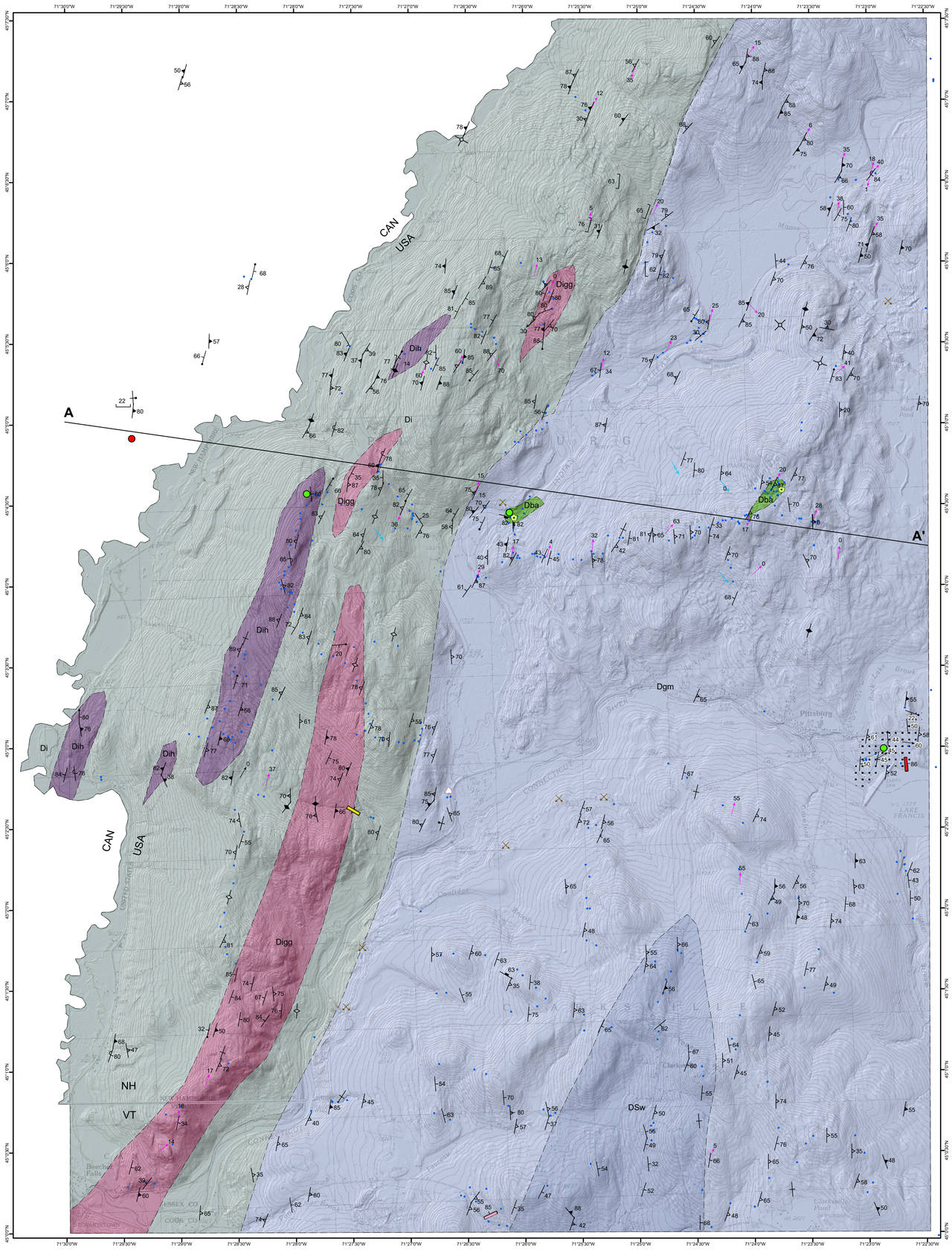
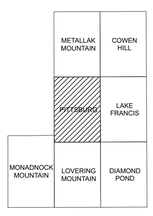
Bedrock Geologic Map of the Pittsburg 7.5' Quadrangle, New Hampshire and Vermont

W.A. Bothner, D.R. Converse, C.E. Jahrling, P.S. Koch, 2020



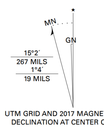


Scale 1:24,000

0 2,500 5,000 10,000 Feet

0 0.5 1 2 Miles

0 1 2 4 Kilometers



UTM GRID AND 2017 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Topographic basemap from the USGS 2012 Pittsburg NH-VT-QC 7.5' quadrangle
Projection: North American Datum 1983 New Hampshire State Plane Feet.
1000 meter grid in UTM zone 19 North, Contour Interval 6 m

Hillshade produced from high resolution (1 meter) LiDAR data

EXPLANATION OF MAP SYMBOLS

- Contact, dashed where approximate
- Observation
- Dike, inclined
- Felsic dike, vertical
- Diabase dike, inclined
- Nematophytales (Prototaxites), Devonian, Emsian?
- Gravel pit

Bedding
- Inclined
- Vertical
- Inclined graded bed, showing topping direction
- Vertical, topping east
- Bedding, Overturned

Bedding (continued)
- Indeterminate bedding and/or S1 foliation
- Indeterminate vertical bedding and/or S1 foliation

Brittle Structure
- Joint

Foliation
- S1

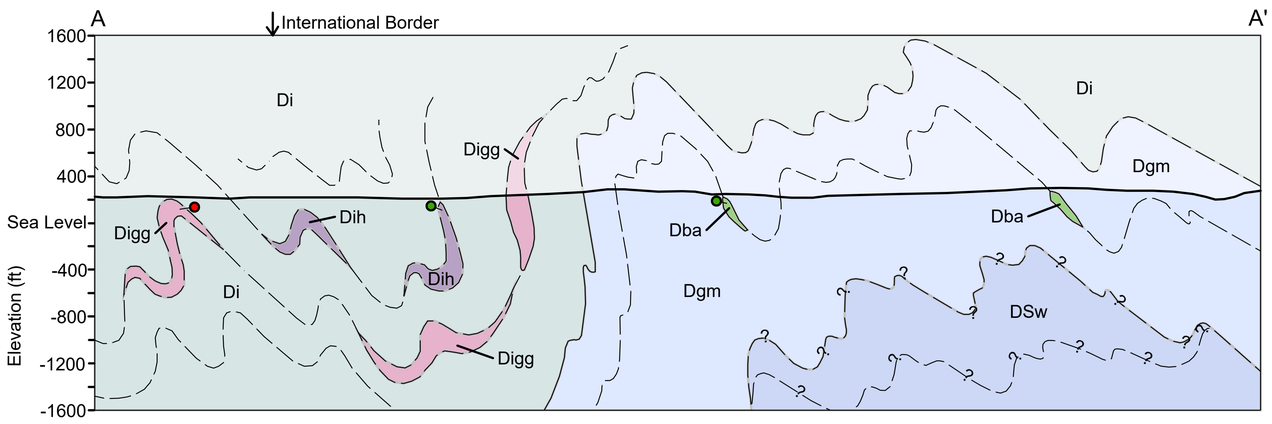
Foliation (continued)
- S1, vertical
- S2
- S2, vertical
- S3

Stipple Overprint
- Calcareous-rich zone

Linear features
- F2 fold axis
- Lineation
- Glacial striae

Samples
- Geochemistry
- Preliminary Zircon U/Pb date (this study)
- Zircon U/Pb (Perrot et al., 2019)

Interpretive Cross Section A - A' (No Vertical Exaggeration)



NHGS Open-File Disclaimer: This map and the accompanying legend(s) are understood to be open-file products. They are draft versions of an unpublished report and represent mapping progress at the time of completion. Newer information may exist. If you have questions, please contact the New Hampshire Geological Survey (NHGS) at: geology@des.nh.gov or (603) 271-1976

EXPLANATION OF MAP UNITS

Igneous and metaigneous units

Mesozoic White Mountain Plutonic-Volcanic Suite

Mzl **Lamprophyre dike at West Road** — Two-meter-thick, fine-grained, porphyritic dike with phenocrysts of zoned oxyhornblende and rare clinopyroxene, plagioclase, and opaques in a fine grained, likely devitrified

Mzd **Mafic Dike** — Dark-gray weathering, black subporphyritic magnetic diabase dike 1 meter thick on north shore of Lake Francis ~100 meters east of Murphy Dam, 2 cm chill margin, olivine and clinopyroxene(?) with thin black alteration haloes in hand specimen, plagioclase, and magnetite.

Mzf? **Felsic Dike** — Light red brown to golden weathering 1-1.2m thick, dark gray fine-grained sugary aplite dike cross-cutting thick-bedded Devonian graywacke in Ad Chase and Middle Branch Indian Stream. Feldspars are dominant, but much altered to form a fine-grained sericitic matrix. Probably related to the Monadnock intrusive complex just west of Colebrook, NH, or possibly the Devonian Averill or Hereford granites in nearby Vermont and Quebec

Late Early Devonian

Dba **Basaltic andesite** — Flow with well-developed pillows (tops to the west interlayered with thin- to thick-bedded graywacke and lesser phyllite of Dgm along Indian Stream near Comstock Hill and as a massive metadiorite (sill?) near the crest of Shatney Mountain (unusual geochemistry is nearly identical at both locations). Dark gray to black, fine-grained and chilled at pillow margins, containing plagioclase (now albitic), chlorite after amphibole, green biotite, interstitial quartz and opaque (brassy mm pyrite cubes in places). Zircon U/Pb analysis yields a preliminary weighted mean age of ca. 406 ± 7 Ma. Older, inherited zircon ages reflect Grenvillian and other Proterozoic sources.

Sedimentary and Metasedimentary Rocks

Di **Ironbound Mountain Formation** — black, metamudstone, slate and phyllite, variably graphitic and pyritic, commonly spotted with either weathered pyrite and/or ankerite. Thin interlayers of fine-grained, light gray to rusty metasiltstone sometimes preserve grading. Where graded beds are preserved, delicate cross-bedding may be seen on cleavage surfaces cutting bedding at a shallow angle. Correlative with Meetinghouse Slate member of the Gile Mountain Formation in Vermont and the Ludger and Lac Drolet members of the Compton Formation in Quebec.

Dih **Hall Stream member of the Ironbound Mountain Formation** — Discontinuous lenses up to a km long and >100 meters wide. May occur in layers a few cm to >3 m thick and is defined when abundant isolated feldspar grains occur in black phyllite; bedding within grit is rare but is recoverable at contact with phyllite. Coarser grit is composed of randomly oriented, euhedral, frequently fractured twinned plagioclase, variable amounts of clear quartz grains, and rare rock fragments in slaty matrix. Detrital zircon U/Pb population density analysis yields a preliminary maximum depositional age of ca. 390 ± 4 Ma.

Digg **Graywacke member of the Ironbound Mountain Formation** — ~380 m thick band of rhythmically graded, gray weathering, fine-grained micaceous feldspathic metasandstone and dark gray metashale member of the Ironbound Mountain Formation. Beds range from 10-30 cm in thickness. Quartz, feldspar, white mica and opaque are dominant phases. Interpreted to equate with Dgg in Vermont (Ratcliffe et al., 2011) and the Lac Drolet member of the Compton Formation (Dcd) in nearby Quebec where Perrot et al. (2018) reported a maximum depositional age of 413±7 Ma from U/Pb analyses of detrital zircons.

Dgm **Gile Mountain Formation** — Thick- to thin-bedded, weathering gray to light brown, variably calcareous feldspathic metasandstone that is 0.5 – 3m thick, meta-siltstone and dark gray phyllite. Often carries ankerite and/or pyrite cubes up to 1 cm across, alteration of both minerals produces a reddish brown weathering surfaces. Graded bedding is rarely preserved; brown weathering carbonate-rich lenses (stippled on the map) are present locally. Detrital zircons from calcareous metasandstone at Murphy Dam yielded a complex age spectra that provides a tentative maximum depositional age of ca. 413 ± 8 Ma. Correlated with parts of the Milan Member / Lac Drolet of the Compton Formation in Southern Quebec and the Gile Mountain Formation (Dgqs) in nearby Vermont. McWilliams et al. (2010) determined an age of 409 ± 5 Ma of the Royalton member of Dgqs. Perrot (2019) determined a maximum depositional age of 401 ± 6 Ma near St. Johnsbury.

Late Silurian - Early Devonian

DSw **Waits River Formation** — Interbedded brown weathering metasiltstone, dark gray phyllite, and brown lenses of meta-limestone and thin, intensely foliated dark gray to black limey metasiltstone as along West Road, Clarksville, NH. Previously interpreted as a calcareous member of the Frontenac Formation (Lyons et al. 1997). Correlated with parts of the Ayers Cliff Formation of Quebec (Perrot et al., 2018). Hatch (1963) suggested that the Waits River could be a calcareous facies of the Gile Mountain. Perrot (2019) presented detrital zircon age dates for the Waits River in northern Vermont near St. Johnsbury, indicating a maximum depositional age of 406 ± 9 Ma. McWilliams et al. (2010) determined two ages in Vermont: 418 ± 7 Ma and 415 ± 2 Ma. Aleinikoff and Karabinos (1990) reported an age of ca. 423 ± 4 Ma on a felsic dike that cross-cut the Standing Pond Volcanics Member.

GEOLOGIC SUMMARY

Introduction

The aim of this project is to provide modern geological maps of northernmost New Hampshire which may be used for both practical and scientific applications. The Pittsburg Geologic Map (Fig.1) is the first of 5 geologic maps that will cover the 1926 Indian Stream 15' quadrangle. Further refinement of this map is anticipated as the remaining maps in Northern New Hampshire are completed.

Preliminary Results

The surficial geology of the Pittsburg Quadrangle consists of Quaternary sediments of fluvial and glacial origin. Glacial striations throughout the quadrangle record a transport direction of ca. 141° (S39°E). The bedrock geology consists of a few unmetamorphosed Mesozoic felsic and mafic dikes and of much older Silurian and Devonian bedrock. The older bedrock consists of low-grade metamorphic slates, siltstones, and sandstones as well as a lesser amount of metamorphosed igneous rock, both volcanic – basaltic andesite pillow lavas and intrusive – diorite dikes/sills.

Figure 1: Location of Pittsburg Quadrangle, NH. The old 1:62500 Indian Stream Quadrangle is outlined in red.

Structurally, at least two major deformational episodes are recognized: 1) the upper Silurian- Lower-Devonian Salinic Orogeny (with both extensional and compressional events) and 2) the Late Devonian Acadian Orogeny compressional event. These deformations folded the older bedrock first in isoclinal folds and then refolded the bedrock into more open folds (e.g., Perrot, 2019, Perrot et al., 2018).

This map includes field data collected from 1976 through 2020. The field data includes structural, mineralogical and lithological data, two new geochemical analyses, and three new age determinations. Data from surface exposures constrain cross-sections that show the interpreted distribution of rock units in the subsurface. Key photos are also included to provide examples of different rock geometries and textures. New zircon age dates of both volcanic and metasediments, provide constraints on when and how the rocks were deposited, and result in new interpretations of subsurface geometries (see cross-sections). These new age data eliminate the need for previously proposed major faults in the Pittsburg Quadrangle. Metamorphosed pillow lavas interbedded with the Gile Mountain metasediments and related intrusive rocks were identified for the first time and provided additional age constraints.

Geologic Summary and Preliminary Interpretations

Regional Geologic Setting

Northernmost New Hampshire is underlain largely by low grade metamorphic Silurian and Devonian rocks of the Connecticut Valley - Gaspe Trough (CVGT). The CVGT is bounded on the west by Ordovician and older rocks of Taconic and Grenville orogenic belts and on the east by the Bronson Hill – Boundary Mountain belt (BHA). The CVGT is fault-bounded on both the east and west (Fig. 2) and recorded initial extensional tectonics as well as compressional tectonics as island arcs and microcontinents collided with North America during the Siluro-Devonian Salinic Orogeny and the Late Devonian Acadian Orogeny. The late Paleozoic Alleghanian orogenic and Mesozoic Atlantic rifting events are poorly represented at this latitude with the exception of plutons and dikes of White Mountain affinity.

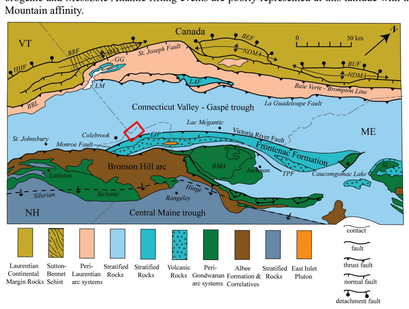


Figure 2. Simplified geologic map (modified after Dorais and others, 2017) showing the location of the Pittsburg quadrangle at the southeastern border of the Connecticut Valley – Gaspé Trough. The Bronson Hill arch separates the CVGT from the Central Maine Trough. The Monroe fault is extended northerly to join the Victoria River (Belle) fault in Quebec and separates the Frontenac Formation from rocks of the CVGT in northern NH. EIP, East Inlet pluton; BMA, Boundary Mountains arch, BRF, Brome fault; BUF, Buckland fault; GG, Glenbrooke Group; HHF, Honey Hollow fault; LAF, Lac Aylmer Formation; LM, Lake Memphremagog; NDMA, Note Dame Mountains anticlinorium; SMA, Sutton Mountains anticlinorium; SL, Spider Lake; TPF, Thrasher Peaks fault.

Geology of the Pittsburg Quadrangle

Pittsburg, the largest town in New Hampshire, is a sparsely inhabited, heavily forested area perhaps best known by loggers, sports fishermen and hunters, and the occasional gold panner, now increasingly by moose tourists and ATV/snowmobile enthusiasts. The first mention of geology is found in Charles Hitchcock's 1877 Geology of New Hampshire and his map folios. Subsequent mapping was performed in nearby areas and the Indian Stream Quadrangle during from 1950s – 1980s by Billings (1956) and students (Hatch, 1963; Green, 1964, 1968; Myers, 1964). Other academic efforts are represented by Converse (1977) and Jahrling (1983). The USGS published a regional map (2° sheet) in 1995 (Moench et al., 1995 and references therein; and Bothner et al., 1997) and a modified version of that regional map was included in the Geologic Map of New Hampshire (Lyons et al., 1997).

Stratigraphy

We recognized three metasedimentary formations from oldest to youngest (Figure 3). These are:

Siluro-Devonian Waits River Formation. Variably calcareous metasandstones, metasiltones, and limey lenses occur in the southern central part of the quadrangle and are continuous with the Waits River mapped by Hatch (1963) in the adjacent Dixville quadrangle to the south (Hatch, 1963). At this time, there is limited control on the age of the Waits River in the Pittsburg Quadrangle.

Lower Devonian Gile Mountain Formation. Micaceous quartzites, thick layered feldspathic metagraywacke and intercalated metasiltones/shales characterize much of this unit (Figs. 5, 6 and 11). In addition there are three small bodies of interlayered metabasaltic andesite /diorite. One body along Indian Stream near Comstock Hill preserves clear pillow structures (Figure 4) with a topping direction to the west.

The age of the Gile Mountain Formation is constrained by : 1) an Emsian (?) plant fossil (Hueber et al, 1990) collected from Route 3 near Tabor Notch Road; 2) a preliminary maximum depositional age of 413 ± 8 Ma (Figure 3) based on U-Pb lead dating of detrital zircons from a calcareous metasandstone bed, located in the spillway of the Lake Francis dam, and 3) a preliminary U/Pb date of 406 ± 7Ma for the crystallization of zircons in pillowed metabasaltic andesite interbedded with Gile Mountain metasediments.

Age analysis of the zircon grains in calcareous metasandstone in the Lake Francis spillway yielded a broad age spectrum with a pronounced peak in the Lowermost Devonian – Upper Silurian as well as three additional peaks in the Proterozoic. Similarly inherited zircon crystals in the meta-basaltic andesite also preserved ages from the MesoProterozoic.

Lower Devonian Ironbound Mountain Formation (considered equivalent to the Compton Formation in neighboring Quebec). Dominated largely by metamudstones/shale (Black Slate/Phyllite) with abundant oxidized pyrite / ankerite ("rust spots") considered to be deposited in deepwater environments with low sedimentation rates. Recognized members include:

The Halls Stream Grits (Dih, Figure 9) is discontinuous slightly reworked crystal tuff that slumped into a dominant muddy substrate of the Ironbound Mountain Formation. Detrital zircon U/Pb analysis yields a preliminary maximum depositional age of ca. 390 ± 4 Ma. The random distribution of plagioclase grains in the mudstone suggest dominantly air fall rather than water transport. Dih occurs as thin lenses that can be mapped along strike. The crystal tuff was probably deposited over a wide area, but removed by later erosion. Similar occurrences of ashfall crystals in Devonian black shales in the Appalachian Basin are described by ver Straeten et al. (2020).

The Graded Graywackes (Digg, Fig. 10) is a discontinuous belt of well bedded micaceous quartzite and metasandtone grading to metashale. Beds range in thickness from 10 to >50 cm and are best exposed just southwest of the Pittsburg Quadrangle in the cliffs along Route 3 where a ~380 meter section was measured. Some beds when exposed on S2 cleavage show a near complete Bouma sequence (e.g., Perrot et al., 2018, fig. 4D and E).

Bedrock Geologic Map of the Pittsburg 7.5' Quadrangle, New Hampshire and Vermont

W.A. Bothner, D.R. Converse, C.E. Jahrling, P.S. Koch, 2020

Digital Compilation by Joshua A. Keeley, David R. Converse, Wallace A. Bothner, and Gregory A. Barker
New Hampshire State Geologist: Frederick H. Chormann, Jr.

Bedrock Geologic Map Open-File Series GEO-008-024000-SMOF

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program under StateMap award number G19AC00384

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Age Control and Stratigraphic Correlations: Figure 3 illustrates stratigraphic correlations with units mapped in neighboring Vermont and Quebec, and their relation to units defined on the 1997 New Hampshire geologic map. Stratigraphic correlation was hampered in this area for many years due to poor age control. Only one Devonian plant fossil locality was identified in the Pittsburg area (Figure 6)). The advent of single crystal zircon age dating has helped immensely (e.g. Perrot et al., 2018) in resolving stratigraphic correlations.

Our work provided three new preliminary U-Pb zircon age dates. Two maximum depositional ages are from detrital zircons – one sample from a calcareous metasandstone tentatively assigned to the lower Gile Mountain Formation near the Lake Francis dam and the other from the Halls Stream Grits Member of the Ironbound Mountain Formation. The remaining age date is from a pillowed meta-basaltic andesite interlayered with Gile Mountain Formation.

Structure

Broadly speaking, the shallow northeast plunging Beaver Brook anticline dominates the eastern half of the quadrangle. The eastern limb is truncated by the west directed Monroe Fault exposed just east of the Pittsburg Quadrangle in the Lake Francis Quadrangle. The western limb of the anticline exposes discontinuous lenses of graded graywacke and grits in an increasingly mudstone-dominant substrate and defines a complex synclinal structure that becomes increasingly overturned to the northeast. See cross-section on map.

No major faults were recognized in the map area. A splay of the Belle (Monroe) fault was proposed by Perrot et al. (2018) to separate members of the Compton Formation as projected into New Hampshire and what was previously considered as the Frontenac Formation in this area (Lyons et al., 1997). Detrital zircon data, subsequent stratigraphic reassignment, and lack of strong field evidence make this proposed fault splay unnecessary.

We show the major fold as a 'simple' anticline/syncline pair with abundant minor folds but recognize the possibility of a more complex refolded nappe structure. These regional structures are present in both the Central Maine terrane and CVGT farther south in New England, often at higher metamorphic grade. We lack evidence of a regional inverted limb at this latitude.

Three deformation events, D1, D2, and D3 are recognized. Rare isoclinal F1 folds in both the Waits River calcareous metasandstones (Fig. 8) and Ironbound Mountain metamudstone/shale, often with well-preserved graded beds (Fig. 10), are refolded about tight, asymmetric generally westerly inclined, northeasterly and southwesterly plunging mesoscopic F2 folds. These folds porpoise as illustrated in Figure 10 (top of Digg in West Stewartstown) and appear to continue at map scale into the adjacent Metallak, Cowen Hill and Greeley Brook quadrangles. Late S3 cleavage in more pelitic layers sparingly represents D3.

Geochemistry

Initial geochemical analysis of the metamorphosed basaltic andesite pillow lavas and the intrusive diorites within the Gile Mt Formation show virtually identical compositions (Figure 12) and are characterized by unusual elemental concentrations (Zr, Rb, Sr, NaO + K20, etc.) that are very different than the Frontenac meta-igneous rocks along First and Second Connecticut Lakes (Dorais et al., 2017) and imply a different origin. Additional analyses will be obtained from the metadiabase and metavolcanic rocks that characterize the Frontenac and related units in the adjacent Lake Francis quadrangle.

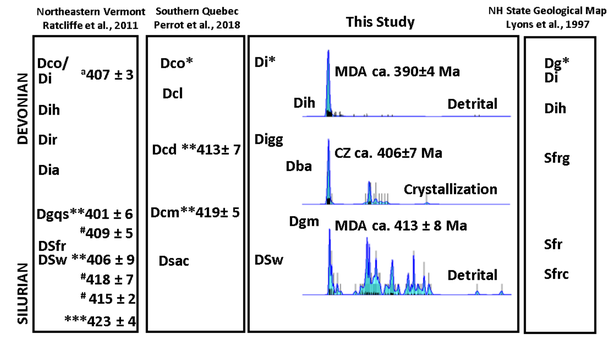


Figure 3. Stratigraphic, geochronological ** (Perrot et al., 2018) and fossil plant* control (Hueber et al., 1990), *** 423 ± 4 Ma is from felsic dike cutting Standing Pond Volcanic unit east of the Chester Dome in Southern VT (Aleinikoff and Karabinos, 1990), # refers to age dates from McWilliams et al.(2010), and 407 ± 3 Ma from felsic volcanic member of the Meetinghouse Slate (Rankin and Tucker, 2009).

Figure 4. Pillowed basaltic andesite exposed along east bank of Indian Stream (19N, 308315E,4994028N) just west of Comstock Hill. Interlayered, conformable contact with heavy bedded brown weathering metasandstone of Dgm. Zircons from IS2019-184 yield a weighted mean U/Pb crystallization age of ca. 406 ± 7 Ma. Tops W in directions of hammer handle.

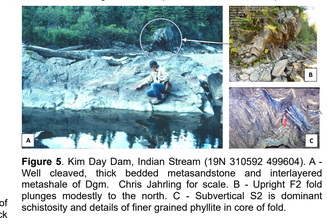


Figure 5. Kim Day Dam, Indian Stream (19N 310592 499604). A - Well cleaved, thick bedded metasandstone and interlayered metashale of Dgm. Chris Jahrling for scale. B - Upright F2 fold plunges modestly to the north. C - Subvertical S2 is dominant schistosity and details of finer grained phyllite in core of fold.

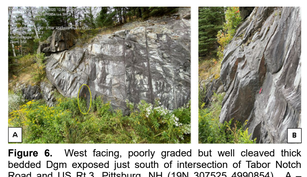
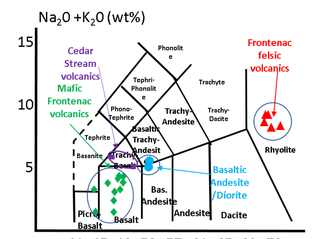


Figure 6. West facing, poorly graded but well cleaved thick bedded Dgm exposed just south of intersection of Tabor Notch Road and US Rt.3, Pittsburg, NH (19N 307525 4990854). A – showing clear reflective S2 cleavage and B – refraction of that cleavage at bedding contacts Emsian? plant fossil locality NM14299 (Huber et al., 1990). in Figures 3 and 10A, and Table 2 (Hueber et al., 1990). 1.5 m walking stick (yellow circle) and pen knife for scale.

Figure 8. A – East-dipping calcareous meta-siltstone/sandstone of Dgm exposed at coffer and overflow channel at Murphy Dam, Pittsburg, NH. Sample IS2019-222 yields a maximum depositional age of ca. 413 ± 8 Ma. B – thick-bedded limey lens and C - refolded F1 in outflow channels at Murphy Dam locality (19N 312472 4992675).

Figure 10. Graded Graywacke along Rt.3 just south of West Stewartstown, NH and south of the Pittsburg Quadrangle (19N 300470 4983545). A (see person for scale) and B - Graded beds are 10-30cm thick, well cleaved and grade to black phyllites to the north where tight doubly plunging folds are preserved as canoe-like form (C and D), facing clearly indicating an upright section some 380m thick. Digg as mapped, but shown as Dgg by Meyers (1964). Dir by Ratcliffe et al. (2011), and probably Dcd by Perrot et al. (2018).



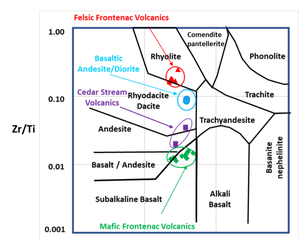


Figure 12. A – Major Element Chemistry – Shatney Mt Diorite / Indian Stream Pillow Basaltic Andesite are very similar but significantly different from the Frontenac mafic volcanics (Dorais et al., 2017). B – Trace element chemistry of the Basaltic Andesite and Diorite is more typical of a felsic volcanic.

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