salt water absorbs more radar energy than fresh water. Transmissive zones are identified by comparing tomographic data collected before the tracer test with data collected after tracer injection.

Radar tomography was used to monitor a saline tracer test in sedimentary rocks at Belvidere, Ill. (Lane and others, 1998). After two hydraulically conductive zones were identified using borehole geophysical logs, flowmeter logs, and straddle-packer testing, a saline tracer was injected into one of the permeable zones. The use of attenuation-difference tomography showed an increase in attenuation in the image plane after the saline-tracer injection that propagated between the boreholes with time (fig. 4).

Mirror Lake, New Hampshire

Attenuation-difference tomography can be used to monitor the movement of saline tracers through fractures across the plane between boreholes by using suitable tracer-injection and radar-acquisition procedures. Time-lapse, attenuation-difference tomography methods were developed at the U.S. Geological Survey Fractured Rock Hydrology Test Site, Mirror Lake, New Hampshire to monitor saline tracer tests in fractured rocks (Lane, Haeni, Placzek, and Wright, 1996; Lane and others, 1999). Because the time required to acquire a single radar-tomography survey is generally longer than the time required to achieve tracer breakthrough and peak-concentration arrival at the pumped borehole, multiple tracer injections were used to capture the movement of the tracer across the image plane.

The borehole arrangement and data-acquisition procedure used for the experiment are shown in figures 5 and 6. A series of time-lapse images that track the movement of the saline tracer through fractures that cross the image plane are shown in figure 7. Measured radar-attenuation differences correspond closely with the chloride concentration at the pumped well (fig. 8).

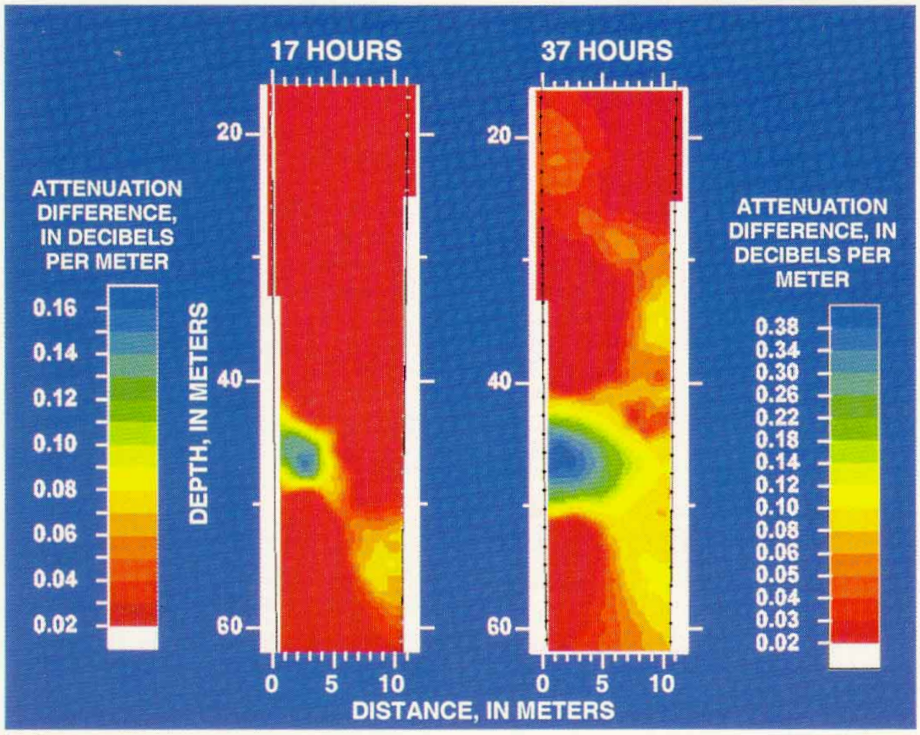

Figure 4. Sixty-megahertz borehole-radar attenuation-difference tomograms collected between two boreholes, Belvidere, Illinois.

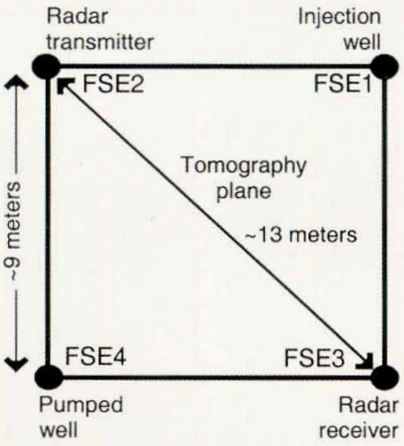

Figure 5. Plan view of FSE1 to FSE4 borehole cluster, FSE well field, Mirror Lake, Grafton County, New Hampshire.

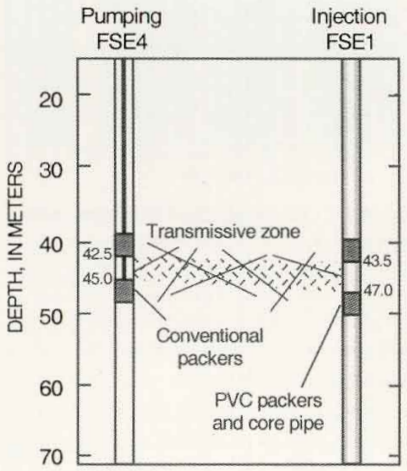

Figure 6. Arrangement of polyvinyl chloride (PVC) and conventional straddle packers in boreholes FSE1 and FSE4, Mirror Lake, Grafton County, New Hampshire.

Loring, Maine

Borehole-radar methods were integrated with surface-geophysical surveys and other borehole-geophysical logging at a site in Loring, Maine to monitor the effects of blast fracturing an on-site recovery trench in a fractured limestone aquifer that was contaminated by petroleum products (Lane, Haeni, Soloyanis,