UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Ground Water Branch

SEISMIC CROSS SECTIONS ACROSS THE SPOKANE RIVER VALLEY AND THE HILLYARD TROUGH, IDAHO AND WASHINGTON

By

R. C. Newcomb and others

Portland, Oregon
August 1953

CONTENTS

SEISMIC CROSS SECTIONS ACROSS THE SPOKANE RIVER VALLEY AND THE HILLYARD TROUGH, IDAHO AND WASHINGTON

By R. C. Newcomb and others

ABSTRACT

Two seismic cross sections were run with a refraction seismograph near Spokane, Wash., in May and June 1951. One section trended north-south across the Spokane River valley plain just east of the Idaho-Washington boundary; the other trended east-west across the strath just north of the Hillyard section of Spokane.

Each section secured data that permitted the compilation of a graphic cross section showing the position of (1) the water table, (2) the base of the glacial and glaciofluviatile deposits, and (3) the generalized base of the Latah formation and associated deposits (which is the top of the consolidated bedrock).

The data confirm the inference of Pardee and Bryan that the granitic bedrock lies at an altitude of about 1,000 feet beneath the valley plain near the State boundary. The base (a heretofore unlocated feature) of the glacial outwash deposits, the main aquifer of the area, was determined as an uneven plane at an altitude of 1,600 to 1,700 feet in the State-boundary district and at 1,700 feet in the Hillyard Trough district.

 (page 3 follows)

INTRODUCTION

General Setting

The Spokane Valley and its northeastward continuation, the Rathdrum Prairie, is a broad terraced valley floor, formed by the trains of glacial outwash that were deposited in the main ancestral drainage outlet of the Purcell Trench of the Rocky Mountains. There is physiographic continuity of these valley terrace lands downslope from the terraces above the southern end of Lake Pend Oreille in Idaho to the Spokane Falls at Spokane. Down-valley from Spokane Falls the same terrace level continues for many miles in the marginal terraces along the valley sides. The topography is shown in a general way on the Spokane and Rathdrum quadrangle maps of the Geological Survey, and in more detail by the recent large-scale resurveys of those and adjacent quadrangles. Plate 1 shows the location of the seismic sections studied.

The sides of the Spokane Valley are largely formed of resistant granitic and metamorphic rock. That rock also crops out from beneath the glacial outwash in the upper end of the valley near Lone Mountain and in the lower part of the valley near Trent. At Spokane the Spokane River falls 141 feet over basalt flows which supposedly belong to an intracanyon lava epoch (Pardee and Bryan, 1925). Below the falls much of the glacial outwash material has been removed from the valley. A tributary strath, known as the Hillyard Trough, enters from the north at Spokane in such a position as to indicate that it was once the main valley of the tributary Little Spokane River.

A large body of ground water discharges an average of about 1,000 cubic feet of water per second (Fosdick, 1924) into the Spokane and Little Spokane rivers in the reaches between Greenacres and the mouth of the Little Spokane River. Its water table slopes gently southwestward from the upper Rathdrum Prairie section, where it is near the level of Lake Pend Oreille, to the Greenacres district, from hence to the falls it is at or near the level of the river. Beneath the Hillyard Trough the water table slopes northward away from the general level of the Spokane River and toward the spring orifices that occur along the south side of the Little Spokane River near Dartford (Newcomb, 1933).

Heretofore, it was not known to what depth the glacial outwash materials extended. Likewise, in the deeper part of the valley, the nature of the rock beneath the glacial-outwash aquifer was unknown. Although Pardee and Bryan (1925) had postulated an altitude of 1,050 feet for the granitic bedrock floor of the valley at the Idaho State boundary, on the basis of known present altitude of bedrock in the Purcell Trench, no actual measurements had ever been obtained. Also unknown were (1) the depth at which the Latah formation and the Columbia River basalt remain in the prebasalt granitic valley, and (2) the possible water-bearing nature of those preglacial materials that filled the ancestral "granite" valley.

Purpose of the Study

The primary objective of the seismic work was to locate the base of the glacial-outwash aquifer. Secondarily, it was desired to determine the type of materials underlying the aquifer and to locate, where possible, the granitic bedrock of the ancestral valley. Charting of the water table and other features of the geology and ground water also was desired in order to help evaluate this exploratory process as a means for obtaining geohydrologic information.

The project was conceived as an effort to secure certain stratigraphic and hydrologic information that is vital to the correct derivation of the basic facts that govern the water resources of the Spokane Valley. It was a part of the over-all Columbia River Basin investigation of the Geological Survey.

Organization of the Work

Selection of Instrument

The Heiland 400 series, 4-channel seismograph instrument of the refraction type belonging to the U. S. Waterways Experiment Station was used.

Coordination of Participating Agencies

The offices of the Ground Water Branch of the Geological Survey in the States of Washington, Idaho, and Oregon each furnished two men for most of the work. Selection of personnel to do the work for laying out the shotlines, for constructing and loading the shotholes, and for helping with the seismograph was made with a view toward achieving the maximum training in the technique of this type of exploration. Personnel working during a part of the project were Don Reis, Bruce Liesch, and Maurice J. Mundorff from the Tacoma office, Don H. Hart and G. M. Hogenson of the Portland office, and James R. Jones of the Boise office. Samuel W. West of the Boise office and R. C. Newcomb of the Portland office worked throughout the project. The field work was done in May and June 1951.

The U. S. Waterways Experiment Station of the U. S. Engineer Department furnished the seismograph instrument and two operators, Peter Mullinix and Joseph J. O'Neil. They supplied a report (O'Neil and Mullinix, 1951) on the work prior to the preparation of this report.

Liaison with the U. S. Bureau of Reclamation was made through Keith Anderson, regional drainage engineer of the Rathdrum Prairie Irrigation Project. The Bureau furnished a base map bearing a 2-foot contour interval for the State-line section.

The Washington Water Power Co. through William A. Hill and Walter E. Johnson gratuitously supplied a power-driven pole-hole auger for a part of one day, appreciably helping the project by digging some 20 shotholes in the difficult boulder gravel of the State-line section. Fred O. Jones of the Engineering Geology Branch of the Geological Survey made his Spokane office available as headquarters for the working party.

The shothole data were computed and graphed by Don H. Hart and the results are shown on plates 4 to 18. Plates 2 and 3 were prepared by R. C. Newcomb.

Landowners and the county road authorities of Spokane and Kootenai counties accorded permission for running the shotlines over their property.

Technical Operations

Location of Sections

During the first two days, while awaiting arrival of the instrument and the arrival of a supply of explosives, the tentative layout of the proposed seismic section lines was reviewed and two lines (one lying in a generally north-south direction across the valley a mile east of the Washington-Idaho boundary and one lying in an east-west direction across the Hillyard Trough north of Francis Street in Spokane) were chosen as best combining the required features.

Layout and Firing of Shotlines

Shotlines were laid out along the line of each section as shown on plates 2 and 3. Each half of each shotline was fired outward, four geophone locations at a time, from the origin or center point, except number 3 of the State-line section, a short line that was fired successively north to south. An effort was made to keep the digging crew ahead so that the firing and instrument crew could remain in continuous operation. That procedure worked out satisfactorily for most of the Hillyard Trough section, but difficulties in getting the holes dug and in getting satisfactory instrument records impeded progress on the State-line section. Shotholes having the heaviest charges were 8 to 10 feet deep on the Hillyard section and 5 to 7 feet deep on the State-line section.

Blasting gelatin (60 percent) was used with standard electrical caps. Seismic-type gelatin was used on the State-line section and standard-type gelatin on the Hillyard Trough section. On the Hillyard Trough section the explosive loads varied generally from 1/2 pound in the holes at stations 0+90 (feet) to 14 or 16 pounds at the stations 14+90 (feet). On the State-line section the loads were as high as 40 pounds in some experimental tests in the holes at greatest distance from the instrument.

Theory and Operation of the Seismograph

General theory.- Refraction seismic methods of determining the subsurface structural relations of different lithologic units and stratigraphic horizons are based on Snell's law. Detailed discussion of the physics of Snell's law, which concerns the refraction of light waves passing through different media in which light waves travel at different velocities, is beyond the scope of this report. It is important, however, to point to the practical applications of the law. Seismic exploration uses waves, which essentially are sound waves, whose speed of travel through earth materials depends upon the elastic properties and the density of the medium.

In the practical application of seismic methods, the term velocity is substituted for speed, thus retaining the same magnitude but including a direction of motion. The velocity of longitudinal seismic waves is obtained by measuring the time between the initiation of the wave by an explosion and the return of impulses, which are recorded by geophones placed some distance from the point of explosion (shot point).

An approximate image of each wave is reproduced on photographic paper by the seismographic instrument. Arrival time and depth calculations give indications of changing media (rock units of different velocities and, hence, different densities and elastic properties) and the depths at which these changes occur. Correlation of this information with available surface and subsurface geologic data makes it possible to infer lithologic and stratigraphic conditions and structural relations in areas beyond, or at depths beneath, those for which the direct observational data are available. When the shotlines are fired in one direction, as in this work, the velocities-of-travel results are specifically known as "apparent" velocities of travel.

Operational process.- After each shot was fired the paper was developed and the elapsed time to the return impulse was recorded for each of the four geophones. Velocities of travel and depth of successive velocity-of-travel units were calculated as shown on plates 4 to 18. From the depth-units determined the stratigraphic cross sections were compiled.

Factors Adversely Affecting Operation

The bouldery character of the glacial outwash deposits near the surface on the State-line section made the digging of shotholes extremely arduous and time consuming. Of the devices used there, the pole-hole power auger was the most satisfactory. On the State-line section, the great thickness of outwash materials so absorbed the explosive impulse and so weakened the return impulse that some of the time readings, for shots at a considerable distance from the instrument, were determined with difficulty.

Presentation of Results

Location and layout of the shotlines are shown on plates 2 and 3. The graphs giving velocity and depth zones encountered were plotted and forwarded with descriptive test by the U. S. Waterways Experiment Station to the Portland office of the Ground Water Branch of the Geological Survey. Those results were recalculated and checked and the cross sections were redrawn for this report.

A discussion of the nature of the recorded data is copied (with insertions) from the report of the U. S. Waterways Experiment Station as follows (O'Neil and Mullinix, 1951, p. 4-5):

"Presentation of data

The results obtained from the test profiles are shown by the inclosures and are briefly discussed herewith. Figures 1 and 2 [now plates 2 and 3] give profile views of the stratigraphic changes indicated from the readings and computation along the State-line and Hillyard line, respectively. Time-distance curves for the State-line profile are shown on figures 5 through 11 [now plates 4 through 10] and for the Hillyard profile on figures 12 through 19 [now plates 11 through 18]. Some very definite peculiarities are noted on the time-distance curves. The State-line plots indicate good recording until the longer shots when scattering is due to the fact that the energy was absorbed to a great extent by the bouldery surface layer. This difficulty could have been partially obviated by using shotholes of considerable depth. The arrival times of some secondary waves were plotted for line 2 South (figure 7) [now pl. 6], in order to help cancel the scattering and obtain more definite information on velocity changes. The plot of line 3 South (figure 9) [now pl. 8] presents this same generalized condition of scatterings. The scattering effect was not evidenced on the Hillyard profile, although a decided peculiarity exists on the curve of line 1 East (figure 12) [now pl. 11]. Almost identical time arrivals, geophone by geophone, from the 800-ft shot through that of 1490 ft indicate a boundary layer which refracted and reflected all oncoming energy. This phenomenon is interpreted as representing a steeply dipping boundary in the plane of the shotline. The curve of line 1 West (figure 13) [now pl. 12] presents erratic values so that, although the same velocity is present, there are two time-intercept values. The curves for line 3 East (figure 16) [now pl. 15] show a possible velocity break around 1100 ft shot distance. However, the computed depth when plotted on the profile, figure 2 [now pl. 3] does not agree with conditions on adjacent shotlines. Therefore, this point has not been considered in plotting the profile. The remaining Hillyard time-distance curves are generally straightforward in appearance."

SEISMIC PROFILES

General Stratigraphic Conditions Observed

In general, four velocity-of-travel zones were detected. They were: (1) the soil and subsoil zone, (2) the "dry" glacial outwash above the water table, (3) the saturated glacial outwash and other unconsolidated materials(?), and (4) the underlying semiconsolidated or consolidated rock. The semiconsolidated or consolidated rock was further differentiated in some shotlines by the distinctive velocities of the granitic rock and the less distinctive velocities of the Latah formation and its (possible?) intercalated igneous rocks.

The apparent velocities of travel (in feet per second) were:

	Hillyard section	State-line section
(1) For the soil and subsoil zone of the glacial outwash	900-1,300	1,230-1,640
(2) For the "dry" glacial outwash	2,150-2,700	3,330-4,500
(3) For the saturated glacial outwash	5,000-7,000	5,660-7,500
(4) For the Latah formation and the Latah with intercalated igneous rocks(?)	7,400-9,600	8,870-12,800
(5) For granitic bedrock	13,200-20,000	13,200-20,000

The time intercepts and calculations on which those velocity-of-travel zones are based are shown on plates 4 to 18.

The velocities obtained for the Latah formation in the State-line profile are so high that it seems reasonable to assume that the basalt sills and dikes like those present in the Latah formation in the Latah Creek vicinity (Pardee and Bryan, 1925) and those visible in the highway cuts just southeast of Coeur d'Alene, Idaho, are present also beneath the State-line area.

The base of the glacial outwash material (or of other unconsolidated material, if any, overlying the Latah formation) is shown as an undulating contact ranging in altitude from 1,600 to 1,750 feet in the State-line section and as a more regular contact at 1,700 feet in the Hillyard Trough section.

If in preglacial time, as postulated by Pardee and Bryan (1925), the Latah formation and basalt were eroded from the valley to an altitude of 1,460 feet (altitude of base of "valley flows" in Davenport Hotel well) before the intracanyon flows filled it to an altitude of 2,200 to 2,400 feet, one would expect to find in these sections some remnants of a semiconsolidated lake deposit lying in the 1,460-2,200-foot interval. If present, such beds must have a velocity of seismic travel that is similar to that of the Latah formation and are included by the writers in the zone of the Latah formation proper.

The apparent position of the base of the glacial outwash at altitudes of 1,600 to 1,750 feet in the State-line section and of 1,700 feet_/ in the Hillyard Trough section, or roughly 100 to 200 feet below the altitude of the bedrock crest of the present falls at Spokane (about 1,860 feet) is significant. It seems to augment the postulation (Newcomb, 1933) that an older preglacial Spokane-River-Falls channel (probably cut to an altitude as low as 1,600± feet) lies buried by the glacial outwash somewhere between the basalt knobs that crop out just north of the present Spokane Falls and the south slope of the Fivemile Prairie outlier.

It seems possible that the basalt at the Spokane Falls is a sill or dike-and-sill complex, on which the normal downward cutting of the Spokane River was base leveled even in preglacial times. If so, the strata of the Latah formation must remain everywhere in the valley areas below the 1,860±-foot altitude of the present channel or, if the older, deeper north-central channel mentioned above exists, at least everywhere below the 1,600- to 1,750-foot altitude of that channel. That such a situation

_/ Weigle (1952) lists some deeper glacial materials in the logs of some wells at the aluminum plant near Mead, 2 miles north of the Hillyard seismic section.

exists is suggested by the lack, in the zone normally occupied by the Latah formation, of any seismic velocities lower than those characteristic of that formation.

Observations on the Water Table

The altitude of the water table, as obtained by these seismic sections, may vary as much as 12 feet from the true altitude existing at the time. The altitude of the water table, by hand tape measurement of the Peter Beck well, 800 feet east of shotline 1 S of the State-line section, was 1,995.6 feet on July 6, 1950 (Fader, 1952), and by interpolation of unpublished hydrographs was 1,991.8 feet on May 24, 1951. The seismic profile places it at 1,980 feet on May 24, 1951. The altitude of the water table in a new well 200 feet west of shotline 4 S in April 1952 was reported by the owner as 1,983 feet (132 feet below land surface). Interpolated from other wells the altitude on June 8, 1951, is estimated as 1,988± feet. The altitude of the water table as determined there by the seismic work on June 8, 1951, was 1,983 feet.

CONCLUSIONS

The general belief that the granitic bedrock valley profile extends to an altitude of 1,000 feet or so beneath the State-line district seems borne out by the velocities of travel found in the strata beneath that seismic section line.

The base of the glacial outwash deposits, the main aquifer of the valley, is an uneven plane at an altitude of 1,600 to 1,750 feet in the State-line district and at 1,700 feet in the Hillyard Trough district.

The water table was recorded with an approximate error of 5 to 12 feet, or a margin of error that may be less than the annual fluctuation of the water table.

Recommendations on the future technique of such surveys include the circumvention of the difficulties encountered in digging shotholes in the bouldery gravel of the State-line section by: (1) use of seismic instrument that has 6 or more channels in order to decrease the number of shotholes necessary, and (2) the construction by churn drill, to a depth of 25 feet or so, of the shotholes beyond the 6+40 station of each shotline.

REFERENCES CITED

Fader, S. W., 1951, Water levels in wells and lakes in Rathdrum Prairie and contiguous areas, Bonner and Kootenai counties, northern Idaho: U. S. Geol. Survey open-file report.

Fosdick, E. R., 1924, Ground water of the Spokane Valley: a private report of Washington Water Power Co.

Newcomb, R. C., 1933, Underground water of the upper Spokane River valley: Washington State Coll. bachelor's thesis.

O'Neil, Joseph J., and Mullinix, Peter, 1951, Seismic survey of the Spokane River valley: U. S. Eng. Dept., Waterways Exper. Sta., typewritten report.

Pardee, J. T., and Bryan, Kirk, 1925, Geology of the Latah formation in relation to the lavas of Columbia Plateau near Spokane, Wash.: U. S. Geol. Survey Prof. Paper 140-A.

Weigle, James E., 1952, Factual data on the ground-water resources of the Spokane valley, Wash.: U. S. Geol. Survey open-file report.