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Memorandum on Ground Water from the Mississippian Rocks in the Vicinity of Miami, Oklahoma[1]

by

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Upon conclusion of the pumping tests on wells at the Goodrich Plant, Miami, Oklahoma, it was determined that sources other than the Ordovician rocks tapped by the existing wells would have to be utilized in order to obtain the required amount of water for the needs of the plant.

The only other ground-water source of large supplies in the area is from the Mississippian rocks overlying the Ordovician and cased off in the Goodrich wells and public-supply wells in the area. This memorandum is a short summary of existing information on the area and is based on published and unpublished reports and a short field reconnaissance. As part of the field work, four samples of water from the Mississippian rocks were collected. These were analyzed by the Austin office of the Quality of Water ~~Division~~ Branch of the Geological Survey and are included in the memorandum. Data concerning dewatering operations along the Melrose shear zones, as yet unpublished, was given by C. C. Knox of the U. S. Department of Interior, Bureau of Mines, and a bibliography of the other literature on the area is included as part of this report.

Rocks of Mississippian age are present at the surface over most of northeastern Oklahoma, and in the vicinity of Miami are present to a depth of about 450 feet. The strata, which are principally limestone and chert, dip to the northwest away from the Ozark uplift at a rate of about 30 feet to the mile. The Mississippian strata are separated from both the Ordovician below and the Pennsylvanian above by major disconformities, and in addition have disconformities between several of the individual formations. The Mississippian formations that are present at Miami and also the disconformities are shown in the graphic geologic section accompanying the pumping test memorandum. The Reeds Spring limestone, the Keokuk-Burlington limestone, and the Warsaw limestone contain large quantities of ground water.

Ground water in these formations occupies the cracks, fissures, and solution channels in the otherwise dense and tight limestone and chert. These openings have been localized both vertically and laterally by the geologic forces that have here been active; and, hence, occurrences of ground water are likely to be similarly localized. Especially important from a ground-water standpoint are the disconformities, or erosional unconformities which are present at the top of the Warsaw limestone, between the Warsaw and the Keokuk-Burlington limestone, and between the Keokuk-Burlington and the Reeds Spring limestone. At one time in the geologic past these horizons were at the surface, and as a result the limestone rock directly below them was extensively dissolved and weathered by the erosive forces active at the surface. The porous zone thus developed was later covered by other strata, and the solution-formed cavities are now filled with water which is confined to the zone by the impermeable limestone above and below.

[1] The use of stratigraphic nomenclature in this paper has not been checked for conformance to Geological Survey usage, nor has the paper been edited to the usual standards.

Structural conditions have also contributed greatly to the development of ground-water reservoirs. The area has undergone several periods of regional deformation related to the uplift of the Ozark mountains, and as a result the beds have been considerably sheared and shattered. The shattering has been to a marked degree localized along certain zones, the most important of which in this area is the Miami shear trough which consists of a series of elongated fault basins with which is associated a great amount of shattering and brecciation. The Miami shear trough trends northeast through the district just west of Afton, Miami, and Picher, Oklahoma, and continues across southeastern Kansas to Waco, Missouri.

Other zones of deformation are the Bendelari trough which trends northwest from its intersection with the Miami trough just west of Picher; and several similar troughs in the area south of Melrose, Kansas.

Major joint and fissure zones occur along and within these shear troughs. The combination of fissures and local structure has enabled underground drainage to remove large amounts of limestone by solution and has produced a porous condition that permits free circulation of ground water. Because of this these fractured shear zones are excellent ground-water reservoirs.

Fracturing localized along more competent beds has also played a part in forming ground-water reservoirs. The Grand Falls chert member, which occurs near the base of the Keokuk-Burlington limestone, is of this nature. This bed is locally called "water flint" because of the abundance of water usually found in it.

Quantity of Water -- The sheared and shattered zones of the Mississippian are, in addition to being excellent ground-water reservoirs, the loci of the rich zinc and lead mineralization of the Oklahoma-Kansas mining district. This conjunction of large quantities of ground water with the ore deposits has complicated the mining operations of the area, and it has been necessary for the mine operators to carry on extensive mine dewatering operations in order that the ore can be made accessible.

In Oklahoma Geological Survey Bulletin No. 56, "The Miami-Picher Zinc-Lead District, Oklahoma", published in 1932, in the Chapter on "Mining Methods" C. F. Williams reported "...A recent survey showed that forty-three stations in the Oklahoma-Kansas field were lifting an average of more than 9,000 gallons a minute over a twenty-four hour period." The total pumpage at present, however, is undoubtedly much greater than this. The unprecedented demand for lead and zinc in the war-time economy has resulted in the reopening of abandoned properties and the carrying of mining operations to a depth formerly not economical, with subsequent multiplication of the dewatering problems. The Eagle-Picher central pumping station at Picher, Oklahoma, pumping from a shaft, is reported to be producing at a constant rate of nearly 5,000 gallons per minute; and two wells on the Park-Walton lease of the United Zinc Smelting Corporation south of Melrose, Kansas, are pumped constantly at a combined rate of more than 2,000 gallons per minute. In addition there are numerous other smaller pumping operations over the area which in aggregate must pump large quantities.

At least two large-scale and long-term pumping tests have been made as studies of the dewatering problem. One was by the Eagle-Picher Mining and Smelting Company at their Garrett lease in sec. 36, T. 34 S., R. 23 E., Cherokee County, Kansas, and the other by the Bureau of Mines at the Park-Walton lease of United Zinc Smelting Corporation in sec. 13, T. 29 N., R. 22 E., Ottawa County, Oklahoma. The Eagle-Picher location is on the Miami shear zone, and the United Zinc location is on the Melrose shear zones.

The Eagle-Picher pumping test has been described by C. E. Abernathy in State Geological Survey of Kansas Bulletin 38, "Ground-Water Resources of Mississippian and Older Rocks in Bourbon, Crawford, Cherokee, and Labette Counties, Southeastern Kansas." He reports that from August 9, 1938, to March 7, 1939, water was pumped from a 5 by 9 foot shaft, 465 feet deep by three deep-well turbine pumps having a combined maximum capacity of 8,000,000 gallons per day. The ground-water reservoir was the Reeds Spring limestone. Abernathy does not give an overall average figure for pumpage but does report that for a period of 67 days near the end of the test the average pumpage was approximately 7,200,000 gallons per day. During the period of the test the water level was lowered from 180 feet to 324.8 feet, or 144.8 feet.

In his conclusions, Abernathy states, "The tests indicate that although the drawdown was very great, water might be withdrawn at this rate (8,000,000 gallons a day) without serious injury to the Reeds Spring groundwater reservoir. Similar conditions favorable for ground-water development probably exist at most localities on the Miami 'fault' area."

The pumping test at the United Zinc property was made by the Bureau of Mines in order to determine the feasibility of dewatering by wells the small lead and zinc deposits along the Melrose shear zones. The complete results of this test are soon to be published as part of "Supplement to War Minerals Report 193" by Clinton C. Knox.

For this test three wells 12¼ inches in diameter and about 370 feet deep were drilled and equipped with 150 h.p. Pomona deep well turbine pumps, each with a rated capacity of 1200 gpm. The wells were spaced at 500 foot intervals. Pumping began with one well on May 7, 1943, the second well was added June 1, and the third was added July 28. All three wells were then pumped continuously except for minor breakdowns, until November 15, 1943, when the test was deemed successful and the pumping plant was turned over to the United Zinc Smelting Corporation for regular operation. During the period of the test the total operating time was 10,568 pump hours, and the total output was 741,000,000 gallons, or an average of 1,170 gpm from each well.

Regular observations of the water level were made in the pumped wells and in ten other wells in the surrounding area. The average water level in the three pumped wells dropped from 180 feet to 316 feet during the period of the test, and in the other wells dropped varying lesser amounts. The shape of the cone of depression formed was very irregular and obviously influenced by the local structural conditions. The pumped wells are located near the northwest corner of the known deformed area, and apparently as a result the water levels in wells as little as a mile to the northwest and southwest were unaffected by the pumpage, while that in wells three miles to the south and east in the direction of the major structural trends was lowered 100 feet or more. The complete extent on the cone of depression was not determined because of the limited number of observation wells available, but it is known that over an area of at least six square miles, nearly all to the southeast of the pumped wells, the water level was lowered 100 feet or more.

There is bitumen in the area, and this caused trouble in one of the wells, clogging the impellers, but was controlled by lowering the discharge and keeping the water level in the well sufficiently above the bowls so that the bitumen, floating on the top, was not sucked down by the action of the impellers.

Since the property has been turned over to the United Zinc Smelting Corporation for development, pumping has been continued at a somewhat reduced rate. At the present time only two wells are in operation, and they are pumping at a combined rate of 2,000 to 2,500 gpm. At this constant rate of pumpage there has been a lowering of the water level of only two feet over a period of approximately nine months.

There are no wells tapping the Mississippian in the immediate vicinity of the Goodrich plant, the nearest being dewatering wells in the mining area about four or five miles to the north. These wells are near the Miami shear zone. There are no large developments at any distance from the shear zones; and, hence, little is known of the possibilities of developing large supplies there. It would seem, however, they would not be nearly as good as in the shattered zones near the fault.

It appears that the Miami shear zone has had directly opposite effects on the Mississippian rocks than on the older rocks as far as ground water is concerned. In the Ordovician beds tapped by the deep wells of the area the fault acts as a barrier to the movement of ground water and, hence, tends to limit the amount of development. In the Mississippian rocks, on the other hand, the faulting has opened the beds to the movement of ground water and increased their capacity as an aquifer. The reason for this seeming contradiction apparently lies in the differences in lithology. The very competent limestone and chert beds of the Mississippian were shattered and broken to a considerably greater degree than the less competent dolomite beds of the Ordovician; and, in addition, the sandstones of the Ordovician Roubidoux formation, which produces a large part of the deep water, was probably silicified and tightened near the faulted zone at the time of deformation. Another factor that is probably important is the greater solubility of limestone over dolomite. This has allowed the percolating ground water to enlarge the openings formed by the shearing to a much greater degree in the Mississippian limestones than in the Ordovician dolomites.

The large-scale pumping operations that have been carried on as a dewatering program and the pumping tests that have been made all clearly indicate that relatively large quantities of water are available from the Mississippian. These pumping operations have, of course, developed a large part of the capacity of the aquifer; but because of their purpose they do not necessarily limit additional development of the aquifer. The aim of the mining companies is not to pump a definite amount of water but only to hold the water level low enough to carry on mining operations; and, hence, pumpage in the area for any other purpose would tend to cause the mining companies to decrease their pumpage. It thus seems that insofar as quantity is concerned the needs of the Goodrich Plant could easily be supplied by properly located wells into the Mississippian formations of the area.

Quality of Water -- At the present time nine analyses of water from the Mississippian rocks are available and are reported in the following table, along with one of the water produced by a deep well at the Goodrich plant. As can be seen, the quality of water from the Mississippian varies greatly; the total solids in the nine samples ranging from 177 to 4320 ppm. The water is, in general, a bicarbonate water but having a considerable amount of chloride and sometimes sulphate. Samples No. 6 and 7 are from the active mining district and have apparently picked up a large amount of sulphate through natural oxidation of the sulphide lead and zinc ores, and as a result are extremely high in total solids. The high sulphate content of samples No. 4 and 5 are probably due to the same cause.

There are no known deposits of lead and zinc beneath the Goodrich tract, and it thus seems unlikely that the sulphate content of water from wells drilled there would be excessive.

The best of the Mississippian waters compare favorably with the Ordovician water of the Goodrich well, that from the spring being even lower in total solids. This spring, however, is approximately 30 miles from the Goodrich plant; and it seems doubtful that water of this quality could be obtained near the plant. The sample of most interest is that from the Park-Walton well. It is from a well of proved high yield, and near enough to the Goodrich plant to give hope that water of like quality could be obtained there. This water has more than double the amount of total solids and about four times the amount of chloride that the Goodrich well water has. For cooling purposes, however, it would be nearly as satisfactory. The total hardness is less, and as a result incrustation caused by its use for heat exchange would probably be less. On the other hand, the high chloride content might make the water slightly corrosive, although the high alkalinity would tend to offset this.

Although it is not reported in the analyses, all of the Mississippian waters carry notable amounts of hydrogen sulphide; and this will probably prove to be the greatest objection to its use. Hydrogen sulphide is highly corrosive, and it might not be practicable to use the water without preliminary treatment. Fortunately hydrogen sulphide can be removed simply from water by aeration. Whether this would raise the temperature of the water too high for use as a cooling agent would have to be determined.

No. in table	Source of Water	Location	Source of Data	Date	Temp. of Water	Aquifer
1	Goodrich well #4, 1235'	Sec. 24, T. 28 N., R. 23 E., Ottawa Co.,Okla.	Analysis by Quality of Water Division, Geological Survey	8-25-44	67° F.	Roubidoux fm. & Ordovician dolomite
2	Spring issuing from Boone limestone	Sec.23,T.23N.,R.23E., Mayes County, Okla.	do.	do.		Mississippian
3	Park-Walton dewatering well, 370'	Sec.13,T.29N.,R.22E., Ottawa County, Okla.	do.	do.	65° F.	do.
4	Jayhawk Ordnance Works well, 175'	Sec.4,T.34S.,R.25E., Cherokee County, Kansas	Geological Survey of Kansas, Bull. 47, Pt. 3.	12-28-41		Mississippian (Reeds Spring fm.)
5	Same well, 244'	do.	do.	12-30-41		do.
6	Eagle-Picher Central Pumping Station	Sec.15,T.29N.,R.23E., Ottawa County, Okla.	Analysis by Quality of Water Division, Geological Survey	8-25-44	58° F.	Mississippian
7	Mine water	Sec.31,T.29N.,R.23E., Ottawa County, Okla.	do.	do.		do.
8	Church Mine water	"North of Miami,Okla."	U.S.G.S. Bull. 606	1911		do.
9	Chapman and Lennan Mine water	do.	do.	1912		do.
10	do.	do.	do.	do.		do.

Table 1. Sources of water for which analyses are reported.

Sample No.	1 PPM	2 PPM	3 PPM	4 PPM	5 PPM	6 PPM	7 PPM	8 PPM	9 PPM	10 PPM
Total hardness	146	148	95	546	728	1980	2080	105	254	137
Total solids	201	177	535	860	1164	2690	4320	443	648	443
Iron				0.94	2.7		iron			
Manganese				0.0	0.2					
Calcium	32	52	20	184	226	530	576	30	74	3.6
Magnesium	16	4.4	11	21	40	161	156	7	17	11
Sodium and Potassium	18	7.5	178	26	27	49	497	96	93	89
Total alkalinity	151	143	308	138	324	169	acid			
Bicarbonate				168	395			180	310	140
Sulphate	15	29	42	430	426	1840	2970		tr.	21
Chloride	32	9.0	132	12	14	25	51	119	144	136
Nitrate	0.2	5.1	0.2	0.75	0.93					
pH	8.4	8.1	8.1			8.0	3.4			

Table 2. Analyses of water from northeastern Oklahoma and southeastern Kansas.

Temperature of Water -- Only two determinations of temperature of the Mississippian water are available, both made by the writer. The water from the Park-Walton wells have a temperature of 65° F. while that pumped at the Eagle-Picher Central Pumping Station eight miles to the east has a temperature of 58° F. The reason for this discrepancy is not apparent, and this office has been at a loss to explain it. Both waters are coming from the same geologic horizon and approximately the same depth, and there are no other discernable factors that might influence temperature. These waters are produced 500 to 600 feet above the water in the Goodrich well; and, hence, with a normal temperature gradient, they should be seven or eight degrees cooler. The Eagle-Picher water is thus of about the expected temperature, while that from the Park-Walton well is unexplainably several degrees too warm, but is still lower than that of the Ordovician waters.

Conclusions -- Enough definite information exists as to actual quantity of water pumped and yield of wells from the Mississippian to indicate clearly that insofar as quantity is concerned the needs of the Goodrich plant could be readily supplied by properly located wells tapping these strata. The yield of individual wells would probably vary considerably and it is impossible to predict the number that would be required without previous test drilling. It seems unlikely that wells with a yield as high as that of the Park-Walton wells (1000-1200 gpm) could be expected.

The quality of the water from the Mississippian varies greatly, some of it being extremely hard and high in total solids while other of it is softer and not much greater in total solids than the water from the deeper Ordovician strata. The high total solid content of some of the water appears to be related to the zinc and lead deposits of the Tri-State mining district; but, since there are no known ore deposits beneath the Goodrich tract, it seems possible that water of reasonably good quality could be obtained there. The greatest deterrent to use of the Mississippian water is the hydrogen sulphide content which would probably necessitate treatment by aeration or some other means.

Temperature data on the Mississippian water are incomplete and somewhat conflicting. The water should, however, be slightly cooler than the deeper Ordovician water, and might possibly prove to be as much as eight or nine degrees cooler.

Because of the questionable quality of water from the Mississippian rocks these strata are not an ideal source of ground water for use by the Goodrich plant. The possibility does exist, however, that water which can be utilized to meet at least a portion of the Goodrich needs could be obtained at or near the plant; and, in view of the widespread lowering of water levels that will occur in the Ordovician aquifer if quantities approaching the estimated 3000 gpm are pumped from it, this possibility would justify further investigation of the source. The only way it can be adequately evaluated is by drilling a test well or wells and running proper pumping tests. This would result in a definite knowledge of the quantity and quality of water available.

(1) Abernathy, G. E., "Groundwater Resources of Mississippian and Older Rocks in Bourbon, Crawford, Cherokee, and Labette Counties, Southeastern Kansas", State Geological Survey of Kansas, Bulletin 38 (1941).

(2) "Deep Water Well at the Jayhawk Ordnance Works in Cherokee County, Kansas," State Geological Survey of Kansas, Bulletin 47, Part 3 (1943).

(3) Fowler, George M., "Tri-State Geology", Engineering and Mining Journal, November 1943.

(4) Knox, Clinton C., "Supplement to War Minerals Report 193", U. S. Bureau of Mines (unpublished).

(5) Siebenthal, C. E., "Origin of Zinc and Lead Deposits of the Joplin Region", U. S. G. S. Bulletin 606 (1915).

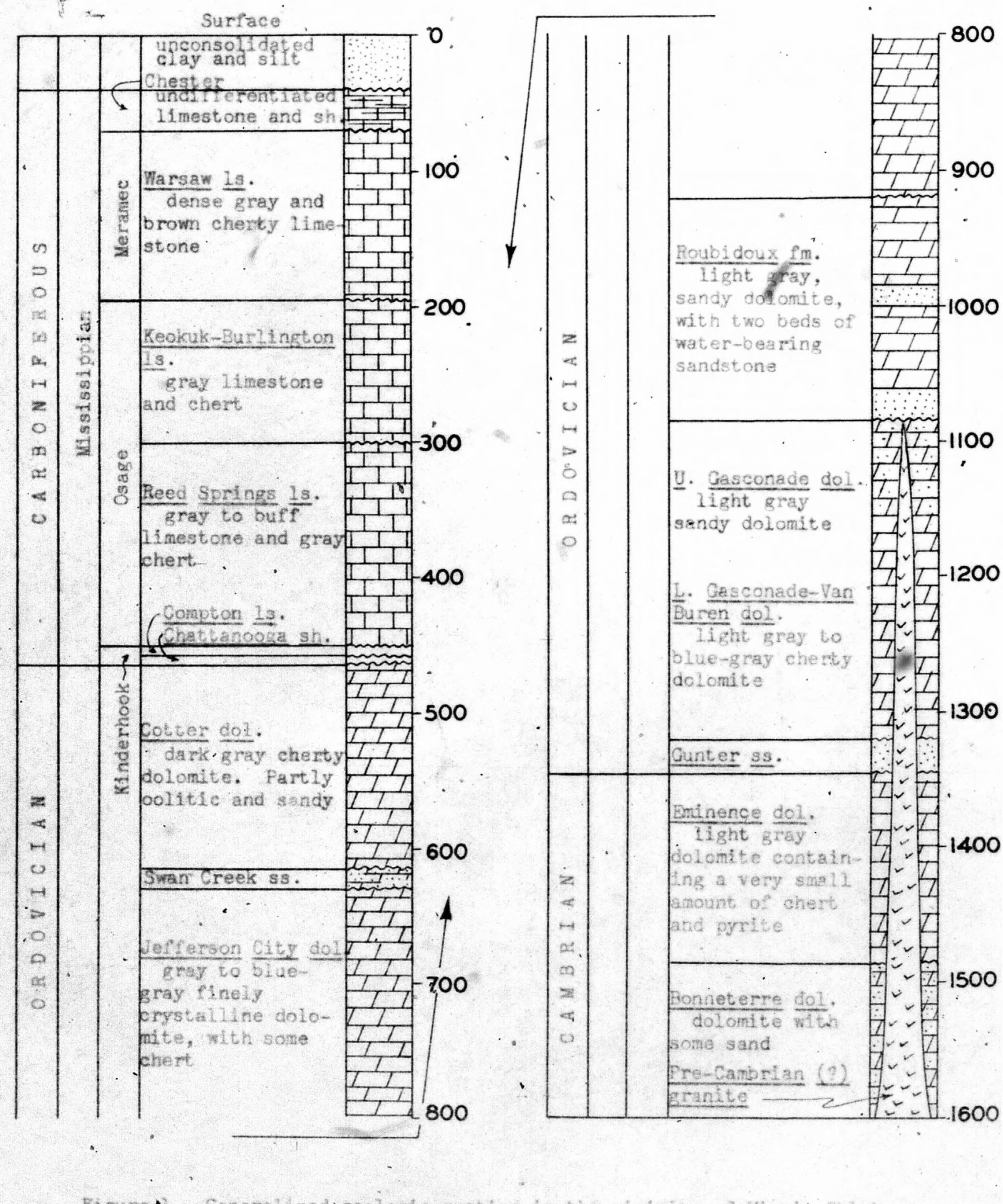

Figure 1. Generalized geologic section in the vicinity of Miami, Oklahoma.