Pamphlet No. 17 November 1926

STATE OF IDAHO

Chas. C. Moore, Governor.

BUREAU OF MINES AND GEOLOGY
Francis A. Thomson, Secretary

GROUND WATER FOR MUNICIPAL SUPPLY

AT

ST. MARIES, IDAHO

By

Virgil R. D. Kirkham

University of Idaho
Moscow, Idaho

Archive Version--January 1991
by the Idaho Geological Survey

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Contents.

INTRODUCTION

PURPOSE AND SCOPE OF THE SURVEY

A belief, upon the part of a considerable portion of the municipality of St. Maries, that untreated stream water constitutes a grave menace to public health, coupled with an equally wholesale dislike, upon the part of a large group, for the taste of the treated water, inaugurated recently a movement to seek for an underground water supply which would be sanitary and of pleasant taste. Through the medium of the city officers this desire was made known to the Idaho Bureau of Mines and Geology, which has made numerous underground water supply surveys for Idaho municipalities.

A brief investigation was conducted about the middle of September wherein the geology and underground water situation of an area of 31 square miles surrounding St. Maries was studied by Virgil R. D. Kirkham, one of the geologists of the Bureau. This area is shown on an accompanying map.

ACKNOWLEDGMENTS

The writer gratefully acknowledges the assistance extended by the city and county officers who facilitated and expedited the work. Much information and service were provided by the Mayor, City Clerk, County Surveyor, and City Water-Supervisor. The only geologic literature touching this region is a report by F. C. Calkins[1], which is rather general in character and which does not cover any of the area south of St. Joe River.

GEOGRAPHY

LOCATION

The area constitutes 31 square miles of territory lying, with the exception of one square mile, in Benewah County, Idaho. The area lies in the north-central part of the county with the city of St. Maries near its central part. Meridian 116° 30' and parallel 47° 20' pass through the area examined, which lies in Tps. 46, and 47 N., and Rs. 2, and 3 W.

TOPOGRAPHY

The entire region lies within the drainage of the St. Joe River and its main tributary, the St. Maries River.

Three types of topography are included in the area: (1) Mountainous provinces made up of metamorphosed sediments in a mature and fairly rough stage of erosion, (2) narrow lava benches and terraces which flank the main valleys, and (3) alluvium-covered, wide valley flood plains. Each of these types is easily seen on the geologic map. The mountainous prov-

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[1] A Geological Reconnaissance of northern Idaho and northwestern Montana; U. S. Geol. Survey Bull No. 384, 1909.

inces are really a dissected plateau which forms a westerly outlier of the Cabinet Range. The entire area lies between 2000 feet and 3500 feet above sea-level and is of medium relief. The harder metamorphosed sediments always form the highest peaks.

SETTLEMENTS, OCCUPATIONS, AND ACCESSIBILITY.

St. Maries, which is the chief center of habitation, contains approximately 3500 inhabitants. The rest of the area examined contains perhaps 500 additional people. Lumbering and milling, along with farming and dairying, are the chief industries. Considerable timber grows on the higher ridges and terraces, and the fertile well-watered bottom-lands yield good crops. The area is adequately served by the Chicago, Milwaukee, and St. Paul Railroad.

GEOLOGY

STRATIGRAPHY, PETROLOGY, AND STRUCTURE.

The rocks in the region, range in age from pre-Cambrian (Algonkian) to Quaternary, and are represented by sediments of the Belt series, Basalt lava, Latah formation, and hillwash and alluvium.

The Belt series in this region are chiefly quartzites and argillaceous quartzites, which lithologically appear to be similar to the Newland (Wallace) or the Ravalli group of the Belt series in the nearby Coeur d' Alene mining district.

These rocks are the lowest, as well as the oldest, formation exposed in the region and underlie all other formations shown on the accompanying map.

They are exposed in the mountainous areas, and in all regions of higher elevation, where they remained uncovered by the fairly wide-spread basalt flows which masked the valleys, foothills, and lower-lying areas. They are also exposed in localities where recent stream or ice erosion has cut through the later basalt and removed it, thus revealing these rocks in the lower valley sides and bottoms with basalt cliffs forming the rim of the valleys.

The areal outcrop of this formation is represented on the map by the horizontally lined areas.

Although a few minor folds and possibly some minor faults exist in the older rocks, lack of time, as well as lack of pertinency to the problem in hand, prevented the identification and mapping of these irrelevant features. The beds, although deposited in an approximately horizontal position, have, during the long ages of their existence, been folded, faulted, and tilted, and they are now exposed in a tilted attitude, dipping for the most part in a southerly direction at angles ranging from observed dips of 30 to 50 degrees. Jointing and bedding are well developed and, with this high dip, the beds immediately absorb any water which falls upon or runs over the surface. Such water, because of the prevailing southerly dip, is conducted with depth to some point far south of the mapped area. The diagonal lines in the accompanying structure section indicate the attitude of bedding planes in these rocks. Because of the attitude of the beds, no permanent springs emerging from these older beds are to be found within the area examined.

BASALT LAVA

Lava flows of Miocene age and representing the more easterly embayments of the vast Colombia River Lava Plateau to the westward are the next oldest rocks in the area. This material, at one time molten viscous lava, was poured out in great quantities over the old land surface, the upper surface of the flow formed a comparatively level floor to the valley. Although considerable time interval elapsed before the occurrence of the next lava extrusion, no more than a few inches, or a few feet, of soil, silt, or lake-bed material, accumulated in the interval. The second flow then poured out on a relatively level surface and its upper surface presented another flat valley floor at a considerably higher level. This was repeated until at least four flows covered part of the area, the later flows, of course, overlapping the higher parts.

A fairly high relief and rugged contour had been established in the Belt sediments prior to the outpouring of the lava and these valley flows were therefore usually confined to old established drainage depressions of considerable width.

The later basalt flows, being successively at higher elevations, in reality overflowed the valleys proper and abutted upon the flanks of the foothills. The higher peaks in these foothills, consequently, became "islands" in this lava "sea" as illustrated on the geologic map and structure section. This shows the nature of the inundation of the older rocks by the Miocene basalt lava flows.

The basalt is a heavy, dark, hard rock, varying greatly in texture and characteristics in the various flows. It shows well-developed fracturing and jointing, wherever observed, and at some places is vesicular and porous.

Its attitude is approximately horizontal although a slight tendency to dip toward the valley center is suggested by the springs emerging on the valleyward side of the basalt cliffs.

Erosion, since the basalt extrusion, has dissected its originally level surface until now the basalt is exposed as terraces, mesas, and buttes near and between the larger streams which have cut through the flows into the underlying metamorphosed sediments. As a result of this active post-basalt erosion, no large areas of uncut lava flows remain in the region. This formation is represented on the geologic map by crosses and in the structure section by vertical lines in layers.

LATAH FORMATION

This formation, made up of silts and sediments, deposited in temporary lakes and ponds, is exposed in a limited outcrop at only one place in the area as far as could be observed during this brief examination. This exposure is in a cut in basalt on the Santa road in the extreme southeastern corner of the region. In Sec. 7, T. 45 N. R. 1 W., these silts, scarcely consolidated, were exposed for a length of perhaps 150 feet and for a thickness not in excess of 100 feet between two lava flows of the above mentioned Miocene basalt. Their age is thus established as being contemporaneous with the basaltic extrusions and they likewise give some criterion by which to judge the time interval which must have elapsed between these two flows. The outcrop lies outside the limits of the mapped area. Carbonaceous and lignitic seams indicate the presence during deposition of swampy growth and plant material. For the most part, the material represented mud, clay, and silt in strata lying approximately horizontally.

From the field relations, as well as from the fact that the formation was not observed to be exposed in any other part of the region, together with the absence of notable terraces in the basalt flows themselves, persuasive evidence is offered that these sediments were local in character and confined to the lower part of the stream valley. They appear to be between the first and second flows and were probably deposited in small lakes or ponds formed as a result of changes in drainage caused by the original lava flow. As the damming was relieved, the ponds and lakes were eliminated and much, and perhaps nearly all, of the unconsolidated sediments were washed away and cleared from the surface of the bottom flow and valley walls. Naturally, occasional erosional remnants were left which were enclosed by the second flow and only revealed by haphazard erosion or by the work of man which, in this case, revealed this remnant by building a highway. No widespread deposit of this nature is believed to lie between any of the basalt flows exposed in the mapped area, although varying thicknesses of soil, up to a few feet, undoubtedly separate nearly all of the flows. Water was seeping into the road from these silts and clays, where exposed, although no spring emerges from them.

HILL WASH AND ALLUVIUM

This material, chiefly Pleistocene and Recent gravel and silt, covers the valley flat of the old sluggish and meandering St. Joe and St. Maries rivers. It contains much surface water and is lower than the surface water-table where swamps exist. It is represented on the geologic map by the stippled or dotted areas.

SOME CONSIDERATIONS OF UNDERGROUND WATER AND THE FACTORS AND ESSENTIALS FOR ITS OCCURRENCE WITH AN EXPLANATION FOR THE LAYMAN OF SOME TECHNICAL TERMS.

Although much water for potable and industrial purposes in supplying cities, towns, factories, farms, and irrigation projects, comes from underground, it originated from some form of precipitation such as snowfall or rainfall at the earth's surface. The melting snow or rain is eliminated by three processes, namely: evaporation, surface run-off in streams, and seepage into the ground. The water thus contained underground is generally conveniently divided into two heads to avoid confusion - these are ground water and artesian water.

GROUND WATER

Although some of the water which is constantly seeping into the ground is retained in the upper soil by capillarity and speedily returned to the surface again by evaporation, most of it sinks deeper into the lower soil and underlying rock masses which it saturates to a certain level. This zone of saturation represents a great body of water which furnishes water for lakes, springs, and streams, and is the water encountered by shallow surface wells. Its upper surface, which is the level maintained in a shallow well, fluctuates with the seasons and the rainfall and snowfall of the area, but actually underlies the land surface at a relatively short distance at all times. When the land surface is irregular so, also, is this upper surface or water-table, but to a lesser degree. Thus the water-table is farther from the surface beneath the hills and closer to the surface beneath the valleys. In many depressions, it comes to the surface as temporary springs, as swamps, as lakes, or as seeps which insure the level of permanent streams. In regions with heavy rainfall, this water-table is close to the surface and in arid regions, it may be several hundred feet below the surface. Its distance from the surface in any region, of course, fluctuates and lags behind the wet and dry seasons. The movement of this water is, as at the surface, in a down-hill direction and it generally comes to the surface, or is concentrated in valleys and generally follows the valley bottom where it may in some cases be entirely separated from an overlying river by an impervious clay layer. It is the most common source of underground water.*

ARTESIAN WATER

The various bed-rock types underlying the surficial layers of soil and unconsolidated materials have varying degrees of porosity and thus varying capacities for holding water. The water collects in cavities such as pores between grains or crystals, joint cracks, bedding planes, vesicles, etc., and saturates the rock to the best of its ability. Many rocks are relatively impermeable to the water and others are porous and can hold or conduct a large amount of it.

When a particularly porous rock is overlain by a relatively impermeable layer, little water may enter it by downward seepage and it may not reach saturation. If, however, this porous rock is folded or tilted so as to be eroded and outcrop at the surface, it may readily become filled with a greater supply than the overlying formation.

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* In the discussion which follows, the possibility of waters derived from other than surface sources, such for example as certain hot springs, is purposely omitted.

True artesian water is that confined in rocks under sufficient hydrostatic pressure to cause the water, when a way of escape is afforded, to rise towards the surface although not necessarily high enough to flow out at the surface. The essential difference then, is the tendency of artesian water to flow toward the surface as a result of confinement and pressure whereas ground water tends to sink away from the surface. The ideal requisite factors, then, for artesian conditions may be stated as comprising: (1) an adequate source of water supply such as heavy rainfall or snowfall, (2) a porous layer or rock area, known as aquifer, well enough equipped with cavaties to contain a large supply of water, (3) a practically impermeable retaining agent which resists the upward progress of the water, (4) and a source of pressure. Numerous conditions exist in rock masses where a variety of water traps are created which possess those four factors. The common one, however, is where stratified beds of varying degrees of permeability have been warped from their original horizontal, or nearly horizontal, depositional position to a tilted or folded position so as to provide an artesian slope or basin wherein the permeable beds, or aquifers, are exposed at the surface and fed therefrom and lie between impermeable or slightly permeable beds. The entering surface water, under these most favorable conditions, flows down hill along these porous beds until it escapes at a lower level or, failing escape, backs up the slopes as the porvious bed is filled, thus developing an increasing degree of saturation until no more can be held. In an artesian slope, an increasing pressure in exerted in a saturated bed from the outcrop to the lowest position on the slope. Should there be a natural outlet at this lowest point, the pressure is relieved. Although artesian conditions may still prevail up the slope, because of the friction and slowness of movement and the size of the reservoir area, flowing surface wells may not be expected because the lack of pressure and true confinement. In an ideal artesian basin, water at the low point in the aquifer receives a hydrostatic pressure from the slopes in every direction and when tapped will flow at the surface providing it is considerably lower in altitude than most points of outcrop of the aquifer.

DEFINITIONS *

<u>Annual ground water increment.</u>- The increment or recharge of ground water may be approximated by a simple calculation. From the annual precipitation of the area is subtracted the stream run-off as measured by stream guages, and from this remainder is subtracted the loss by evaporation and vegetal usage, which usually must be approximated. The final remainder enters the ground in the catchment and intake areas and represents so many inches, or fractions thereof, which are converted then into acre-feet by multiplying by the size of the catchment area, thus making it possible to determine the amount of water that can be extracted from an artesian basin without impairing its producing possibilities.

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* For a more adequate discussion of this subject the reader is referred to Meinzer, Oscar E; Outline of Ground Water Hydrology: U. S. Geol. Survey Water-Supply Paper 494, 1923.

Aquifer.- Any permeable, porous formation, (layer, rock, or substance) which will permit water under ordinary pressure to move through it perceptibly.

Confining Bed.- Any impermeable or impervious formation(layer, rock, or substance) which will not permit movement of ground water under ordinary pressure.

Intake area.- The intake area is the actual surface dimension occupied by the outcrop of the aquifer. It usually slopes away from the flanks of an elevated area where exposed by erosion or by unconformity. The outcrop may occupy a narrow belt or an irregular area and dips into the basin where it is covered by the confining bed. The size of the intake area varies with its nature, thickness and inclination as well as the topography of the region. In a relatively flat region, a gently tilted aquifer of great thickness would have an enormous intake area. In a similar region a vertically tilted aquifer of the same thickness would have a very small intake area.

Catchment area.- Most of the water which enters an aquifer through its intake area is water which fell elsewhere and drained to it rather than that which falls immediately thereon. That area whose drainage crosses an intake area is called the catchment area and always includes the intake area. Elevated regions near intake areas are generally catchment areas and the surface stream-drainage divide becomes also the catchment divide.

Static level.- The level at which water stands in an artesian well at any one point in an aquifer. It may be higher or lower at a different well in the same aquifer at some distance. It is similar to the surface water-table but is independent of it.

Piezometric surface.- An imaginary surface that everywhere coincides with the static level of water in an aquifer.

Isopiestic line.- This is a line on the piezometric surface whose every point is an equal distance above sea-level. It is a contour line.

Hydraulic gradient.- This is the vertical drop or rise per unit of length of the piezometric surface of an aquifer. It is a measure of the pressure drop as the water moves through the aquifer. The speed of underground flow is proportional to the steepness of this gradient. Artesian water flows from a few hundred feet to a few hundred yards per year.

THE GROUNDWATER SUPPLY AT ST. MARIES

The average annual precipitation at St. Maries is approximately 27 inches. It is assumed that approximately 15 inches of this escapes by stream run-off and that nine inches is used in evaporation and vegetal discharge. This leaves three inches which enters the catchment area and constitutes the annual ground-water increment.

Considering the area, shown on the map, lying south of the town of St. Maries as a possible source of underground water, we find a total catchment area of 3050 acres situated north of the catchment divide and south of the upper basalt rimrock which borders the south shore of the St. Joe River. This, when computed, results in 762 acre-feet of water, or approximately 33,150,000 cubic feet, equivalent to 247 million gallons per year.

The city officials are seeking a water supply which will provide them with an average of 400 gallons of usable water per minute. This amount is equivalent to 210 million gallons of water per year or only slightly less than the annual increment of the reservoir under consideration. Thus, discouragement is encountered in dealing with the first factor, which is an adequate water supply. It should be understood that the rainfall and snowfall are sufficient but that the catchment area is barely sufficient provided ideal conditions exist for artesian storage.

The area is actually a very imperfect reservoir, as it is in a constant state of drainage, because of the many spring outlets. The annual increment accordingly is never cumulative because of lack of proper confining agencies. Very likely no more than this annual increment is ever in the reservoir. Regardless of the number of wells and springs used as a water supply, it would be a practical impossibility to recover any large portion of the annual intake because of seepages impossible to tap and because of mechanical difficulties in well extraction. Approximately one-half of the catchment area is composed at the surface of quartzites and argillites dipping at steep angles to the south. These beds in themselves are, because of their cemented and metamorphosed condition, nearly impermeable, except along bedding planes and joints and fractures, which conduct the water to great depths from which its recovery is impossible. This same condition exists under the basalt, and whatever water escapes through it meets the same fate. The alluvium and hill wash are saturated with suspended surface water which is not a practical source of supply because of pollution. The Latah formation appears to have insufficient extent to deserve consideration although it would be satisfactory in other respects.

Basalt flows usually make excellent aquifers in as much as the fine-grained part of the flow often acts as the impermeable layer and a lower vesicular, porous jointed and broken zone is often an excellent aquifer. Where more than one flow exists another impermeable zone also exists and so on. There is usually a layer of soil or thin sediments between flows which also acts as a passage way for the water.

The intake area occurs where the basalt abuts against the Belt rocks, as it does south of town. It is relatively narrow and, curiously enough, is on the under side of the flows rather than exposed at the surface.

The upper surface of the flat-lying basalt acts also as an inefficient intake area since it permits some water to descend into underlying aquifers by means of the columnar joints, which are perpendicular to them. These are found in the fine-grained and supposedly impermeable zones between the more porous zones or layers.

The efficacy, as water carriers, of the basalt flows in the St. Maries region is indicated by the springs, numbered 3 and 8 on the map, which emerge from the bottom lava flow or fourth aquifer. These are permanent and fairly copious. Springs 1 and 2 come from a higher aquifer, (No. 3) and spring 4 comes from a still higher one (No. 2). Any one of these springs produces from 4 to 6 gallons of water per minute and shows very little if any seasonal variation.

Springs No. 5 and 6 come from the lower aquifer and spring No. 7 emerges from the aquifer (No. 3) next above the lower one. Well No. 4 also gets its water from the lower aquifer. It produces at about the same rate when pumped as do the springs. Well No. 3 gets water from the second aquifer from the top. Although only eight springs were visited, examined, and mapped, the same horizons from which these springs arise also bear springs in the northern and western part of the area. Wells No. 1 and 2 and many others in the northern sections of the area also produce from the aquifers in the basalt flows at rates similar to the spring flows mentioned.

The area reveals further unfavorable conditions when examined for artesian factors No. 3 and No. 4. Although the basalt can act as an agent to deter the upward rise of the water, it has no opportunity to serve this purpose because the aquifers have been cut by erosion in the stream valleys and lose their charge by way of the many springs. This also prevents the accumulation of pressure, as the water runs out as fast as it runs in. The distance from the intake area to the point of the escapement is too short to permit the building up of any notable hydrostatic head through friction and slow movement. A well tapping the upper aquifer would develop a flow similar and equal to one of these springs. By sinking deeper and tapping 3 aquifers, it would get the flow of three springs. The upper basalt flow does not appear to have permanent springs at its base so it either has no aquifer or it has no large water supply. Three aquifers are known and a fourth is possibly present. Consequently, a well penetrating all four of them need only expect a supply approximately equal to 4 springs such as outcrop along the bases of the cliffs. That means that such a well is not likely to develop more than 20 to 25 gallons per minute. Assuming that enough water were stored in the rocks to supply the amount required, it would take 18 or 20 wells of 250 to 300 feet depth to supply the 400 gallons per minute demanded by this growing municipality.

The same conditions exist on every other basalt terrace or mesa in the region. A study of the drilled wells on Harrison Flats in the northern part of the area showed the results to be expected by drilling on other terraces. All of these wells produced water sufficient for rural potable uses but insufficient for municipal supply. The average rate of flow in these wells, as tested by pumps, would be from 4 to 6 gallons per minute. In an area of about 4 square miles represented by Secs. 29 and 32, T. 47 N., R. 2 W.,and Secs. 25 and 36, T. 47 N., R. 3 W., the approximate records of several drilled wells were secured.

The Emil Miller well is No. 1 on the map and is all in basalt except for a slight mantle of surficial material. Some surface water was obtained but this leaked out of the well at the depth of 90 feet where a porous unsaturated zone occured. From this depth to 116 feet the well was dry. An insufficient water flow at the latter depth caused drilling to proceed to 163 feet where a strong flow was encountered. The well was deepened to 168 1/2 feet and the water rises to the zone 90 feet from the surface where it appears to escape in a very porous layer. If this well were cased, the water would rise higher, but perhaps would not flow at the surface. A test was reported to have produced 21 gallons per minute for four minutes but the pump at the well at the time of the examination appeared not to have so large a pumping capacity. The "draw-down" was reported to be negligible. According to all reports, this is the best well in the entire country.

The Charles Wanamaker well, more than a half mile distant and at a higher elevation is 244 feet deep and all in basalt. It struck water at 205 feet. The flow into this well is 2 1/2 gallons per minute as measured by the pump. When pumped at a higher rate, the well is emptied.

The H. Fabrisions well is 185 feet deep in basalt. Water was struck at 175 feet. The water stands 40 feet in the hole and is lowered 20 feet by constant pumping at a rate of 3 1/2 gallons per minute which is the maximum capacity of the pump. It has never been pumped dry.

The Jones well struck water at a depth of 100 feet, and is 140 feet deep in basalt. The well has 40 feet of water in it which, according to authentic report, is now lowered by pumping at a rate of 3 1/2 gallons per minute.

The James W. Miller well struck a strong flow of water at 90 feet. Authentic information as to flow in this well was unavailable.

The Fly well is 200 feet deep in basalt and is reported to have less water than the Chas. Wanamaker well.

Most of the above described wells are producing water from at least two aquifers and the supply appears to be somewhat varied according to report. Under the most optimistic considerations the best well is likely to produce less than 50 gallons per minute and the average well of this group would perhaps produce 4 to 6 gallons per minute. In as much as the catchment, intake, and reservoir areas of this section are larger than those bordering the city of St. Maries and other conditions are similar, it is logical to conclude that results of drilling on the terraces closer to town would certainly not be any better, but on the contrary would probably be less productive of water.

CONCLUSIONS

The nearly flat lying basalt flows of the St. Maries region contain water which is technically artesian water and which would be suitable for a sanitary city water supply.

Were it not for erosion by St. Joe and St. Maries rivers and their tributaries, a fairly good artesian basin and reservoir would be present. Unfortunately, these lava flows may be likened to a leaking bucket out of which water escapes as fast as it is poured in.

Most of the catchment, intake, and reservoir areas are so small that the annual ground water increment of any one terrace or mesa is insufficient for the necessary production but providing such an area existed which had sufficient increment, a battery of 18 or 20 wells from 250 to 300 feet deep would be necessary to furnish a suitable quantity. The distance from the city mains would require several miles of pipe line. A large expenditure would be required in drilling numerous wells and procuring pumps, pipe lines, and other equipment, as well as for annual upkeep. The amount necessary, in the writer's opinion, would not be justified by the water recovered unless no other source of supply were available. Another solution, of course, is the establishment of a protected water shed where all possible means for prevention of pollution should be taken. This plan would probably require several miles of pipe line and an expensive upkeep. Treatment of surface waters seems to be the most practicable solution to the problem if the cost of a protected water shed is out of the question.

Since this type of surface supply lies outside the province of the Bureau, it will not be discussed in this report.