Conductive strikes identified by square-array resistivity, with the same orientation as fractures identified in outcrop, or remotely sensed lineaments, likely are related to fracture zones. Array 1 has a primary strike direction that is the same as the three lineaments striking 71×, 74×, and 77×. These lineaments cross line 3 and line 4 on the location of steeply dipping anomalies identified with 2-D resistivity. Array 1 has a primary bedrock strike of 75× that has the same orientation as a small peak in the geologic-fracture data analysis (68×±11×), and both fractures dipping south and parting along foliation dipping north in an adjacent outcrop.

Electromagnetic (EM and VLF) surveys indicate electrically conductive anomalies that are consistent with fractured bedrock. DC-resistivity surveys and arrays, and geologic information also indicate fractured bedrock. These surveys show that the lineaments are close to dipping planar features that may represent fractured-bedrock zones. The possible fracture zones, indicated by lineaments LOWALT 74, LOWALT 71, and CIR 77, probably are a southward dipping fracture zone that allows for transmission of water to well WPW 133 (fig. 9). Near-horizontal conductive features in bedrock, that cannot be identified with a lineament analysis, were identified on line 1 with GPR and 2-D resistivity surveys. These near-horizontal features are interpreted as sheeting fracture zones and may serve to connect near-vertical fracture zones.

Site 3, Pelham, New Hampshire

Site 3 on State Route 128 in Pelham, N.H., is set in grassy lots in a shallow valley containing Beaver Brook. The elevation ranges from 150 to 170 ft where the data were collected. Walsh and Clark (1999) mapped the bedrock geology of this area as the Berwick Formation (fig. 20). Overburden material at the site is mapped as a fine-grained (clay to fine sand) stratified drift. Transmissivity of the stratified-drift aquifer is less than 1,000 ft^2/d (Stekl and Flanagan, 1992). Lineaments mapped at the site were SLAR trending 329° and 325° (Ferguson and others, 1997), and CIR trending 303° (fig. 20). The 303° trending lineament was fracture correlated using the domain-analysis technique (R.B. Moore and others, U.S. Geological Survey, written commun., 2001). These lineaments have identifying criteria visible at the site such as a small wetland, and a valley trend of 300° at survey line 1, and a straight reach of stream with a trend of 320° south of line 2 (fig. 20). Fracture data in a 4,000-ft radius of the site has four peak orientations: 282°±8° (100 percent, normalized height), 304°±6° (90 percent, normalized height), 28°±4° (17 percent, normalized height), and 325°±13° (24 percent, normalized height).

At site 3, well PAW 131 was drilled to a depth of 240 ft and has a reported yield of 120 gal/min. The drilling log indicates that a fracture zone was intersected between 225 and 240 ft deep. The static water level in the well is at 12 ft and bedrock is at 11 ft below land surface. Well PAW 420 was drilled at 115 ft along line 2 at site 3 during this study. The overburden consisted of 7 ft of poorly sorted fine to coarse sands, gravels, and cobbles. The well was completed at 300 ft below land surface when a sufficient supply for domestic use was obtained at a reported yield of 30 gal/min. At 19 ft below the land surface, the well yield was 2 gal/min from fractures between soft and hard variations of the Berwick Formation. The high-producing zone for the well is at 277 ft in an open fracture. The open fracture is below an approximately 1-ft thick silicified zone with quartz-biotite black schist and quartzite above and Berwick granofels below (S.F. Clark, Jr., U.S. Geological Survey, written commun., 1999).

Probabilities of exceeding a yield of 40 gal/min from a 400-ft deep well at this site ranged from 12 to 19 percent. A 12-percent probability is calculated for the 98.4-ft (30-m) square cell that well PAW 131 is in (R.B. Moore and others, U.S. Geological Survey, written commun., 2001). Well PAW 420 is within a cell with a 13-percent probability. Variations in probability at the site appear to be caused by proximity to surface water and topography.

Two geophysical survey lines were located to cross lineaments on each side of well PAW 131. Line 1, which extends 440 ft from southwest to northeast, is along the property line of two developed lots and in a vacant lot to the northwest of well PAW 131. Line 2, southeast of PAW 131, is in a channel of Beaver Brook, and extends 440 ft from southwest to northeast. Well PAW 420 was drilled directly adjacent to line 2 at approximately 100 ft along the line. Two array locations were sited on electrically conductive anomalies after a preliminary analysis of other geophysical data; array 1 was set at 215 ft on line 1, array 2 was set at 200 ft on line 2 (fig. 20).

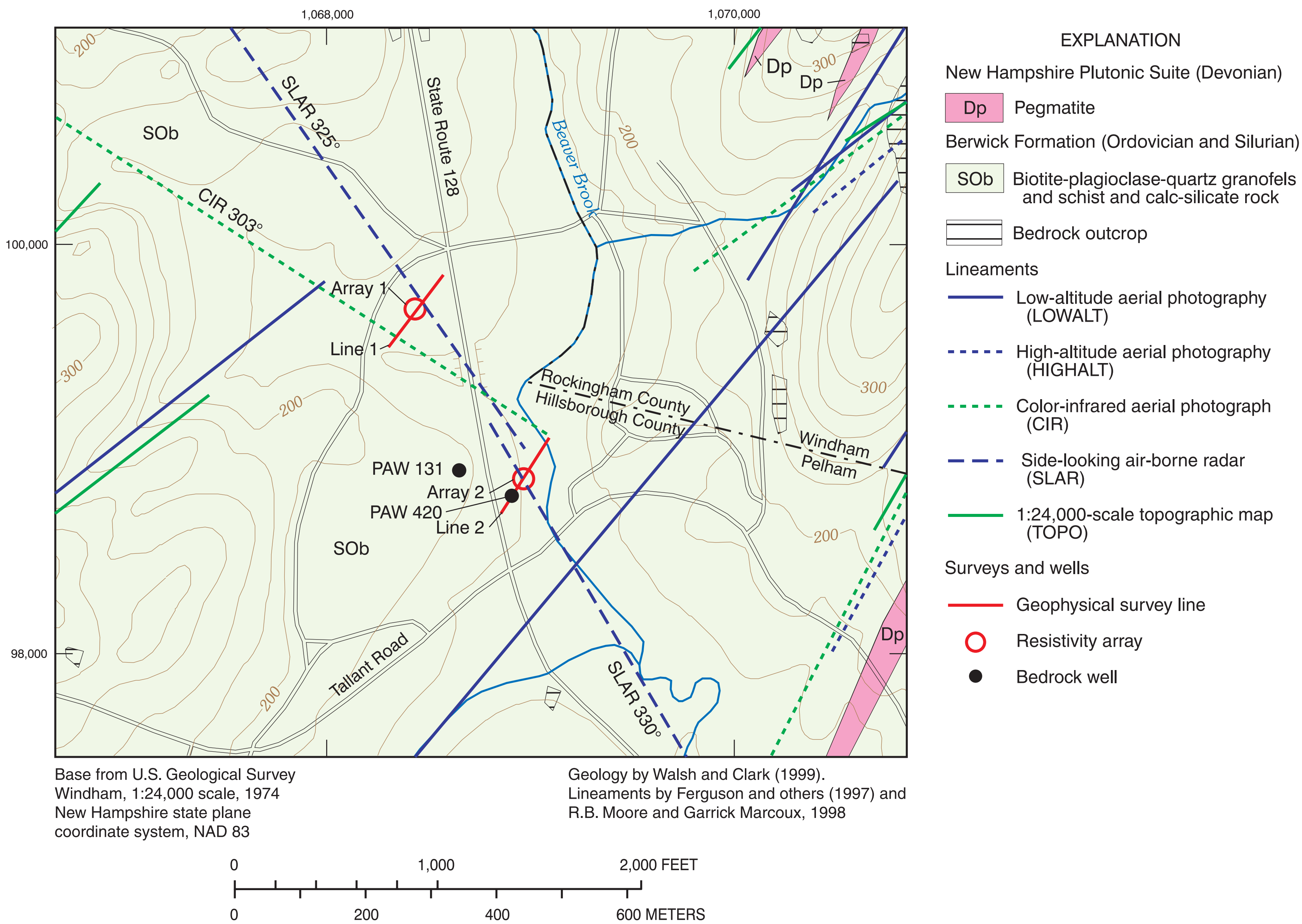

Figure 20. Geophysical survey locations, bedrock geology, and lineaments at site 3, Pelham, N.H. Site location is shown on figure 1.

Geophysical Surveys and Interpretation

Six geophysical surveys were used to characterize site 3. Overburden thickness and physical properties were derived from the GPR, EM, and 2-D resistivity survey results. Bedrock properties were determined by magnetometer, 2-D resistivity, and square-array resistivity. Anomalies that could be caused by bedrock fractures are seen in the magnetometer, VLF, EM, 2-D resistivity and square-array resistivity survey results (figs. 21-25).

GPR data were collected on lines 1 and 2. The GPR record from line 1 indicates bedded sands, with attenuation of the record before the bedrock is detected. Reflectors from the bedded sands dip towards the center of the cross-section. The GPR record from line 2 has a reflector that is interpreted to be the bedrock surface. From 195 to 205 ft along line 2, this reflector drops from 7 to 14 ft in depth, indicating a depression in the bedrock surface. The GPR record did not return any clear reflectors in the bedrock and is not presented in this report.

Magnetometer measurements were made along line 1 and line 2 (figs. 21 and 22). The average magnetic field measure at this site during the surveys is 109 nT. Line 2 survey results indicate anomalous lows of ñ35 nT at 120 ft, and 50 nT at 300 ft (fig. 22a). The steel-well casing at 115 ft along line 2 from well PAW 420 could affect the anomaly at 120 ft, considering the magnetic high just before it along the line.

VLF tilt-angle measurements were made along lines 1 and 2. VLF data from line 1 indicates a weak inflection at 210 ft, but was dominated by power-line noise at its northeastern end (fig. 21b). An anomalous inflection is at 175 ft along line 2 (fig. 22b). The suspected fracture zone orientations at site 2 in relation to the transmitter are not ideal.

EM surveys were collected on lines 1 and 2 at site 3. The survey along line 1 was shortened because of interference from power lines (fig. 21c), and the remaining data may be affected. The EM results from line 2 indicate a near-vertical conductor anomaly at 155 ft along the line (fig. 22c).

2-D resistivity surveys were run at lines 1 and 2. Four primary resistivity units from line 1 and line 2 can be represented by resistive unsaturated and conductive saturated sediments, and resistive competent and conductive fractured bedrock. Below the interpreted bedrock surface at 230 ft along line 1 is a conductive anomaly penetrating into the bedrock. This anomaly was interpreted with an apparent dip to the southwest (fig. 23). Near horizontal conducive

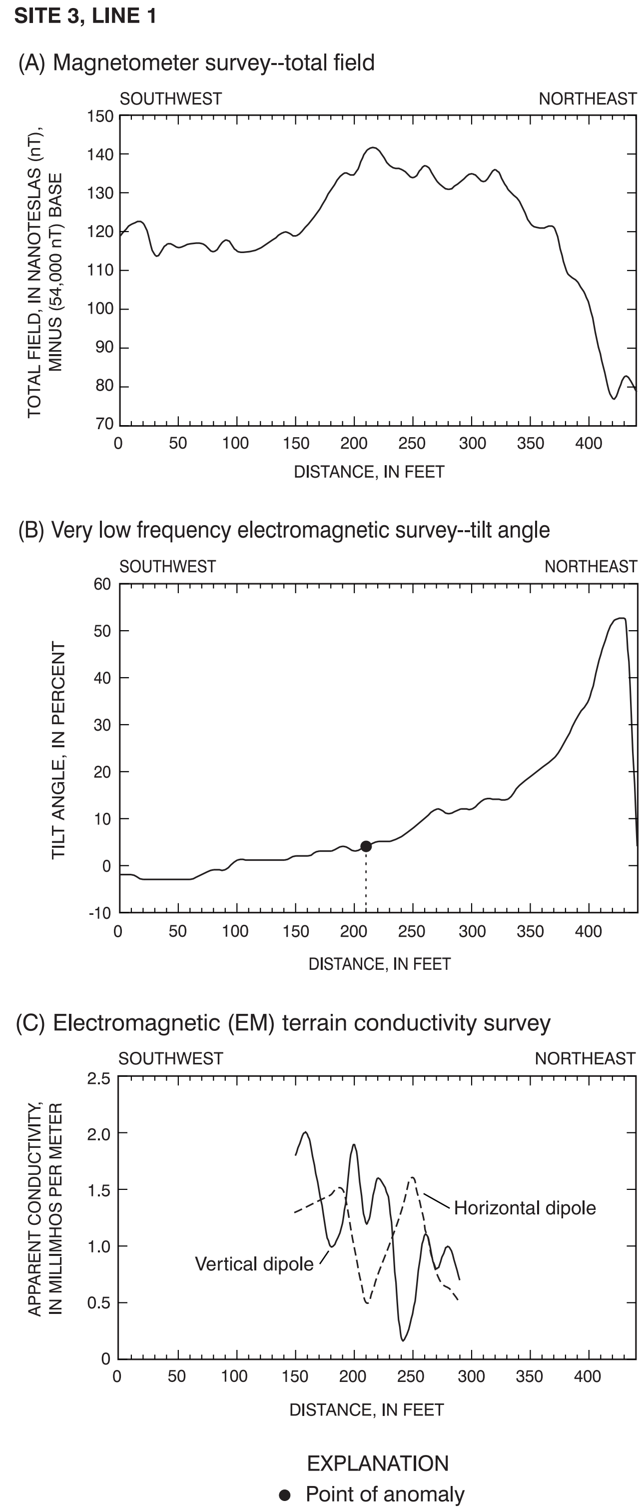

Figure 21. Magnetic and electromagnetic surveys at site 3 from line 1, Pelham, N.H. (A) magnetometer survey; (B) very low frequency (VLF) electromagnetic survey; (C) electromagnetic (EM) terrain conductivity survey with a 20-meter (65.6-foot) coil spacing. Site and line locations are shown on figures 1 and 20, respectively.

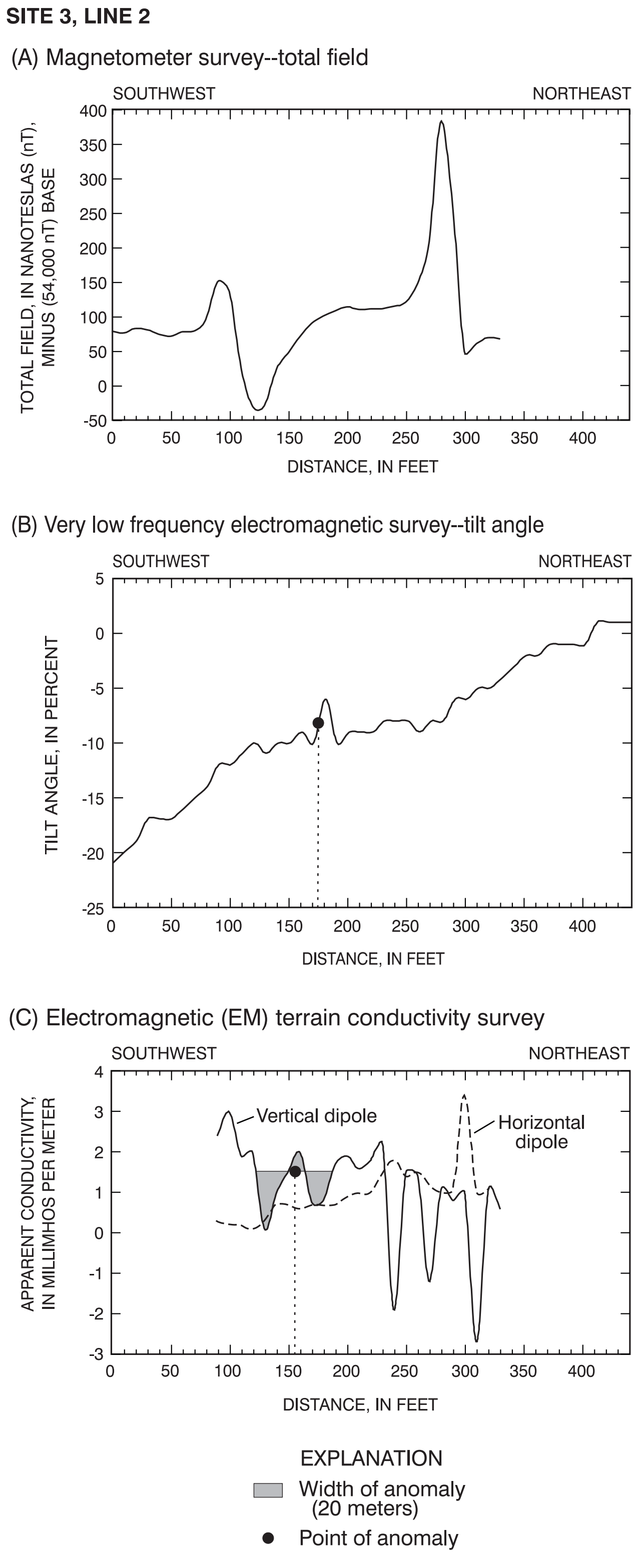

Figure 22. Magnetic and electromagnetic surveys at site 3 from line 2, Pelham, N.H. (A) magnetometer survey; (B) very low frequency (VLF) electromagnetic survey; (C) electromagnetic (EM) terrain conductivity survey with a 20-meter (65.6-foot) coil spacing. Site and line locations are shown on figures 1 and 20, respectively.

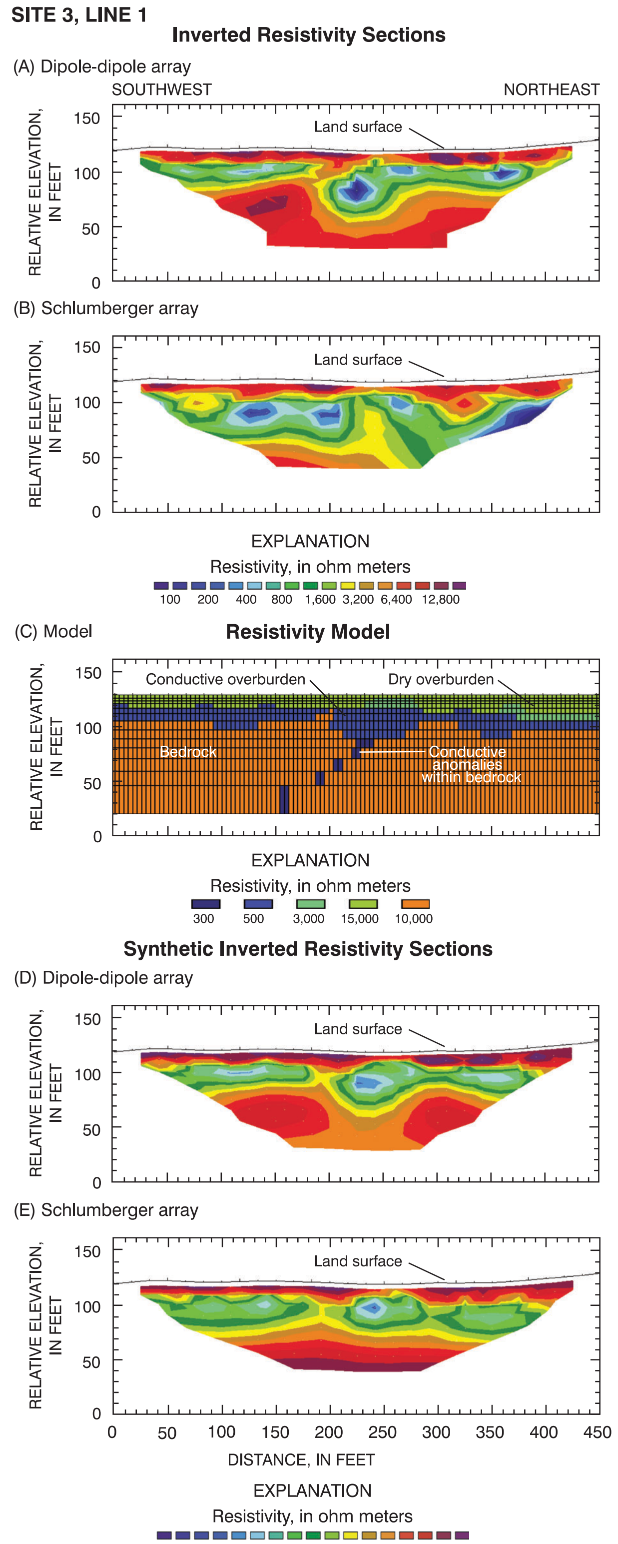

Figure 23. Cross sections showing (A and B) inverted resistivity sections of two-dimensional, direct-current resistivity data at site 3 from line 1, Pelham, N.H.; (C) model based on field data from A and B; and (D and E) synthetic resistivity output data from Model C. Site and line locations are shown on figures 1 and 20, respectively.

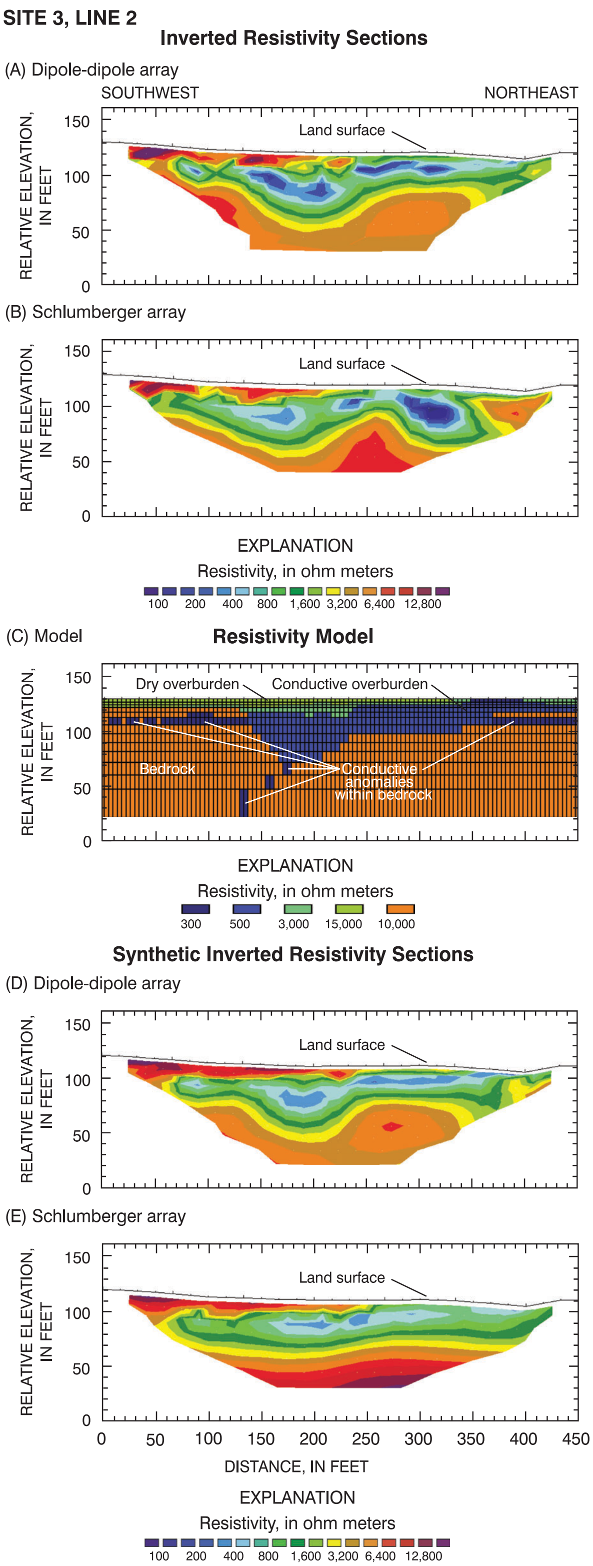

Figure 24. Cross sections showing (A and B) inverted resistivity sections of two-dimensional, direct-current resistivity data at site 3 from line 2, Pelham, N.H.; (C) model based on field data from A and B; and (D and E) synthetic resistivity output data from Model C. Site and line locations are shown on figures 1 and 20, respectively.

features just below the surface of the bedrock could be the reason conductivity is high along line 2. A trough in the bedrock surface and a conductive bedrock anomaly is at 165-205 ft along line 2. The conductive anomaly in the bedrock is interpreted with an apparent dip to the southwest (fig. 24). Square-array resistivity surveys were run at array 1 and array 2 (fig. 25). At the largest A-spacing (10 m) array 1 shows a primary and secondary conductive strike of 345× and 90×, with a low resistivity value at 330×. Measurements made with small A-spacings from array 1 show a decrease in resistivity from the 5-m A-spacing to the 7.1-m A-spacing. This decrease indicates three layers; resistive (unsaturated overburden) at the surface, a conductive middle layer (saturated overburden), to a resistive lower layer (bedrock). At the largest A-spacing (10 m), array 2 results indicate a primary conductive strike of 15× and a secondary strike of 330(fig. 25).

Integration of Results

A 2-D resistivity and VLF anomaly are at about 210 ft on line 1. Line 2 has a conductive southwest-dipping 2-D resistivity anomaly in bedrock that is bounded at the surface of the bedrock by a VLF anomaly at 175 ft and an EM anomaly at 155 ft along the line. A magnetic low coincides with the bottom the modeled 2-D resistivity conductive feature at 120 ft.

Conductive strikes from square-array resistivity surveys with the same orientation as fractures identified in outcrops, or remotely sensed lineaments, likely are related to fracture zones. The secondary conductive strike from array 2 square-array resistivity results of 330× has the same orientation as the SLAR lineaments that cross lines 1 and 2, and corresponds the analysis of geologic-fracture data. Array 1 does not have a graphically determined primary or secondary conductive strike matching the lineaments, but the resistivity low for the largest A-spacing at 330does match.

Electromagnetic (EM or VLF) and 2-D resistivity surveys indicate electrically conductive anomalies that are consistent with the presence of fractured bedrock along lines 1 and 2. These surveys indicate that the 325× and 330× striking lineaments detected with SLAR are electrically conductive and could be steeply dipping features. These features may represent water bearing fractured-bedrock zones.