DELINEATION OF AQUIFER GEOMETRIES, CONNECTICUT VALLEY, MASSACHUSETTS

Faculty

Robert Burger, Smith
Timothy Vick, Carleton

Students

Robert Andrews, Wooster
Rowland Cromwell, Carleton
Lawrence Meckel, Williams
Todd Reichart, Franklin and Marshall
Sis Tiernan, Smith

DELINEATION OF AQUIFER GEOMETRIES, CONNECTICUT VALLEY, MASSACHUSETTS, USING GEOPHYSICAL TECHNIQUES

H. Robert Burger
Department of Geology
Smith College
Northampton MA 01063

Our groundwater supplies are becoming increasingly contaminated due to improper disposal of hazardous wastes, unwise irrigation practices, leakage of storage facilities housing toxic chemicals, high septic system densities, and myriad other uniformed or criminal practices. This increasingly serious situation demands detailed knowledge of the shallow subsurface both for preventative and remedial measures. In the majority of instances the only cost-effective method in defining aquifer and aquitard geometries is geophysical. Fortunately, this requirement for greater knowledge of the shallow subsurface coincides with a leap in the price/performance ratio of geophysical equipment and the advent of personal computers with significant computing capabilities. Nowhere have these trends had greater impact than in seismic exploration.

Seismic refraction has been the method of choice in the past for shallow subsurface investigations, especially for determining the depth to the water table and the bedrock surface. As the refraction method is based on first arrival times at a number of source-geophone distances, only relatively simple analog equipment is required and little, if any, computer capability is necessary. Clearly, this method has the advantage of being relatively inexpensive because of equipment requirements, but it also supports good determination of seismic velocities and is a fairly quick way to determine depths to interfaces with substantial velocity contrasts. Unfortunately, if the target interface is at substantial depth (e.g. 100 meters in shallow work), long geophone spread lengths are required as are large explosive charges. In many areas, either or both may be impossible. Also, the refraction approach assumes that velocities increase with depth. While this often is the case in shallow work, it is not always so. Depending on the relationship between unit thicknesses and seismic velocities, some layers may not be "seen" (the blind zone or hidden layer problem). Finally, most routine refraction work simply does not map detailed structure (Fig. 1), either in terms of relief on surfaces or in terms of information between major interfaces.

Seismic reflection has long been used by petroleum companies for exploration purposes but only recently has this method been applied to any extent to the shallow subsurface. Presently, with the noted improvements in geophysical equipment and personal computers, reflection surveying is becoming the method of choice. Field techniques have improved as well (Fig. 2). The reflection method uses the full waveform at each geophone, not just the first arrival, and is very dependent on the transmission of high frequency energy. It thus has the disadvantage of requiring more sophisticated equipment than the refraction method, and, since the data must be processed by computer, the equipment must have digital recording capabilities. Thus, costs are higher. Other disadvantages of this method include the fact that it is a poor way to determine seismic velocities and, as it is so dependent on high frequency energy transmission, its usefulness is very site dependent. The advantages of the reflection method are many. It requires quite short geophone spread lengths and small energy sources in order to penetrate to depths of at least 100 meters. Reflections can map very irregular topography on subsurface horizons and can resolve detailed structure between major seismic interfaces (Fig. 3). No problem exists if low velocity layers are present nor is there a "hidden layer" problem. The detailed subsurface information revealed by the reflection method makes it suitable not only for groundwater studies but for many other uses as well.

Electrical resistivity studies have not been transformed to the same extent as seismic investigations. Computer processing, however, has changed what was once a very time-consuming and tedious chore to one much less so. Historically, resistivity work often has been coordinated with refraction investigations in order to definitively resolve subsurface relationships. However, due to the relatively generalized geology provided by refraction techniques, correlations between resistivity and seismic information often was difficult. The detail offered by reflection work suggests that some past difficulties may be overcome by careful design of the field survey.

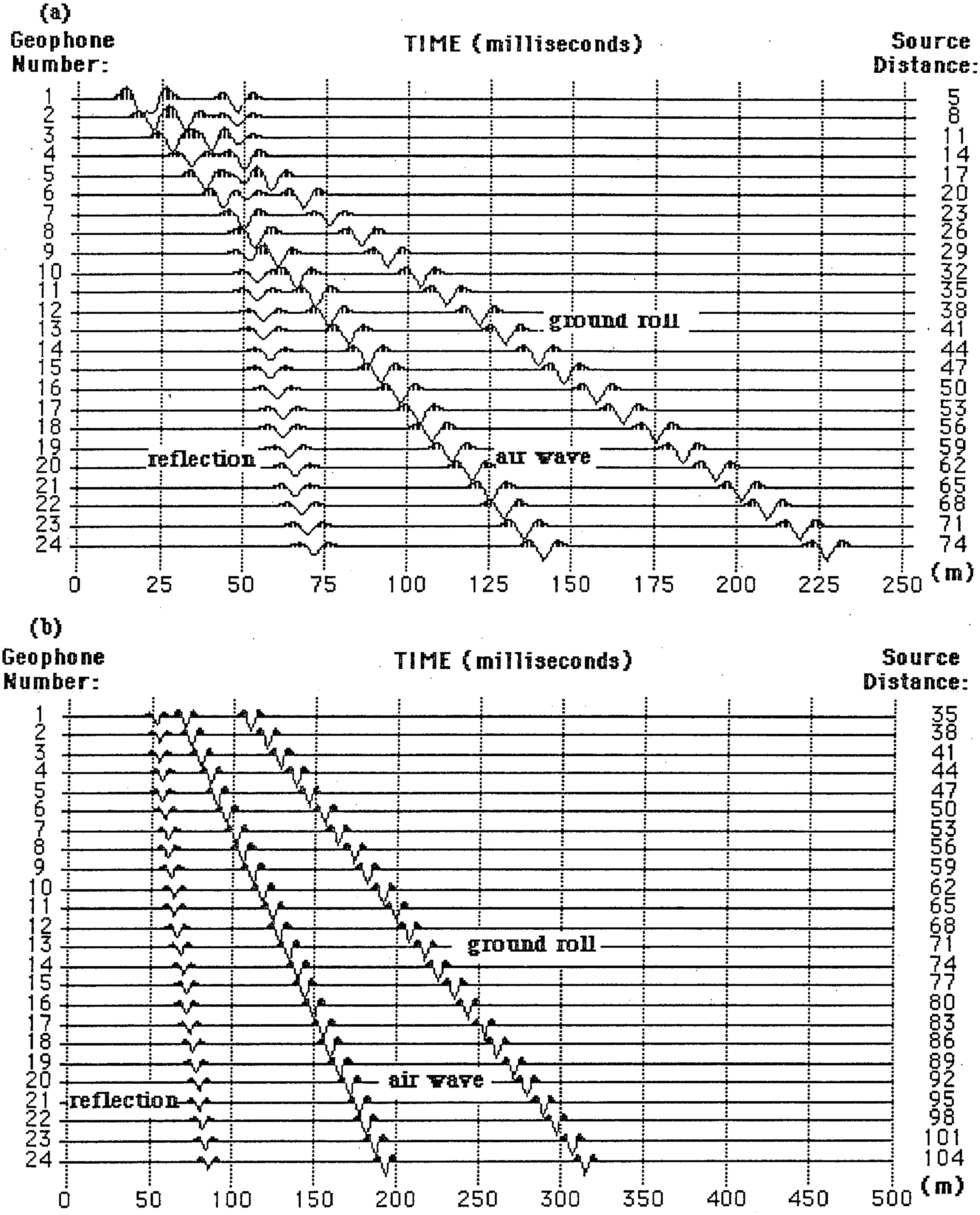

Figure 2. Illustration of the importance of determining proper shot offset in reflection surveying. In (a) the offset is 5 meters and early reflection arrivals are obscured by the air wave and ground roll. In (b) the offset is increased to 35 meters, and the reflection is more clearly defined.

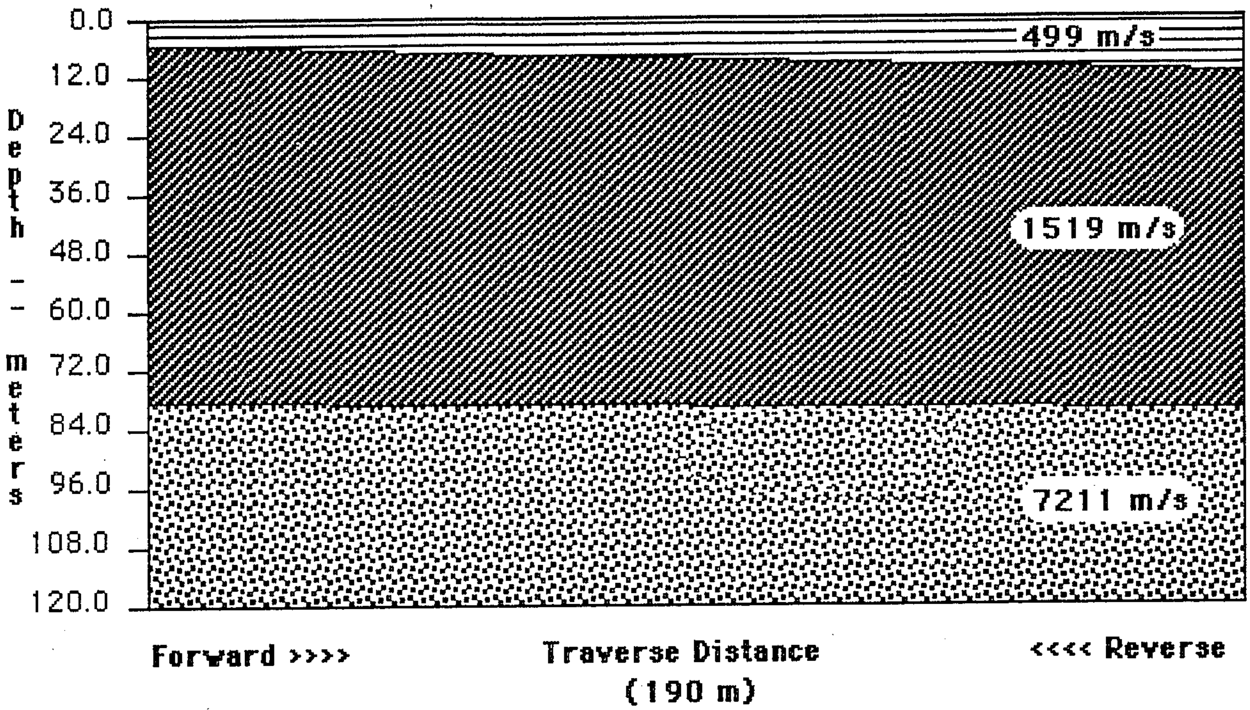

Figure 1. Typical result of a refraction survey. Although major layer thicknesses and velocities are determined, no detailed information is available. Compare with Figure 3.

The Connecticut Valley of western Massachusetts is ideal for research into the applicability of these techniques for various groundwater studies. Alluvial deposits are exposed at the surface on the floodplain of the Connecticut River. These are underlain by Pleistocene deltaic sands and gravels, dune sands, lake clays, and tills. The Pleistocene deposits rest on bedrock (mostly arkosic sandstones of the New Haven Formation) which varies in depth from 0 to 100 meters and often has substantial relief. Many local communities depend on groundwater supplies for a significant percentage of their total water consumption. Both confined and unconfined aquifers are present, and various levels of contamination exist in both.

During August, 1988, the Keck Massachusetts Geophysics Project selected the goal of determining the applicability of various combinations of seismic and resisitvity methods to groundwater studies. During the first week of the project the participants acquired the necessary geophysical background in each of the methods to be employed. Because of equipment and time limitations, two research parties were formed: a resistivity group headed by Timothy Vick of Carleton College and a seismic group headed by Robert Burger of Smith College. Resistivity group projects included a detailed study of water table elevations as determined by Schlumberger and Wenner electrode configurations (Robert Andrews, College of Wooster) and a detailed comparison of resistivity and refraction methods (Todd Reichart, Franklin and Marshall College). Both seismic projects focused on a comparison of refraction and reflection studies at sites with varying geology (Rowland Cromwell, Carleton College, and Lawrence Meckel, Williams College). A fifth project (W.T. Tiernan, Smith College) served as connector between the resistivity and seismic groups and attempted to correlate the refraction, reflection, and resistivity results. The results of each of these projects is reported elsewhere in this volume.

The Geophysics Project is grateful to the Keck Foundation for the funding which supported this field work and which partially supported the development of computer programs to assist project participants in data analysis.

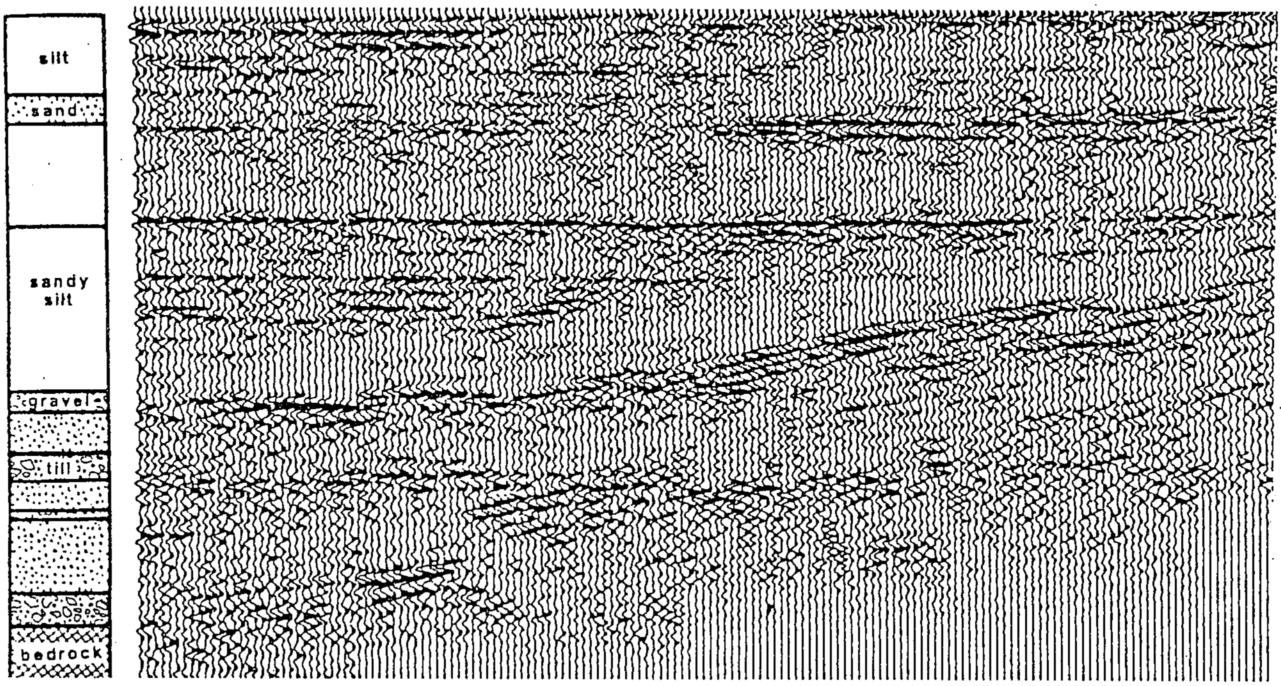

Figure 3. Shallow reflection record obtained by common offset technique (courtesy James Hunter and Susan Pullan, Canadian Geological Survey).