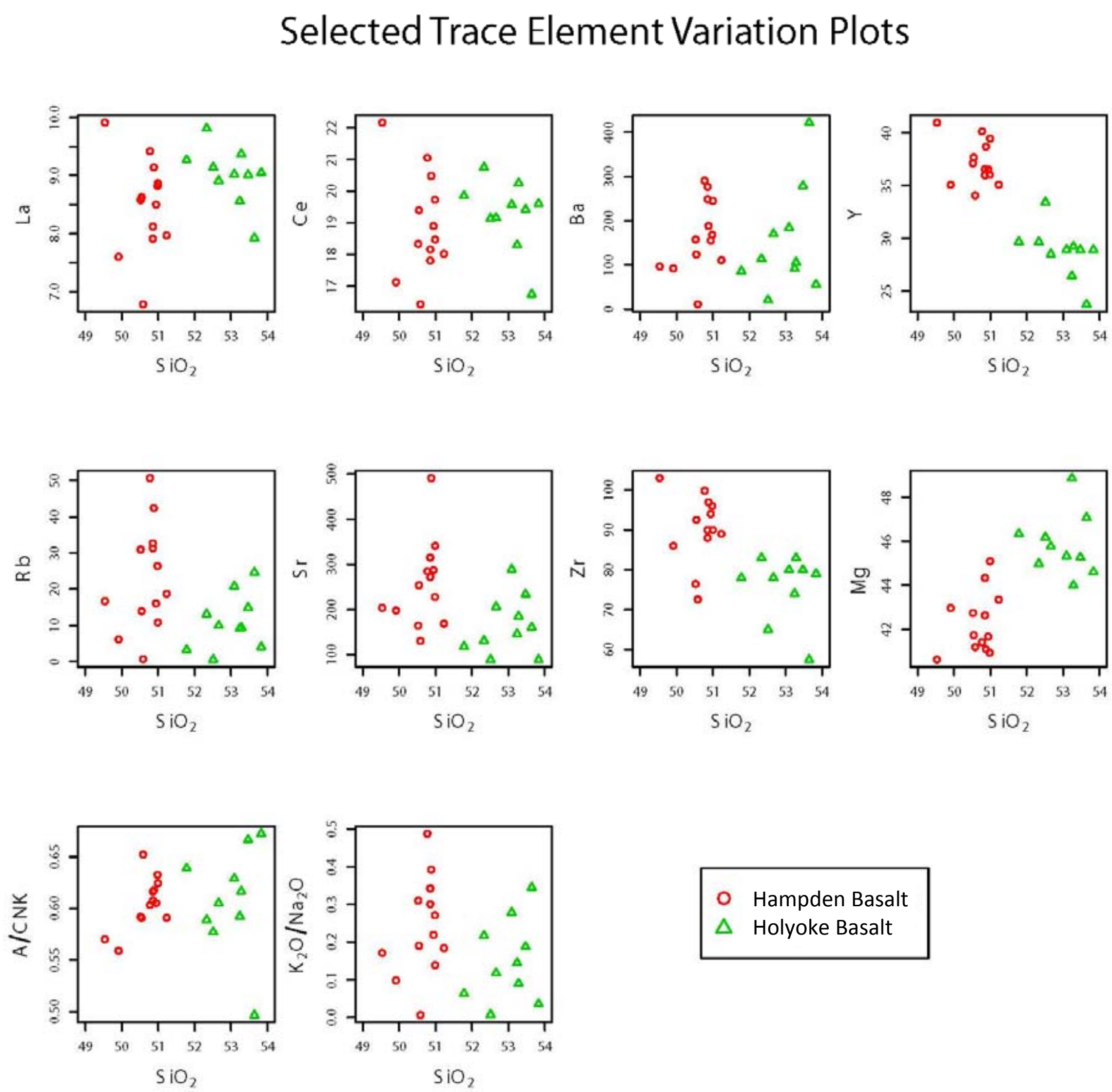


Figure 23. Plots of selected trace element concentrations versus SiO_2 for samples from both the Hampden and Holyoke Basalts.

Figure 22 shows major element concentrations in Holyoke basalt and Hampden basalt vs. SiO_2 from XRF analyses. Many of the variation diagrams show distinct fields between basalt compositions, allowing for simple distinction between the two basalt units present in the Hartford South quadrangle. The Holyoke Basalt has, on average, has higher silica, higher aluminum, lower iron, and lower titanium concentrations than the Hampden Basalt. This is consistent with earlier researchers, who found that the Hampden has generally more iron and titanium than the Holyoke (Philpotts and Reichenbach, 1985). Other elements, including K, Mg, and Ca have overlapping concentration ranges in the Hampden and the Holyoke Basalts.

Figure 23 contains plots of the differences in trace element compositions between the Holyoke and Hampden Basalts. Many of these variation diagrams contain distinct fields for each unit, which made for relatively simple distinction between basalt units. In particular, the Hampden Basalt contains significantly more Yttrium and Zirconium than the Holyoke Basalt.

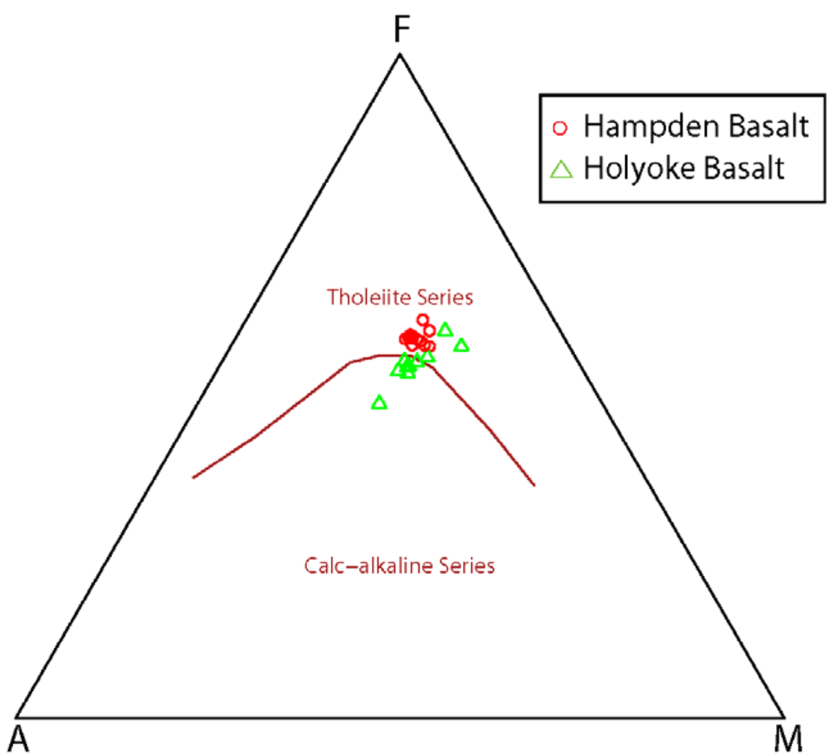


Figure 24. AFM plot of basalt samples from the Hartford South quadrangle. The compositional fields are from Irvine and Baragar, 1971. See the text for a description of this plot.

Figure 24 is an AFM classification diagram (after Irvine and Baragar, 1971), where A = (K_2O + Na_2O), F = total FeO, M = MgO, and A + F + M = 100 %. The fields suggest that the Hampden Basalt has tholeiite characteristics, while the Holyoke Basalt is transitional between tholeiite and calc-alkaline.

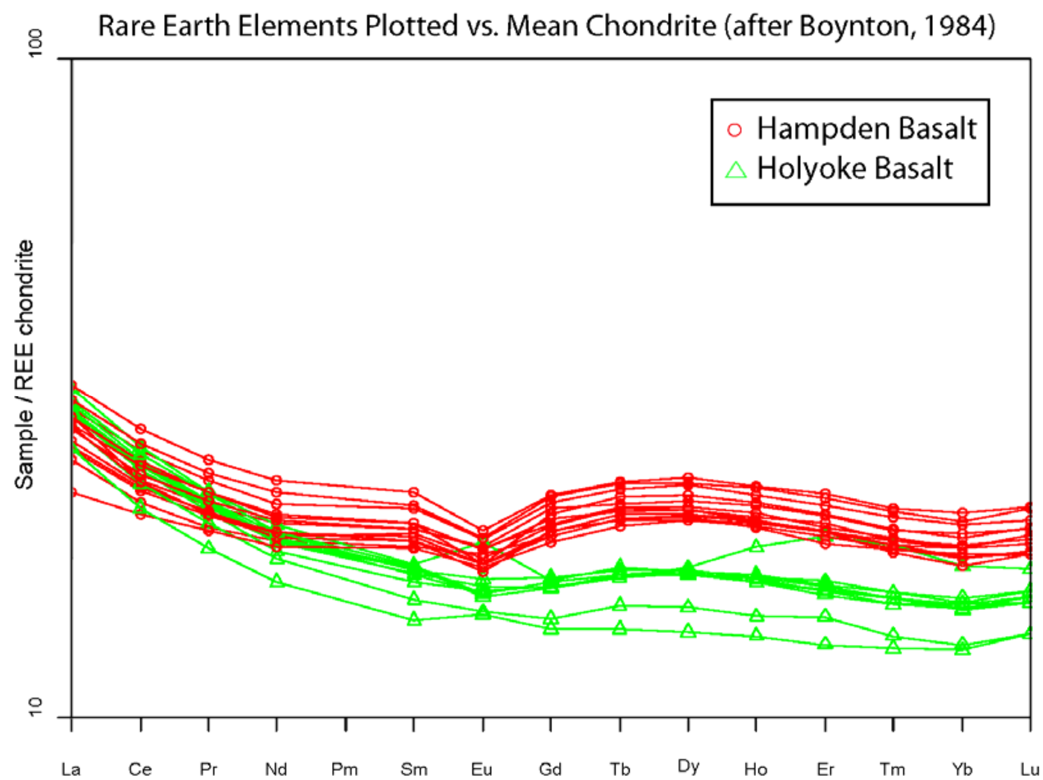


Figure 25. Rare Earth Element data for the Hampden and Holyoke basalts.

Figure 25 is a plot of Rare Earth Element (REE) concentrations normalized to mean chondrite (using the chondrite REE model from Boynton, 1984). REE patterns in the Holyoke Basalt are distinct from those in the Hampden Basalt. The Holyoke Basalt shows significantly more depletion of heavy Rare Earth Elements than the Hampden Basalt. In addition, the Hampden shows a conspicuous negative Europium anomaly that is not present in the Holyoke Basalt. This pattern is consistent with earlier researchers' interpretation based on petrography and major element geochemistry that the Hampden Basalt crystallized under more oxidizing conditions than the Holyoke (Philpotts and Reichenbach, 1985). At higher oxygen fugacity in the Hampden Basalt, Europium would more likely be present as Eu^{3+}, and would not substitute for Ca in plagioclase.

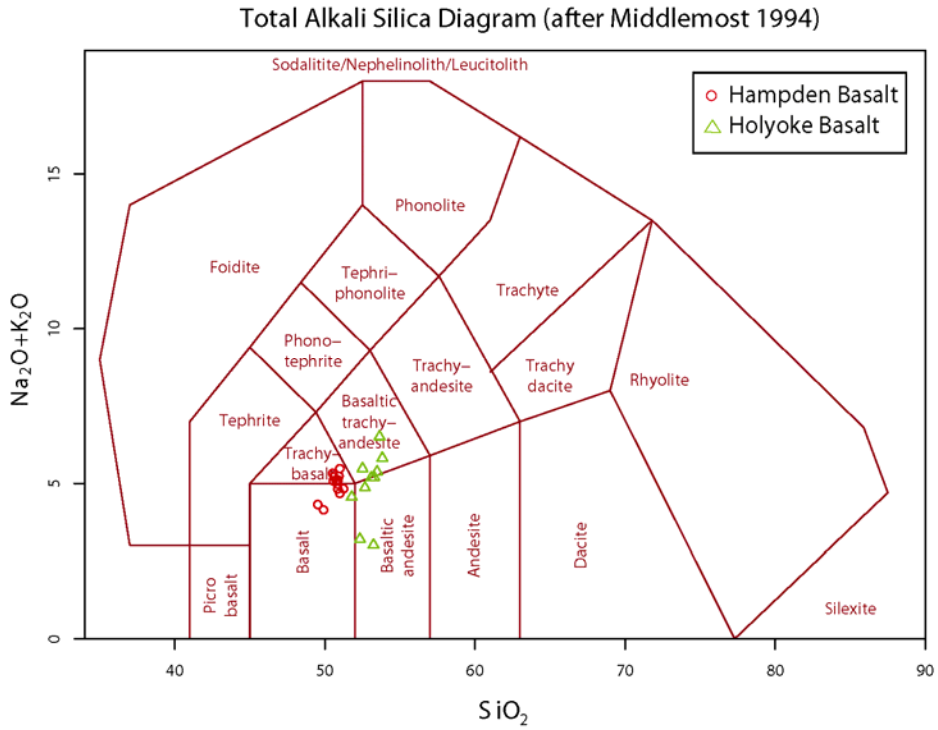


Figure 26. Total Alkali versus Silica Content classification diagram for the Hampden and Holyoke Basalts.

Finally, Figure 26 is a Total Alkali versus Silica Content Classification Diagram (after Middlemost, 1994) for the Hampden and Holyoke Basalts. The two basalts plot within distinct fields.

The geochemical data presented above clearly demonstrates that the Hampden and Holyoke Basalts have very distinct major and trace element compositions, allowing easy geochemical distinction between the units in outcrops that occur in separate fault blocks. The Holyoke Basalt has a steeper REE element profile (Figure 25), lower Fe & Ti contents, and higher Si (Figure 22) content than the younger Hampden Basalt, suggesting that Hampden most likely did not evolve by simple fractionation from the Holyoke magma. This conclusion is consistent with the interpretations of earlier researchers (Philpotts and Reichenbach, 1985). The distribution of basalt samples analyzed in the Hartford South quadrangle constrain the stratigraphic interpretation of the quadrangle, and provide the foundation for the structural interpretation.

Structural Interpretation

Structural Elements

The dominant structures in the Hartford South quadrangle are the east-west trending Rocky Hill Anticline and by numerous north-south to northeast-southwest trending faults that cut the anticline (Figure 1). These are dominantly normal faults that are responsible for repeating the sedimentary and volcanic section across the quadrangle several times. Deformation was initiated during the Triassic and Jurassic Periods (Schlische and Olsen, 1990; Schlische, 1993, 2003), when the basin was actively rifting in association with the opening of the North Atlantic Ocean. Slickensides indicating dominantly horizontal motion preserved in fault surfaces (Figure 27) suggest possible strike-slip reactivation of the faults following rifting. Fission track ages suggest deformation on faults in the Hartford Basin may have persisted into the Cretaceous Period (Roden-Tice and Wintsch, 2002).

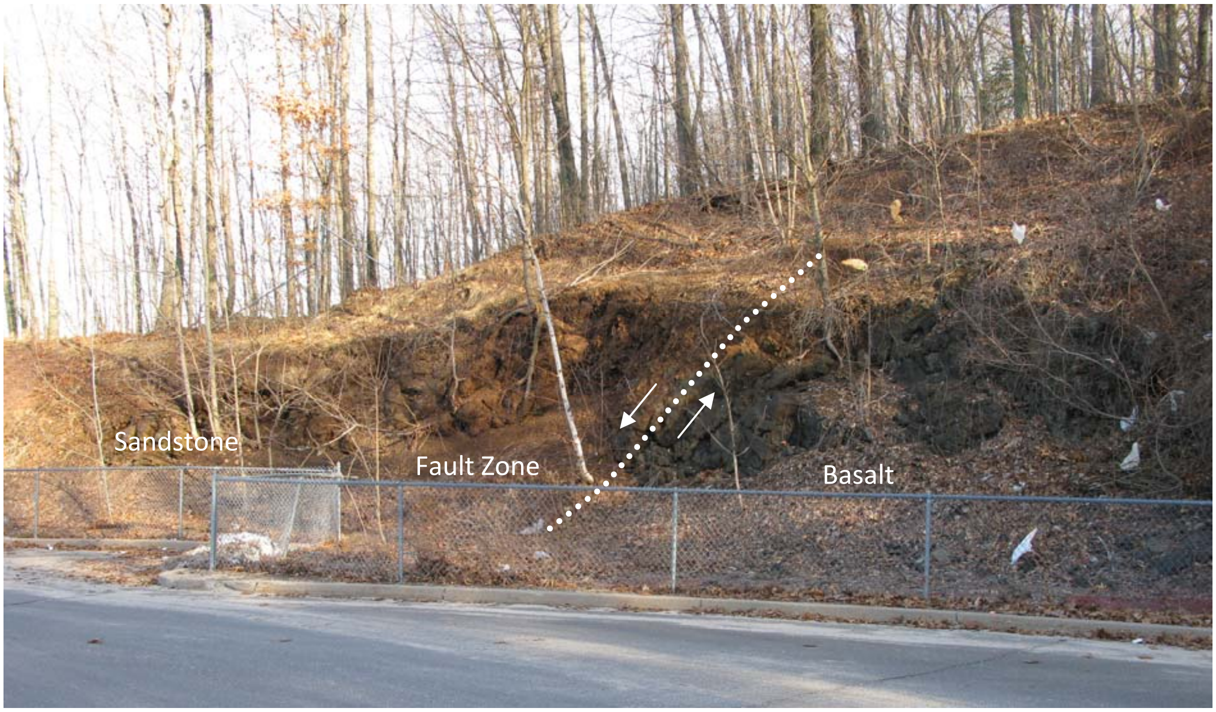
The Rocky Hill Anticline is oriented approximately N110°E, and plunges shallowly to the east. Based on its proximity to a major bend in the Eastern Border Fault, the anticline is interpreted to have formed as a fault deflection fold at the relay zone between two fault segments of the border fault system (Schlische, 2003). It is cross-cut by all generations of faulting in the Hartford South quadrangle, and does not appear to have folded any these faults, suggesting that it predates or is synchronous with intra-basin faulting. It is interpreted to have formed during displacement along the major Eastern Border Fault system to the east, which was initiated in the Triassic Period (Schlische, 1993, 2003), and likely continued during and after the basin-filling period.

Several generations of normal faults with different orientations are found throughout the Hartford South quadrangle. They are recognized primarily by offsets in basalt ridges, but some have been directly observed in the field (Figure 27). Two dominant orientations of faults have been recognized, one that is approximately N10°E and one that is approximately N50°E (Figure 28). These fault orientations are similar to those mapped in the New Britain quadrangle immediately to the west (Simpson, 1966), but only one major orientation of normal faults (approximately N30°E) is found in New Britain (Figure 28).

Faults with the N10°E orientation are synthetic to the Eastern Border Fault system. They extend across the entire mapping area. The fault planes dip to the west, and the hanging wall occurs on the west side of the faults. The fault planes with the N50°E orientation are typically shorter than the N10°E faults, and dissect these faults. Most of these younger fault planes dip to the northwest, but some are interpreted to be antithetic to the major fault system, and dip to the southeast.

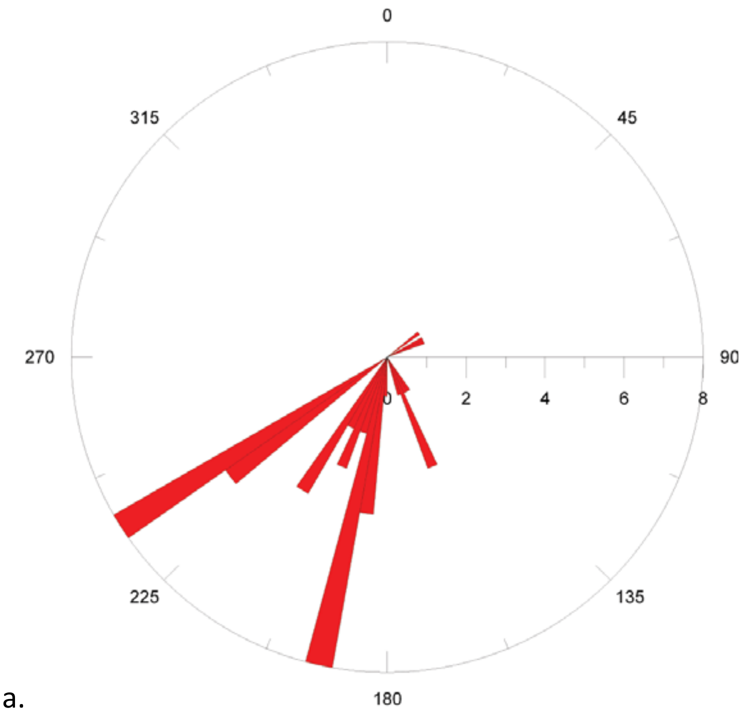
Structural History

Crosscutting relationships have permitted an interpretation of the relative timing of major structural events in the Hartford South quadrangle. Several distinct phases with different structural styles are recognized to have occurred during and perhaps following formation of the Hartford Basin. Figure 29 shows two structural cross-sections that illustrate the structural history of the Hartford South quadrangle.

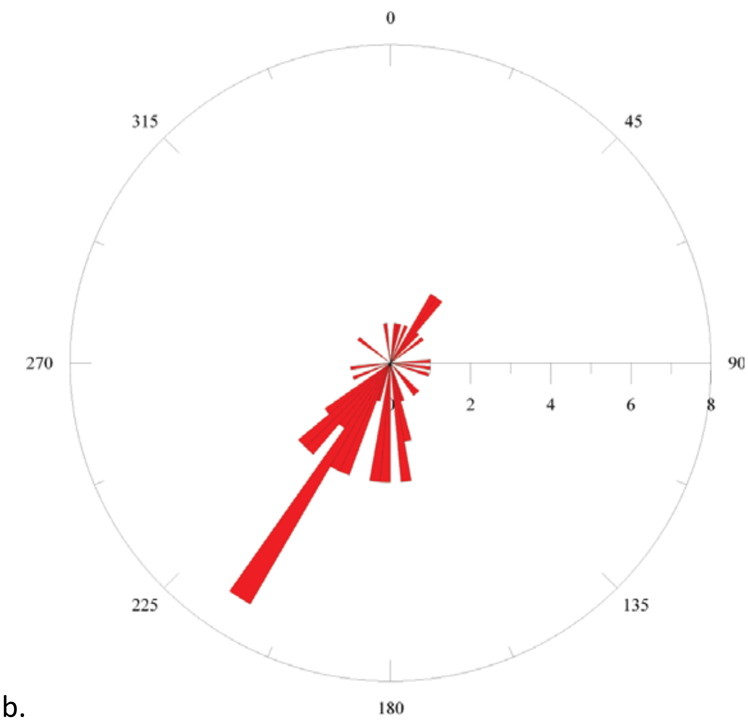
a. 

b. 

Figure 27. Normal fault exposed in the parking lot of Stop and Shop Supermarket on the Berlin Turnpike / Wilbur Cross Highway in Newington, CT. a. Interpreted photograph of the north side of the fault (the fence is approximately 4 feet high). b. Fault surface showing nearly horizontal slickensides in the basalt on the footwall (the photo view is approximately 1 foot across).



a.



b.

Figure 28. Rose diagrams of faults within the Hartford South and New Britain quadrangles. a. Data from the Hartford South quadrangle. b. Data from the New Britain quadrangle (Simpson, 1966). The New Britain quadrangle is directly west of Hartford South quadrangle. The radial scale is the number of faults counted, and the azimuth is based on the right hand rule. Most of the faults dip to the north and west.

The recognized structural phases include:

- Phase 1: The earliest deformation in the Hartford South quadrangle appears to have been the formation of the Rocky Hill Antilcline. It likely formed in association with rifting along the major Eastern Border Fault system that created the half-graben basin, and is located to the east of the mapping area. This fault system was active in the late Triassic and early Jurassic, based on the age of the sediment that fills the Hartford Basin (Schlische and Olsen, 1990; Schlische, 2003). The anticline folds sedimentary and volcanic rocks that are of earliest Jurassic age.

- Phase 2: Normal faults with an approximate N10°E strike that dip dominantly to the west formed next within the Hartford South quadrangle, and displace the Rocky Hill Anticline (phase 1). These faults were likely active concurrently with the major Eastern Border Fault system to the east. These faults are roughly parallel to the Eastern Border Fault and are the primary structures responsible for repeating the basin's sedimentary and volcanic section several times across the quadrangle.

- Phase 3: Northeast (and some northwest) striking faults displace the faults of phase 2. The northeast striking faults are approximately N50°E in orientation. Outcrop patterns suggest that these faults may have originally been active as normal faults, but slickensides (phase 4) indicate that at least the last motion on these faults was dominantly strike-slip.

- Phase 4: Reactivation of all faults with dominantly strike-slip motion. Slickensides with rakes less than 20° degrees were measured on all faults visible, and indicate that the last motion, including the phase 2 and phase 3 faults, was dominantly strike-slip.

Comparison to Previous Mapping Efforts

The initial comprehensive mapping effort by Gray (1978; Appendix 2) formed the basis of the current project, and much of the lithological and structural data presented on the current map came from Gray (1978). The current map and Gray's (1978) map contain multiple generations of faults that have similar orientations. One notable difference between the maps is that on the current map, faults were placed only where there was direct evidence of stratigraphic offset (such as observed faults and offset basalt ridges), whereas the map of Gray (1978) also included an interpretation of faults apparently based on a dip domain analysis (see Wise, 1992).

Weitz (1972; Appendix 1) measured the orientation of 464 joints and fractures in the Hartford South quadrangle. His data show trends in fracture orientation that are similar to those collected in this study, but shows a third orientation (N125°E) as well (Figure 30). This NW-SE

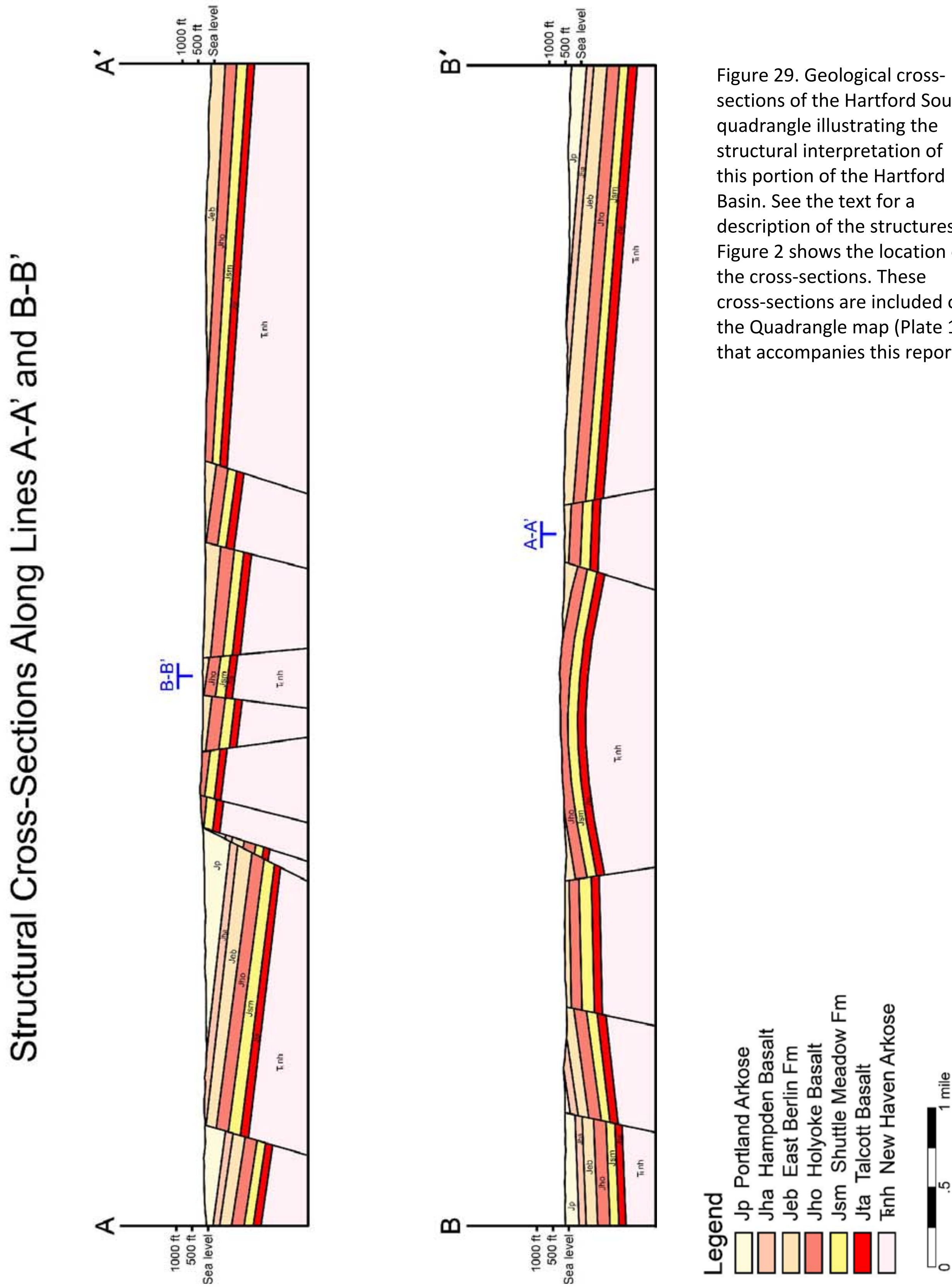


Figure 29. Geological cross-sections of the Hartford South quadrangle illustrating the structural interpretation of this portion of the Hartford Basin. See the text for a description of the structures. Figure 2 shows the location of the cross-sections. These cross-sections are included on the Quadrangle map (Plate 1) that accompanies this report.

trending structural element is consistent with several faults identified on the geological map. A cursory review of state LIDAR imagery suggests these trends may occur statewide.

The map by Gray (1978) was used in construction of the State Bedrock Geological Map of CT (Rodgers, 1985). The geology presented in the current Hartford South quadrangle map is very similar to the Rodgers (1985) map in terms of the structural style and the distribution of the stratigraphic units. The quadrangle is mapped at a more detailed scale, and thus contains several small faults that do not appear on the Bedrock Geological Map. Both maps are dominated by an east-west trending anticline that is dissected by several generations of mostly normal faults.

Significant differences between the Hartford South quadrangle map and the Bedrock Geological Map of Connecticut include:

- Several smaller faults were identified in the Hartford South quadrangle that do not appear on the State Bedrock Geological Map.
- A major NNE trending fault on the State Bedrock Geological Map (that truncates the isolated exposure of the Holyoke Basalt in the SE portion of the quadrangle) is mapped as two parallel faults on the quadrangle map on the basis of basalt ridge offsets. These parallel faults are interpreted to contain numerous offsets created by smaller faults.
- A major fault (trending nearly due north-south) along the western side of the Hartford South quadrangle occurs in both maps. On the quadrangle map, it has been shown to be offset by numerous smaller NE and NW trending faults. Less Shuttle Meadow Formation is interpreted to occur on the footwall of this fault than is shown on the State Bedrock Geological Map. This interpretation results from the investigation of new exposures that were not available to previous workers.
- The relations between the two generations of faults in the SW corner of the quadrangle map vary from the State Bedrock Geological Map. This is attributed to the more detailed nature of the quadrangle map, as well as the addition of many new outcrops in that portion of the quadrangle as a result of construction over the past several decades.

Summary

A bedrock map of the Hartford South quadrangle was constructed by examining all available outcrops within the limits of the quadrangle, and merging these observations with those of previous mapping efforts in the area (Deane, 1967; Gray, 1978; Rodgers, 1985). Rapid suburban development over the past few decades resulted in the continual exposure of new outcrops and the burial of previously exposed rocks. The Hartford South bedrock map will assist in

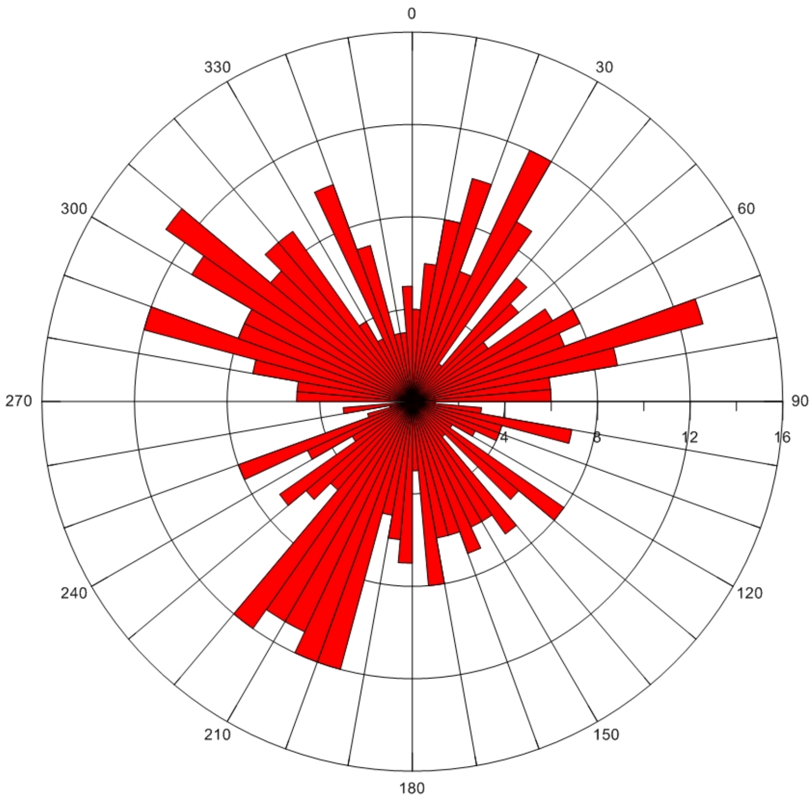


Figure 30. Rose diagram showing the orientation of fracture and fault data in the Hartford South quadrangle provided by Weitz. Note that there is a third data trend (NW-SE) not identified in the current study.

balancing the management of Connecticut’s natural resources with the needs of local communities as development continues within the area.

Mapping was completed by chemically identifying and correlating the well exposed basalt formations within the Hartford South quadrangle. Poorly exposed sedimentary formations were mapped by noting their stratigraphic positions relative to the basalt layers. Few geological structures were directly observed. Most were mapped by recognizing offsets, terminations, and flexures of basalt ridges. Throughout the mapping activities, effort was taken to maintain continuity with the Bedrock Geological Map of Connecticut of Rodgers (1985).

Acknowledgements

The authors would like to thank Michael Wizevich for consultation during the field portion of this project, and Norman Gray for a constructive critique of the final map. The map was completed while the principal author was on sabbatic leave at the Connecticut State Geological and Natural History Survey, Department of Environmental Protection (now Department of Energy and Environmental Protection). Financial support for this project was provided by the National Cooperative Geologic Mapping Program, Educational Mapping Component (EdMap) of the United States Geological Survey (award number 07HQAG0055).

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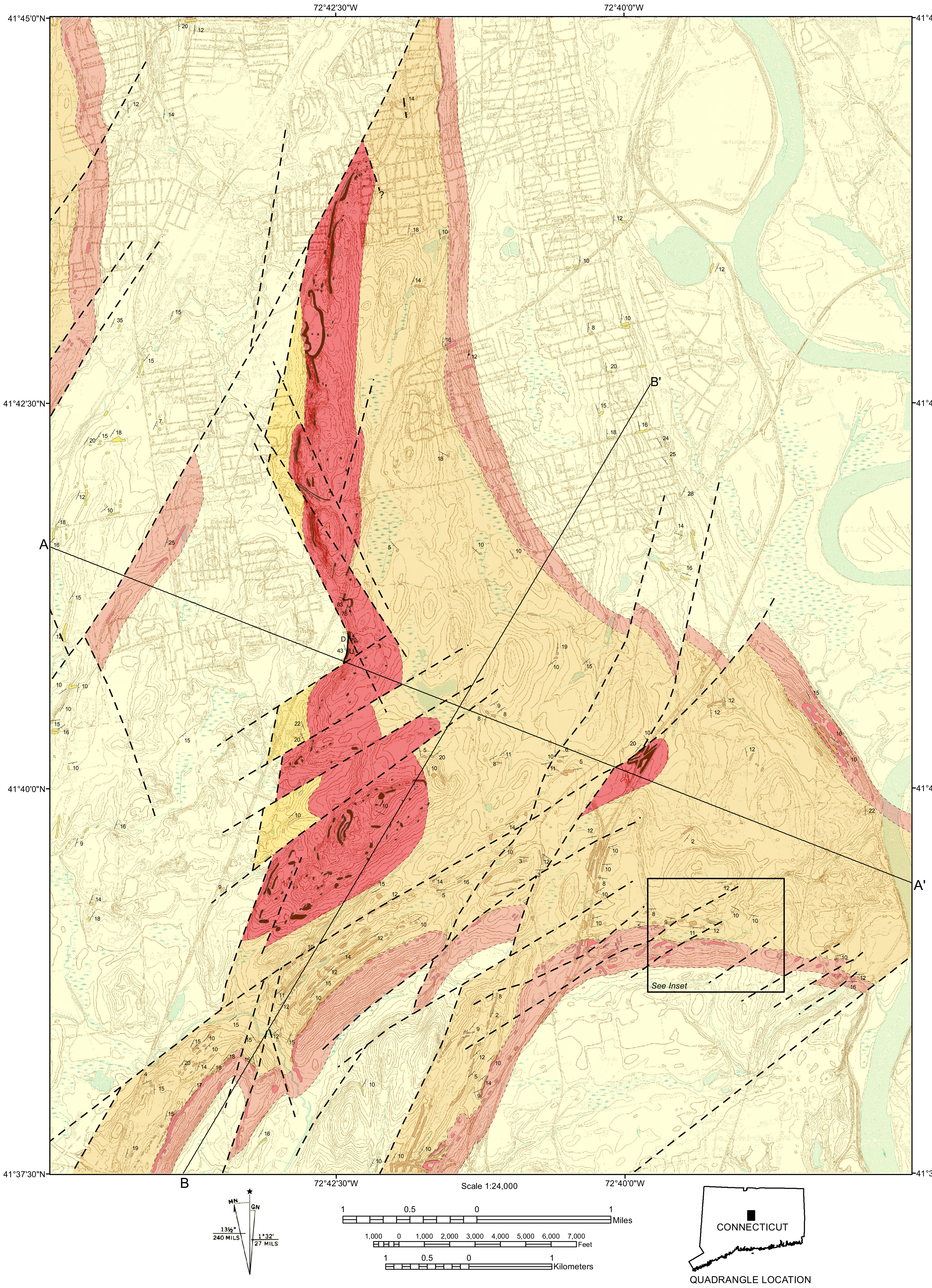
STATE GEOLOGICAL AND NATURAL HISTORY SURVEY OF CONNECTICUT
DEPARTMENT OF ENERGY AND ENVIRONMENTAL PROTECTION

QUADRANGLE
REPORT No. 40
Plate 1



Explanation

Individual outcrops shown as darker color within map unit

Historical outcrops also shown with hatched pattern where temporarily exposed during construction

Jp Portland Formation

Reddish brown, reddish gray, and dark gray shale siltstone, sandstone, sandstone, and conglomerate; micaceous and feldspathic. Forms local outcrops of limited extent; even where ridge forming, it is generally covered by glacial till. Lower part of formation mostly interbedded reddish gray fine- to coarse-grained sandstone interbedded with siltstone beds cut by desiccation cracks and containing local pedogenic features; redbeds punctuated by light gray fine- to medium-grained sandstone and gray and dark gray silstone and shale. Gray beds not known to crop out in quadrangle but are reported from borings. Upper part of formation may contain coarser-grained sediments but does not crop out in quadrangle. Deposited in alluvial plain, playa, and perennial lake environments. Thickness not determined, but may be greater than 2000 m.

Jha Hampden Basalt

Basalt and diabase, gray, dark gray and greenish gray on freshly broken surface, weathers to tea-brown patina. Composed of gray plagioclase feldspar laths and phenocrysts up to 1 mm in length and dark gray stubby about 0.5 mm. pyroxene crystals in a gray groundmass. Basal contact chilled and very fine grained, but with 5% plagioclase phenocrysts. Contains pipe vesicles in lowest several decimeters indicating northeast flow direction. Middle portion massive. Upper may be vesicular and amygdaloidal; flow top breccia preserved in some locations. Cannot be distinguished in field with certainty from Holyoke Basalt. Chemically distinct, however. Ridge forming with local cliffs. 45-50 m thick.

Jeb East Berlin Formation

Reddish brown, reddish gray, gray and dark gray shale, siltstone, sandstone, and conglomerate; micaceous and feldspathic. Only upper half is exposed; lower half forms widely scattered local outcrops of limited extent. Upper half composed of interbedded reddish gray fine- to coarse-grained sandstone interbedded with siltstone beds cut by desiccation cracks and containing local pedogenic features; redbeds punctuated by light gray fine- to medium-grained sandstone and gray and dark gray siltstone and shale. Formation is prolific producer of fossil dinosaur tracks; several of the dark gray shale layers produce fish fossils. One gray shale contains tuff bed 1-2 mm thick. Phyllite clast conglomerate in eastern outcrops. Deposited in alluvial plain, playa, and perennial lake with fan deltaic environments. Thickness of 118 m exposed along southern quadrangle boundary; total thickness may exceed 150 m.

Jho Holyoke Basalt

Basalt and diabase, gray, dark gray and greenish gray on freshly broken surface, weathers to tea-brown patina. Composed of gray plagioclase feldspar laths up to 0.5 mm in length and dark gray stubby about 0.5 mm pyroxene crystals in a gray groundmass. Neither base nor top exposed at natural outcrops in quadrangle (base may be exposed in local quarry near northern end of outcrop belt. Lower third with columnar joints and segregation sheets composed of gabbro. Splintery fracture in upper part. Curvilinear columnar entablature reported in some locations. Vesicles and amygdales reported in upper part of unit. Some locations have flow-top breccia. Cannot be distinguished in field with certainty from Hampden Basalt. Chemically distinct, however. Ridge forming with local cliffs. Approximately 200 m thick.

Jsm Shuttle Meadow Formation

Reddish brown to grayish red siltstone and very fine-grained sandstone. Poorly exposed in quadrangle and difficult to distinguish from similar lithologies in East Berlin and Portland Formations. Thickness not determined.

Structure

Bedding (showing strike and dip)

Fracture (showing strike and dip)

Contacts

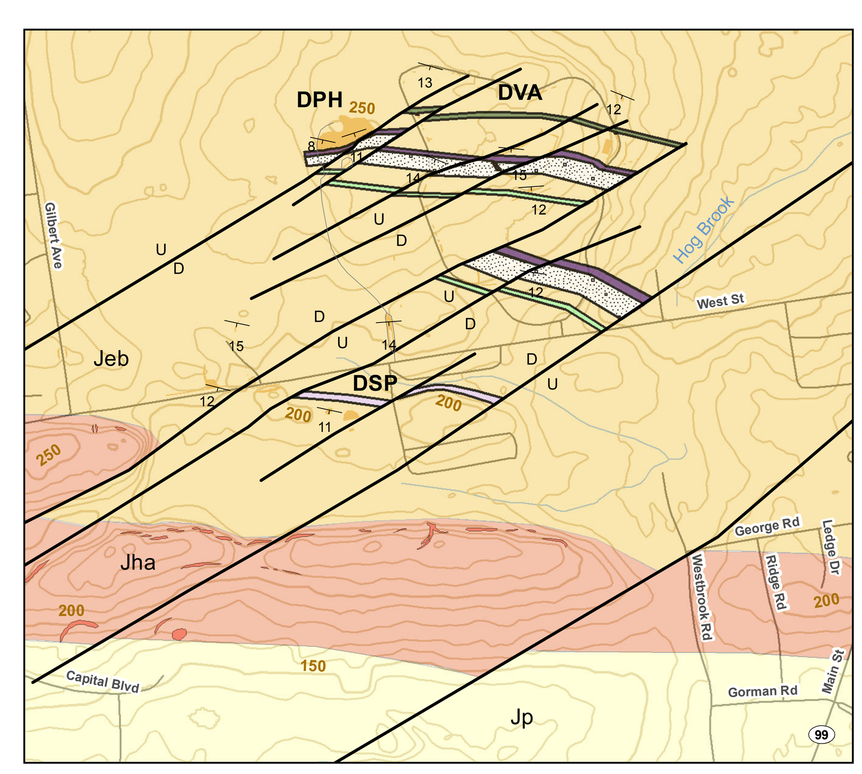
Inferred

Observed

Faults

Inferred

Observed



Legend

Portland Formation

Hampden Basalt

East Berlin Formation

Mappable beds of Jeb at scale shown

Dinosaur Park Lacustrine Bed

Upper Lacustrine Bed

Phyllite Clast Conglomerate

Middle Lacustrine Bed

Lower Lacustrine Bed

Strike and Dip of Bedding

Fault Showing Sense of Movement

Inset Geologic Map of State Projects along West St. Rocky Hill, CT (Steinen 2006 - 2010)
DPH: Department of Public Health Laboratory; DVA: Department of Veteran Affairs
DSP: Department of Energy and Environmental Protection, Dinosaur State Park

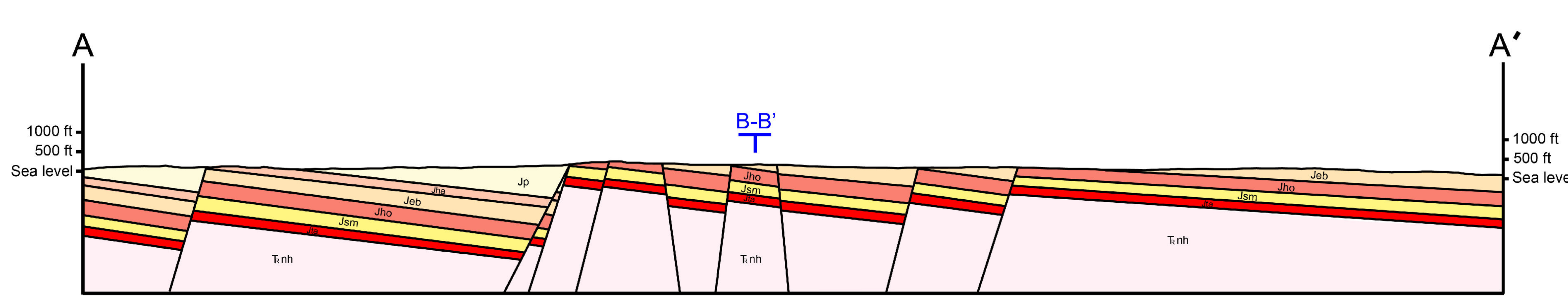
0 0.5 1 Miles
0 400 800 1,200 1,600 2,000 Meters

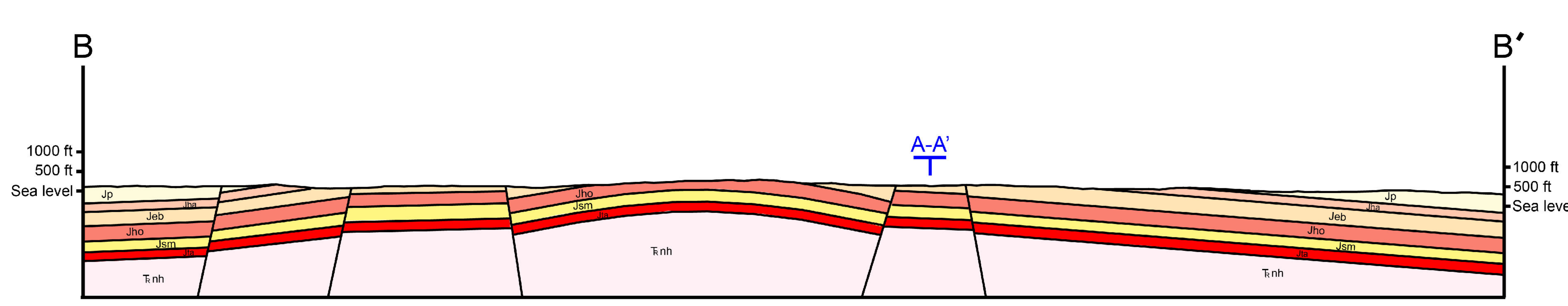
Bedrock Geologic Map of the Hartford South Quadrangle, Connecticut

Peter A. Drzewiecki, Timothy Schroeder, Randolph P. Steinen, and Margaret A. Thomas
Assisted by: Justin Milardo, Brian Clark, Matthew DePan, Kevin Beiler, and Allen Dwyer III

2012

Structural Cross-Sections Along Lines A-A' and B-B'





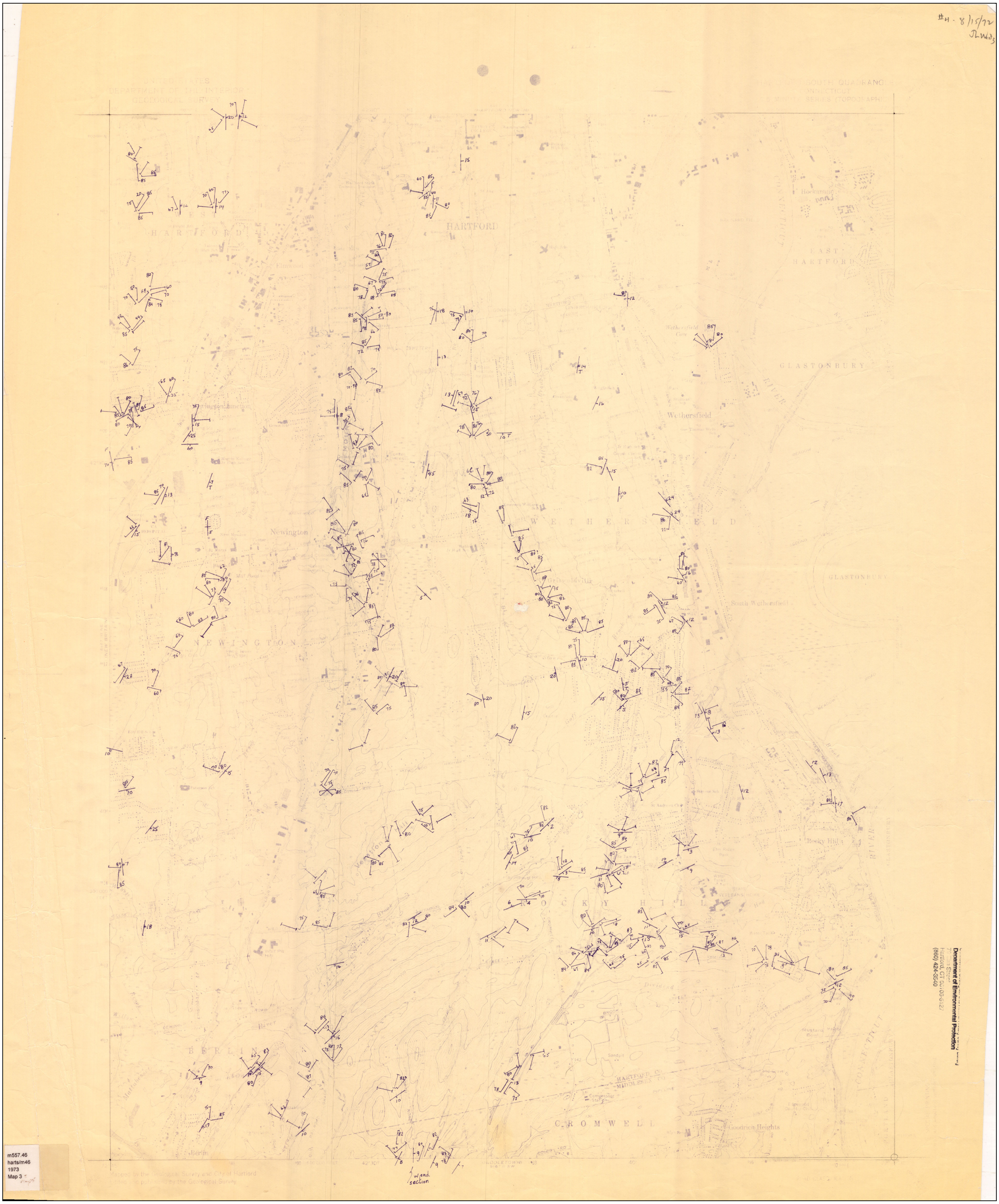
Legend

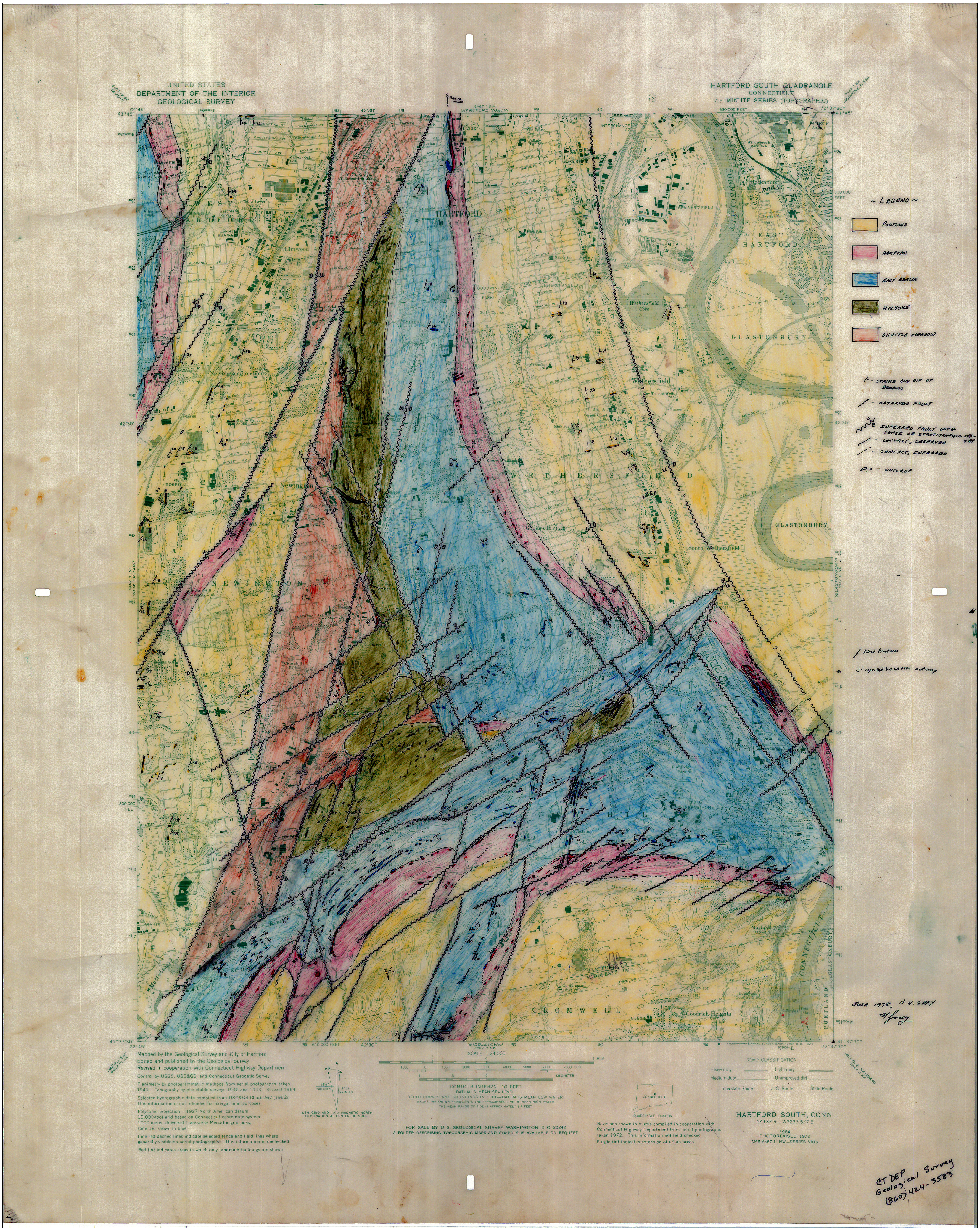
- Jp Portland Arkose
- Jha Hampden Basalt
- Jeb East Berlin Fm
- Jho Holyoke Basalt
- Jsm Shuttle Meadow Fm
- Jta Talcott Basalt
- T̄nh New Haven Arkose

0 .5 1 mile

Funded in part by the Educational Component of the National Cooperative Geologic Mapping Program, (EDMAP), U.S. Geological Survey award number 07HQAG0055.
http://ncgmp.usgs.gov/about/edmap.html

EASTERN CONNECTICUT STATE UNIVERSITY


HARTFORD
EAST HARTFORD
GLASTONBURY
Wethersfield
WETHERSFIELD
Newington
NEWINGTON
South Wethersfield
ROCKY HILL
BERLIN
CROMWELL
Goodrich Heights
m557.46
harts/m46
1973
Map 3


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
HARTFORD SOUTH QUADRANGLE
CONNECTICUT
7.5 MINUTE SERIES (TOPOGRAPHIC)
HARTFORD
EAST HARTFORD
WETHERSFIELD
GLASTONBURY
NEWINGTON
CROMWELL
~ LEGEND ~
PORTLAND
HAMPDEN
EAST BERLIN
HOLYOKE
SHUTTLE MEADOW
- STRIKE AND DIP OF BEDDING
- OBSERVED FAULT
INFERRED FAULT WITH SENSE OF STRATIGRAPHIC OFFSET
- CONTACT, OBSERVED
- CONTACT, INFERRED
- OUTCROP
filled fractures
reported but not seen outcrop
JUNE 1978, N. H. GRAY
Mapped by the Geological Survey and City of Hartford
Edited and published by the Geological Survey
Revised in cooperation with Connecticut Highway Department
Control by USGS, USC&GS, and Connecticut Geodetic Survey
Planimetry by photogrammetric methods from aerial photographs taken 1941. Topography by planetable surveys 1942 and 1943. Revised 1964
Selected hydrographic data compiled from USC&GS Chart 267 (1962)
This information is not intended for navigational purposes
Polyconic projection. 1927 North American datum
10,000-foot grid based on Connecticut coordinate system
1000-meter Universal Transverse Mercator grid ticks, zone 18, shown in blue
Fine red dashed lines indicate selected fence and field lines where generally visible on aerial photographs. This information is unchecked
Red tint indicates areas in which only landmark buildings are shown
UTM GRID AND 1972 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE MEAN RANGE OF TIDE IS APPROXIMATELY 1.7 FEET
FOR SALE BY U. S. GEOLOGICAL SURVEY, WASHINGTON, D. C. 20242
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
QUADRANGLE LOCATION
Revisions shown in purple compiled in cooperation with Connecticut Highway Department from aerial photographs taken 1972. This information not field checked
Purple tint indicates extension of urban areas
ROAD CLASSIFICATION
Heavy-duty
Light-duty
Medium-duty
Unimproved dirt
Interstate Route
U.S. Route
State Route
HARTFORD SOUTH, CONN.
N4137.5—W7237.5/7.5
1964
PHOTOREVISED 1972
AMS 6467 II NW—SERIES V816
CT DEP
Geological Survey
(860) 424-3583