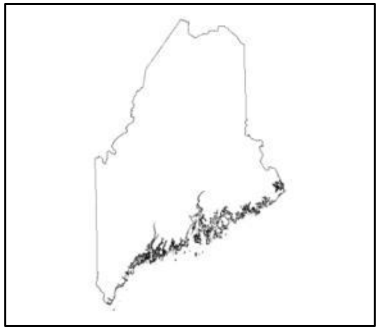
Geologic Site of the Month

March, 2004

Seismic Refraction Profiling: An important tool used in mapping sand and gravel aquifers



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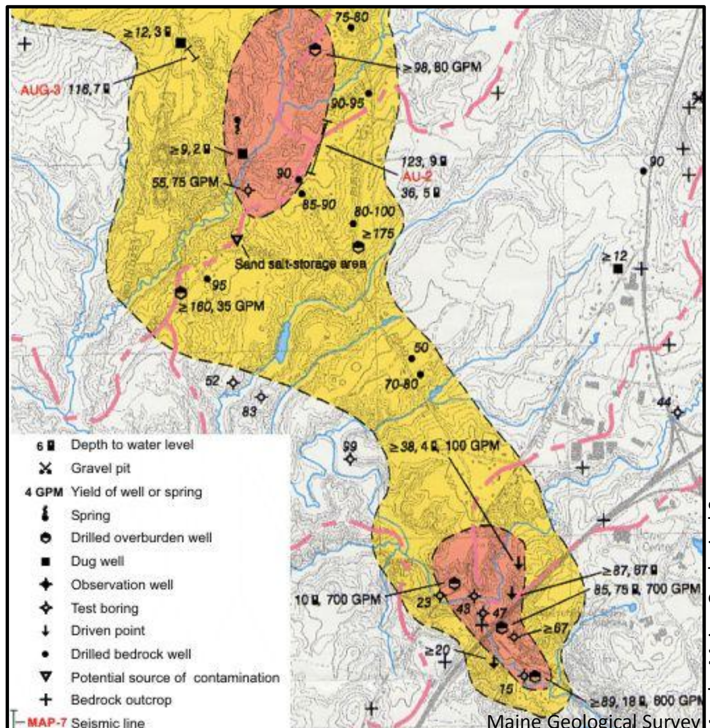
Introduction

The Maine Geological Survey (MGS) in cooperation with the United States Geological Survey (USGS), and the Maine Department of Environmental Protection (MDEP) has been mapping Maine's sand and gravel aquifers since 1978 and has been utilizing seismic refraction techniques since 1981. The process of mapping sand and gravel aquifers and refining their boundaries involves the collection and compilation of many types of data. Typically, if the area has been previously mapped, we start with the existing surficial and aquifer map data and look for areas where additional data is needed. If an area has never been mapped, we conduct a more comprehensive information collection effort. While in the field, we collect stratigraphic information from and note the locations of surficial deposit exposures found in gravel pits as well as stream and river cut exposures. When visiting the pits, we note if the excavation has advanced below the water table. We also note the locations of bedrock outcroppings, springs and spring yield, municipal water supply wells, and potential sources of contamination such as sand-salt storage facilities, petroleum bulk storage tanks, municipal wastewater treatment facilities, closed and open landfills, large manure piles, sludge spreading sites, and documented hazardous waste sites. From 1981 to 1997 observation well drilling and water quality sampling was also conducted.

In the office, we collect and compile bedrock well information from the State's bedrock well database, test drilling and test pit information from contamination and development sites found in MDEP and Land Use Regulation Commission (LURC) files, bridge and roadway borings from Maine Department of Transportation (MDOT) files, borings associated with dams from dam owners, and well logs from the Maine Department of Human Services (MDHS) public water supply data base. We also examine aerial photographs and topographic maps, as well as existing soil survey maps, in order to better understand the landforms and soil parent material.

Mapping Aquifers

In addition to all of this data collection and compilation, we conduct seismic refraction surveys in order to provide greater subsurface detail, particularly in areas where there are no well or test borings. Since many of the areas where we work are remote and subsurface information simply does not exist, these surveys provide the only subsurface information from which to identify the aquifers and aid in the delineation of aquifer boundaries.



Map by Maine Geological Survey

Figure 1. Section of the Maine Geological Survey Sand and Gravel Aquifer Map for the Augusta quadrangle illustrating many of the types of data used in delineating sand and gravel aquifers.

Mapping Aquifers

Also, since seismic refraction profiling is significantly more cost-effective than drilling test borings, it provides the geologist a very important tool in the identification and characterization of sand and gravel aquifers. Figures 1 and 2 shows the types of data that we collect and portray on our aquifer and materials maps.

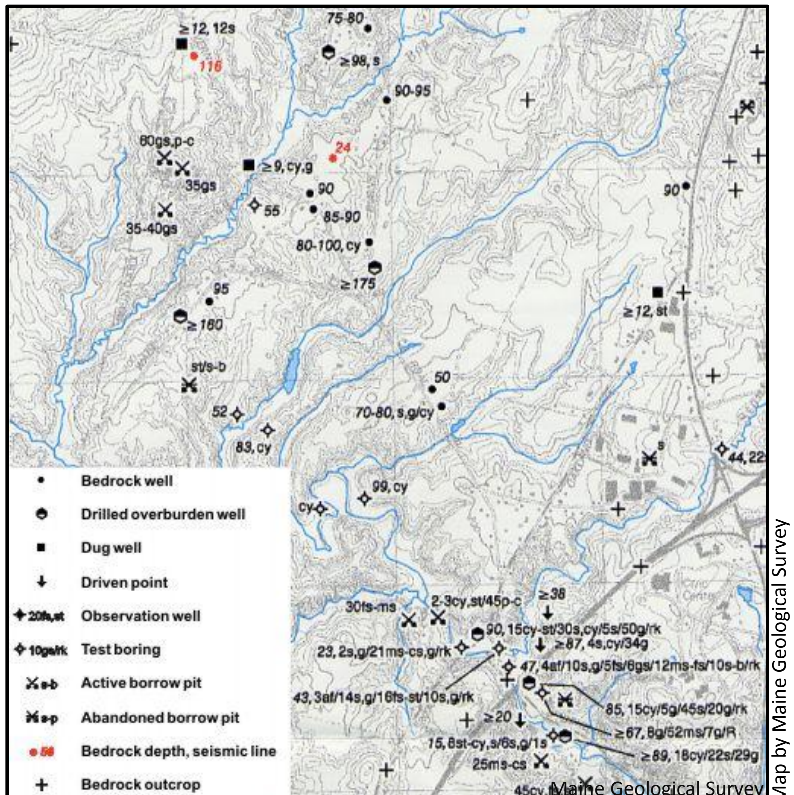
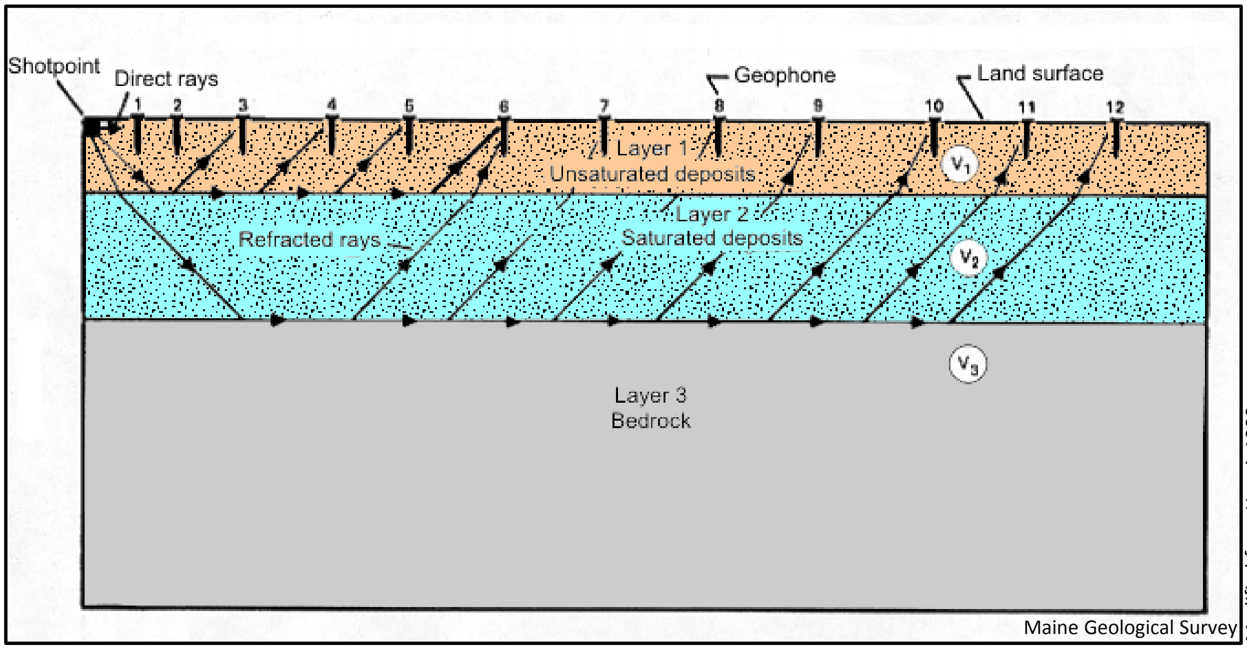


Figure 2. Section of the Maine Geological Survey Surficial Materials Map for the Augusta quadrangle illustrating pit descriptions as well as other data used for delineating sand and gravel aquifers.

Seismic Refraction Profiling

Seismic refraction is a geophysical technique used to determine the thickness of underlying geologic strata, depth to the water table, and bedrock surfaces. Seismic refraction methods use sound waves to determine the thickness and extent of aquifer materials. A prerequisite for success of this technique is that each major successive underlying geologic layer must increase in density as well as thickness (Figure 3 illustrates this requirement).



Modified from Haeni, 1988

Figure 3. Illustration of the transmission of seismic energy through the subsurface. In order for seismic refraction to be successful, the thickness and density and velocity must increase with depth. Unsaturated sand and gravel commonly has seismic velocities of about 1500 feet/second whereas water-saturated sand and gravel is typically around 5000 feet/second and bedrock has velocities of 10,000 feet/second or greater.

Seismic Refraction Methods

The principle of seismic refraction is founded on the fact that sound waves travel through different earth materials such as dry (unsaturated) sand and gravel, wet (saturated) sand and gravel, and bedrock at different velocities. The denser the material, the faster the waves travel.

Photo from Maine Geological Survey

Figure 4. Set up for seismic refraction where seismic waves are generated by hitting a metal plate with a hammer.

Seismic Refraction Methods

These seismic waves can be generated by hitting a metal plate with a hammer (Figures 4 - 5), dropping a heavy weight, or by the detonation of buried explosive charges (Figures 6 - 7).

Photo from Maine Geological Survey

Figure 5. Generation of seismic waves by hitting a metal plate with a hammer.

Seismic Refraction Methods

Energy from these sound waves is transmitted through the ground by elastic waves. These waves are referred to as elastic because as they pass though the geologic formation, particles are momentarily distorted, but immediately return to their original position after the wave passes. Types of waves that can be created include compressional waves, shear waves, and surface waves.

Photos from Maine Geological Survey

Figure 6. (Left) Portable drill used for drilling shot holes. (Right) Explosives used as a sound source.

Seismic Refraction Methods

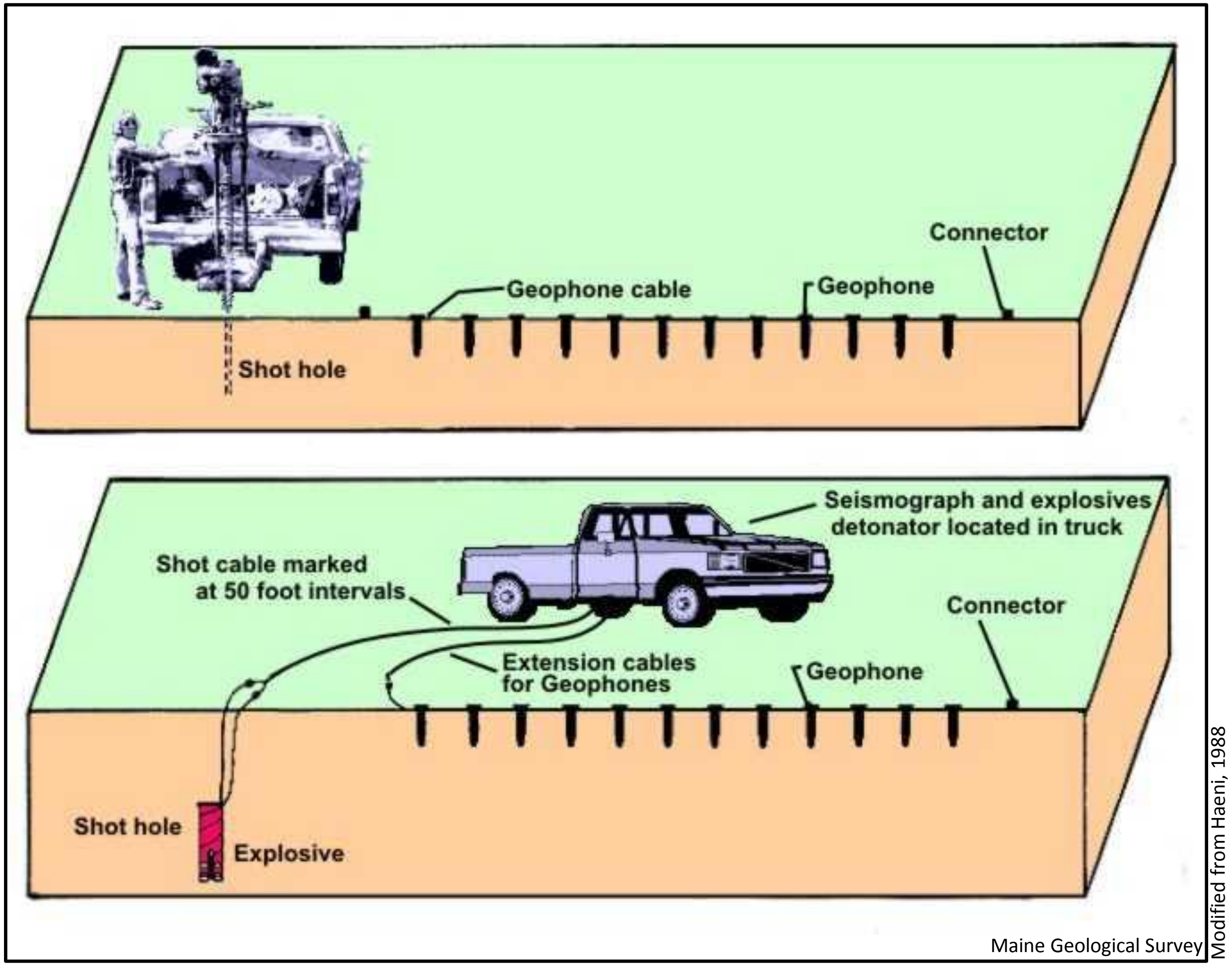


Figure 7. Field setup of seismic truck, geophones, and shot hole.

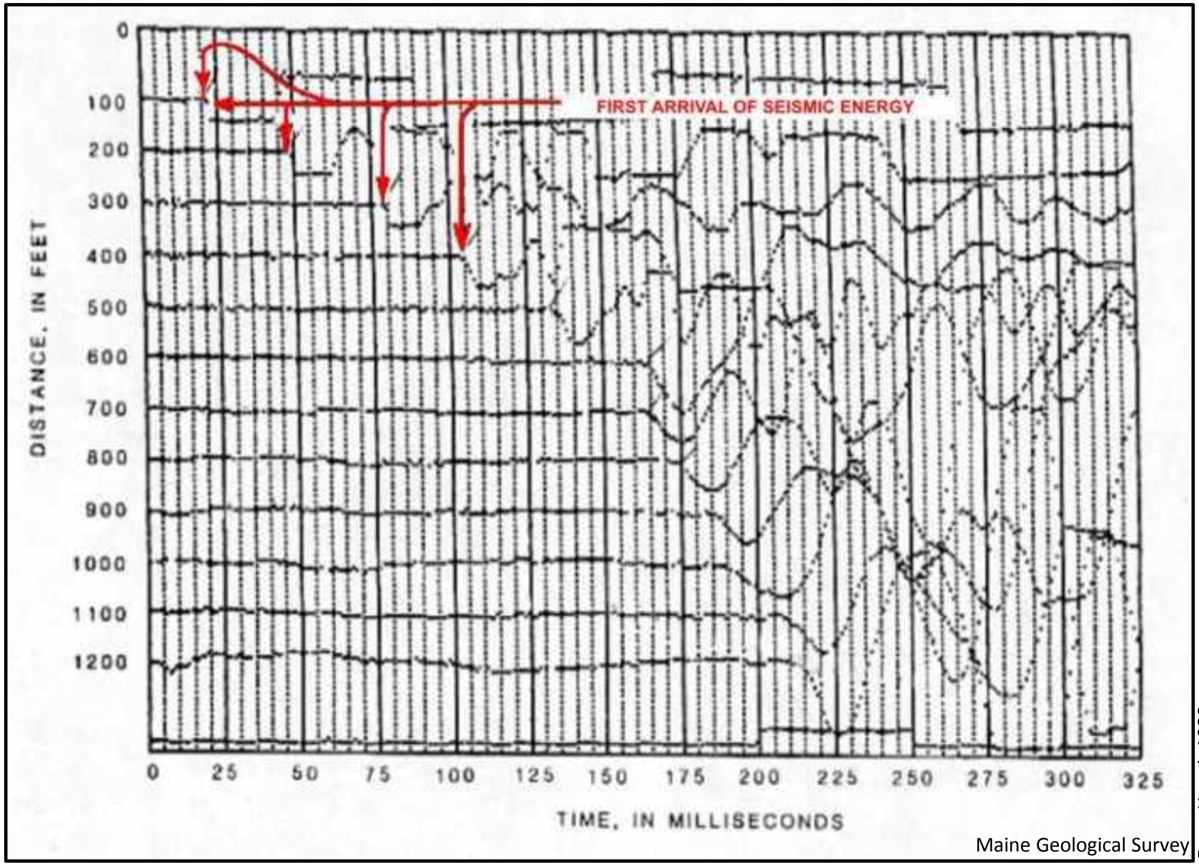
Seismic Refraction Methods

The arrival of a seismic wave is detected by geophones, or motion sensitive earth sensors, which are placed firmly in the ground (Figure 8).

Figure 8. (Left) Setting a geophone in the ground. (Right) Close up of geophone.

Seismic Refraction Data

Compressional waves are the first to arrive at the geophones and consequently are of the most use in seismic refraction surveys (Figure 9).



From Haeni, 1988

Figure 9. Twelve-channel digital seismograph record from Little Androscoggin River valley, Maine, showing sharp first breaks produced by an explosive sound source in an area with low background noise.

Seismic Refraction Data

Typically, the higher the density and elasticity of the earth material, the faster the transmission of the compressional wave. Conversely, the velocity of compressional waves is quickly dissipated in dry, unconsolidated sediments thus providing a lower velocity. This relationship is illustrated in Figure 3. During a seismic refraction survey, the seismograph measures the time the seismic wave takes to reach one or more geophones placed at known distances from the sound source (Figure 10).

Figure 10. (Left) A seismic survey technician adjusts the trace sizes of the record in order to more accurately identify the first arrival times. (Right) A close-up view of the seismic refraction survey record.

Seismic Refraction Results

By plotting the first arrival times of the shock waves arriving at the individual geophones placed along the survey line and making corrections for elevational differences as well as any offsets to the line, it is possible to infer a profile of the land surface, water table surface, and bedrock surface (Figures 11 - 12).

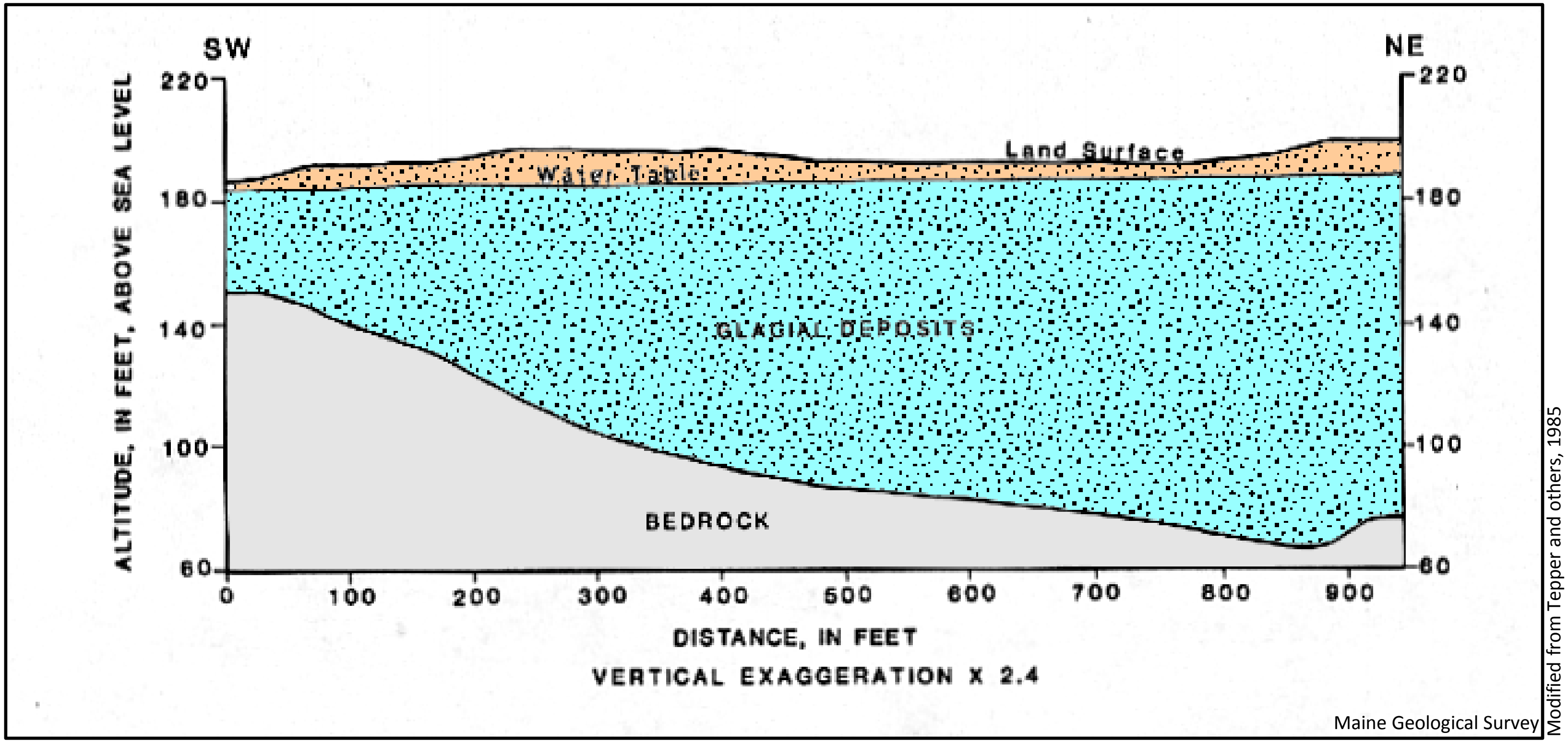


Figure 11. LineAU-2 - Augusta 7.5' quadrangle. Line of section in field on east side of Mt. Vernon Road, 0.3 miles north of the intersection with Burns Road, in Augusta.

Seismic Refraction Results

These interpreted cross-sections are made with the aid of a computer program which allows for numerous calculations as certain inputs are adjusted.

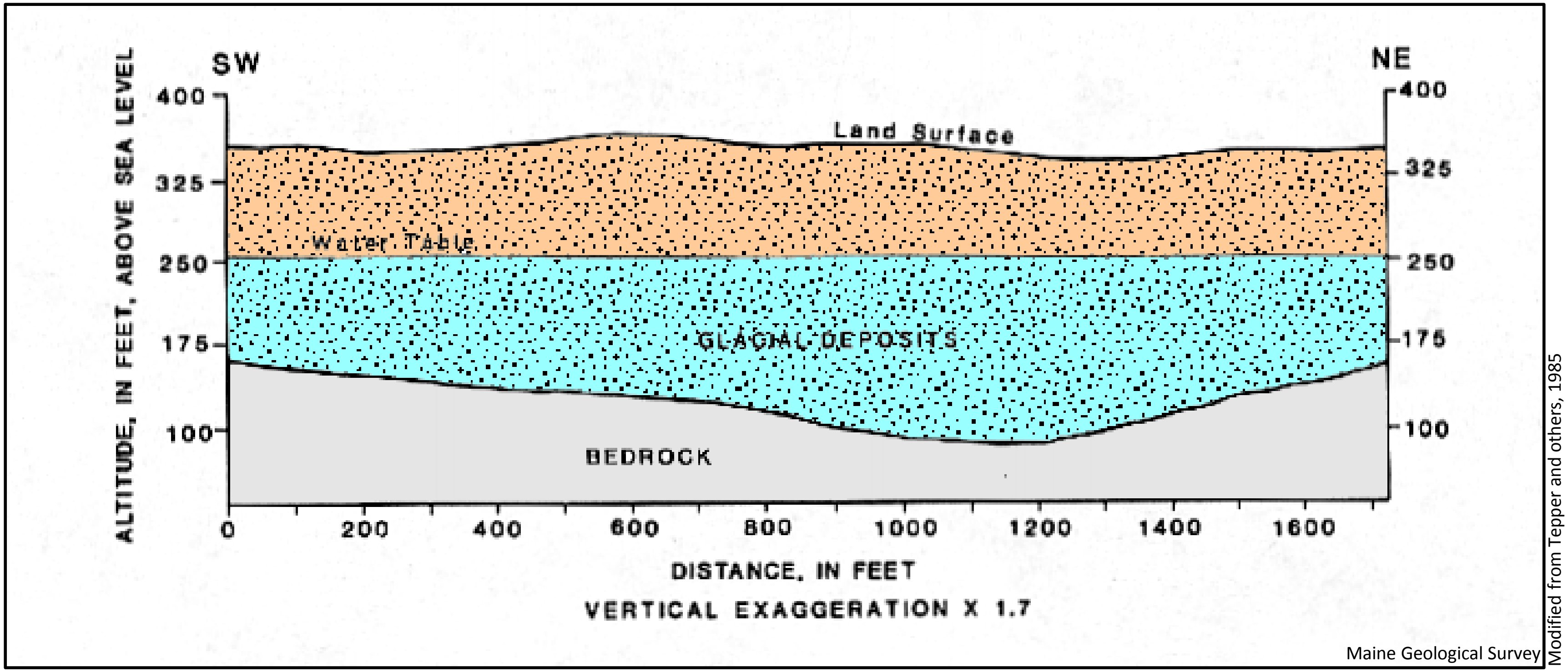


Figure 12. Line AU-4/5 - Augusta 7.5' quadrangle. Line of section on Belgrade Road, 0.25 miles north of the intersection with Mt. Vernon Road, in Manchester.

References and Additional Information

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Application of Surface Geophysics to Ground-water Investigations

Application of Seismic-Refraction Techniques to Hydrologic Studies