UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Technical Letter
Dribble-11
December 7, 1961

Federal Center, Denver 25, Colorado

Mr. James E. Reeves
Assistant Manager for Test Operations
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Dear Mr. Reeves:

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TECHNICAL LETTER: DRIBBLE-11

VELOCITY FUNCTIONS COMPUTED FROM WELL GEOPHONE
SURVEYS WITHIN A 25-MILE RADIUS OF TATUM
SALT DOME, LAMAR COUNTY, MISSISSIPPI.

By

R. A. Black and D. F. Balsinger

December 7, 1961

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Additional copies have been distributed as indicated below.

Sincerely yours,

W. S. Twenhofel

W. S. Twenhofel
Program Supervisor, Dribble
Special Projects Branch

Enclosures

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By

R. A. Black and D. F. Balsinger

Tatum salt dome, Lamar County, Mississippi is the proposed site for a series of experiments, code name Dribble, in the Vela Uniform program for improving the detection of underground nuclear explosions. An analysis has been made of all well geophone velocity surveys in wells near Tatum Dome (fig. 1) to determine the vertical velocity function that best fits the observed times at each well. The results are presented in this technical letter. These velocity functions provide a part of the knowledge of seismic velocities of the rocks surrounding Tatum Dome that is required to interpret seismic measurements that will be made during the Dribble tests.

The well velocity data have been furnished by various oil companies with the understanding that the data will be treated as "Company Confidential" and will not be published or otherwise disseminated in total or in part to the general public or to any individual or organization not directly involved in the Vela Uniform program.

An interpretation of data from a seismic reflection survey over Tatum Dome has been made to determine if the dome is large enough for the proposed series of experiments, and to assist in the selection of the most suitable

sites for the proposed tests. The results of this interpretation have been presented in U. S. Geological Survey Technical Letter Dribble-1 (Black, R. A., and Twenhofel, W. S., June, 1961). The accuracy of the interpretation is related to the velocity function used in reducing the seismic data. At the time the analysis of the seismic data was made, velocity information was available for five wells near Tatum Dome. From a study of the velocity survey data for these five wells a velocity function of the type $V_Z = V_0 + AZ$ was obtained, where V_Z is the velocity at any depth Z ; V_0 is the initial velocity at the datum plane; and A is a constant. The parameters V_0 and A were determined to be 6100 fps and .7 respectively, and the formula $V_Z = 6100 + .7Z$ was used in the interpretation of the seismic reflection data for Tatum Dome.

Since the completion of the analysis of the seismic reflection measurements, velocity data have been obtained for twenty additional wells within a 25-mile radius of Tatum Dome. A list of wells for which velocity data are available, and a map showing well locations with respect to Tatum Dome are given in U. S. Geological Survey Technical Letter Dribble-2 (Black, R. A., and Twenhofel, W. S., July 1961).

Of the ten velocity surveys described herein, only one (the Biglane, Ballew, and Laub No. 1 Crosby) was available at the time the seismic reflection data were interpreted. Average values for the parameters V_0 and A for the ten wells are 6039 fps and .694 respectively, which compare closely with the values of 6100 fps and .7 used in the interpretation of the seismic reflection data.

In the Gulf Coast area, where there are thousands of feet of sediments composed of sands and shales of similar origin and mode of deposition,

it has long been recognized that the seismic velocity generally increases with depth. This is probably a result of compaction and possibly increased cementation with greater age. There are a number of types of equations that have been used to account for the observed increase in velocity with depth, but the linear first degree equation of the form $V_Z = V_0 + AZ$ has been most widely used.

For a linear increase in velocity with depth the travel time from the shot point (corrected to the datum elevation) to the well geophone at any depth Z is:

$$(1) \quad T = \left(\frac{1}{A}\right) \cosh^{-1} \sqrt{1 + A^2 (D^2 + Z^2) / 2V_0 (V_0 + AZ)}$$

where A = constant in formula $V_Z = V_0 + AZ$
 Z = depth below datum in feet
 D = horizontal offset from shot point to well
 V_0 = initial velocity in fps at datum plane

Solving for V_0 we get:

$$(2) \quad V_0 = (AZ/2) \left\{ \sqrt{1 + 2 \left(\frac{D}{Z}\right)^2 + 1} / (\cosh AT - 1) \right\}^{\frac{1}{2}} - 1$$

The procedure used to obtain solutions for the linear velocity formulas that best satisfy observed travel times at the ten wells is as follows:

- 1) three observed times (for example points 1, 2, and 3 in figures 2) were chosen from the observed travel time curves for each well, and the equation (2) given above for V_0 was solved for each of these times for values of $A = 0.5, 0.6, 0.7, \text{ and } 0.8$.
- 2) these values of V_0 were then plotted versus the A values as shown in insert I, figure 2.

- 3) the intercepts of the three lines were then averaged to get values for V_0 and A
- 4) using these average values, theoretical travel times were computed from equation (1) and plotted on the travel time curves to determine how well the linear velocity formula fits the observed times.

Pertinent data for the velocity surveys of the ten wells used in this analysis, and the velocity function determined for each well are given in table 1. The numbers (1-10) shown opposite the well symbols in figure 1 correspond to the numbers assigned to the wells in table 1. The travel time curves for the ten wells are given in figures 2 to 11. The observed times shown on these graphs represent slant times as reported for each velocity survey, corrected for travel time from the shot point to a datum elevation using the weathered layer and sub-weathered layer velocities given in the respective reports on the velocity surveys. These graphs also show the theoretical travel times computed for the velocity function determined for each well.

It is possible to obtain a close fit to the observed travel times with a velocity function of the type $V_Z = V_0 + AZ$ for most of the wells described in this technical letter. The velocity functions determined for the ten wells showed a range in values of V_0 from 5830 to 6250 fps and in values of A from .68 to .72. The formulas determined for each well are shown in figure 1. Average values for the parameters V_0 and A for the ten wells are 6039 fps and .694 respectively. Wells 2, 9, 8, and 5 (fig. 1) are on a line that nearly coincides with the

Table 1.--Data On Geophone Velocity Surveys And Velocity Function Computed For Each Well.

Well Number on index map	Name of well	Location	Date of well survey	No. and location of shot points	Elevation of well from drill floor (feet)	Elevation of datum plane (feet)	Number of recording points and location	Linear velocity formula determined from graphical analysis	Remarks
1	Sinclair Oil and Gas Company No. 1 Miller Aultman	2,000 feet west and 600 feet north of the SW cor. sec. 2, T. 6 N., R. 16 W., Covington County, Miss.	June 1957	Seven shot holes offset on arc 1,000 feet west of well	242	sea level	24 depths ranging from 1,214 to 14,928 feet below datum elevation	$V_Z = 6,000 + .69Z$	Theoretical times fit the observed time curve closely.
2	Deep Rock Oil Corporation No. 1 John Allen	SE cor. sec. 14, T. 3 N., R. 13 E., Marion County, Miss.	May 1952	Four shot holes, two offset 785 feet southwest of well and two offset 785 feet southeast of well	148	sea level	24 depths ranging from 352 to 10,360 feet below datum elevation	$V_Z = 6,040 + .69Z$	Good fit between observed times and theoretical times.
3	Shell Oil Company No. 1 Newman Lumber Company	1,980 feet east and 720 feet south of NW cor. sec. 12, T. 5 N., R. 19 W., Jefferson Davis County, Miss.	February 1952	Four shot holes, two offset 500 feet north of well and two offset 1,000 feet south of well	294	202	21 depths ranging from 1,500 to 9,990 feet below datum elevation	$V_Z = 5,840 + .67Z$	Well survey data is questionable for interval between 5,000 and 6,500 feet because of poor records.
4	Union Producing Company No. 1 Bradshaw	663 feet north and 1,985 feet west of SE cor. sec. 19, T. 3 N., R. 16 W., Lamar County, Miss.	August 1948	Seven shot holes, two offset 700 feet and one offset 800 feet northwest of well and two offset 700 feet and two offset 800 feet southeast of well	390	200	19 depths ranging from 810 to 10,465 feet below datum elevation	$V_Z = 6,020 + .68Z$	In general, the velocity survey data for this well is of poor quality because of interference from stray alternating currents.
5	Southern Natural Gas Company No. 1 Bass	1,650 feet south and 330 feet east of the NW cor. sec. 36, T. 2 N., R. 14 W., Lamar County, Miss.	February 1960	Seven shot holes, four offset 790 feet north of well and three offset 800 feet southwest of well	228	180	11 depths ranging from 1,955 to 10,702 feet below datum elevation	$V_Z = 6,150 + .71Z$	Theoretical times fit the observed time curve well except for the observed time at 6,075 feet below the datum.
6	Honolulu Oil Corporation No. 1 Newman	2,350 feet east and 750 feet south of the NW cor. sec. 22, T. 5 N., R. 16 W., Lamar County, Miss.	December 1949	Five shot holes offset 1,000 feet north of well	373	239	18 depths ranging from 1,306 to 9,575 feet below datum elevation	$V_Z = 5,830 + .69Z$	Good fit between observed times and theoretical times to a depth of 7,000 feet below the datum.
7	Humble Oil and Refining Company No. 1 Gaylord	1,993 feet west and 1,987 feet north of the SE cor. sec. 42, T. 1 S., R. 14 E., Washington Parish, La.	June 1946	Eighteen shot holes, five offset 500 feet north of well, four offset 600 feet north of well, five offset 500 feet south of well, and four offset 600 feet south of well	137	60	22 depths ranging from 1,923 to 11,363 feet below datum elevation	$V_Z = 5,920 + .72Z$	Theoretical times fit the observed time curve closely.
8	Shell Oil Company Hibernia Bank and Trust No. 1	790 feet east and 320 feet south of the NW cor. sec. 14, T. 2 N., R. 16 W., Lamar County, Miss.	December 1944	One shot hole offset 1,520 feet west of well	338	300	18 depths ranging from 562 to 9,462 feet below datum elevation	$V_Z = 6,250 + .7Z$	Poor fit between observed times and theoretical times for the interval between 3,000-6,000 feet below the datum.
9	Gulf Oil Corporation No. 3 Bradshaw	1,980 feet north and 660 feet east of SW cor. sec. 29, T. 3 N., R. 17 W., Marion County, Miss.	January 1945	Two shot holes offset 740 and 860 feet to the southwest of the well	232	100	22 depths ranging from 368 to 9,468 feet below datum elevation	$V_Z = 6,140 + .69Z$	Theoretical times fit the observed time curve closely.
10	Biglane, Ballew, and Laub No. 1 Crosby	1,320 feet west and 1,950 feet south of the NE cor. sec. 20, T. 2 S., R. 16 W., Pearl River County, Miss.	July 1956	Six shot holes, three offset 500 feet northwest of well and three offset 500 feet southeast of well	215	sea level	17 depths ranging from 1,785 to 9,785 feet below datum elevation	$V_Z = 6,200 + .7Z$	Theoretical times fit the observed time curve closely.

strike of the sedimentary rocks, and the formulas determined for these wells show a small range in values of V_0 and A. There is a suggestion of an increase in velocity down dip (to the southwest) as the values for V_0 and A are generally smaller for the northermost wells than for those to the south.

FIGURE 1.- MAP OF PARTS OF MISSISSIPPI AND LOUISIANA SHOWING LOCATIONS OF WELLS WITHIN A 25-MILE RADIUS OF TATUM DOME IN WHICH GEOPHONE VELOCITY SURVEYS HAVE BEEN MADE

Figure 2.--Observed travel times (corrected to datum plane at elevation +100 feet) for Gulf Refining Company Well Number 3 Bradshaw; insert showing plot of V_o versus A for points 1, 2, and 3, and travel times computed from velocity formula $V_z = 6,140 + .69Z$

Figure 3.--Observed travel times (corrected to datum plane at elevation +202 feet) for Shell Oil Company Number 1 Newman Lumber Company well, and travel times computed from velocity formula $V_z = 5840 + .67Z$

Figure 4.--Observed travel times (corrected to datum plane at elevation +200 feet) for Union Producing Company Number 1 Bradshaw well and travel times computed from velocity formula $V_Z = 6020 + .68Z$

Figure 5.--Observed travel times (corrected to datum plane at elevation +180 feet) for Southern Natural Gas Company Number 1 Bass well, and travel times computed from velocity formula $V_z = 6150 + .71Z$

Figure 6.--Observed travel times (corrected to datum plane at elevation +239 feet) for Honolulu Oil Corporation Number 1 Newman well, and travel times computed from velocity formula $V_z = 5830 + .69Z$

Figure 7.--Observed travel times (corrected to datum plane at elevation +300 feet) for Shell Oil Company Hibernia Bank and Trust Number 1 well, and travel times computed from velocity formula $V_z = 6250 + .7Z$

Figure 9.--Observed travel times (corrected to datum plane at sea level) for Deep Rock Oil Corporation Number 1 John Allen Well, and travel times computed from velocity formula $V_Z = 6040 + 0.69Z$

NO PAGE FOR FIGURE 10

Figure 11.--Observed travel times (corrected to datum plane at elevation +60 feet) for Humble Oil and Refining Company Number 1 Gaylord well, and travel times computed from velocity formula $V_z = 5920 + .7Z$