FIRECRACKERS FOR SHALLOW SEISMIC SURVEYS

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INTRODUCTION

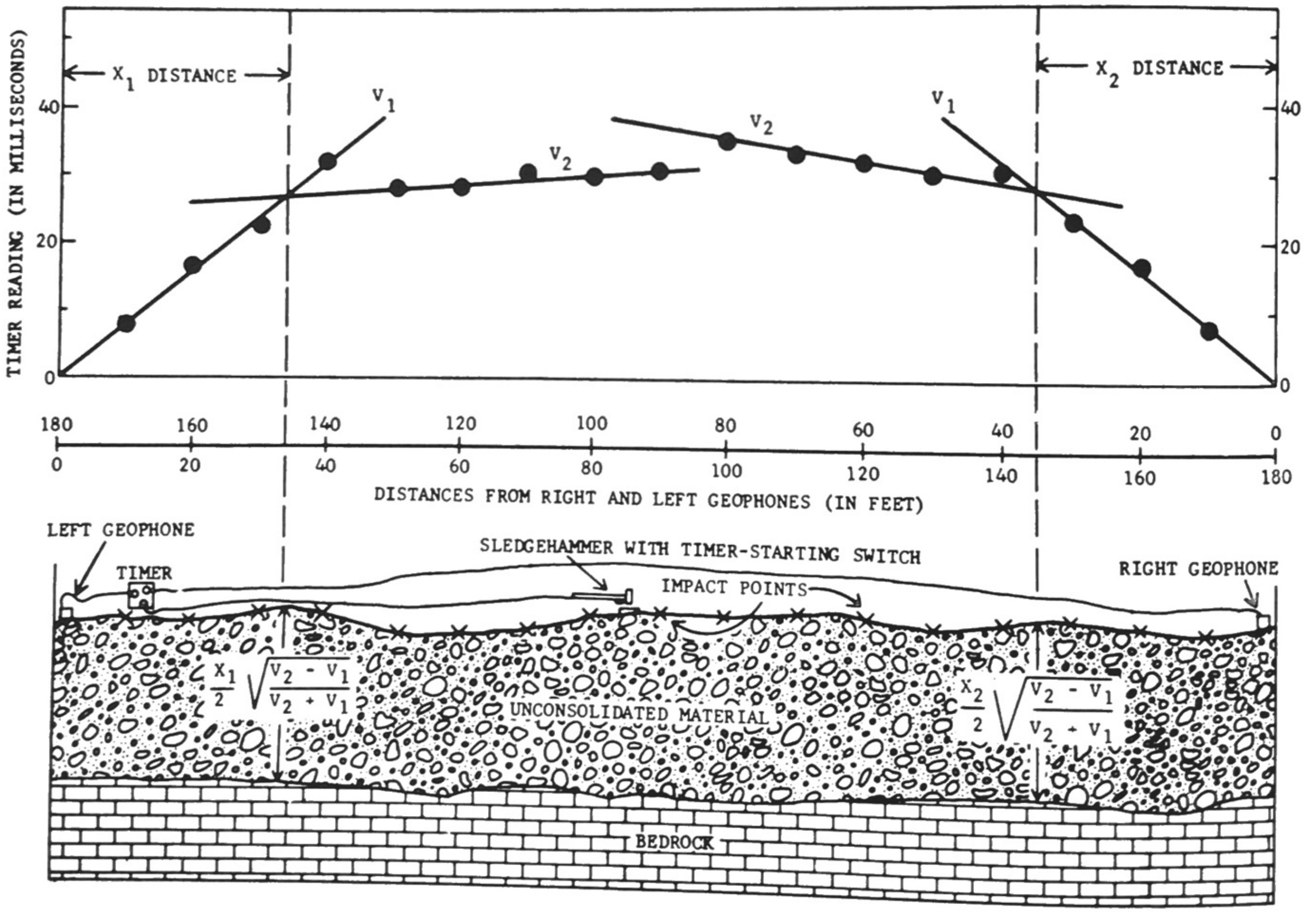
The seismic method of determining bedrock and formational-contact depths and density of the materials is still one of the most reliable and widely used methods known. However, the high cost of surveying small areas was prohibitive in many instances until the advent of the portable "Seismic timer." One project of the U.S. Geological Survey in Tennessee is a water-resources study of such an area—too large to drill to bedrock for sufficient control—and control was to be obtained by use of the seismic timer. Failure to obtain accurate results with the "Thumper" led to the use of firecrackers as a source of the shock wave.

THE PROBLEM

One of the problems of this project was to obtain sufficient control by seismic surveying to delineate and map the bedrock surface. Bedrock crops out along the brows of some of the low hills in the long narrow Trace Creek Basin, Humphreys County, Tennessee, and generally deepens toward the creek to about 30 feet below land surface in the central valley. Subsurface "gorges" (breaks or depressions) in the bedrock, as much as 300 feet wide and ranging from 40 to more than 100 feet deep, presumably extend across the Trace Creek valley. The gorges are believed to be aligned with the tributaries to Trace Creek, although there may not be a gorge for every stream entering the creek. The bedrock gorges have no surface expression and are filled with layered silt, siltstone, clay, sand, gravel, and chert of Mississippian age.

It is believed that some water in Trace Creek and in the shallow or water-table aquifer moves downward through the permeable material in the bedrock gorges, enters a deeper aquifer, and at some places probably moves laterally out of the basin area. The problem of locating the gorges and apparent areas of water loss by seismic surveying led to the modification of the instrument and surveying method after several false answers were obtained with the "Thumper."

[1] The author believes that when writing for publication one should consider most people in professions other than his own to be lay readers. So, with this in mind, pen in hand, and, at times, tongue in cheek this paper was written. A paper of similar content was orally presented by the author at the Geological Society of America Conference in Nashville, Tenn. April 8-10, 1965.



A TYPICAL "THUMPER" SEISMIC SURVEY, PLOT OF RESULTANT DATA, AND DEPTH TO BEDROCK COMPUTATIONS.

Figure 1

Seismic Surveying with the "Thumper"

The "Thumper" operation is simple. An electronic clock or timer is the central part of the instrument. A sledgehammer, equipped with a timer-starter switch, is used to create a shock wave at a point on the ground and start the timer with the same blow. Two geophones are used, alternately, to stop the timer—generally the geophone stops the timer when it receives a sufficiently heavy shock Generally, several sledgehammer blows at each 10-foot interval along a survey line are necessary to determine the shock-wave travel-time from each point to each geophone. An arithmetic plot of travel-time versus distance indicates shock-wave velocities in the subsurface materials from which depth to formational contacts can be computed (figure 1). The first curve V_1, indicates the velocity of the shock wave in shallower material and indirectly the density of the material. V_2 is the velocity in the second or deeper layer of more dense material. The depth to the second layer can be computed by the formula shown on figure 1.

Lines to be surveyed with the "Thumper" were selected at several locations in the project area where ground- and surface-water sections were to be measured and where geology and topography are favorable for possible bedrock gorges. Surveying was started and, at best, three men rotating the hammering at 10-foot intervals and 10 blows per point could cover about 1,000 feet per day. In two weeks we had almost completely incapacitated two engineers, three geologists, two engineering aids, and a local day-laborer who lasted four hours.

The data collected appeared to be valid and bedrock determinations seemed reasonable, although shallower than expected, but no gorges in the bedrock were indicated by the seismic surveying. During and generally following the seismic survey several holes were augered to check the survey results, collect geologic information, and construct observation wells in suitable holes in the area. Augering proved that the seismic survey results depicted only the water table and very shallow formational contacts, not the bedrock. All the data collected were proven useless for determinations of bedrock-depth. It is believed that the shock waves generated by the sledgehammer blows were too weak to reach bedrock in the area at depths greater than five feet. Background "noise" caused by air, road, and rail traffic throughout the basin required a low instrument-sensitivity setting and may have been partly the cause of inaccurate results. Whatever the cause, it was certain that stronger shock waves would be necessary to complete a successful survey.

Trial and Error Search for a Shock Source

Several other shock producing devices were tried, including anchor-bolt-projectile guns. None were successful. Fireworks were considered, at first satirically then seriously when other methods failed, and in the end appeared to be the best, reasonably safe method of generating a suitable shock wave.

The first trial use of fireworks consisted of exploding several sizes of firecrackers as they are normally used by the young—and not so young—celebrants on July 4th. Firecrackers containing one gram of black powder were satisfactory up to 700 feet. Three-gram firecrackers were used at the 800- and 900-foot distances. Tests proved that firecrackers would generate a shock wave that could be detected by the geophone at low sensitivity settings over a conveniently long survey line.

However, another problem had to be solved—that of starting the seismic timer at the exact time of the firecracker explosion or start of the shock wave. The timer-starting switch was taped to a heavy steel plate, and the plate was placed over the firecracker before it was exploded. The first shot started the timer and the shock created stopped the timer; however, the shot apparently damaged the starting switch and further tests were not made.

The final test employed the dynamite-cap exploder and a small low-power electrical detonator or cap, called a squib. The squib normally is used to ignite fireworks displays and it was believed that it would function equally as well to explode firecrackers. Furthermore, it is reported to be safe, requiring no more care in handling than an ordinary match. Testing proved that the instrument exploder would fire the squib and start the timer simultaneously.

Field Surveying Tests

About 50 charges were prepared for the first survey line of a field test. These charges were made of M-80 salutes by removing the fuses and inserting a squib in each (figure 2). Collodion, fingernail polish, glue,

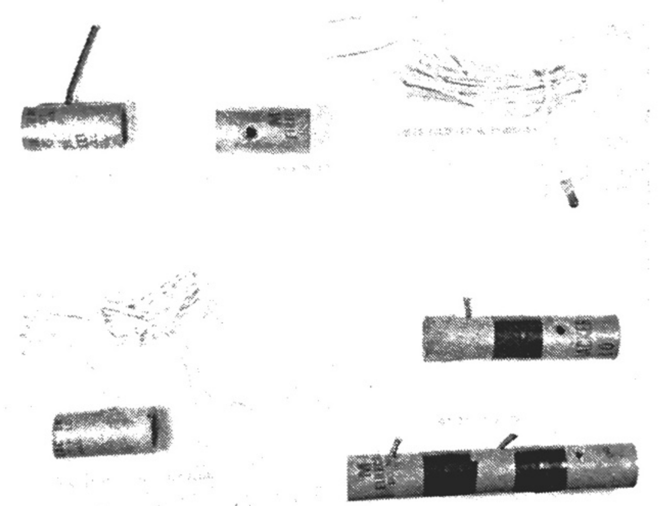
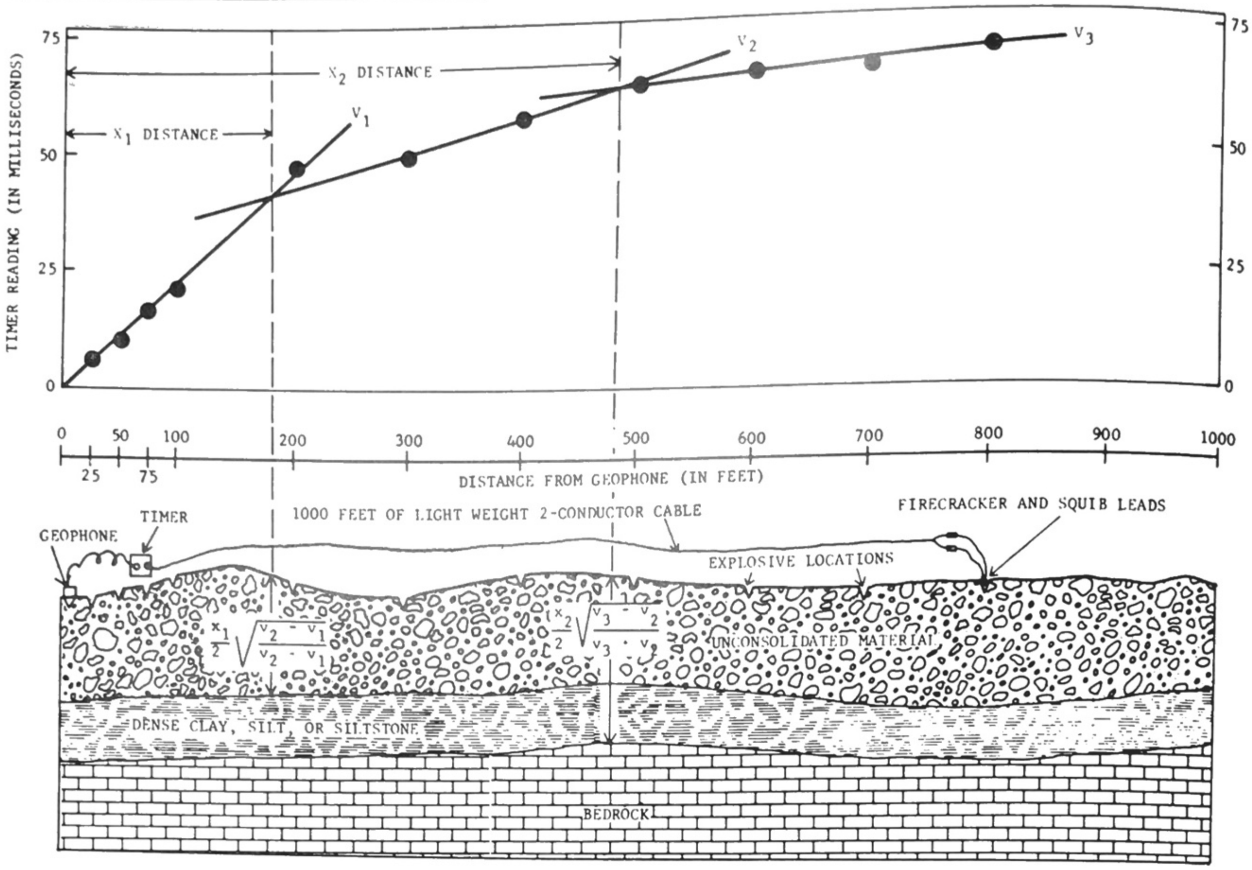


Figure 2.—Converting the M-80 firecracker for seismic surveying, using a low-power electrical detonator.

or putty and masking or electrical insulating tape were used to secure the squib in place and to prevent loss of powder and absorption of moisture from the ground when buried. Where heavier charges were needed, one or more salutes (without a squib) were taped to an



A MODIFIED "THUMPER" SURVEY USING EXPLOSIVES AND ONE GEOPHONE, A PLOT OF THE RESULTANT DATA, AND SAMPLE COMPUTATIONS OF DEPTH TO PROGRESSIVELY DENSE MATERIALS.

Figure 3

armed salute; the number of salutes generally depending on the distance from a geophone. One squib will explode as many firecrackers as may be taped together.

An east-west survey line was selected near an observation well that had been augered to bedrock. The survey was conducted in the manner outlined in the instrument manual for the sledgehammer method, with one exception. Distances between shots were generally greater than the distance interval for the sledgehammer method. Two geophones were used, one at each end of the survey line. The length of the line was limited mainly by the available footage of coaxial cable necessary for geophone connections to the timer. Firecrackers were placed in holes in the ground punched with a crowbar and loose material was tamped in the hole over them; care was used to prevent damage to the squib leads extending out of the hole. On completion of the east-west survey line bedrock was computed to be 64 feet at a point 200 feet east of the observation well. The augered depth to bedrock at the observation well is 63 feet.

This method, using two geophones, was not entirely satisfactory because considerable time was spent in laying down 500 feet or more of heavy 2-conductor coaxial cable between the geophones. Extra lengths of coaxial cable at about $0.50 per foot could run the cost of a survey to the prohibitive level.

The next survey line (figure 3) was conducted by using one geophone connected to the timer with only 15 feet of coaxial cable and about 1,000 feet of very inexpensive lightweight twin-conductor thermostat cable connected to the exploder. The other end of the lightweight cable was connected to the charges as surveying progressed from 10 to about 900 feet from the geophone. This modification greatly accelerated surveying speed, precluded the need for expensive coaxial cable except for one short geophone lead, and reduced the weight and bulk of equipment to be moved along a continuing survey line or to another location.

Conclusions and Suggestions

The results of the forementioned tests indicate that the firecracker method of seismic surveying with a modified "Thumper" provides more reliable data, requires less manpower, is faster, and will survey greater depths than is possible with the sledgehammer method. The explosives used are moderately safe, although extreme care was (and should be) exercised while handling all explosives. Further modification to the single geophone method appears to be another distinct advantage because of the reduction in weight to be moved and elimination of the necessity for moving to the opposite end of the survey line until charges are fired.

The M-80 salutes cost about $3.00 per hundred and squibs about $25.00 per hundred. Larger orders placed with manufacturers probably would afford considerable savings.

It was learned after seismic surveying was concluded that the electronic clock or seismic timer is started by a simple "make and break," normally open or normally closed switch. The opening of a closed switch or closing of an open switch connected to the starter outlet on the instrument will start the seismic timer. This discovery led to the following suggested procedure. If the lightweight twin-conductor cable is connected directly to the starter outlet of the seismic timer and the other ends to a loop of fine-gauge wire which has been inserted in a firecracker, then the explosion of the firecracker will break the fine wire, acting as a switch to start the timer, and creating a shock wave at the same time. The dynamite-cap exploder and the squib would not be needed. Once the timer is started only the geophone will stop it. The firecracker, of course, would be exploded by a burning fuse instead of a squib, which would afford a saving of about $0.25 per shot. The one disadvantage in this method is that longer fuses would be required for firecrackers buried more than a few inches in the ground. Since this paper was prepared an agent of an explosives company called to say that he will have a very inexpensive detonator in early 1965 that will replace the squib. The use of a detonator probably will be the better method than the fine-gauge, wire-loop method.

The usefulness of the several other portable seismic instruments on the market probably can be enhanced by the use of firecrackers. At least one other instrument appears to be ideally suited to their use, although it was not actually tested. It is also recognized that there are probably better methods of preparing charges than those used here. Emphasis was placed on completing the survey, not on finding a better firecracker or less expensive detonator.

It is hoped that enough interest has been generated to start a development movement that will eventually make your portable seismic surveying instrument a more valuable geophysical tool.