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Bedrock, Borehole, and Water-Quality Characterization of a Methane-Producing Water Well in Wolfeboro, New Hampshire

By James R. Degnan, Gregory J. Walsh, Sarah Flanagan, and Robert C. Burruss

Open-File Report 2008–1333

U.S. Department of the Interior
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Suggested citation:
Degnan, J.R., Walsh, G.J., Flanagan, Sarah, and Burruss, R.C., 2008, Bedrock, borehole, and water-quality characterization of a methane-producing water well in Wolfeboro, New Hampshire: U.S. Geological Survey Open-File Report 2008–1333, 47 p. (Available online.)

Cover: Borehole logging and water sampling at the NH-WRW-37 well in Wolfeboro, N.H. Investigators shown are, from left to right, James R. Degnan (U.S. Geological Survey, USGS), David Wunsch (New Hampshire State Geologist), and Robert C. Burruss (USGS). Inset at upper left shows a bedrock outcrop on the shore of Wentworth Lake, N.H. Inset at bottom right shows the optical televiewer log from depths of approximately 635 to 665 feet. Photographs by Gregory J. Walsh, USGS.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
Inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Flow rate	
liter per second (L/s)	15.85	gallon per minute (gal/min)
	Transmissivity*	
meter squared per day (m^2/d)	10.76	foot squared per day (ft^2/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:
°F=(1.8×°C)+32
Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:
°C=(°F-32)/1.8
*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.
Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25°C).
Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).
Degrees = °

Bedrock, Borehole, and Water-Quality Characterization of a Methane-Producing Water Well in Wolfeboro, New Hampshire

By James R. Degnan, [1] Gregory J. Walsh, [2] Sarah Flanagan, [1] and Robert C. Burruss [3]

Introduction

In August 2004, a commercial drill rig was destroyed by ignition of an explosive gas released during the drilling of a domestic well in granitic bedrock in Tyngsborough, MA. This accident prompted the Massachusetts Department of Environmental Protection (MassDEP) to sample the well water for dissolved methane—a possible explosive fuel. Water samples collected from the Tyngsborough domestic well in 2004 by the MassDEP contained low levels of methane gas (Pierce and others, 2007). When the U.S. Geological Survey (USGS) sampled this well in 2006, there was no measurable amount of methane remaining in the well water (Pierce and others, 2007). Other deep water wells in nearby south-central New Hampshire have been determined to have high concentrations of naturally occurring methane (David Wunsch, New Hampshire State Geologist, 2004, written commun.). Studying additional wells in New England crystalline bedrock aquifers that produce methane may help to understand the origin of methane in crystalline bedrock.

Domestic well NH-WRW-37 was chosen for this study because it is a relatively deep well (705 ft, table 1) completed in crystalline bedrock, it is not affected by known anthropogenic sources of methane, and it had the highest known natural methane concentration (15.5 mg/L, U.S. Geological Survey, 2007) measured in a study described by Robinson and others (2004). This well has been in use since it was drilled in 1997, and it was originally selected for study in 2000 as part of a 30 well network, major-aquifer study by the U.S. Geological Survey's (USGS) New England Coastal Basins (NECB) study unit of the National Water-Quality Assessment (NAWQA) Program. Dissolved methane in drinking water is not considered an ingestion health hazard, although the occurrence in ground water is a concern because, as a gas, its buildup in confined spaces can cause asphyxiation, fire, or explosion hazards (Mathes and White, 2006). Methane occurrence in the fractured crystalline bedrock is not widely reported or well understood.

Borehole-geophysical surveys, bedrock outcrop observations, and water-quality analyses were used to define the geologic and hydrologic characteristics of NH-WRW-37 (fig. 1). Collection of additional information on the hydraulic and geologic characteristics of the fractured bedrock and on water quality was initiated in an attempt to understand the setting where methane gas occurs in the bedrock ground water. The origin of dissolved methane in this and other wells in New Hampshire is the subject of ongoing investigations by the State of New Hampshire, the New Hampshire Geological Survey and the USGS.

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Purpose

The purpose of this report is to present the results of borehole-geophysical logging, geologic characterization, and water-quality analyses that were used to characterize the Wolfeboro, NH, domestic supply well. This well is analyzed as a part of a larger study being conducted to gain insight into the nature, occurrence, and origin of methane in ground water from crystalline rock aquifers in New England. Dissolved gases in this well and other wells in New England are being analyzed.

Borehole-geophysical logs collected from the well include caliper, fluid-temperature and conductivity, electromagnetic formation conductivity, natural gamma emission, acoustic televiewer (ATV), and optical televiewer (OTV) logs. Selected outcrops within a radius of approximately 0.5 mile (mi) radius were studied for comparison with rock observed in the well. Field water-quality characteristics were measured at the time of water and gas sampling, and water was analyzed for major ions and trace elements. Dissolved-gas samples were analyzed for molecular and isotopic composition, including the analysis of selected rare gases and are not presented in this report.

Hydrogeologic Setting

The Lower Silurian Rangeley Formation and Lower Devonian Littleton Formation metapelitic rocks are intruded by the Early Devonian Winnipesaukee Tonalite in the area surrounding well NH-WRW-37 according to the geologic map of New Hampshire (Lyons and others, 1997). The Rangeley Formation is a gray, thinly laminated metapelite (Lyons and others, 1997). The Littleton Formation is a gray to rusty-brown, fine- to coarse-grained schist (Quinn, 1953). The Winnipesaukee Tonalite is part of the New Hampshire Plutonic Suite and varies from massive to foliated gray tonalite that includes minor amounts of quartz diorite, granodiorite, and granite.

Drilling notes from well NH-WRW-37 and drill logs from nearby wells completed for an aquifer study (Ayotte, 1997) indicate the presence of soft and loose “rotten” rock, also known as grus, beneath till and over competent bedrock (table 1). The Wentworth and Winnipesaukee Lake basins formed in the Winnipesaukee Tonalite because it is more susceptible to erosion than the neighboring rocks (Quinn, 1953), such as the Concord Granite northeast of the site (also part of the New Hampshire Plutonic Suite). The Winnipesaukee Tonalite contains both albite and anorthite feldspars (Dorais, 2003); these plagioclase feldspars contain sodium and calcium and are more susceptible to weathering than potassium feldspars (Hem, 1985). Rocks of the New Hampshire Plutonic Suite also contain pegmatite, which has columbite and beryl in addition to minerals commonly found in pegmatite (large crystals of mica, feldspar, and quartz) (Quinn, 1953).

The Winnipesaukee Tonalite had a negative effect on predicted well yields when tested in a regression model (Moore and others, 2002). Well NH-WRW-37 and nearby well NH-WRW-87 were inventoried by the New Hampshire Department of Environmental Services and were drilled relatively deep (700 and 1,503 feet (ft), table 1) and have low yields (1 and 2 gallons per minute (gpm), respectively), as do other nearby domestic bedrock wells. Depths to the ground-water table in the underlying bedrock (28.5 to 60 ft, table 1) are much deeper than the surface water and overburden water table (4.7 ft, table 1) in this area and indicate a poor hydrologic connection between the overburden and bedrock aquifers.

The overburden at the site of well NH-WRW-37 is mapped as sandy wash with kames of washed sand just to the northwest, north, and east of the site (Goldthwait, 1968). Detailed mapping of the stratified-drift aquifer identified the materials overlying the bedrock at and around the well as coarse-grained stratified drift over fine-grained stratified drift having a transmissivity of less than 1,000 feet squared per day (ft^2/d) (Ayotte, 1997). The water table in the overburden is near the surface, as observed in the nearby monitoring well NH-WRW-1, which was drilled by the USGS for the project to map stratified-drift aquifer (table 1), and as indicated by the nearby surface water in Fernald and Wiley Brooks and Wentworth Lake (fig. 1).

Methods

Investigation of ground-water flow and water quality in crystalline bedrock involves understanding the lithology, physical characteristics and patterns of fractures in the rock, transmissivity, hydraulic head, gradients, and chemical properties of the water. Borehole-geophysical logs are used in this study to measure rock properties beneath the surface. Analysis of data from nearby outcrops adds to a three-dimensional picture of the structure and lithology. Measurements of field water-quality parameters, determination of concentrations of major ions, and trace-element data can help to build a conceptual model of rock-water interactions.

Strikes of features identified in the borehole and outcrops in this report are discussed in "right-hand-rule" format. By this convention, with the right hand palm-up and the right thumb pointing in the dip direction, the index finger will point in the strike direction. Orientations of features are presented on lower hemisphere equal-area projections (stereonets) and azimuth-frequency (rose) diagrams using software developed by Salvini (2004).

Borehole-Geophysical Logging

Borehole-geophysical logs were used to identify, characterize, and measure fractures, foliation and lithologic contacts in the well. Logs that were collected for this study from August 28 to 31, 2007, included standard and advanced logs. Standard logs were caliper, fluid temperature and electrical conductivity, electromagnetic (EM) formation conductivity, and natural gamma emmisions logs; advanced logs were acoustic televiewer (ATV) and optical televiewer (OTV) logs. Geophysical-log depths were referenced to the top of the steel well casing. Bedrock characteristics (orientations of foliations, contacts, and fractures) were primarily identified by OTV and supplemented by data from the ATV logs. ATV and OTV logs also contain orientation and inclination data with depth that were used to plot borehole deviation.

Geophysical surveys (Zohdy and others, 1974; Keys, 1990) are used to map changes in rock properties, such as variations in electrical conductivity or acoustic velocity caused by changes in lithology or water-filled fractures in the bedrock. Advanced methods and equipment for borehole ATV and OTV well-imaging surveys were described by Mack and others (1998) and Johnson (1996), respectively. These methods were used in similar detailed fractured-bedrock studies in central and southeastern New Hampshire (Johnson and others, 1999; Moore and others, 2002; Mack and Degnan, 2003).

Potentially transmissive fracture zones were identified by indirect observation of other physical properties, such as changes in fluid properties or iron staining near fractures in a borehole. Fractures that were sealed at the borehole wall were noted; they may be open in other locations because of differences in fracture fillings or aperture (Mack and Degnan, 2003).

Bedrock-Outcrop Characterization

At outcrops near well NH-WRW-37, brittle and ductile structures were measured by following procedures described by Barton and others (1993). Geologic outcrop observations included describing rock characteristics such as mineral composition, size, shape, color, and texture and measuring foliations, contacts, and fractures. Changes in rock type, internal structure, and grain size may be associated with different fracture characteristics. Basic rock characteristics are needed to develop an understanding of the lithology and fracturing in areas where bedrock is not exposed at the land surface; they can be interpreted from cores or geophysical surveys.

Water Sampling

Water samples were originally collected and analyzed for a variety of water-quality constituents from well NH-WRW-37 in August 2000 by the USGS as part of the NAWQA Program (Coakley and others, 2001). It should be noted in comparing water-quality data from the NAWQA study and this investigation that the NAWQA water samples (where required) were filtered through a capsule filter, but whole-water samples were collected for this study. However, for both studies, untreated water samples were collected from the same tap (at the pressure tank) and after field parameters (pH, dissolved oxygen, water temperature, and specific conductance) were recorded and stabilized. In addition, sample bottles were preserved and acidified for both studies, where required, and kept chilled prior to analysis. CFCs were used to determine the age of the water during the NAWQA study and are one of several tools used to date young water (50 years old or less) (Plummer and Busenberg, 2000).

In this investigation, untreated whole-water samples from well NH-WRW-37 were collected from the inside tap on August 7, 2007, and analyzed for major ions, selected trace elements, and nutrients by the New Hampshire Department of Environmental Services Water Laboratory. Water samples collected with a pump from an open borehole represent a transmissivity weighted average of all the water-producing fractures in the borehole (Shapiro, 2002). On August 27, 2007, the existing submersible pump was removed so that geophysical logs in the open borehole could be collected (see discussion on "Geophysical Logs" in the next section). Samples of mixed ground water were collected (by use of a fluid sample chamber) from specified depths (165, 210, 335, 500, 600, and 675 ft) that were selected to coincide with significant borehole fluid conductivity zones noted during geophysical logging. The fluid sampling chamber is lowered to a specific depth with a borehole logging winch. Water samples are collected by electronically opening and closing a valve to capture and seal the water sample for retrieval. Water collected with the sample chamber is likely a mix of water from different fractures and does not necessarily come from fractures near the sample location.

Well NH-WRW-37

Plots of log data for well NH-WRW-37 (fig. 2) are discussed in the section below on "Geophysical Logs." The logs were used to identify the location of fractures and changes in water chemistry, lithology, and geologic structure. Information from all the logs was considered in developing a schematic log (fig. 3A). Patterns in brittle and ductile feature orientations in the boreholes are discussed in the section on "Bedrock Structure" and illustrated in stereonets and rose diagrams (figs. 3B, 4, 5, 6).

Geophysical Logs

Standard geophysical logs were used to help interpret features seen, imaged, and measured in the advanced logs. In the three-arm and acoustic caliper logs, a fracture appears as an increase in the borehole diameter, and large spikes or enlargements in the caliper log usually correlate with fractures identified in the televiewer logs (fig. 2, apps. 1, 2, 3). Potential zones of water inflow and outflow were assessed by observations of iron mineral staining and changes in fluid temperature and conductivity under ambient conditions. Transmissive fracture zones that contribute water to the well during ambient (nonpumping) conditions may create an anomaly in the fluid conductivity or temperature log with depth if the water coming out of the fracture has a different quality than the water in the borehole. The fluid logs did not show extended zones with the same temperature or conductivity and thus did not indicate significant vertical flow between fractures with different heads (Johnson and others, 2005). Fracture zones often have a more electrically conductive response in the EM formation conductivity log due to water and mineral fillings. Gamma logs help differentiate lithology changes seen in the OTV log. The mean amplitude log is a derivative of the ATV image; fractured areas have lower amplitude, and different lithology also can affect the amplitude of the reflected acoustic wave.

The two caliper logs show a general high density of fracturing, especially above 300 ft (fig. 2); this density is consistent with the findings of Johnson and Dunstan (1998). The most prominent caliper enlargements that are recorded in both caliper logs are in a fractured zone at 405 ft.

Typical thermal gradients in wells are 0.56 °C per 100 ft (Keys, 1990). The temperature log for this well spans approximately 650 ft of saturated borehole, and so the expected rise due to Keys' (1990) geothermal gradient from the water surface to the bottom of the hole should be 3.6 °C, but the temperature in the well rises 5.4 °C, or 0.83 °C per 100 ft (fig. 2). This is considerably higher than the gradient measured in the deep methane-yielding well (which is no longer yielding methane) in Tyngsborough, MA (0.21 °C per 100 ft) Pierce and others, 2007).

The primary rock type of the borehole consists largely of medium- to light-gray, medium- to coarse-grained, moderately to poorly foliated, weakly layered tonalite with gradational and sharp contacts subparallel to the foliation (fig. 3A). This main rock type resembles nearby outcrops of tonalite. Minor variations in grain size in the tonalite are visible in the borehole, and they are identified as coarse- or medium-grained rocks in the log. Because the grain-size difference is not always readily apparent and because some contacts are uncertain or gradational, the log in this respect is subjective in some places. The tonalite is cut by abundant dikes of white granite or pegmatite throughout the borehole. Because the dikes are so abundant, we did not measure all the orientations in the borehole, just representative or obvious dikes. The larger dikes correspond with high natural gamma count responses (fig. 2). Dark-gray zones of foliated rock are common in the tonalite deeper in the borehole, below 450 ft (fig. 3A; apps. 1, 2). These dark zones are intruded by lighter tonalite, pegmatite, and granite and are the oldest rocks in the borehole. They are either foliated mafic enclaves in the tonalite or xenoliths of country rock, which was reported to be schist of the Devonian Littleton Formation (Quinn, 1953).

Through a combined interpretation of all of the logs, several zones in the well were identified that may contribute water of varying amounts and quality to the borehole. Major fractures seen in the OTV and caliper logs and fluid changes in the borehole were observed at approximately 151, 289, and 568 ft and a fracture with iron was observed at 353 ft (fig. 2; app. 2). Small vugs (cavities) occur at 396, 405, and 432 ft. A significant fracture zone and vug at 405 ft in the OTV log is also the largest fracture zone measured by both caliper logs. This feature correlates with a strong conductive EM response and, slight fluid anomalies and strikes west with a moderate to steep north dip. The vug at 432 ft is irregularly shaped according to the OTV log and occurs in a zone between fractures at 430 to 433 ft in the same location as a caliper enlargement and a significant conductive EM anomaly. There is a major fracture with fluid change with an eastward strike and moderate southward dip in this zone.

The most significant zone of changing water quality and lithology is deep in the borehole from 639 to 650 ft. Several fluid property changes are noted near fractures that are parallel to pegmatite and dark-gray host-rock zones in the tonalite, and iron staining is found on fractures above and below the zone (figs. 2, 3A; apps. 1, 2). The borehole deviation also changes orientation slightly throughout this zone (app. 4). At a depth of 620 ft, the fluid conductivity begins rapidly increasing with depth until 650 ft, where it goes off the scale an order of magnitude (fig. 2); measurements were not possible below this depth. This zone was logged three times on two separate days to confirm the measurement and attempt to get conductivity measurements below this zone. Suspended particles, such as iron, may have formed a bridge on the conductivity probe sensor, producing a response similar to that observed when the tool penetrates silt and clay at the bottom of a borehole. The temperature gradient in this zone also increases at 640 ft and returns to the normal gradient for this borehole at 670 ft (fig. 2).

Bedrock Structure

Fractures in well NH-WRW-37 have a wide variety of trends, though horizontal and sub-horizontal fractures are not present (fig. 4A). Fractures show two significant moderately dipping concentrations (fig. 4A): (1) NNE striking and ESE dipping and (2) SSW striking and WNW dipping. A subset of the steeply dipping fractures (dip ≥60º) shows a significant trend of NNE (19º, fig. 4B). The majority of fractures in the well (115 out of 178) do not appear to contribute water to the well (fig. 4C). These minor and sealed fractures do not appear open or significant at the wellbore, but they may be elsewhere in the aquifer. Because this subset of the fracture data is dominant, it shows trends (figs. 4C, 4D) similar to those in the complete fracture data set (figs. 4A, 4B). Fractures that may contribute water to the borehole are dominated by the NNE-striking and ESE-dipping orientation (fig. 4E) and have a primary peak trend of 18.6° (fig. 4F), different from that of the minor and sealed features (39º, fig. 4D). These fractures include major fractures, iron-stained fractures, and fractures associated with a fluid anomaly. Although the fracture density was lower by almost half in the bottom half of the well (apps. 1, 2), general trends did not vary with depth and are not shown in this report.

Metamorphic and igneous structures including contacts, foliation, and dikes observed in well NH-WRW-37 show preferred gently dipping to S-striking and W-dipping orientations (fig. 5A). Metamorphic and igneous structures were grouped by depth for analysis and show variations in trend with depth (figs. 5B, 5C, 5D, 5E). Horizontal features present from 120 to 260 ft are absent in the next two intervals, which are 260 to 410 ft and 410 to 560 ft (figs. 5B, 5C, 5D). North-striking, east-dipping features appear in the interval from 260 to 410 ft (fig. 5C).

Most of the foliation observed in well NH-WRW-37 strikes south with a moderate west dip (fig. 6A; app. 1) (intervals from 363 to 497 ft and 576 ft through the bottom of the well); two observations have a strike and dip in the opposite direction. The foliations measured closest to the surface in a zone from 178 to 260 ft depth have east, southeast, southwest, and northwest strikes. From 497 to 564 ft depth, the foliation changes from a south to north to south to southeast strike (app. 2). The medium- and coarse-grained tonalite and the granite have several nearly horizontal contacts (figs. 6B, 6C, 6D). Pegmatites and enclaves or xenoliths in the tonalite show southeast-ranging strike trends and a lack of nearly horizontal contacts (figs. 6E, 6F).

In summary, the borehole walls consist largely of foliated tonalite that is cut by abundant dikes of granite and pegmatite. Xenoliths or mafic enclaves are more abundant in the deeper part of the borehole (fig. 3A). There appear to be two significant orientations for structures in the borehole that are related to fluid flow: (1) crosscutting fractures that strike NNE and dip steeply ESE and (2) fractures that are subparallel to the metamorphic and igneous features that generally strike SSW and dip moderately to the WNW (fig. 3B).

Bedrock Outcrops

In August 2007, general characteristics of 12 bedrock outcrops within a radius of approximately 0.5 mi from well NH-WRW-37 were studied. Geologic characterization of nearby outcrops was conducted for comparison with the borehole (fig. 1). Nearby outcrops consist largely of Devonian Winnipesaukee Tonalite (fig. 1) (Lyons and others, 1997). The tonalite was previously named the Winnipesaukee Quartz Diorite (Quinn, 1953). The rock ranges from a gray to light-gray, medium- to coarse-grained, weakly to moderately foliated biotite tonalite to biotite granodiorite. White-weathering feldspars, combined with black biotite and gray quartz, give the rock its characteristic gray appearance (figs. 7A, 7B, 7C, 7D). Where the foliation is moderately developed, the rock has a gneissic texture defined largely by aligned biotite and recrystallized quartz and feldspar. The Winnipesaukee Tonalite is cut by dikes, sills, and irregular intrusive bodies of very weakly foliated to unfoliated, fine- to coarse-grained biotite granite or muscovite-biotite granite (fig. 1). These relatively younger granites may be correlative with the Devonian Concord Granite or unnamed Permian granites found throughout New Hampshire (Lyons and others, 1997). Tabular dikes of very coarse grained pegmatite and less common dikes of fine-grained granitic aplite crosscut all rocks and are the relatively youngest rocks in the area.

Structural analysis and fracture characterization were conducted at 12 nearby outcrops (fig. 1). Orientation data are shown in figure 8, and a summary of the findings includes the following:

- Moderately dipping foliation shows variable orientations (fig. 8A) but generally strikes NE and dips NW near the well and strikes NW and dips SW north of the well (fig. 1). The foliation exhibits parting, or fracturing along the foliation, at only one outcrop along Route 28 (station 11, fig. 1).

- Tabular dikes, ranging in thickness from 0.02 to 0.40 meter (m), show variable orientations (fig. 8B) and only limited parting (only 2 of 11 dikes).

- Brittle faults show the most consistent orientation of any structures observed in the area (fig. 8C). Six observed faults strike NNE and dip moderately to the ESE and contain east-trending downdip slickensides. Relative motion sense on the faults is normal on four, and it is reverse or undetermined on the other two. The faults indicate ESE extension.

- Measured joints are dominated by steeply dipping joints. Joint spacing, where uniform, ranges from 0.05 to 1.00 m, but most joints are unevenly spaced. Joint connectivity is a ratio of the percentages of blind (or dead), crossing, and abutting fractures (Barton and others, 1993). The ratio in the vicinity of the well site is 16 percent blind, 58 percent crossing, and 26 percent abutting. Fifty-five percent of the joints are throughgoing, meaning they transect the entire outcrop rather than terminate within the outcrop area.

- Gently dipping fractures, with dips $\leq 25^{\circ}$, were observed at only one roadcut on Route 28 north of Wolfeboro Center (fig. 1). Spacing on these fractures ranges from 0.5 to 1.0 m. Most of the outcrops observed in this study show limited vertical relief, and the data show a sampling bias to steeply dipping fractures (fig. 8D).

- Steeply dipping joints show two principal trends of 356º and 61º (fig. 8E). These two fracture directions have subvertical to steeply west to northwest dips (fig. 8D).

Water Quality

Water-quality results from the 2000 NAWQA study and from this investigation are listed in table 3. Water-quality data for the nearby domestic well NH-WRW-87 (about 800 ft southwest of well NH-WRW-37 (fig. 1)) also are discussed and compared in this section. Dissolved gases are being analyzed.

Ground water sampled from well NH-WRW-37 in 2000 had a chlorofluorocarbon (CFC)-derived date of approximately 1953, which is relatively old for New England ground water, although results indicate that younger water may be mixed in. The year 1953 represents the estimated date of recharge (Plummer and Busenberg, 2000), when the water originated as precipitation.

The field specific conductance (1,220 microsiemens per centimeter (µS/cm)), bicarbonate (606 mg/L as $CaCO_3$), and field pH (8.7) values measured in ground water from well NH-WRW-37 in 2000 were some of the highest values reported for the 17 domestic bedrock wells sampled in New Hampshire for the NAWQA study (table 2) Coakley and others, 2001). Ground water in well NH-WRW-37 is dominated by an alkaline sodium-bicarbonate system that is chemically mature; the maturity is reflected by the relatively old age of the water. A relatively high pH of 8.5 also was measured in the nearby well NH-WRW-87 (table 2).

Sodium concentrations in well NH-WRW-37 were identical (260 mg/L) (table 3) in filtered samples taken from the tap in 2000 and whole-water samples in 2007. Chloride concentrations also were similar between the 2000 and 2007 sampling events (50 and 46 mg/L, respectively) (table 3). This similarity may be because sodium and chloride ions usually occur in the dissolved phase in natural waters and are not often affected by filtering processes.

Fluoride concentrations in water from well NH-WRW-37 were about four times greater than the maximum contaminant level (MCL). Fluoride concentrations decreased slightly from 2000 to 2007 in samples collected at the tap from well NH-WRW-37 (18 and 15 mg/L) (table 1). A fluoride concentration reported in the nearby well NH-WRW-87 was slightly higher (19 mg/L) (Richard Moore, 2007, written commun.). In a study of bedrock ground-water quality in New Hampshire, fluoride was significantly greater in wells completed in felsic igneous rocks, such as the Winnipesaukee Tonalite, than in other groups of rocks (Moore, 2004).

The whole-water iron concentration (115 micrograms per liter (µg/L)) in a sample collected from the tap in 2007 was about twice the concentration of the filtered water sample collected from the tap in 2000 (64 µg/L, table 3). Iron concentrations in these samples may be affected by the filtering process, especially under reducing conditions, where the dissolved oxygen measured in the well water in 2000 was 0.1 mg/L (table 2). The iron concentration reported for the nearby well NH-WRW-87 was about twice the concentration (200 µg/L) (Richard Moore, 2007, written commun.) of samples collected from well NH-WRW-37 (table 3). Results of analysis from samples collected at depth with the sample chamber in well NH-WRW-37 showed iron concentrations increasing sharply; values were 4,780 µg/L at 500 ft and 12,500 µg/L at 675 ft.

Lithium commonly occurs in ground water in minor (microgram per liter) amounts, but it was measured at unusually high levels in ground water from well NH-WRW-37 in the 2000 NAWQA study and in this investigation. Lithium concentrations were measured at 1,230 µg/L in filtered water samples from 2000 and 1,820 µg/L in whole-water samples in 2007. There are no established drinking-water guidelines for lithium, though it can be toxic to plants at low levels (Hem, 1985). Lithium is not common in the ground water of New England in the high concentrations measured in this and previous studies; however, it is found in similar concentrations (2,000 to 5,000 µg/L) in geothermal wells and springs of Yellowstone National Park (Hem, 1985).

Summary

Characteristics, measurements, and analyses from this study and others describe the crystalline bedrock aquifer system where dissolved methane occurs in ground water from well NH-WRW-37 in Wolfeboro, NH. Fractures store and transmit water that chemically interacts with the rock in this system. Data on water quality, including concentrations of major ions and trace elements, may indicate what minerals were affected during and after water-rock chemical interactions.

Bedrock fractures in the borehole have trends that are similar to but not the same as those measured in nearby outcrops. Steeply dipping north-trending fractures are common in both the borehole and the outcrops, and principal trends overlap within the standard deviation (5º ± 5º and 356º ± 4º). Principal steeply dipping fractures that trend ENE (61º ± 6º) in outcrops are present but subordinate in the borehole. Principal fractures in the borehole strike NNE and dip moderately to steeply ESE; their orientations are similar to those of brittle faults observed at outcrops. The orientations of planar metamorphic and igneous features in the borehole overlap with similar features at the outcrops and show considerable variability.

The borehole walls consist largely of foliated tonalite that is cut by abundant dikes of granite and pegmatite. Xenoliths or mafic enclaves are more abundant in the deeper part of the borehole. There appear to be two significant orientations for structures in the borehole that are related to fluid flow: (1) crosscutting fractures that strike NNE and dip steeply ESE and (2) fractures that are subparallel to the metamorphic and igneous features that generally strike SSW and dip moderately to the WNW (fig. 3).

Ground water in well NH-WRW-37 is dominated by an alkaline sodium-bicarbonate system that is chemically mature and contains high amounts of dissolved solids; the maturity is reflected by the estimated age (1953) of the water. The water from NH-WRW-37 contains sodium that may be due to the breakdown of the rock. Feldspars are often among the first minerals to break down as rock weathers; those containing calcium and sodium (such as albite and anorthite found in the Winnipesaukee Tonalite) are more susceptible to chemical breakdown than feldspars containing potassium (Hem, 1985). The abundance of albite and anorthite may explain the presence of soft, loose, and rotten rock noted in the well logs (table 1).

Ground water from wells NH-WRW-37 and NH-WRW-87 are high in fluoride, which may result from the dissolution of fluorite or other minerals. Well NH-WRW-37 has ground water that is high in lithium, which can be found in muscovite as a minor substitution; (muscovite is present in the tonalite and associated pegmatite dikes at the borehole). Lithium also can be found in lepidolite, which is known to occur in nearby Maine, and in beryl minerals as a replacement for beryllium oxide (Klein and Hurlbut, 1993), which is found nearby in pegmatite dikes in this region (Quinn, 1953). Well NH-WRW-87 is about 800 ft down gradient from NH-WRW-37, and the water samples from this well were similar to samples from well NH-WRW-37. High concentrations of lithium are not common in the ground water of New England although it is found in similar concentrations in geothermal wells and springs.

Acknowledgments

The authors would like to thank the homeowners who participated in this study by granting access to their well and property. Insight into methane occurance in New Hampshire and assistance in searching for wells that produce methane by David Wunsch, State Geologist of the State of New Hampshire, New Hampshire Geological Survey, has been important to this study. Appreciation is expressed to the New Hampshire Department of Envirionmental Services for assistance with lab analysis of water samples.

References Cited

Ayotte, J.D., 1997, Geohydrology and water quality of the stratified-drift aquifers in the Winnipesaukee River basin, central New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 94-4150, 193 p., 8 pls., scale 1:24,000.

Barton, C. C., Larsen, E., Page, W. R., and Howard, T. M., 1993, Characterizing fractured rock for fluid-flow, geomechanical, and paleostress modeling: Methods and preliminary results from Yucca Mountain, Nevada, U.S. Geological Survey Open-File Report 93-269, 62 p.

Coakley, M.F., Keirstead, Chandlee, Brown, R.O., and Kiah, R.G., 2001, Water resources data for New Hampshire and Vermont, water year 2000: U.S. Geological Survey Water-Data Report NH-VT-00-1, 192 p.

Dorais, M.J., 2003, The petrogenesis and emplacement of the New Hampshire Plutonic Suite: American Journal of Science, v. 303, May 2003, p. 447-487.

Goldthwait, R.P., 1968, Surficial geology of the Wolfeboro-Winnipesaukee area, New Hampshire: New Hampshire Department of Resources and Economic Development, 60 p., 2 pls., scale 1:62,5000.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p., 3 pls. (Reprinted in 1986 and 1989.) (Also available online at *http://pubs.usgs.gov/wsp/wsp2254/.*)

Johnson, C.D., 1996, Use of borehole color video camera to identify lithologies, fractures, and borehole conditions in bedrock wells in the Mirror Lake area, Grafton County, New Hampshire, in Morganwalp, D.W., and Aronson, D.A., eds., U.S. Geological Survey Toxics Substances Hydrology Program: Proceedings of the technical meeting, Colorado Springs, Colo., September 20-24, 1993: U.S. Geological Survey Water-Resources Investigations Report 94-4015, v. 1, p. 89-93.

Johnson, C.D., and Dunstan, A.H., 1998, Lithology and fracture characterization from drilling investigations in the Mirror Lake area, Grafton County, New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 98-4183, 211 p.

Johnson, C.D., Dunstan, A.H., Mack, T.J., and Lane, J.W., Jr., 1999, Borehole-geophysical characterization of a fractured-bedrock aquifer, Rye, New Hampshire: U.S. Geological Survey Open-File Report 98-558, 61 p.

Johnson, C.D., Joesten, P.K., and Mondazzi, R.A., 2005, Borehole-geophysical and hydraulic investigation of the fractured-rock aquifer near the University of Connecticut Landfill, Storrs, Connecticut, 2000 to 2001: U.S. Geological Survey Water-Resources Investigations Report 03-4125, 133 p.

Keys, W.S., 1990, Borehole geophysics applied to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. E2, 150 p. (Also available online at *http://pubs.usgs.gov/twri/twri2-e2/.*)

Klein, Cornelis, and Hurlbut, C.S., Jr., 1993, Manual of mineralogy, twenty-first edition: New York, John Wiley and Sons, 681 p.

Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B., Jr., 1997, Bedrock geologic map of New Hampshire: Reston, Va., U.S. Geological Survey, 2 sheets, scales 1:250,000 and 1:500,000.

Mack, T.J., and Degnan, J.R., 2003, Geophysical characterization of fractured bedrock at Site 8, former Pease Air Force Base, Newington, New Hampshire: U.S. Geological Survey Open-File Report 02- 279, 22 p., available only online at *http://pubs.water.usgs.gov/ofr02-279* .

Mack, T.J., Johnson, C.D., and Lane, J.W., Jr., 1998, Geophysical characterization of a high-yield, fractured-bedrock well, Seabrook, New Hampshire: U.S. Geological Survey Open-File Report 98-176, 28 p.

Mathes, M.V., and White, J.S., 2006, Methane in West Virginia ground water: U.S. Geological Survey Fact Sheet 2006-3011, 2 p. (Also available online at *http://pubs.usgs.gov/fs/2006/3011/.*) (Accessed 2/12/2008.)

Moore, R.B., 2004, Quality of water in the fractured-bedrock aquifer of New Hampshire: U.S. Geological Survey Scientific Investigations Report 2004-5093, 30 p. (Also available online at http://pubs.usgs.gov/sir/2004/5093/.) [citation moved above Moore and others]

Moore, R.B., Schwarz, G.E., Clark, S.F., Jr., Walsh, G.J., and Degnan, J.R., 2002, Factors related to well yield in the fractured-bedrock aquifer of New Hampshire: U.S. Geological Survey Professional Paper 1660, 51 p. 2 pls. (Also available online at *http://pubs.usgs.gov/pp/pp1660/*.)

New Hampshire Geological Survey, 2007, One Stop, WSEB Water Well Query: New Hampshire Department of Environmental Services Web page at *http://www2.des.state.nh.us/OneStop/Well_Query.aspx* (Accessed 12/13/2007.)

Pierce, H.A., Walsh, G.J., Burruss, R.C., and Degnan, J.R., 2007, Borehole characterization of a methane-yielding bedrock well, Tyngsborough, Massachusetts: U.S. Geological Survey Open-File Report 2007-1399, 1 DVD. (Also available online at *http://pubs.usgs.gov/of/2007/1399/*.)

Plummer, L.N., and Busenberg, E., 2000, Chlorofluorocarbons, in Cook, P.G., and Herczeg, A.L., eds., Environmental tracers in subsurface hydrology: Boston, Kluwer Academic Publishers, p. 441-478. (Also available online at *http://water.usgs.gov/lab/chlorofluorocarbons/background/*. (Accessed 1/9/2008.)

Quinn, Alonzo, 1953, The geology of the Wolfeboro quadrangle, New Hampshire: New Hampshire State Planning and Development Commission, scale 1:62,500, 24 p.

Robinson, K.W., Flanagan, S.M., Ayotte, J.D., Campo, K.W., Chalmers, Ann, Coles, J.F., and Cuffney, T.A., 2004, Water quality in the New England coastal basins, Maine, New Hampshire, Massachusetts, and Rhode Island, 1999-2001: U.S. Geological Survey Circular 1226, 38 p. (Also available online at *http://pubs.usgs.gov/circ/2004/1226/*.) [URL revised]

Salvini, F., 2004, Structural Data Integrated System Analyzer software: (DAISY 4.01), Dipartimento di Scienze Geologiche, Universita degli Studi di “Roma Tre”, Rome, Italy, *ftp://ftp.u-cergy.fr/geol/Daisy/*

Shapiro, A.M., 2002, Cautions and suggestions for geochemical sampling in fractured rock: Ground Water Monitoring and Remediation, v. 22, no. 3, p. 151-164.

U.S. Geological Survey, 2007, New England Coastal Basins NAWQA Program: Major Aquifer Study 2: Felsic igneous and undifferentiated metasedimentary rocks: U.S. Geological Survey Web page at *http://nh.water.usgs.gov/projects/nawqa/gw_mas2.htm*. (Accessed 12/21/2007.)

Zohdy, A.A.R., Eaton, G.P., and Mabey, D.R., 1974, Application of surface geophysics to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. D1, 116 p. (Also available online at *http://pubs.usgs.gov/twri/twri2-di/)*

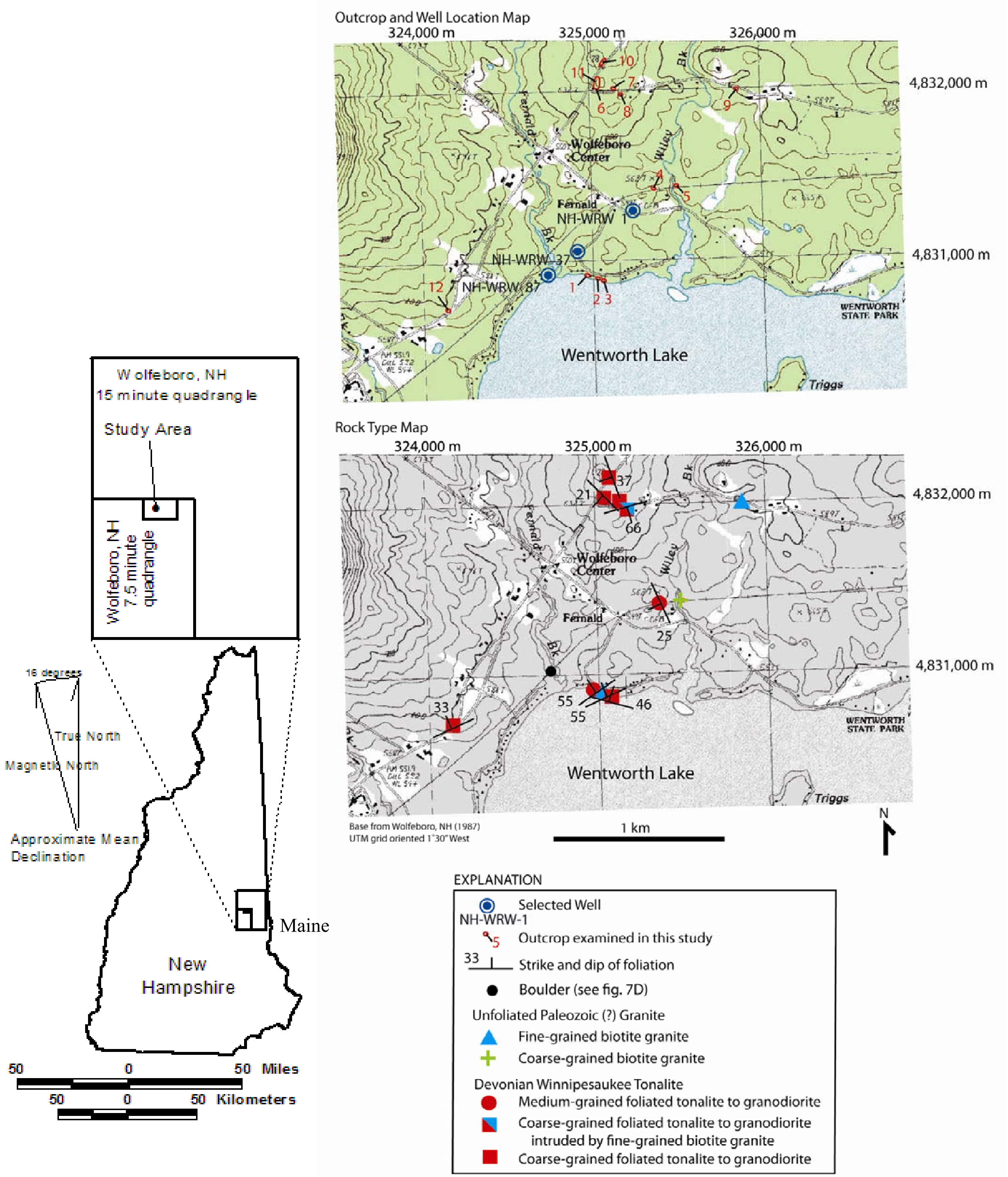


Figure 1. Maps showing location of wells and nearby bedrock outcrops (top) and rock types (bottom) in the study area in Wolfeboro, NH. Base from U.S. Geological Survey topographic map of the Wolfeboro, NH, 7.5-minute quadrangle (1987).

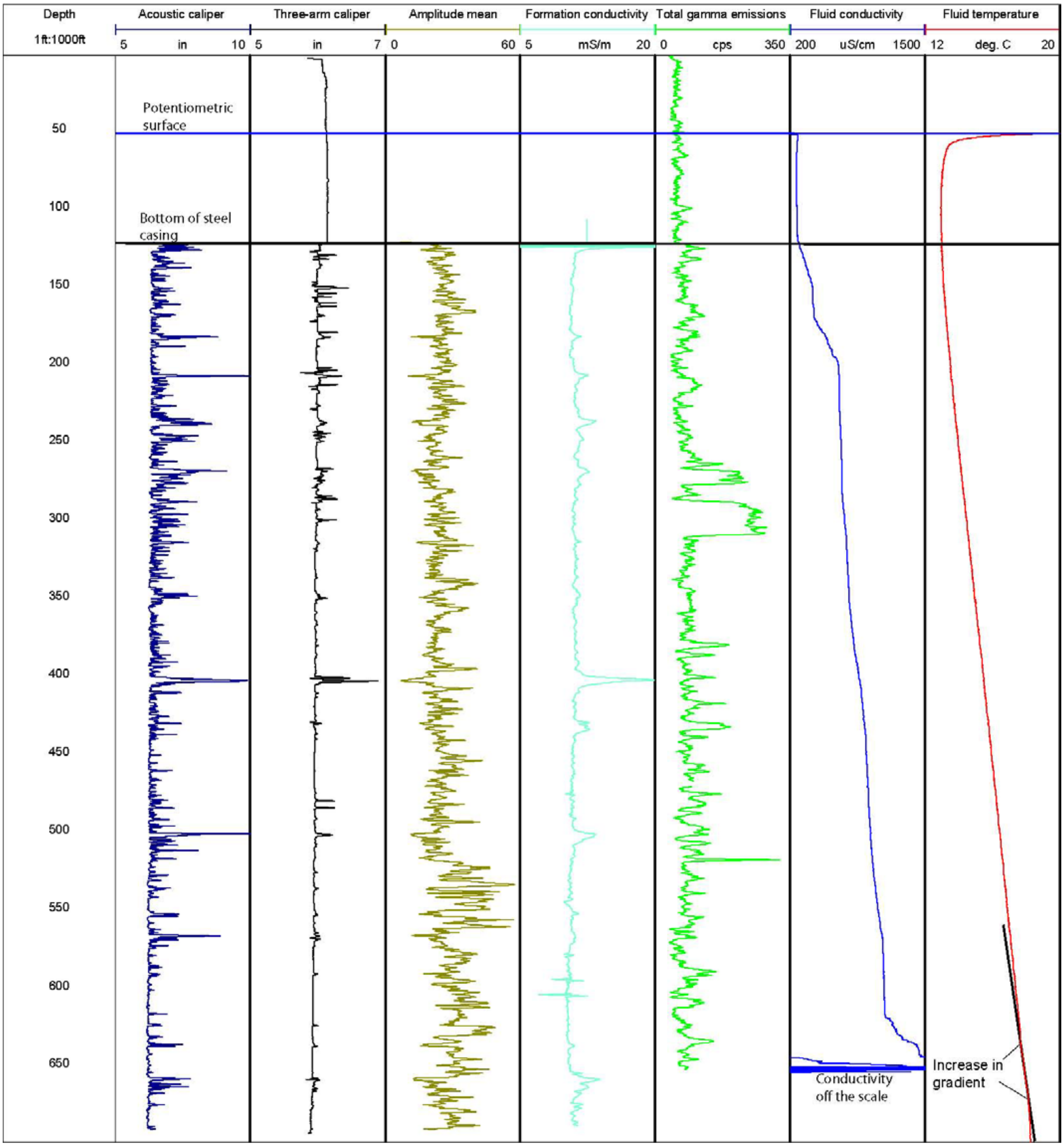


Figure 2. Borehole-geophysical logs of well NH-WRW-37, including acoustic caliper, three-arm (mechanical) caliper, amplitude mean (from acoustic televiewer), formation electromagnetic (EM) conductivity, natural gamma, and fluid conductivity and temperature logs. ft = feet; in. = inch, mS/m = millisiemens per meter, cps = counts per second, µS/cm = microsiemens per centimeter, deg. C = degrees Celsius.

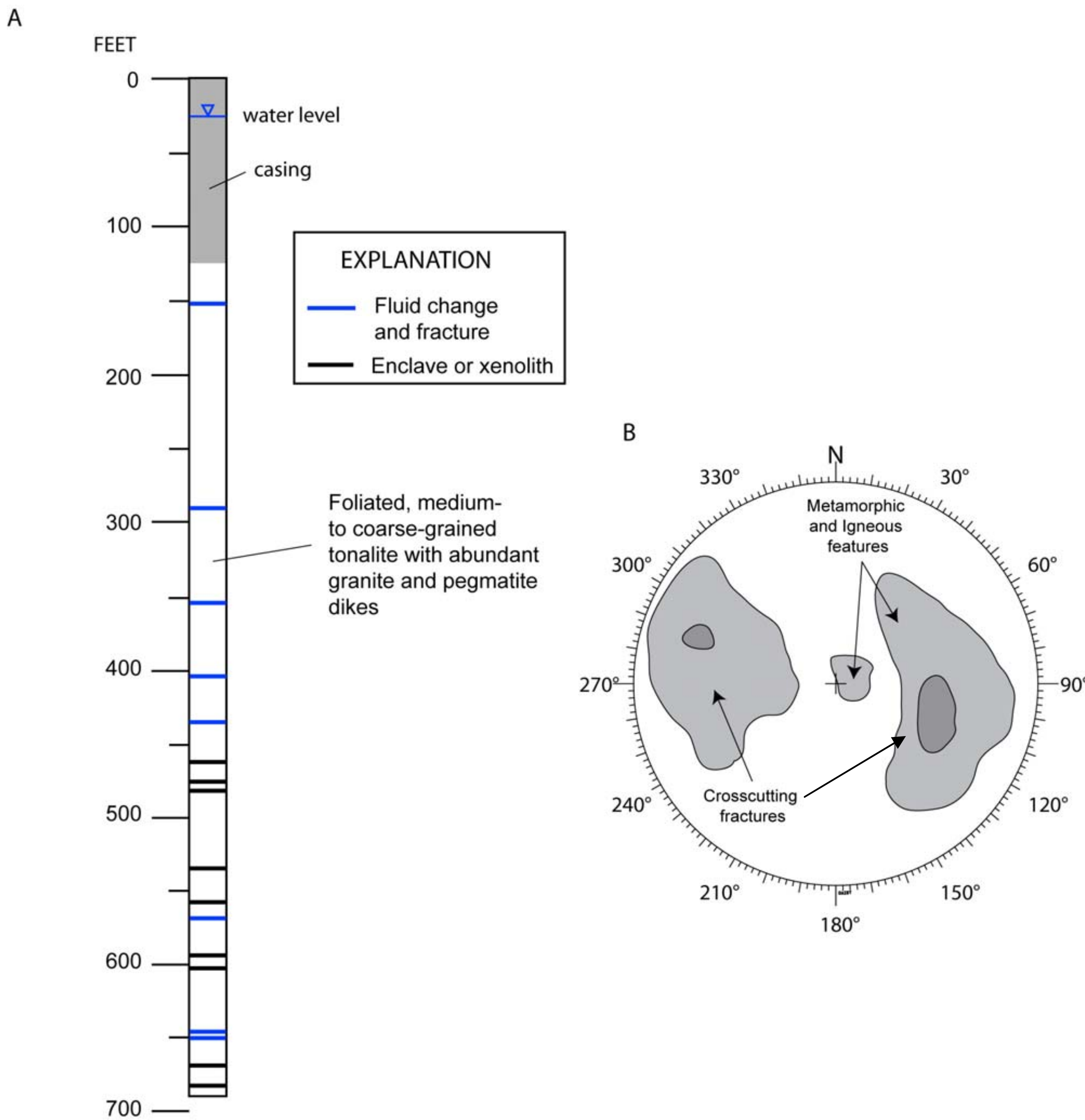


Figure 3. Log and stereonet summarizing fluid anomalies and other structures in well NH-WRW-37. *A,* Schematic well log showing location of significant fluid anomalies and location of mafic enclaves or xenoliths of schist. Derived from logs in figure 2. *B,* Lower hemisphere equal-area projection (stereonet) showing schematic orientations of all crosscutting fractures and metamorphic and igneous features discussed in text.

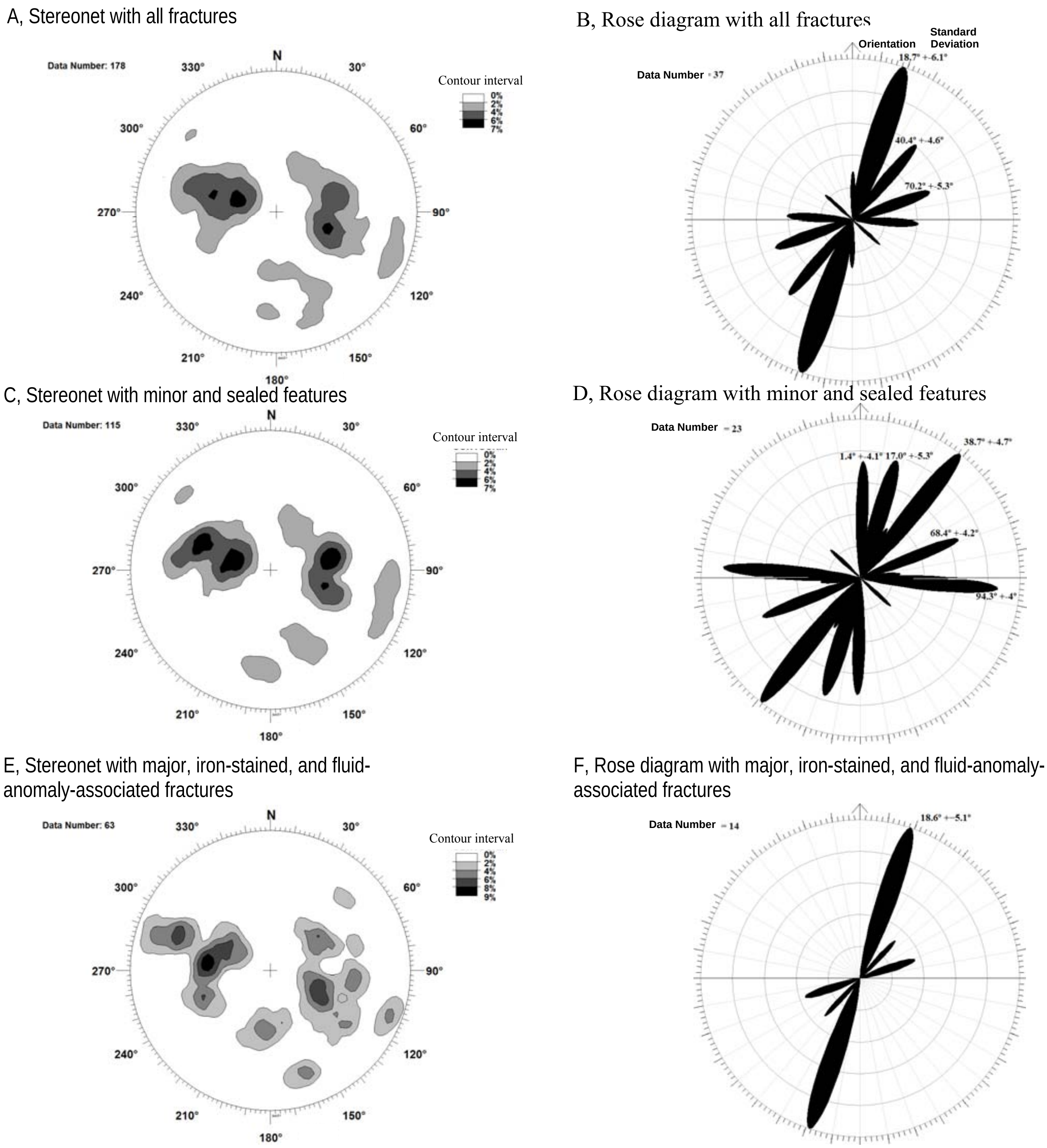


Figure 4. Lower hemisphere equal-area projections (stereonets) containing contoured poles to planes and rose diagrams (for dips greater than or equal to 60 degrees) showing orientation of bedrock fractures observed in the optical televiewer log from well NH-WRW-37. The length of a petal in a rose diagram indicates the normalized height; circle intervals are 20 percent increasing outward. *A*, Stereonet with all fractures; *B*, Rose diagram with all fractures; *C*, Stereonet with minor and sealed features; *D*, Rose diagram with minor and sealed features; *E*, Stereonet with major, iron-stained, and fluid-anomaly-associated fractures; *F*, Rose diagram with major, iron-stained, and fluid-anomaly-associated fractures.

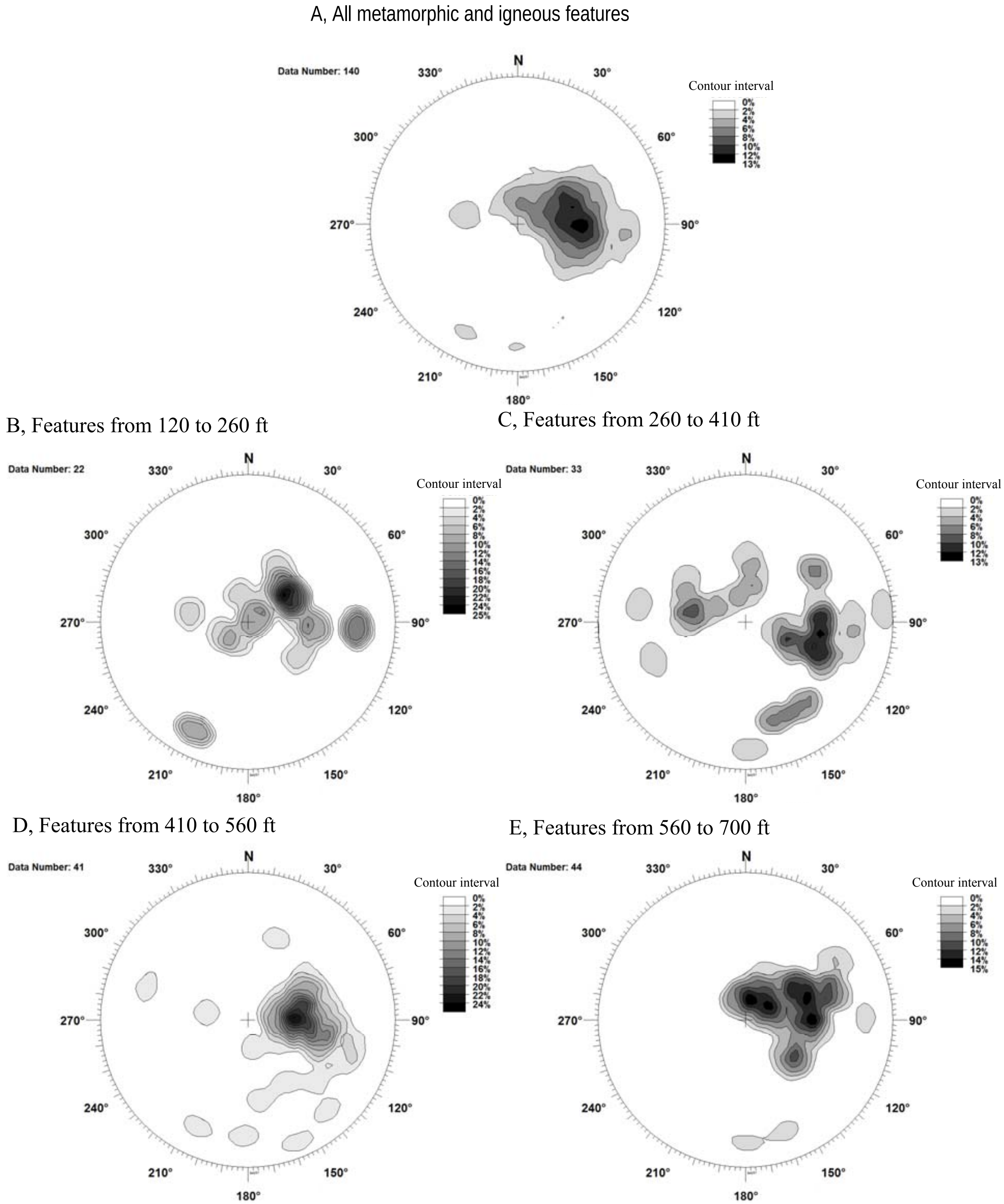


Figure 5. Lower hemisphere equal-area projections (stereonets) containing contoured poles to planes of bedrock structures observed at different depths in the optical televiewer log from well NH-WRW-37. *A*, All metamorphic and igneous features; *B*, Features from 120 to 260 ft; *C*, Features from 260 to 410 ft; *D,* Features from 410 to 560 ft; *E*, Features from 560 to 700 ft.

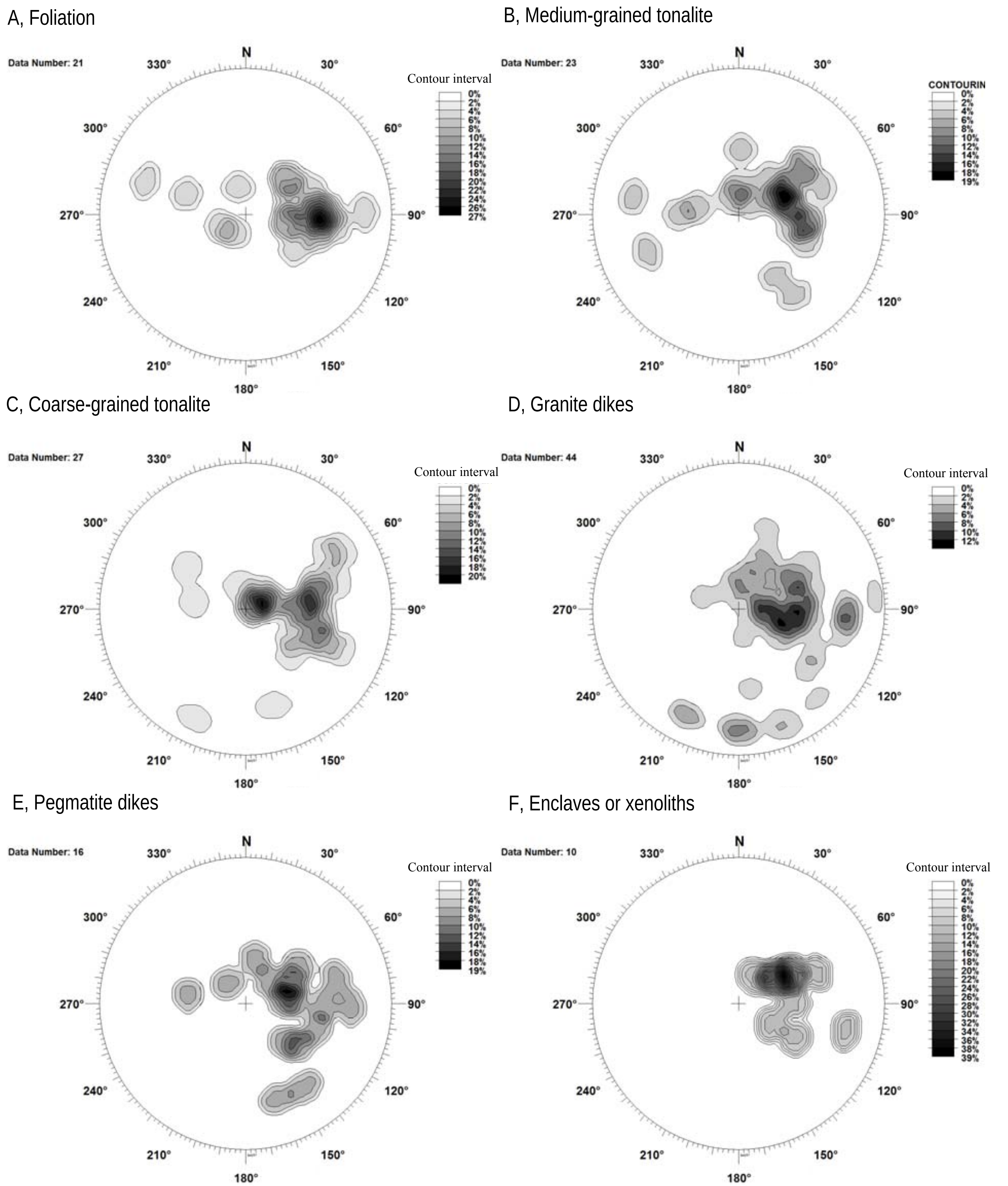
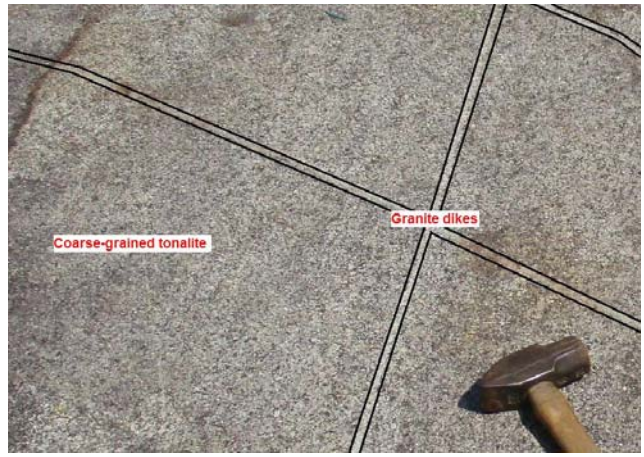


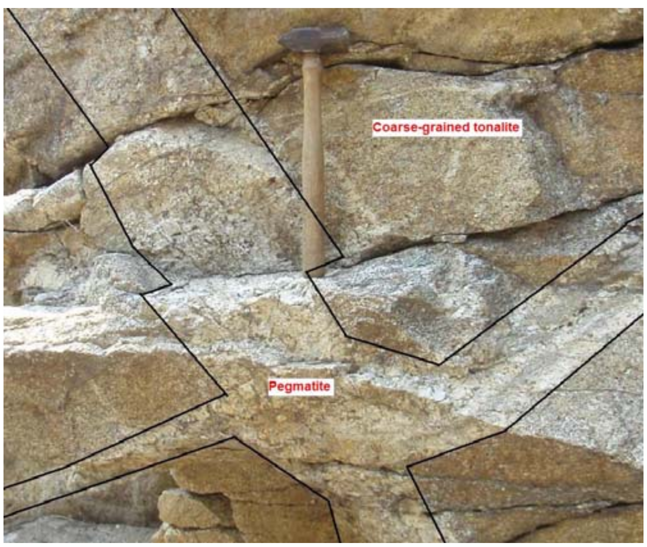
Figure 6. Lower hemisphere equal-area projections (stereonets) containing contoured poles to planes of bedrock structures observed for different rock types in the optical televiewer log from well NH-WRW-37. *A*, Foliation; *B*, Medium-grained tonalite; *C*, Coarse-grained tonalite; *D,* Granite dikes; *E*, Pegmatite dikes; F, Enclaves or xenoliths.

A, Coarse- and medium-grained tonalite (station 8, fig. 1)

B, Coarse-grained tonalite cut by granite (station 8, fig. 1)



C, Coarse-grained tonalite cut by pegmatite (station 10, fig. 1)



D, Coarse- and medium-grained tonalite cut by pegmatite and granite in boulder (fig. 1)

Figure 7. Photographs of Devonian Winnipesaukee Tonalite in bedrock outcrops and a boulder near well NH-WRW-37. *A*, Coarse- and medium-grained tonalite (station 8, fig. 1); *B,* Coarse-grained tonalite cut by granite (station 8, fig. 1); *C*, Coarse-grained tonalite cut by pegmatite (station 10, fig. 1); *D*, Coarse- and medium-grained tonalite cut by pegmatite and granite in boulder (fig. 1). Photographs by Gregory J. Walsh

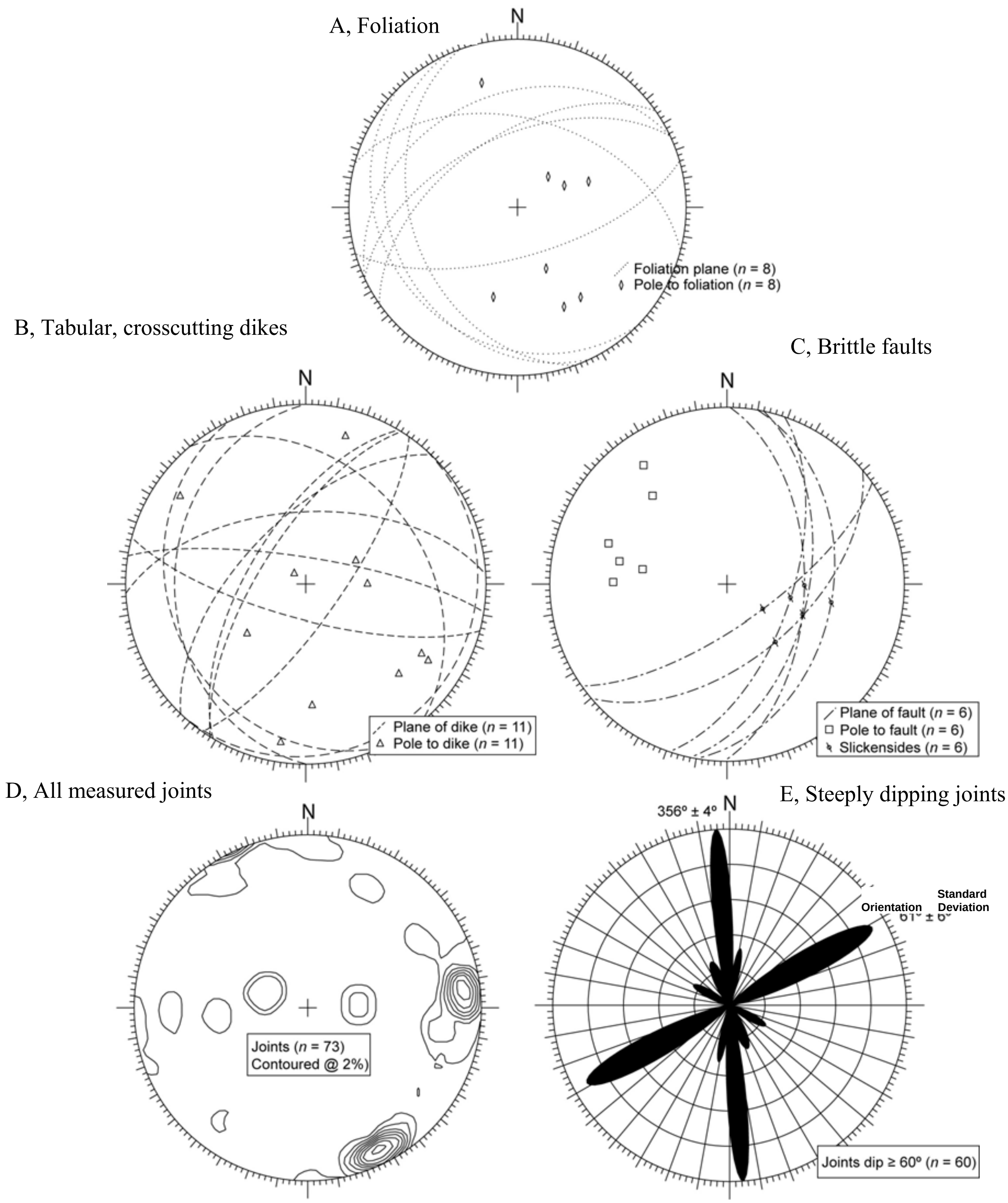


Figure 8. Lower hemisphere equal-area projections (stereonets) containing contoured poles to planes and great circles (*A*-*C*), contours of poles to planes (*D*), and a rose diagram (*E*) showing bedrock structures in outcrops near well NH-WRW-37 (fig. 1). The length of a petal in the rose diagram indicates the normalized height; circle intervals are 20 percent increasing outward. *A,* Foliation; *B,* Tabular, crosscutting dikes of biotite granite, granitic aplite, and pegmatite; *C,* Brittle faults showing trend and plunge of slickensides; *D,* All measured joints; *E,* Steeply dipping joints (for dips greater than or equal to 60 degrees). N = north; *n* = number of points in the dataset.

Table 1. Well construction characteristics, Wolfeboro, NH

[ID = identifier, ft = feet, TOC = top of casing, gpm = gallons per minute, LSD = land surface datum, in. = inch, ND = no data]

Local well ID	Length of casing (ft)	Depth from LSD to Bedrock (ft)	Estimated yield (gpm)	Depth from TOC to water (ft)	Depth of well from LSD (ft)	Aquifer	Comments
NH-WRW-1[1]	17.5	27.5	ND	4.7	20	Sand	2 in. of rotten rock before refusal.
NH-WRW-37[2]	124	60	1	28.5[3]	705	Bedrock	Soft rock from 60 to 114 ft.
NH-WRW-87[2]	43	23	2	60	1503	Bedrock	Elevated fluoride and manganese.

[1]Data from Ayotte, 1997.
[2]Data from New Hampshire Geological Survey, 2007.
[3]Data from U.S. Geological Survey, 2007.

Table 2. Field water quality parameters of ground water from wells in crystalline aquifers, Wolfeboro, NH

[TOC = top of casing, µS/cm = micro siemens per centimeter, SpC = specific conductance at 25°, deg. C = degrees Celsius, DO = dissolved oxygen, mg/L = milligrams per liter**,** ft = feet, ND = no data] the 2000 data are from Coakley and others (2001)

Well/sample name	Sample Date	pH	Total alkalinity (mg/L as $CaCO_3$)	SpC (µS/cm)	Temperature (deg. C)	DO (mg/L)
NH-WRW-37[2]	4/17/2000	8.7	ND	1,011	9.8	0.15
NH-WRW-37[2]	8/28/2000	8.7	518	1,220	ND	0.1
NH-WRW-37[2]	8/07/2007	8.5[1]	ND	1,100[1]	ND	ND
NH-WRW-37 Borehole Sampler at 600 feet below TOC	8/30/2007	8.5[1]	ND	800[1]	ND	ND
NH-WRW-37 Borehole Sampler at 675 feet below TOC	8/30/2007	8.3	ND	1,640	18.2	ND
NH-WRW-87 Pumped sample	ND	8.5[1]	ND	ND	ND	ND

[1] Measured by the New Hampshire Department of Environmental Services Laboratory.
[2]Pump set at 600 ft.

Table 3. Major ions and trace elements in ground water from well NH-WRW-37, Wolfeboro, NH

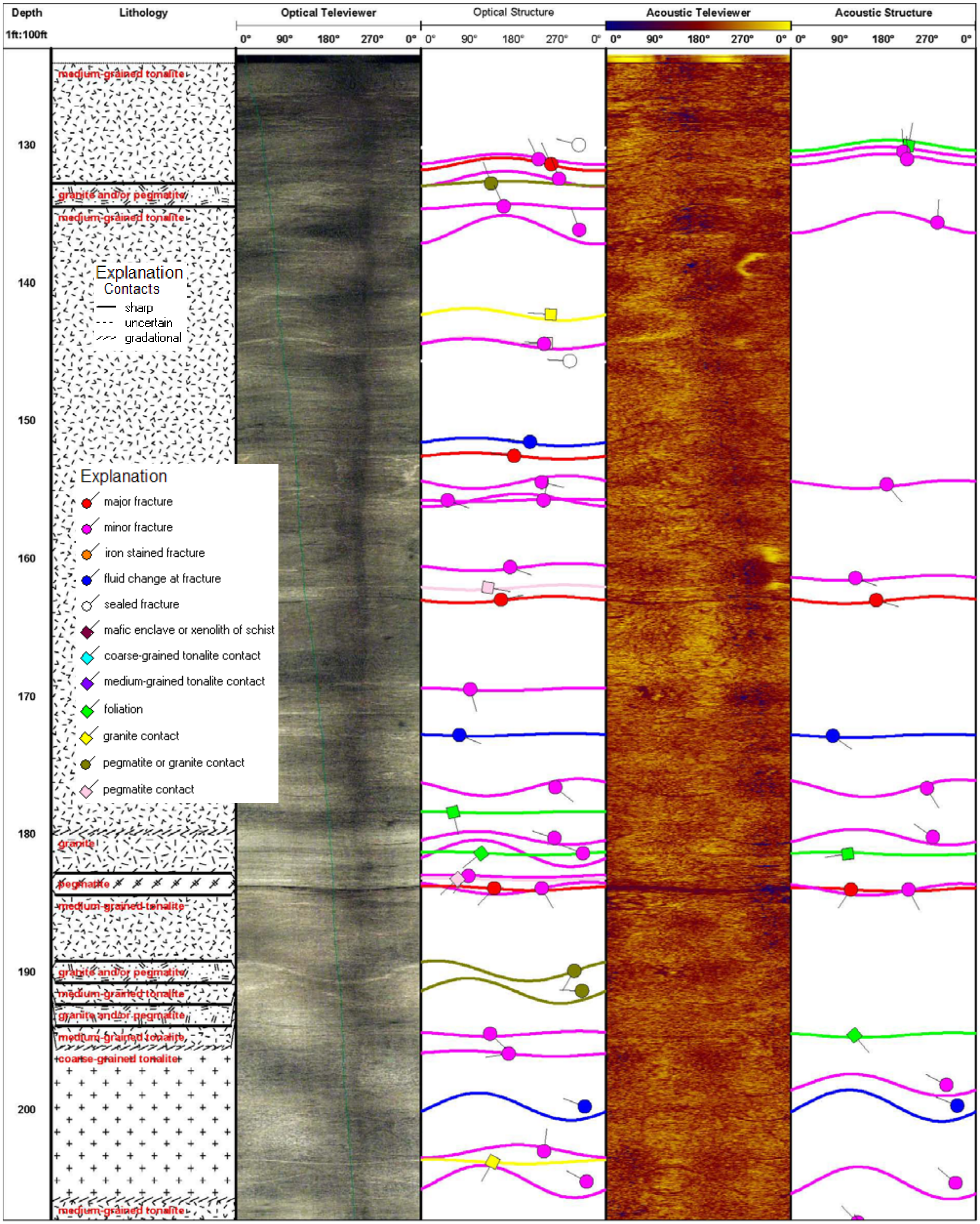
[mg/L = milligrams per liter, µg/L = micrograms per liter, MCL = Maximum contaminant level (New Hampshire Department of Environmental Services)]

	Unit	MCL	Pumped filtered	Pumped raw
Sample Date			8/28/2000[1]	8/07/2007[2]
Calcium	mg/L		3.2	3.5
Magnesium	mg/L		2.4	2.65
Potassium	mg/L		1.4	2.35
Sodium	mg/L	250	260	260
Alkalinity	mg/L		518	
Bicarbonate	mg/L		606	
Carbonate	mg/L		8	
Chloride	mg/L	250	50	46
Fluoride	mg/L	4	18	15
Silica	mg/L		11	
Sulfate	mg/L		<0.3	<1
Sulfide	mg/L		0.008	
Nitrate, as N	mg/L		0.05	<0.050
Ammonia, as N	mg/L		<0.02	<0.05
Nitrite, as N	mg/L		<0.01	<0.05
Phosphorus	mg/L		0.016	0.018
Solids	mg/L		652	
Aluminum	µg/L		3	<30
Antimony	µg/L		<1	
Arsenic	µg/L	10	<0.9	<1
Barium	µg/L	2,000	29	39.3
Berylium	µg/L		<1	
Boron	µg/L		39.4	
Bromide	µg/L		0.27	
Cadmium	µg/L	5	<1	<2
Chromium	µg/L		<0.8	
Cobalt	µg/L		<1	
Copper	µg/L	1,300	<1	0.5
Iron	µg/L	300	64	115
Iron Ferrous	µg/L		50	
Lead	µg/L	15	<1	<1
Lithium	µg/L		1,230	1,820
Manganese	µg/L		3	<10
Molybdenum	µg/L		1	
Nickel	µg/L	100	<1	<0.5
Selenium	µg/L		<0.7	
Silver	µg/L		<1	
Strontium	µg/L		313.3	
Thalium	µg/L		<0.9	
Vanadium	µg/L		1.7	
Zinc	µg/L	5,000	<1	<25
Uranium	µg/L	30	1	1

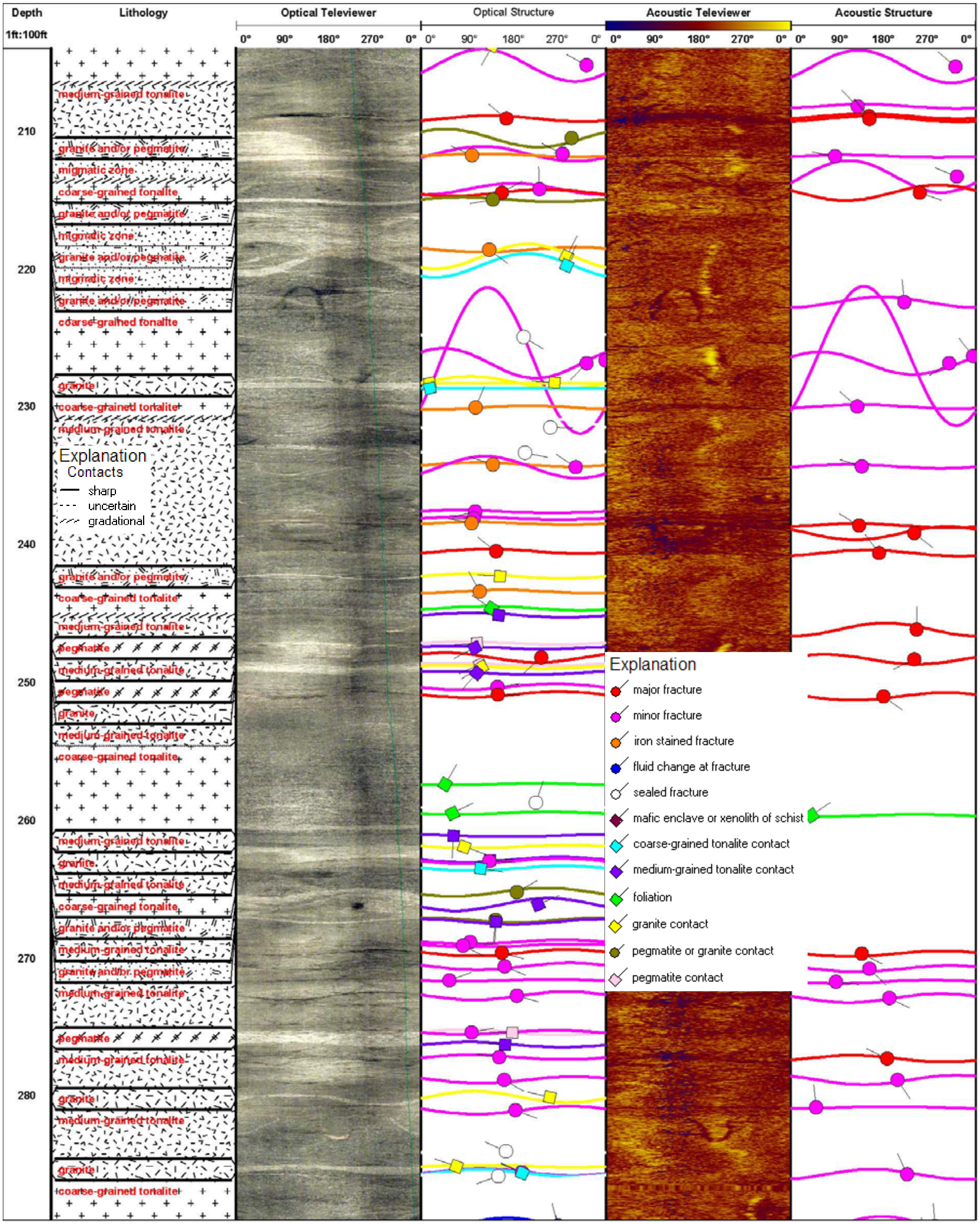
[1]Analyzed at the U.S. Geological Survey National Water Quality Laboratory (Coakley and others, 2001).

[2] Analyzed at the New Hampshire Department of Environmental Services Laboratory.

Appendix 1. Lithologic interpretations, optical and acoustic televiewer borehole-geophysical logs, and interpreted structure of well NH-WRW-37 (Page 1 of 7)



Appendix 1, continued. Lithologic interpretations, optical and acoustic televiewer borehole-geophysical logs, and interpreted structure of well NH-WRW-37 (Page 2 of 7)



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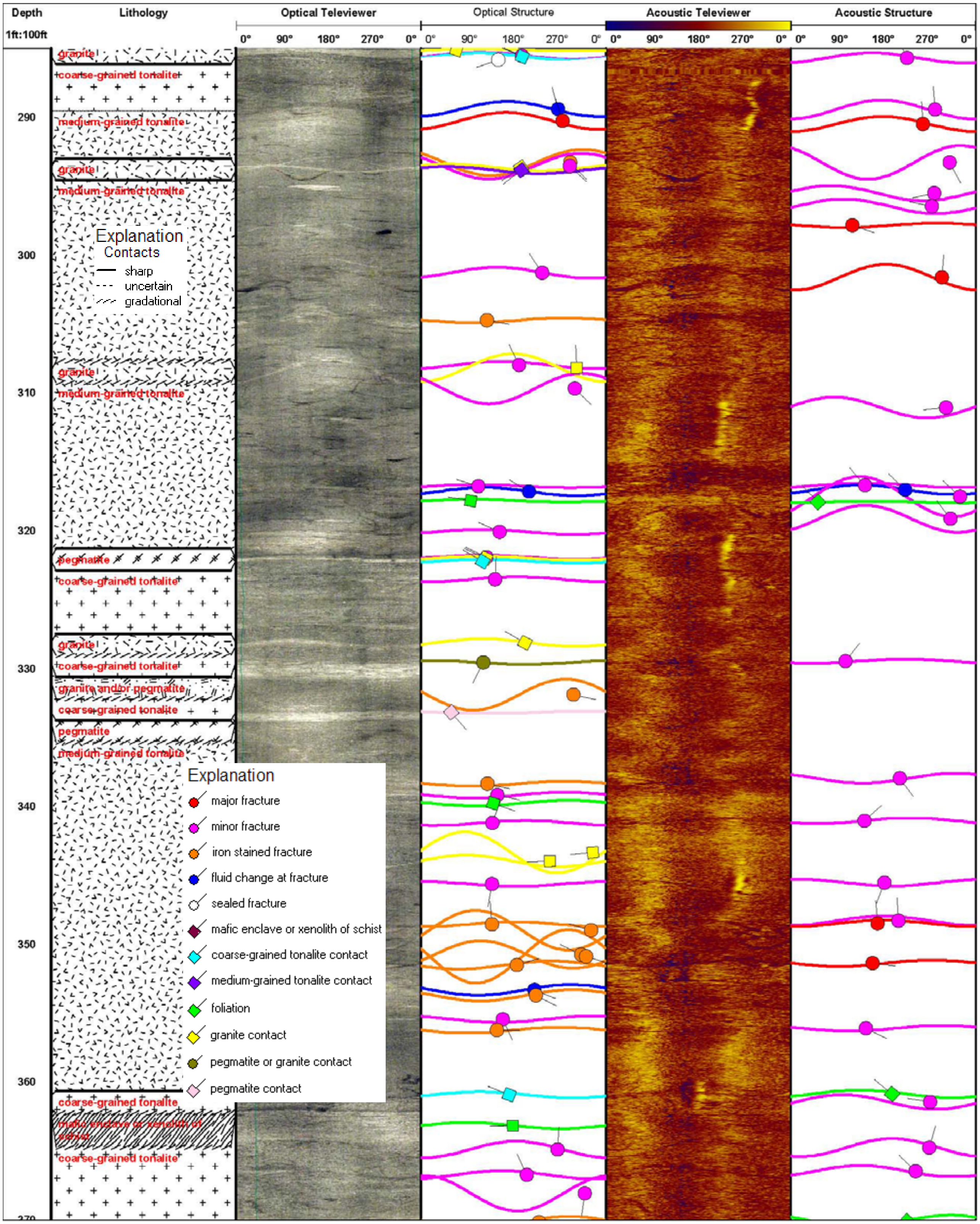

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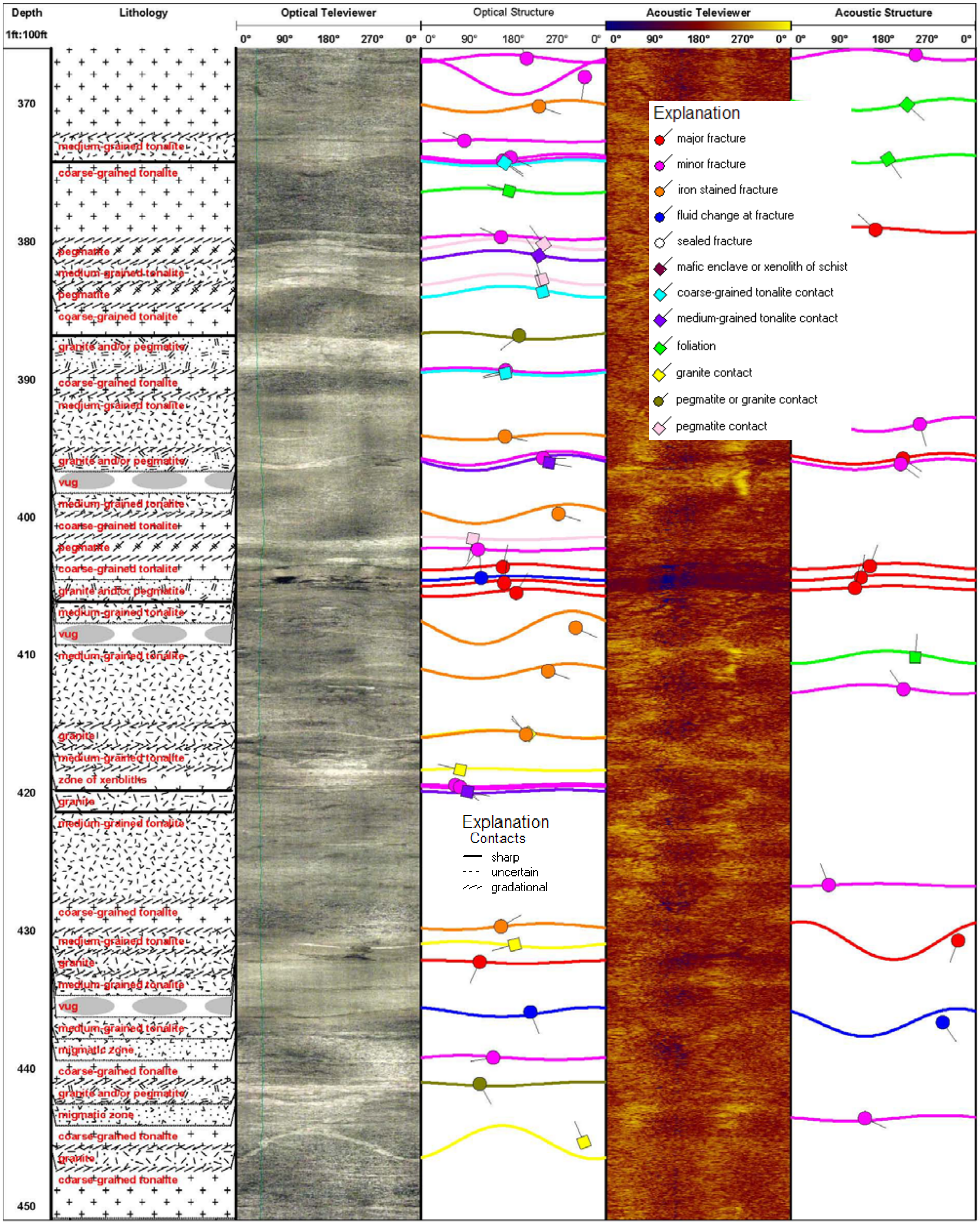
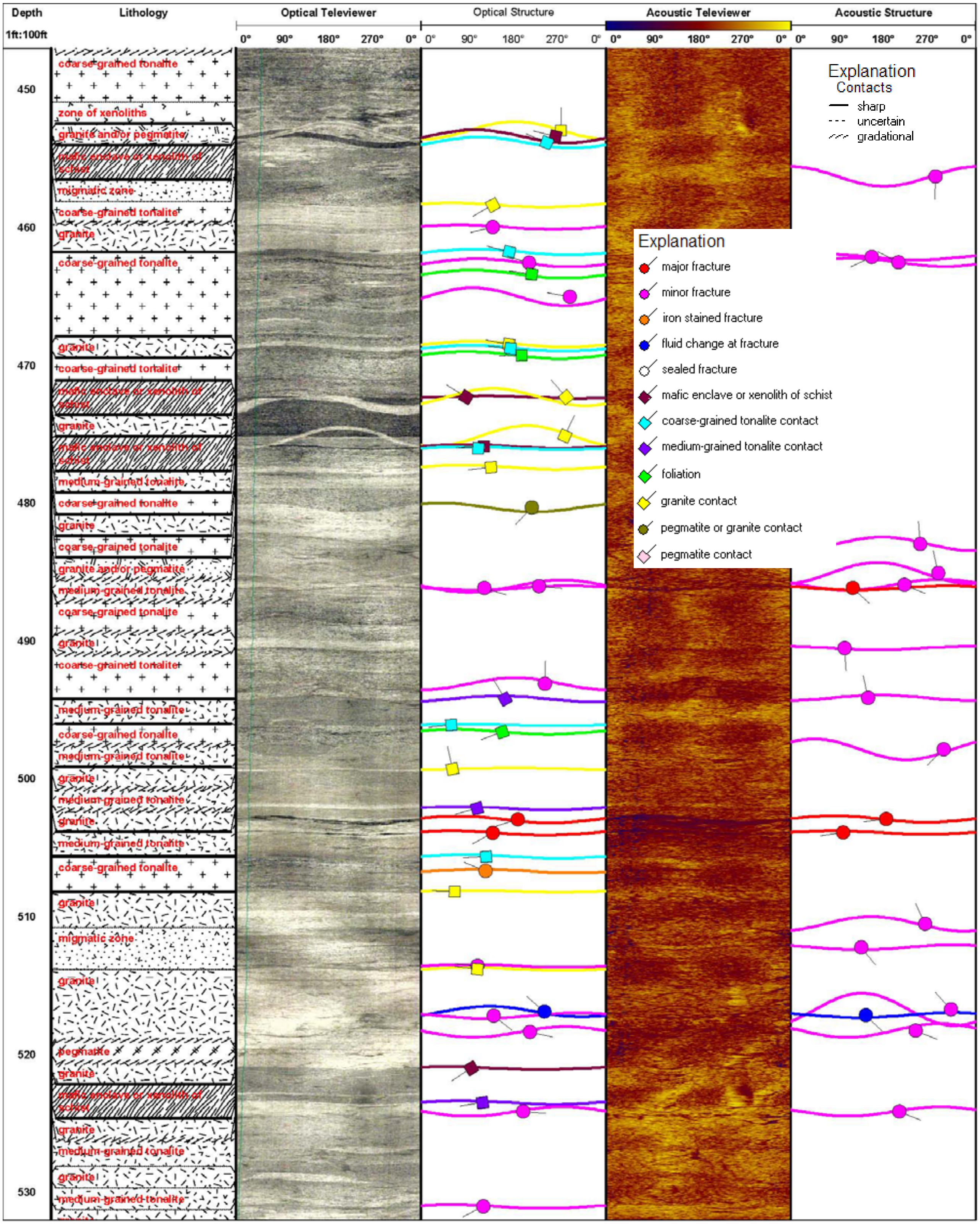


Appendix 1, continued. Lithologic interpretations, optical and acoustic televiewer borehole-geophysical logs, and interpreted structure of well NH-WRW-37 (Page 5 of 7)



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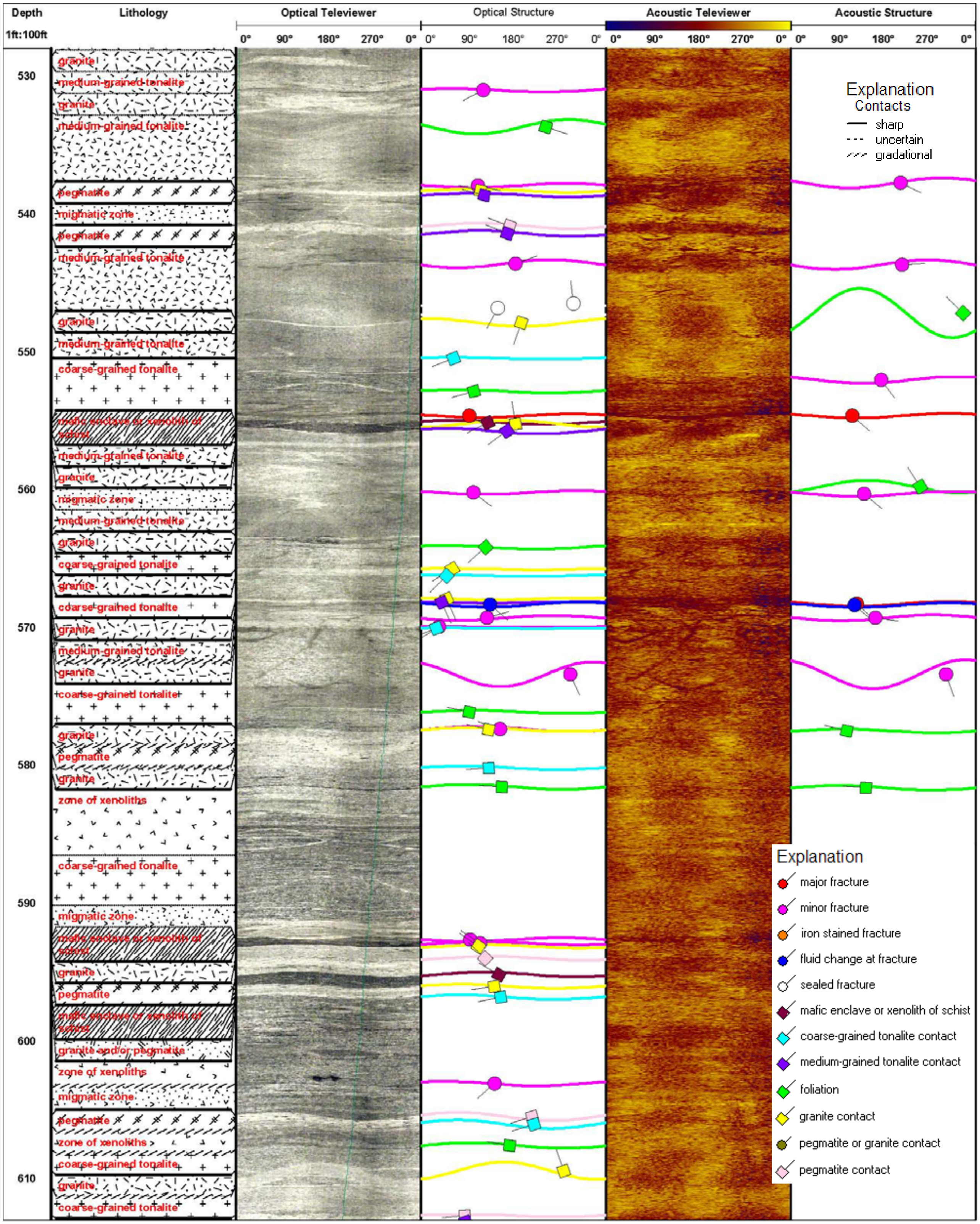
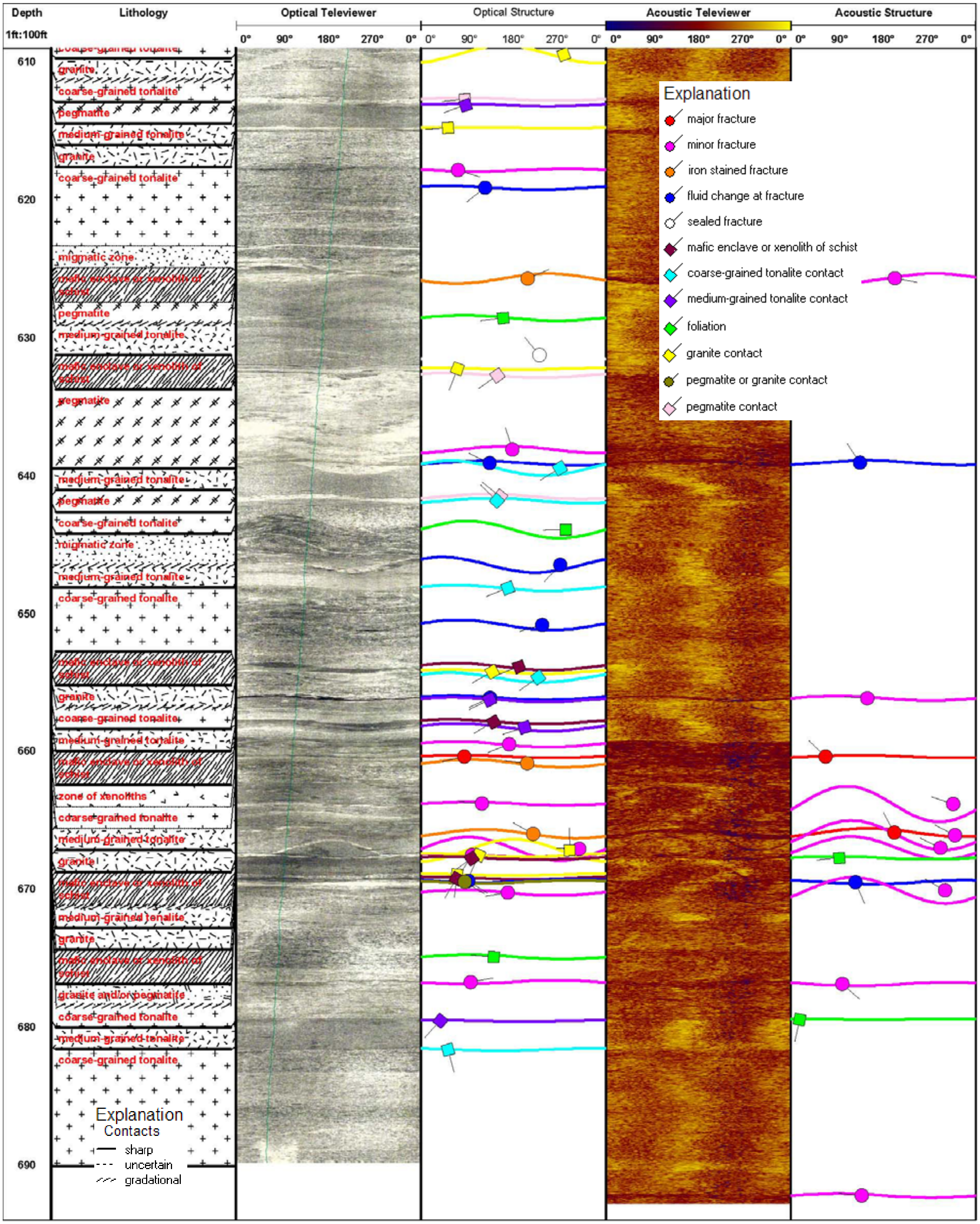


Appendix 1, continued. Lithologic interpretations, optical and acoustic televiewer borehole-geophysical logs, and interpreted structure of well NH-WRW-37 (Page 7 of 7)



Appendix 2. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 1 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
130.0	285	195	77	W	Nearly vertical	Sealed fracture
131.0	335	245	57	NW	Steep	Minor fracture
131.4	336	246	63	NW	Steep	Major fracture
132.5	341	251	67	N	Steep	Minor fracture
132.8	341	251	34	N	Moderate	Pegmatite or granite contact
134.5	336	246	40	NW	Moderate	Minor fracture
136.2	341	251	77	N	Nearly vertical	Minor fracture
142.3	274	184	63	W	Steep	Granite contact
144.4	272	182	61	W	Steep	Pegmatite contact
144.4	270	180	60	W	Steep	Minor fracture
145.7	274	184	73	W	Nearly vertical	Sealed fracture
151.5	277	187	53	W	Steep	Fluid change at fracture
152.6	276	186	46	W	Moderate	Major fracture
154.5	103	13	59	E	Steep	Minor fracture
155.8	12	282	60	N	Steep	Minor fracture
155.8	110	20	13	E	Shallow	Minor fracture
160.7	109	19	43	E	Moderate	Minor fracture
162.1	99	9	33	E	Moderate	Pegmatite contact
163.0	79	349	39	E	Moderate	Major fracture
169.5	164	74	24	S	Shallow	Minor fracture
172.8	111	21	19	E	Shallow	Fluid change at fracture
176.6	128	38	65	SE	Steep	Minor fracture
178.4	166	76	16	S	Shallow	Foliation
180.3	288	198	65	W	Steep	Minor fracture
181.4	291	201	79	W	Nearly vertical	Minor fracture
181.4	232	142	29	SW	Shallow	Foliation
183.1	221	131	23	SW	Shallow	Minor fracture
183.3	228	138	18	SW	Shallow	Pegmatite contact
183.9	150	60	59	SE	Steep	Minor fracture
183.9	223	133	36	SW	Moderate	Major fracture
189.9	210	120	75	SW	Nearly vertical	Pegmatite or granite contact
191.4	271	181	79	W	Nearly vertical	Pegmatite or granite contact
194.5	132	42	34	SE	Moderate	Minor fracture
195.9	261	171	43	W	Moderate	Minor fracture
199.8	291	201	80	W	Nearly vertical	Fluid change at fracture
203.0	6	276	60	N	Steep	Minor fracture

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37, (Page 2 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
203.8	209	119	35	SW	Moderate	Granite contact
205.2	298	208	81	NW	Nearly vertical	Minor fracture
209.1	310	220	42	NW	Moderate	Major fracture
210.5	228	138	73	SW	Nearly vertical	Pegmatite or granite contact
211.6	298	208	69	NW	Steep	Minor fracture
211.7	294	204	25	NW	Shallow	Iron-stained fracture
214.2	358	268	58	N	Steep	Minor fracture
214.5	61	331	40	NE	Moderate	Major fracture
215.0	260	170	35	W	Moderate	Pegmatite or granite contact
218.6	126	36	33	SE	Moderate	Iron-stained fracture
219.1	27	297	71	NE	Nearly vertical	Granite contact
219.8	25	295	71	NE	Nearly vertical	Coarse-grained tonalite contact
224.9	120	30	50	SE	Steep	Sealed fracture
226.6	129	39	90	SE	Nearly vertical	Minor fracture
226.8	224	134	81	SW	Nearly vertical	Minor fracture
228.2	275	185	65	W	Steep	Granite contact
228.3	256	166	5	W	Nearly horizontal	Granite contact
228.6	257	167	5	W	Nearly horizontal	Coarse-grained tonalite contact
230.0	22	292	27	N	Shallow	Iron-stained fracture
231.5	91	1	63	E	Steep	Sealed fracture
233.3	101	11	51	E	Steep	Sealed fracture
234.2	289	199	35	W	Moderate	Iron-stained fracture
234.4	304	214	75	NW	Nearly vertical	Minor fracture
237.6	256	166	27	W	Shallow	Minor fracture
238.1	268	178	26	W	Shallow	Minor fracture
238.5	281	191	25	W	Shallow	Iron-stained fracture
240.5	308	218	37	NW	Moderate	Major fracture
242.3	274	184	39	W	Moderate	Granite contact
243.4	332	242	29	NW	Shallow	Iron-stained fracture
244.6	304	214	34	NW	Moderate	Foliation
245.1	278	188	38	W	Moderate	Medium-grained tonalite contact
247.1	266	176	27	W	Shallow	Pegmatite contact
247.5	242	152	26	SW	Shallow	Medium-grained tonalite contact
248.2	228	138	59	SW	Steep	Major fracture
248.7	245	155	29	SW	Shallow	Pegmatite contact
248.9	240	150	30	SW	Shallow	Granite contact

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 3 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
249.3	221	131	27	SW	Shallow	Medium-grained tonalite contact
250.3	81	351	37	E	Moderate	Minor fracture
250.9	90	0	37	E	Moderate	Major fracture
257.4	30	300	12	NE	Shallow	Foliation
258.7	19	289	56	N	Steep	Sealed fracture
259.5	64	334	15	NE	Shallow	Foliation
261.1	183	93	16	S	Shallow	Medium-grained tonalite contact
261.9	110	20	21	E	Shallow	Granite contact
262.9	90	360	34	E	Moderate	Medium-grained tonalite contact
263.0	91	1	33	E	Moderate	Minor fracture
263.5	99	9	29	E	Shallow	Coarse-grained tonalite contact
265.2	61	331	47	NE	Moderate	Pegmatite or granite contact
266.1	67	337	57	NE	Steep	Medium-grained tonalite contact
267.2	186	96	36	S	Moderate	Pegmatite or granite contact
267.3	183	93	37	S	Moderate	Medium-grained tonalite contact
268.8	96	6	24	E	Shallow	Minor fracture
269.1	116	26	21	SE	Shallow	Minor fracture
269.6	105	15	40	E	Moderate	Major fracture
270.6	112	22	41	E	Moderate	Minor fracture
271.6	71	341	14	E	Shallow	Minor fracture
272.7	105	15	47	E	Moderate	Minor fracture
275.4	271	181	45	W	Moderate	Pegmatite contact
275.4	80	350	25	E	Shallow	Minor fracture
276.3	274	184	41	W	Moderate	Medium-grained tonalite contact
277.2	278	188	38	W	Moderate	Minor fracture
278.8	120	30	41	SE	Moderate	Minor fracture
280.1	283	193	63	W	Steep	Granite contact
281.1	110	20	46	E	Moderate	Minor fracture
284.0	294	204	42	NW	Moderate	Sealed fracture
285.1	289	199	17	W	Shallow	Granite contact
285.5	294	204	49	NW	Moderate	Minor fracture
285.6	293	203	49	NW	Moderate	Coarse-grained tonalite contact
285.8	250	160	38	W	Moderate	Sealed fracture
289.4	346	256	67	N	Steep	Fluid change at fracture
290.3	344	254	69	N	Steep	Major fracture
293.3	136	46	73	SE	Nearly vertical	Iron stained fracture

Appendix 2, continued Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37, (Page 4 of 9).
[RHR = right-hand rule; see “Methods”]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
293.5	132	42	73	SE	Nearly vertical	Minor fracture
293.6	236	146	49	SW	Moderate	Granite contact
293.8	232	142	49	SW	Moderate	Medium-grained tonalite contact
301.3	326	236	59	NW	Steep	Minor fracture
304.7	100	10	32	E	Moderate	Iron stained fracture
308.0	334	244	48	NW	Moderate	Minor fracture
308.2	358	268	76	N	Nearly vertical	Granite contact
309.7	133	43	75	SE	Nearly vertical	Minor fracture
316.7	287	197	28	W	Shallow	Minor fracture
317.1	301	211	53	NW	Steep	Fluid change at fracture
317.8	280	190	24	W	Shallow	Foliation
320.1	295	205	39	NW	Moderate	Minor fracture
321.9	296	206	32	NW	Moderate	Minor fracture
322.0	295	205	32	NW	Moderate	Granite contact
322.2	300	210	30	NW	Moderate	Coarse-grained tonalite contact
323.5	2	272	36	N	Moderate	Minor fracture
328.1	299	209	51	NW	Steep	Granite contact
329.6	207	117	30	SW	Moderate	Pegmatite or granite contact
331.9	102	12	74	E	Nearly vertical	Iron-stained fracture
333.2	139	49	15	SE	Shallow	Pegmatite contact
338.3	102	12	33	E	Moderate	Iron-stained fracture
339.2	102	12	37	E	Moderate	Minor fracture
339.8	109	19	35	E	Moderate	Foliation
341.2	19	289	35	N	Moderate	Minor fracture
343.3	265	175	84	W	Nearly vertical	Granite contact
344.0	268	178	63	W	Steep	Granite contact
345.6	189	99	35	S	Moderate	Minor fracture
348.6	356	266	35	N	Moderate	Iron-stained fracture
349.0	286	196	83	W	Nearly vertical	Iron-stained fracture
350.8	296	206	78	NW	Nearly vertical	Iron-stained fracture
350.9	107	17	80	E	Nearly vertical	Iron-stained fracture
351.5	74	344	47	E	Moderate	Iron-stained fracture
353.3	112	22	55	E	Steep	Fluid change at fracture
353.7	116	26	56	SE	Steep	Iron-stained fracture
355.4	155	65	40	SE	Moderate	Minor fracture
356.2	91	1	37	E	Moderate	Iron-stained fracture

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 5 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
360.9	292	202	43	W	Moderate	Coarse-grained tonalite contact
363.2	269	179	45	W	Moderate	Foliation
364.9	4	274	67	N	Steep	Minor fracture
366.7	335	245	52	NW	Steep	Minor fracture
368.1	188	98	80	S	Nearly vertical	Minor fracture
370.2	110	20	58	E	Steep	Iron-stained fracture
372.7	291	201	21	W	Shallow	Minor fracture
373.9	113	23	44	SE	Moderate	Minor fracture
374.1	123	33	40	SE	Moderate	Minor fracture
374.3	125	35	41	SE	Moderate	Coarse-grained tonalite contact
376.3	286	196	43	W	Moderate	Foliation
379.7	294	204	39	NW	Moderate	Minor fracture
380.2	324	234	60	NW	Steep	Pegmatite contact
381.0	325	235	57	NW	Steep	Medium-grained tonalite contact
382.8	342	252	59	N	Steep	Pegmatite contact
383.6	344	254	59	N	Steep	Coarse-grained tonalite contact
386.8	232	142	48	SW	Moderate	Pegmatite or granite contact
389.4	256	166	41	W	Moderate	Minor fracture
389.6	258	168	41	W	Moderate	Coarse-grained tonalite contact
394.1	101	11	41	E	Moderate	Iron-stained fracture
395.7	89	359	60	E	Steep	Minor fracture
396.1	99	9	62	E	Steep	Medium-grained tonalite contact
399.7	107	17	67	E	Steep	Fracture with iron staining
401.6	192	102	25	S	Shallow	Pegmatite contact
402.3	216	126	28	SW	Shallow	Minor fracture
403.6	12	282	40	N	Moderate	Major fracture
404.4	357	267	29	N	Shallow	Fluid change at fracture
404.8	6	276	41	N	Moderate	Major fracture
405.5	29	299	46	NE	Moderate	Major fracture
408.0	114	24	75	SE	Nearly vertical	Iron-stained fracture
411.2	109	19	62	E	Steep	Fracture with iron staining
415.8	312	222	53	NW	Steep	Granite contact
415.8	323	233	51	NW	Steep	Iron-stained fracture
418.3	283	193	19	W	Shallow	Granite contact
419.5	119	29	17	SE	Shallow	Minor fracture
419.6	124	34	19	SE	Shallow	Minor fracture

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 6 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
419.9	101	11	23	E	Shallow	Medium-grained tonalite contact
429.7	61	331	39	NE	Moderate	Iron-stained fracture
431.0	255	165	46	W	Moderate	Granite contact
432.3	204	114	29	SW	Shallow	Major fracture
435.9	157	67	53	SE	Steep	Fluid change at fracture
439.2	261	171	35	W	Moderate	Minor Fracture
441.1	150	60	29	SE	Shallow	Pegmatite or granite contact
445.4	338	248	79	N	Nearly vertical	Granite contact
453.0	2	272	68	N	Steep	Granite contact
453.4	284	194	65	W	Steep	Mafic enclave or xenolith of schist
453.8	293	203	61	NW	Steep	Coarse-grained tonalite contact
458.3	241	151	35	SW	Moderate	Granite contact
460.0	256	166	35	W	Moderate	Minor fracture
461.8	285	195	43	W	Moderate	Coarse-grained tonalite contact
462.5	288	198	53	W	Steep	Minor fracture
463.4	278	188	54	W	Steep	Foliation
465.0	281	191	73	W	Nearly vertical	Minor fracture
468.4	280	190	43	W	Moderate	Granite contact
468.8	276	186	44	W	Moderate	Coarse-grained tonalite contact
469.2	269	179	49	W	Moderate	Foliation
472.3	303	213	22	NW	Shallow	Mafic enclave or xenolith of schist
472.3	319	229	71	NW	Nearly vertical	Granite contact
475.1	25	295	70	NE	Nearly vertical	Granite contact
475.9	269	179	31	W	Moderate	Mafic enclave or xenolith of schist
476.0	273	183	28	W	Shallow	Coarse-grained tonalite contact
477.4	264	174	34	W	Moderate	Granite contact
480.3	223	133	54	SW	Steep	Pegmatite or granite contact
486.0	95	5	58	E	Steep	Minor fracture
486.1	107	17	31	E	Moderate	Minor fracture
493.1	1	271	60	N	Steep	Minor fracture
494.2	329	239	41	NW	Moderate	Medium-grained tonalite contact
496.1	265	175	15	W	Shallow	Coarse-grained tonalite contact
496.6	249	159	40	W	Moderate	Foliation
499.3	348	258	16	N	Shallow	Granite contact
502.1	254	164	27	W	Shallow	Medium-grained tonalite contact
503.0	253	163	47	W	Moderate	Major fracture

Appendix 2, continued Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 7 of 9).
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
503.9	242	152	35	SW	Moderate	Major fracture
505.6	267	177	32	W	Moderate	Coarse-grained tonalite contact
506.7	292	202	32	W	Moderate	Iron-stained fracture
508.2	271	181	17	W	Shallow	Granite contact
513.6	275	185	28	W	Shallow	Minor fracture
513.8	276	186	28	W	Shallow	Granite contact
516.9	311	221	60	NW	Steep	Fluid change at fracture
517.2	128	38	36	SE	Moderate	Minor fracture
518.4	102	12	53	E	Steep	Minor fracture
521.0	237	147	24	SW	Shallow	Mafic enclave or xenolith of schist
523.5	261	171	30	W	Moderate	Medium-grained tonalite contact
524.1	94	4	50	E	Moderate	Minor fracture
531.0	243	153	30	SW	Moderate	Minor fracture
533.7	108	18	61	E	Steep	Foliation
537.9	103	13	28	E	Shallow	Minor fracture
538.3	282	192	29	W	Shallow	Granite contact
538.6	284	194	31	W	Moderate	Medium-grained tonalite contact
540.9	290	200	43	W	Moderate	Pegmatite contact
541.4	292	202	42	W	Moderate	Medium-grained tonalite contact
543.6	70	340	46	E	Moderate	Minor fracture
546.5	354	264	74	N	Nearly vertical	Sealed fracture
546.8	208	118	38	SW	Moderate	Sealed fracture
547.9	199	109	49	S	Moderate	Granite contact
550.5	249	159	16	W	Shallow	Coarse-grained tonalite contact
552.9	255	165	26	W	Shallow	Foliation
554.6	119	29	24	SE	Shallow	Major fracture
555.1	243	153	33	SW	Moderate	Mafic enclave or xenolith of schist
555.2	351	261	46	N	Moderate	Granite contact
555.8	234	144	42	SW	Moderate	Medium-grained tonalite contact
560.2	127	37	26	SE	Shallow	Minor fracture
564.2	228	138	32	SW	Moderate	Foliation
565.8	238	148	15	SW	Shallow	Granite contact
566.2	225	135	13	SW	Shallow	Coarse-grained tonalite contact
567.9	156	66	13	SE	Shallow	Granite contact
568.2	156	66	10	SE	Shallow	Medium-grained tonalite contact
568.4	130	40	34	SE	Moderate	Fluid change at fracture

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 8 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
569.3	75	345	32	E	Moderate	Minor fracture
570.0	238	148	9	SW	Nearly horizontal	Minor fracture
570.1	248	158	8	W	Nearly horizontal	Coarse-grained tonalite contact
573.4	155	65	73	SE	Nearly vertical	Minor fracture
576.1	282	192	24	W	Shallow	Foliation
577.4	289	199	39	W	Moderate	Minor fracture
577.4	283	193	33	W	Moderate	Granite contact
580.2	266	176	33	W	Moderate	Coarse-grained tonalite contact
581.6	274	184	39	W	Moderate	Foliation
592.7	92	2	24	E	Shallow	Minor fracture
592.9	304	214	29	NW	Shallow	Minor fracture
593.1	305	215	28	NW	Shallow	Granite contact
594.0	314	224	31	NW	Moderate	Pegmatite contact
595.2	301	211	38	NW	Moderate	Mafic enclave or xenolith of schist
596.1	261	171	36	W	Moderate	Granite contact
596.8	259	169	39	W	Moderate	Coarse-grained tonalite contact
603.1	229	139	36	SW	Moderate	Minor fracture
605.5	253	163	54	W	Steep	Pegmatite contact
606.0	253	163	55	W	Steep	Coarse-grained tonalite contact
607.6	279	189	43	W	Moderate	Foliation
609.4	340	250	70	N	Steep	Granite contact
612.7	265	175	21	W	Shallow	Pegmatite contact
613.1	251	161	22	W	Shallow	Medium-grained tonalite contact
614.7	266	176	13	W	Shallow	Granite contact
617.8	107	17	18	E	Shallow	Minor fracture
619.1	233	143	31	SW	Moderate	Fluid change at fracture
625.7	67	337	52	NE	Steep	Fracture with iron staining
628.6	264	174	40	W	Moderate	Foliation
631.3	321	231	58	NW	Steep	Sealed fracture
632.2	201	111	18	S	Shallow	Granite contact
632.7	235	145	37	SW	Moderate	Pegmatite contact
638.1	343	253	44	N	Moderate	Minor fracture
639.1	296	206	33	NW	Moderate	Fluid change at fracture
639.4	238	148	68	SW	Steep	Coarse-grained tonalite contact
641.5	309	219	39	NW	Moderate	Pegmatite contact
641.8	314	224	37	NW	Moderate	Coarse-grained tonalite contact

Appendix 2, continued. Midpoint depth, strike, and dip of features identified in optical televiewer logs from domestic well NH-WRW-37 (Page 9 of 9)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
643.9	269	179	71	W	Nearly vertical	Foliation
646.5	223	133	68	SW	Steep	Fluid change at fracture
648.2	248	158	42	W	Moderate	Coarse-grained tonalite contact
650.8	254	164	59	W	Steep	Fluid change at fracture
653.8	249	159	48	W	Moderate	Mafic enclave or xenolith of schist
654.2	240	150	35	SW	Moderate	Granite contact
654.7	235	145	57	SW	Steep	Coarse-grained tonalite contact
656.1	245	155	34	SW	Moderate	Fluid change at fracture
656.2	244	154	34	SW	Moderate	Medium-grained tonalite contact
657.9	239	149	35	SW	Moderate	Mafic enclave or xenolith of schist
658.3	252	162	51	W	Steep	Medium-grained tonalite contact
659.5	249	159	43	W	Moderate	Minor fracture
660.4	258	168	21	W	Shallow	Major fracture
660.9	277	187	52	W	Steep	Iron-stained fracture
663.8	275	185	30	W	Shallow	Minor fracture
666.0	300	210	55	NW	Steep	Fracture with iron staining
667.1	271	181	77	W	Nearly vertical	Minor fracture
667.2	359	269	73	N	Nearly vertical	Granite contact
667.5	212	122	25	SW	Shallow	Minor fracture
667.5	204	114	28	SW	Shallow	Granite contact
667.8	234	144	25	SW	Shallow	Mafic enclave or xenolith of schist
668.9	187	97	18	S	Shallow	Granite contact
669.2	210	120	18	SW	Shallow	Mafic enclave or xenolith of schist
669.4	122	32	23	SE	Shallow	Fluid change at fracture
669.5	120	30	21	SE	Shallow	Pegmatite or granite contact
670.3	261	171	42	W	Moderate	Minor fracture
674.9	274	184	36	W	Moderate	Foliation
676.7	79	349	24	E	Shallow	Minor fracture
679.5	221	131	10	SW	Nearly horizontal	Medium-grained tonalite contact
681.6	165	75	13	S	Shallow	Coarse-grained tonalite contact

Appendix 3. Midpoint depth, strike, and dip of features identified in acoustic televiewer logs from domestic well NH-WRW-37 (Page 1 of 4)

[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
130.0	11	281	57	N	Steep	Foliation
130.5	357	267	55	N	Steep	Minor fracture
131.1	360	270	57	N	Steep	Minor fracture
135.6	3	273	71	N	Nearly vertical	Minor fracture
154.6	139	49	47	SE	Moderate	Minor fracture
161.4	109	19	32	E	Moderate	Minor fracture
163.0	106	16	42	E	Moderate	Major fracture
172.9	125	35	21	SE	Shallow	Fluid change at fracture
176.7	149	59	66	SE	Steep	Minor fracture
180.2	306	216	69	NW	Steep	Minor fracture
181.4	261	171	28	W	Shallow	Foliation
184.0	213	123	29	SW	Shallow	Major fracture
184.0	152	62	57	SE	Steep	Minor fracture
194.6	140	50	31	SE	Moderate	Foliation
198.2	298	208	76	NW	Nearly vertical	Minor fracture
199.7	293	203	81	NW	Nearly vertical	Fluid change at fracture
205.3	311	221	80	NW	Nearly vertical	Minor fracture
208.2	317	227	33	NW	Moderate	Minor fracture
208.9	321	231	38	NW	Moderate	Major fracture
209.1	323	233	38	NW	Moderate	Major fracture
211.8	281	191	22	W	Shallow	Minor fracture
213.3	292	202	81	W	Nearly vertical	Minor fracture
214.5	109	19	63	E	Steep	Major fracture
222.4	355	265	55	N	Steep	Minor fracture
226.3	322	232	89	NW	Nearly vertical	Minor fracture
226.8	237	147	77	SW	Nearly vertical	Minor fracture
230.0	311	221	32	NW	Moderate	Minor fracture
234.3	287	197	35	W	Moderate	Minor fracture
238.6	302	212	33	NW	Moderate	Major fracture
239.2	127	37	60	SE	Steep	Major fracture
240.6	324	234	43	NW	Moderate	Major fracture
246.2	1	271	61	N	Steep	Major fracture
248.3	245	155	60	SW	Steep	Major fracture
251.0	124	34	45	SE	Moderate	Major fracture
259.6	56	326	10	NE	Shallow	Foliation
269.7	116	26	35	SE	Moderate	Major fracture

Appendix 3, continued. Midpoint depth, strike, and dip of features identified in acoustic televiewer logs from domestic well NH-WRW-37 (Page 2 of 4)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
270.8	134	44	38	SE	Moderate	Minor fracture
271.7	96	6	22	E	Shallow	Minor fracture
272.9	115	25	48	SE	Moderate	Minor fracture
277.3	296	206	47	NW	Moderate	Major fracture
278.8	145	55	52	SE	Steep	Minor fracture
280.8	354	264	12	N	Shallow	Minor fracture
285.7	336	246	57	NW	Steep	Minor fracture
289.4	355	265	70	N	Nearly vertical	Minor fracture
290.5	357	267	64	N	Steep	Major fracture
293.3	151	61	77	SE	Nearly vertical	Minor fracture
295.5	258	168	70	W	Steep	Minor fracture
296.4	282	192	69	W	Steep	Minor fracture
297.8	108	18	30	E	Moderate	Major fracture
301.6	4	274	74	N	Nearly vertical	Major fracture
311.1	265	175	76	W	Nearly vertical	Minor fracture
316.7	320	230	36	NW	Moderate	Minor fracture
317.0	315	225	56	NW	Steep	Fluid change at fracture
317.5	314	224	82	NW	Nearly vertical	Minor fracture
317.9	318	228	13	NW	Shallow	Foliation
319.1	324	234	78	NW	Nearly vertical	Minor fracture
329.5	38	308	27	NE	Shallow	Minor fracture
338.0	143	53	53	SE	Steep	Minor fracture
341.0	49	319	36	NE	Moderate	Minor fracture
345.5	201	111	46	S	Moderate	Minor fracture
348.3	357	267	52	N	Steep	Minor fracture
348.5	357	267	42	N	Moderate	Major fracture
351.4	97	7	40	E	Moderate	Major fracture
356.1	115	25	37	SE	Moderate	Minor fracture
360.9	310	220	49	NW	Moderate	Foliation
361.5	280	190	68	W	Steep	Minor fracture
364.8	16	286	68	N	Steep	Minor fracture
366.5	314	224	61	NW	Steep	Minor fracture
370.1	132	42	57	SE	Steep	Foliation
374.0	145	55	48	SE	Moderate	Foliation
379.2	312	222	41	NW	Moderate	Major fracture
393.3	163	73	63	S	Steep	Minor fracture

Appendix 3, continued. Midpoint depth, strike, and dip of features identified in acoustic televiewer logs from domestic well NH-WRW-37 (Page 3 of 4)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
395.8	124	34	55	SE	Steep	Major fracture
396.1	126	36	54	SE	Steep	Minor fracture
403.6	20	290	39	N	Moderate	Major fracture
404.4	9	279	34	N	Moderate	Major fracture
405.2	12	282	31	N	Moderate	Major fracture
410.2	5	275	61	N	Steep	Foliation
412.5	326	236	55	NW	Steep	Minor fracture
426.7	340	250	19	N	Shallow	Minor fracture
430.7	201	111	81	S	Nearly vertical	Major fracture
436.7	145	55	74	SE	Nearly vertical	Fluid change at fracture
443.6	114	24	36	SE	Moderate	Minor fracture
456.3	182	92	71	S	Nearly vertical	Minor fracture
462.1	245	155	40	SW	Moderate	Minor fracture
462.5	298	208	52	NW	Steep	Minor fracture
483.0	356	266	63	N	Steep	Minor fracture
485.1	348	258	72	N	Nearly vertical	Minor fracture
485.9	112	22	55	E	Steep	Minor fracture
486.2	133	43	30	SE	Moderate	Major fracture
490.5	176	86	26	S	Shallow	Minor fracture
494.1	348	258	38	N	Moderate	Minor fracture
497.9	226	136	74	SW	Nearly vertical	Minor fracture
502.9	264	174	47	W	Moderate	Major fracture
503.9	263	173	26	W	Shallow	Major fracture
510.5	335	245	65	NW	Steep	Minor fracture
512.2	140	50	34	SE	Moderate	Minor fracture
516.7	318	228	78	NW	Nearly vertical	Minor fracture
517.2	134	44	37	SE	Moderate	Fluid change at fracture
518.3	111	21	61	E	Steep	Minor fracture
524.1	111	21	53	E	Steep	Minor fracture
537.8	115	25	54	SE	Steep	Minor fracture
543.7	86	356	54	E	Steep	Minor fracture
547.2	314	224	84	NW	Nearly vertical	Foliation
552.1	142	52	44	SE	Moderate	Minor fracture
554.6	131	41	30	SE	Moderate	Major fracture
559.8	328	238	63	NW	Steep	Foliation
560.3	129	39	36	SE	Moderate	Minor fracture

Appendix 3, continued. Midpoint depth, strike, and dip of features identified in acoustic televiewer logs from domestic well NH-WRW-37 (Page 4 of 4)
[RHR = right-hand rule; see "Methods"]

Depth in feet	Dip azimuth	Strike in RHR	Dip	Dip direction	Dip description	Feature description
568.3	132	42	32	SE	Moderate	Major fracture
568.4	130	40	31	SE	Moderate	Fluid change at fracture
569.3	98	8	41	E	Moderate	Minor fracture
573.4	160	70	75	S	Nearly vertical	Minor fracture
577.5	283	193	27	W	Shallow	Foliation
581.6	275	185	37	W	Moderate	Foliation
625.7	100	10	51	E	Steep	Minor fracture
639.1	326	236	34	NW	Moderate	Fluid change at fracture
656.1	273	183	37	W	Moderate	Minor fracture
660.4	314	224	17	NW	Shallow	Major fracture
663.8	289	199	79	W	Nearly vertical	Minor fracture
665.9	332	242	51	NW	Steep	Major fracture
666.1	297	207	80	NW	Nearly vertical	Minor fracture
667.0	296	206	73	NW	Nearly vertical	Minor fracture
667.7	265	175	24	W	Shallow	Foliation
669.5	157	67	32	SE	Moderate	Fluid change at fracture
670.1	301	211	75	NW	Nearly vertical	Minor fracture
676.9	130	40	25	SE	Shallow	Minor fracture
679.4	192	102	5	S	Nearly horizontal	Foliation
692.2	276	186	35	W	Moderate	Minor fracture

Appendix 4. Borehole deviation plot, computed from acoustic televiewer depth, magnetometer, and inclinometer logs for well NH-WRW-37