THREE-DIMENSIONAL VELOCITY LOG IN GROUNDWATER

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INTRODUCTION

The "Three Dimensional" or "3-D" velocity log was developed in the late 1950's. The 3-D velocity logs initial application was in rock mechanic studies associated with dam construction, tunnels and canals, and for foundation studies.

The mineral and petroleum industry found the 3-D velocity log to be an excellent tool for cement bonding evaluation, rock porosities, fracture locations, and gas and water contact zones.

PRINCIPLE CONCEPT

The 3-D velocity logging system utilizes transmitting and receiving transducers placed at a known distance from each other as shown in Figure 1. The transmitter generates pulses of 22 microseconds in width at rate of 20 times per second. The receiving transducer detects any pressure waves reaching it in a borehole and converts these pressure waves to electric signals which are transmitted to the surface recording equipment. The total wave train, including pressure, shear, and boundary waves, can be displayed as a variable density by a specially designed camera.

APPLICATION IN GROUNDWATER STUDIES

The 3-D velocity log was used on the Nevada Test Site, starting in the late 1960's. Its use was for rock mechanic studies but the application for hydrogeological studies became apparent.

The single most intensive application for the 3-D velocity log was in the Tucson and Avra Valley basins. Starting in September, 1972, over two hundred exploration testholes and production wells have been logged by various geophysical borehole tools, including the 3-D velocity log.

The 3-D velocity log proved to be the best geophysical tool for groundwater studies for the economical benefits derived.

FEATURE BENEFITS

1. Top of the static water level. The first signals to be recorded will be in the unconsolidated saturated alluvial aquifers. In many areas, the depth of the water table is unknown and errors are made on these assumptions.

2. Perched water table. Has been used for contaminated groundwater studies from mine tailing ponds and infiltration studies.

3. Applicable to large diameter holes. Has been used in large reverse rotary holes of greater than 30 inches. The majority of other borehole geophysical tools are limited to a maximum of 18 inches.

4. Feasible in small exploration holes. Has been used in small NX type holes where again, the size of most other tools makes it impractical.

5. Total porosity. The 3-D velocity logs are borehole compensated, so that the true velocity matrix of the formation can be determined. All of the other borehole tools are affected by dulling conditions and borehole environment. This single condition has caused many water wells to be designed improperly due to erroneous interpretation.

6. Determine the type of material the formation consists of. This is helpful in determining the accuracy of the borehole cuttings as to the relationship of the percent of clay vs. sand and gravel.

7. Lithology. Has been able to correlate as far as six miles with 3-D velocity logs in an alluvial valley (Figure 2). This alone has done more for the advancement of groundwater technology than other borehole logs. Prior to the use of this log, the general feeling was that no meaningful correlation could be done beyond a short distance.

8. Fractures. It is the only tool beside a calipher log that determines accurately the fracture pattern in a borehole. This has proven to be valuable in semi to consolidated conglomerates, sandstone and other hardrock formation, where groundwater is produced.

9. Subsidence studies. Computer programs can compute the corrected compressional and shear wave velocities from the 3-D velocity log and the density log.

10. Non-radioactive tool. This reduced the high risk normally associated with radioactive tools. In some states, radioactive tools cannot be used in shallow groundwater studies.

COST SAVING BENEFITS

In addition to the above feature benefits, the cost saving derived from 3-D velocity logs are many.

1. Minimizes the need for other borehole logs. In new areas, where borehole logs are few or scarce, other borehole logs should be run, if economically feasible, to determine more accurately the quantity and quality of the water in storage. Once an area has these logs and the 3-D velocity log can be correlated over a vast area, then the need for other logs is greatly reduced.

2. Design of the water well. The 3-D velocity log has helped pay for itself by determining the depth to the hydrological bedrock where no additional water can be obtained economically. The majority of groundwater wells in the southwest, today, are dulled or deepened beyond an economical return of capital investment.

3. Screen setting is maximized. Groundwater wells have used 1/3 to 1/2 the previous amount of footage of screen necessary when using 3-D velocity logs as tool selection. This is especially important in large deep deposits of alluvial material where the best production zones can be determined. In massive sandstone, consolidated rock and conglomerate formations, the fractures can be screened only.

4. Enhances the exploration program. More areas can be covered than previously possible with the exploration program. Also gives a new direction to the use of a testhole.

5. Continuous objective record.

LIMITATIONS OF THE 3-D VELOCITY LOG

The majority of limitations for the 3-D velocity log are not applicable to groundwater studies, such as the maximum temperature cannot exceed 121°C. The limitations that are applied are:

1. Water filled holes.

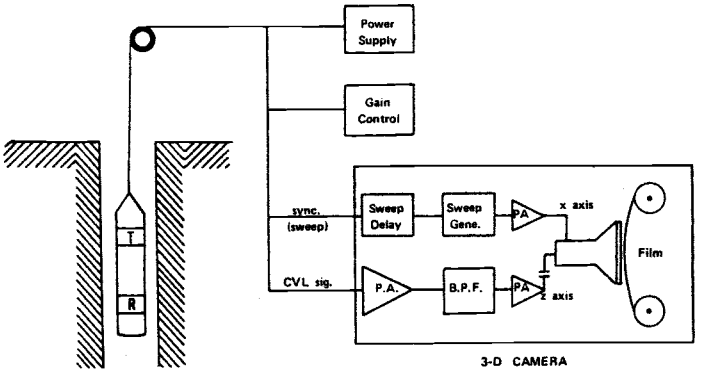
2. Run with centralizers.

3. Must be an open hole. It can be used in cased holes for cement bond evaluation and in some of older cable tool driven wells.

The biggest major limitation at this time is interpretation. Very few groundwater specialists and logging company engineers know how to interpret it as well as other borehole logs. This paper is one of the first on the 3-D velocity log as a groundwater tool.

SUMMARY

Over the past seven years, the success of the Tucson project resulted in more groundwater wells being logged. In other alluvial basins in the southwest, much of it was due to the success of the 3-D velocity log. Today some 100 wells alone have been logged, although this is a small percentage of wells being drilled today.



(a) MEASURING SYSTEM

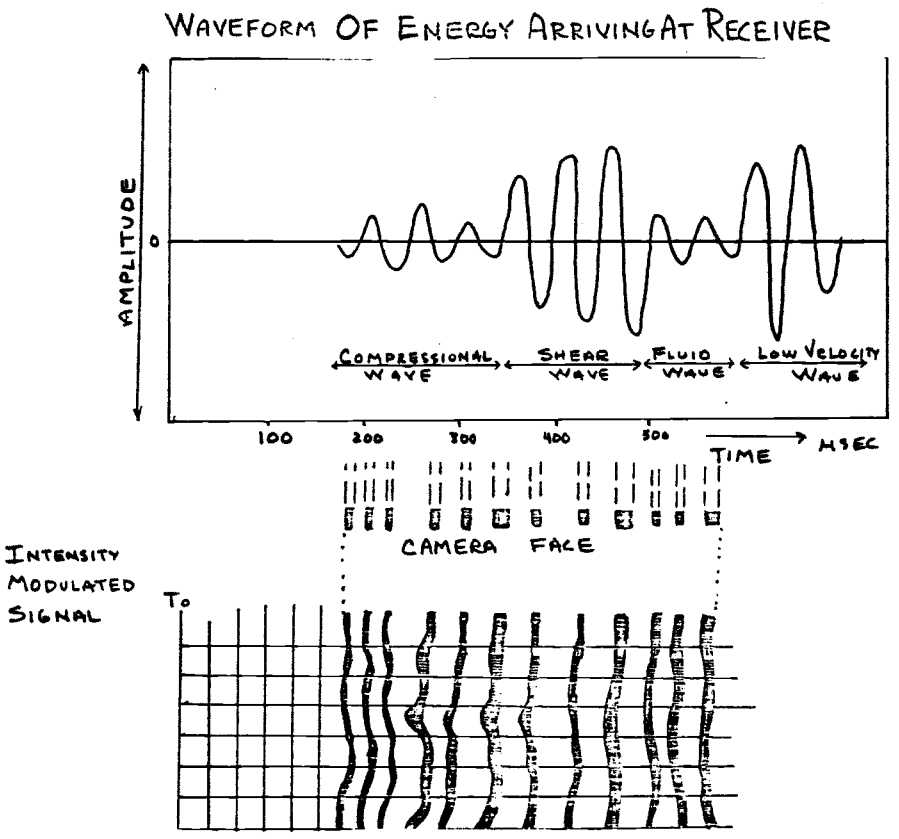
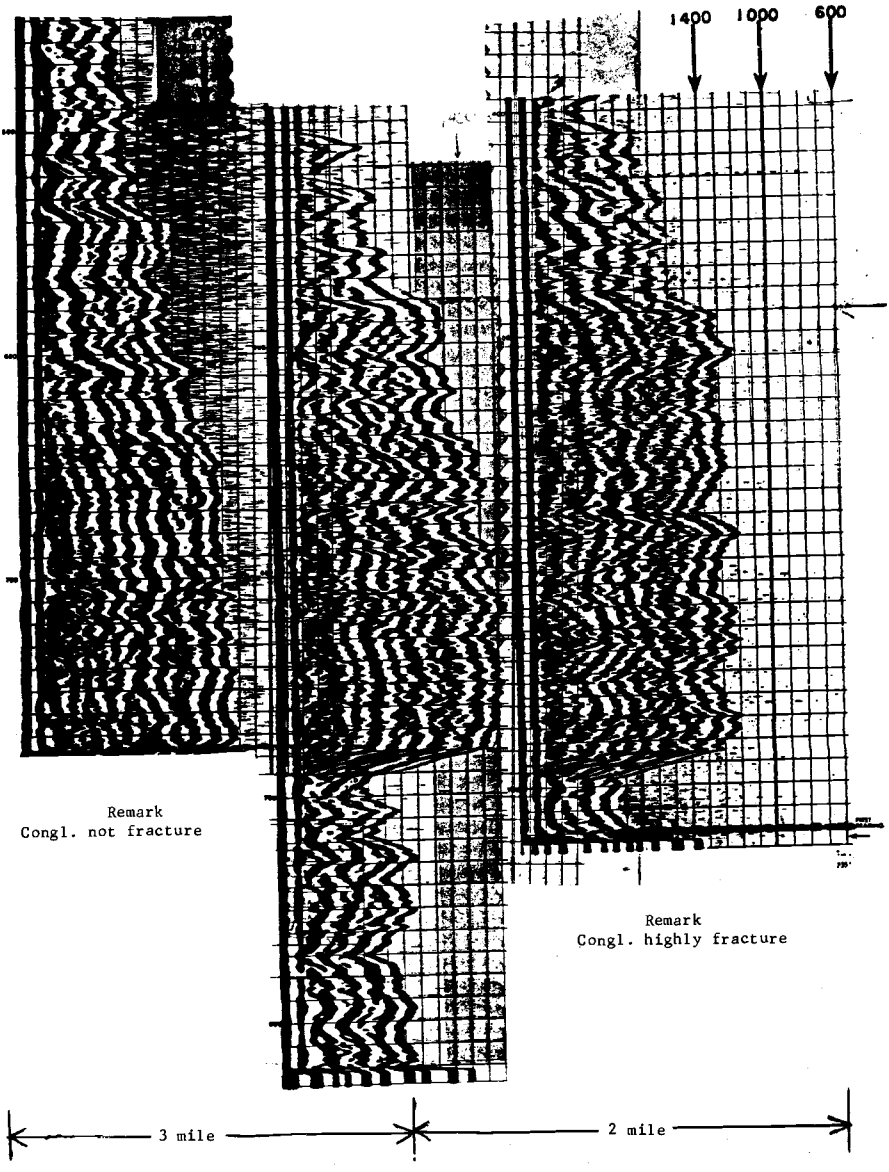


Figure 1. Principle Concept of 3-D Velocity Log



Well No.	D.V.10	D.V. 9	D.V.10
SWL	530 ft.	480 ft.	490
GPM	500	800	800
0.0	95 ft.	66 ft.	15
Spec. Cap.	5.3	12.1	52.2
Upper alluvial	sandy clay	sandy gravel	none
Conglomerate	630-780	545-680	430-685
Mud stone	780-790	680-830	685-735

Figure 2. Deer Valley Well Field, Phoenix, Ariz.
3-D Velocity Logs

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