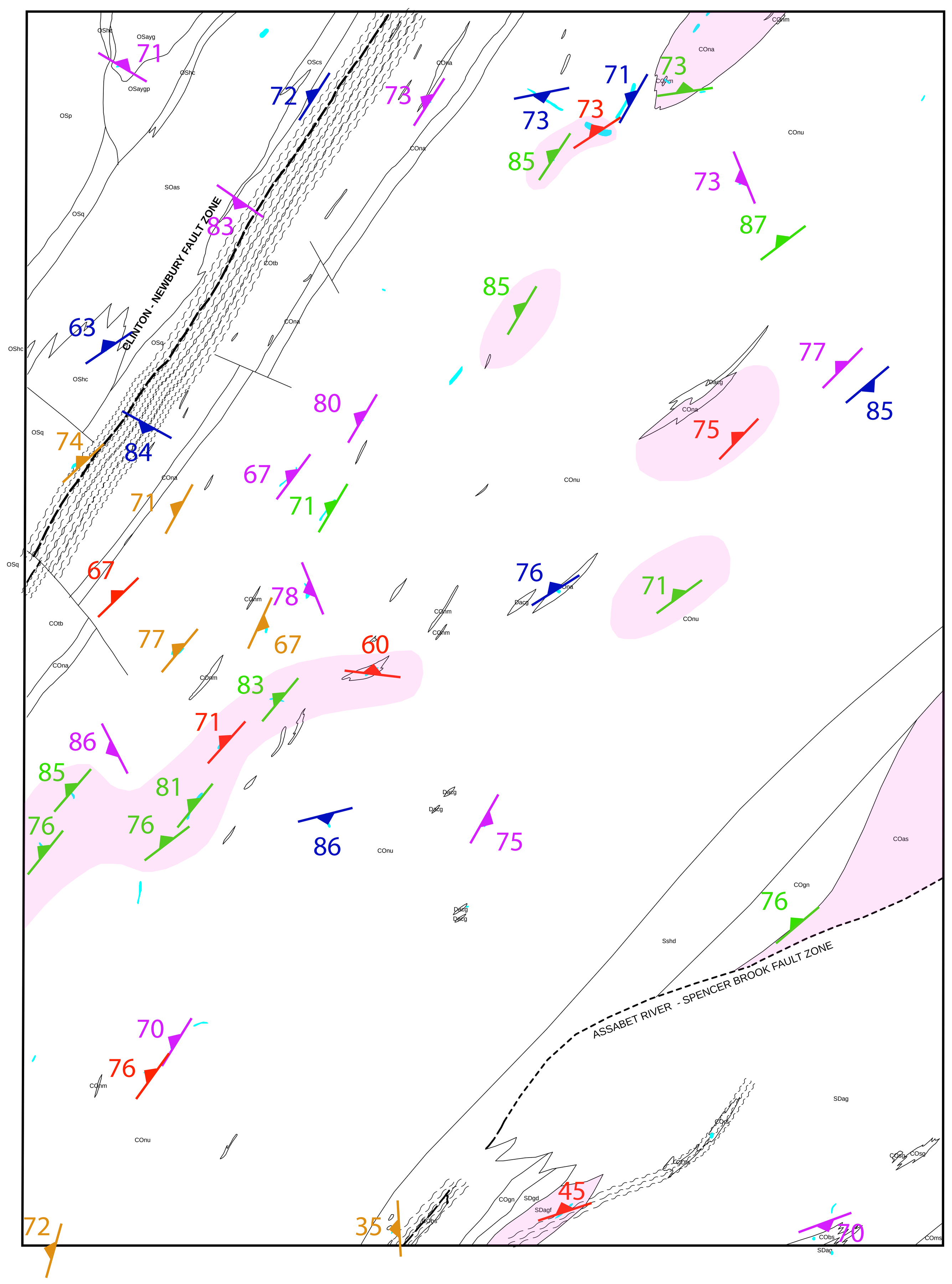
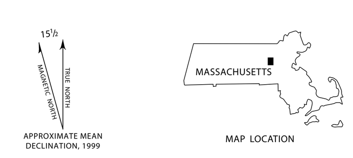
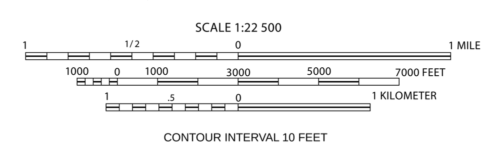
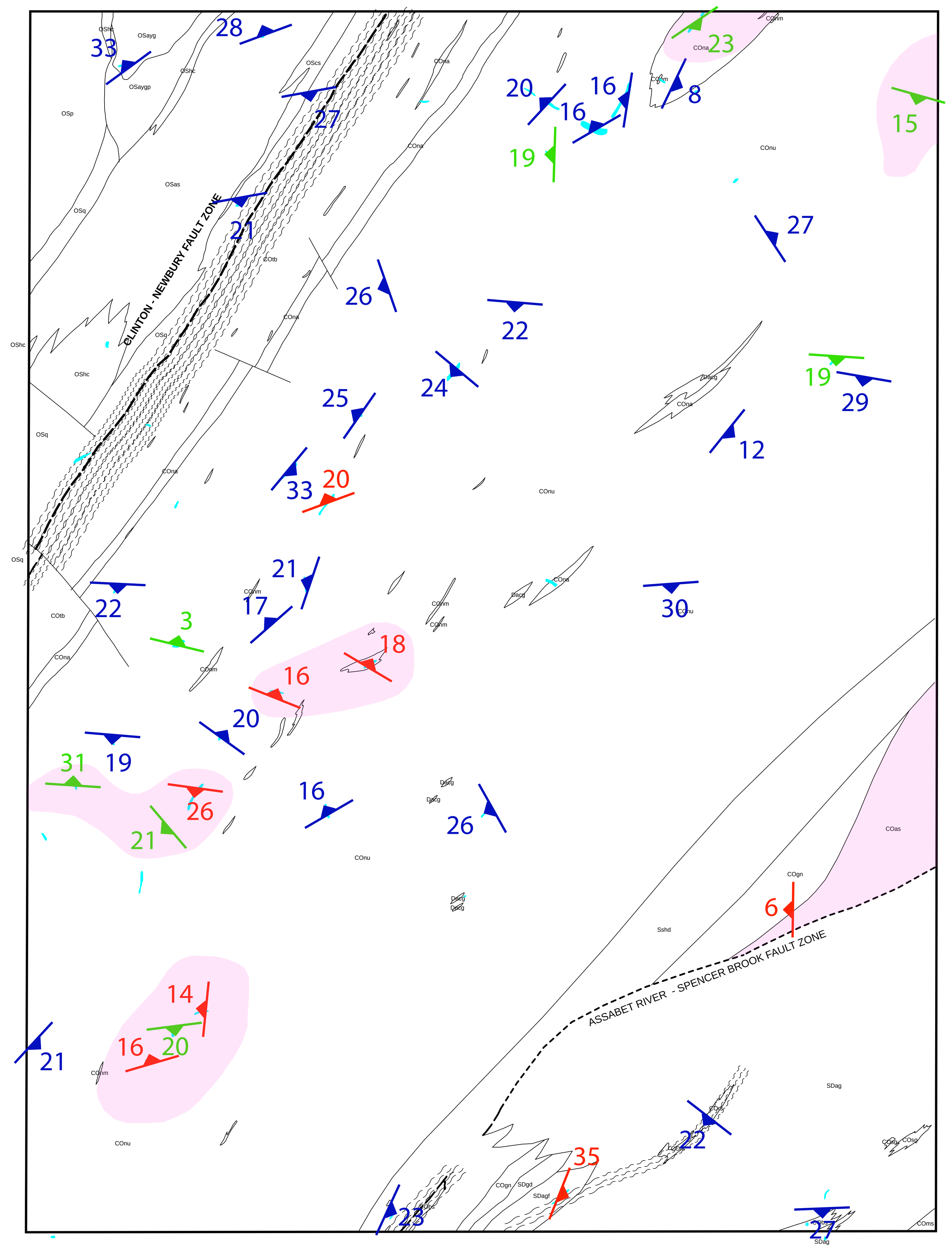


Orientation of Dominant Foliation with Intensity of Partings Parallel to Foliation







Orientation of Sheeting Joints Categorized by Intensity of Development

EXPLANATION

Intensity of Parting (Opening) Development Parallel to Foliation

56 STRONG - Outcrops show strong tendency to part parallel to foliation. Partings are pervasive, through-going and extend across the entire outcrop. Spacing between partings is generally less than 0.5 m. Partings are open.

56 MODERATE - Outcrops show moderate tendency to part parallel to foliation. Partings are generally pervasive, do not always extend across the outcrop and are not always through-going. Spacing between partings is generally less than 1.0 m. Most partings are open.

56 WEAK - Outcrops show weak tendency to part parallel to foliation. Partings are not pervasive across the outcrop and not always through-going. Spacing between partings typically greater than 1.0 m

56 VERY WEAK - Outcrops show very weak tendency to part parallel to foliation. Partings are poorly developed, and are typically widely spaced across the outcrop (>1.5 m).

56 NO PARTINGS - No tendency to develop partings parallel to foliation. Partings not observed in outcrops; rock appears tight.

Area showing strong to moderate tendency to part (open) parallel to dominant foliation.

Note: Structure symbol shows the mean vector and average dip of partings parallel to dominant foliation. Small blue polygons are bedrock outcrops at which fracture measurements were made.

Figure C1. Example of a strongly foliated gneiss in the Nashoba Formation. Foliation is visible as layering that strikes left to right across the picture and dips steeply into the hill away from the face of the wall. Dark areas are localized wet spots; moisture is weeping down the plane of foliation in the center of the picture. Despite the strong foliation development the rock exhibits very little to no tendency to open parallel to foliation. This photograph was taken in an active quarry. The foliation planes exposed here are due to recent blasting. The foliation offers a convenient pre-existing plane of weakness that can be exploited easily during quarrying operations.

EXPLANATION

Intensity of Subhorizontal Fracture Development

14 STRONG - Outcrops show strong subhorizontal fracture development. Fractures are pervasive, through-going and extend across the entire outcrop. Spacing between partings is generally less than 0.5 m. Trace lengths often exceed the length of the outcrop. Fractures are often open and show evidence of recent water movement.

14 MODERATE - Outcrops show moderate development of subhorizontal fractures. Fractures are generally pervasive but do not always extend across the outcrop. Spacing between fractures is generally less than 1.0 m. Trace lengths typically exceed 5 m. Some fractures are open and transmissive.

14 WEAK - Outcrops show weak development of subhorizontal fractures. Fractures are not pervasive across the outcrop and not always through-going. Spacing between partings typically greater than 1.0 m. Trace lengths are are typically less than 5 m.

Areas showing strong to moderate sheeting development

Note: Structure symbol shows the mean vector and average dip of outcrops showing formation of one dominant subhorizontal fracture system. Small blue polygons show bedrock outcrops at which fracture measurements were made.

Figure C2. Example of gneiss in the Nashoba Formation showing weakly developed sheeting joints. Field book is resting on a sheeting joint. Spacing between sheeting joints is about 20 cm but joints are very short and terminate as blind endings in the rock mass. There are a few steeply dipping cross joints in the center of the picture to the left of the field book, however, they are not through-going and terminate often against sheeting joints. The smooth vertical face of the roadcut is a foliation plane exposed during road construction.

EXPLANATION OF LITHOLOGIC UNITS

NASHOBA TERRANE (LATE PROTEROZOIC - EARLY PALEOZOIC (?))

Stratified Rocks

Nashoba Formation (Cambrian - Ordovician?)

- COnu - Nashoba Formation migmatitic gneisses, undifferentiated
- COna - Amphibolite
- COnm - Marble and calc-silicate rocks

COtb - Tadmuck Brook Schist, Cambrian-Ordovician (?)

CObs - Unnamed biotite-silliminite schist and altered/sheared rock, Cambrian-Ordovician (?)

COgn - Unnamed amphibole gneiss, Cambrian-Ordovician (?)

COms - Unnamed muscovite schist, Cambrian-Ordovician (?)

COrs - Unnamed rusty-weathering schists, Cambrian-Ordovician (?)

COsg - Unnamed rusty-weathering schist and granulite-gneiss, Cambrian-Ordovician (?)

COrs - Unnamed amphibole and biotite schists, Cambrian-Ordovician (?)

Intrusive Rocks

Dacg - Acton granite, Devonian(?)

SDag - Andover granite, pegmatitic phase, Silurian-Devonian

SDagf - Andover granite, foliated binary phase, Silurian-Devonian(?)

SDgd - Unnamed foliated coarse-grained granodiorite, Silurian-Devonian(?)

Pegmatite, Devonian (?)

Sshd - Straw Hollow Diorite, Silurian (?)

MERRIMACK BELT (PALEOZOIC)

Stratified Rocks

OSas - Altered and sheared gneisses and schists, Ordovician-Silurian (?)

OScs - Unnamed chlorite schist and altered/sheared rock, Ordovician-Silurian (?)

OShc - Unnamed metaconglomerate at Harvard, Ordovician-Silurian (?)

OSp - Unnamed phyllite, Ordovician-Silurian (?)

OSq - Unnamed quartzite at Vaughn Hills, Ordovician-Silurian (?)

Intrusive Rocks

OSayg - Ayer granite, Ordovician-Silurian (?)

OSaygp - Ayer granite, porphyritic phase, Ordovician-Silurian (?)

EXPLANATION OF MAP SYMBOLS

Lithologic Contacts

Contact (dotted where concealed by water) location generally approximate

Contact, gradational, of plutonic rocks Where contact consists of dikes or foliation-parallel sills interfingered with country rock at scale too small to delineate on map. (dotted where concealed by water)

Faults

Only faults traceable at map-scale and on surface are shown. Please see accompanying fracture map for outcrop-scale and subsurface faults.

Location inferred

Location approximate (within 200 m

Zone of sheared and cataclastic rocks

Bedrock Exposure

Outcrops where fracture measurements were taken

DISCUSSION

Previous work by Lyford et al. (2003) shows the importance of foliation as an influence on groundwater flow. In particluar, foliation that indicates a strong tendency to develop transmissive partings parallel to the layering can have a strong influence on flow anisotropy in the bedrock. In addition, the development of subhorizontal sheeting joints also provides important pathways allowing groundwater to migrate laterally for considerable distances. In some instances, recharge to the bedrock may migrate along sheeting joints from source areas that are located beyond the local topographic divides. The tendency to develop partings parallel to foliation and sheeting were categorized by their relative strength of development. These are indicated by a color coding system on the maps. The two large maps show the foliation and sheeting distribution as observed in outcrops and are categorized by their strength of development.

Dominant foliation exhibits a consistent NE trend with occasional east-west to southeast trends in local areas or areas of weak to very weak foliation development. Foliation trends are more NNE in the western half of the quadrangle particularly along the Clinton-Newbury Fault Zone. To the northeast and southeast the foliation trends become northeast to east northeast. Foliation dips generally to the northwest and ranges from 60° to 87°. Openings in partings parallel to foliation are generally poorly developed and are not considered as transmissive as the penetrative cross joints and brittle faults. Openings are best developed in the amphibolite units and foliated Andover granite. Partings parallel to foliation are weakly developed in the gneisses, migmatitic gneisses, schists and meta-sedimentary rocks northwest of the Clinton-Newbury Fault Zone (Figure C1).

Sheeting joints are also poorly developed in the quadrangle (Figure C2). Trends and dips of sheeting tend to follow local topography and show no consistent pattern.

REFERENCES CITED

Lyford, F.P., C.S. Carlson and B.P. Hansen. 2003. Delineation of water sources for public-supply wells in three fractured-bedrock aquifer systems in Massachusetts. Water-Resources Investigation Report 02-4290, 113p.

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Citation:

Mabee, S.B. Fracture characterization map of the Hudson quadrangle, Massachusetts. Massachusetts Geological Survey (4rth), (in review, June 2005).

FRACTURE CHARACTERIZATION MAP OF THE HUDSON QUADRANGLE, MASSACHUSETTS: APPENDIX C: FOLIATION AND SHEETING ANALYSIS - SHEET 4 OF 5

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2005