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Distribution and Source of Barium in Ground Water at Cattaraugus Indian Reservation, Southwestern New York

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By Richard B. Moore and Ward W. Staubitz

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CONTENTS

ILLUSTRATIONS

PLATES
(in pocket)

TABLES

CONVERSION FACTORS AND ABBREVIATIONS

The following factors may be used to convert inch-pound units of measurement to the International System of Units.

Multiply inch-pound unit	by	To obtain SI unit
inch (in)	2.540	centimeter (cm)
foot (ft)	3.048×10^{-1}	meter (m)
mile (mi)	1.609	kilometer (km)
degree Fahrenheit (°F)	5/9 (F°-32)	degree Celsius (°C)

Abbreviations used in the text of this report include:

mg/L, milligrams per liter
ug/L, micrograms per liter
gal/min, gallons per minute
ml, milliliter

DISTRIBUTION AND SOURCE OF BARIUM IN GROUND WATER AT CATTARAUGUS INDIAN RESERVATION, SOUTHWESTERN NEW YORK

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ABSTRACT

High concentrations of dissolved barium have been found in ground water from bedrock wells on the Seneca Nation of Indians Reservation on Cattaraugus Creek in southwestern New York. Concentrations in 1982 were as high as 23.0 milligrams per liter, the highest concentration reported from any natural ground-water system in the world. The highest concentrations are in a bedrock aquifer and in small lenses of saturated gravel between bedrock and the overlying till. The bedrock aquifer is partly confined by deposits of silt, clay, and till. The highest barium concentrations are attributed to dissolution of the mineral barite ($BaSO_4$), which is in the bedrock and possibly in overlying silt, clay, and till. The dissolution of barite apparently is controlled by the action of sulfate-reducing bacteria, which alter the $BaSO_4$ equilibrium by removing sulfate ions and permitting additional barite to dissolve.

Ground water from the overlying unconsolidated deposits and surface water in streams contain little or no barium. Because barium is chemically similar to calcium, it probably could be removed by cation exchange or treatments similar to those used for water softening.

INTRODUCTION

Barium is present naturally in the ground water of New York State. A recent study of public-water supplies in New York State reported that barium concentrations range from less than 0.001 mg/L to 2.3 mg/L, with the highest values in western New York (Cartwright and Ziarno, 1980). The New York State drinking-water standard for barium is 1.0 mg/L. Ingestion of barium in high concentrations may result in vomiting, diarrhea, spasms, and in some cases, paralysis. The fatal dose of barium for man is reported to be 550 to 600 mg (U.S. Environmental Protection Agency, 1976).

In 1981, the U.S. Environmental Protection Agency and the New York State Department of Health sampled two public-water supplies that obtain ground water from wells 6 miles apart on the Cattaraugus Indian Reservation (fig. 1). Results of the sampling showed barium concentrations of 21.5 mg/L in one system amd 6.13 mg/L in the other. Because the residents of the reservation rely on these two public water supplies and on many other private wells, an investigation of the high barium concentrations was begun.

Little research has been done to identify the cause of high barium concentrations in ground water. The Cattaraugus Indian reservation, which lacks industries or other obvious manmade sources of barium, made an ideal area for study. In the spring and summer of 1982, the U.S. Geological Survey, in cooperation with the Seneca Nation of Indians, conducted a single sampling of 100 wells and springs on the reservation to determine the distribution and concentration of barium in ground water.

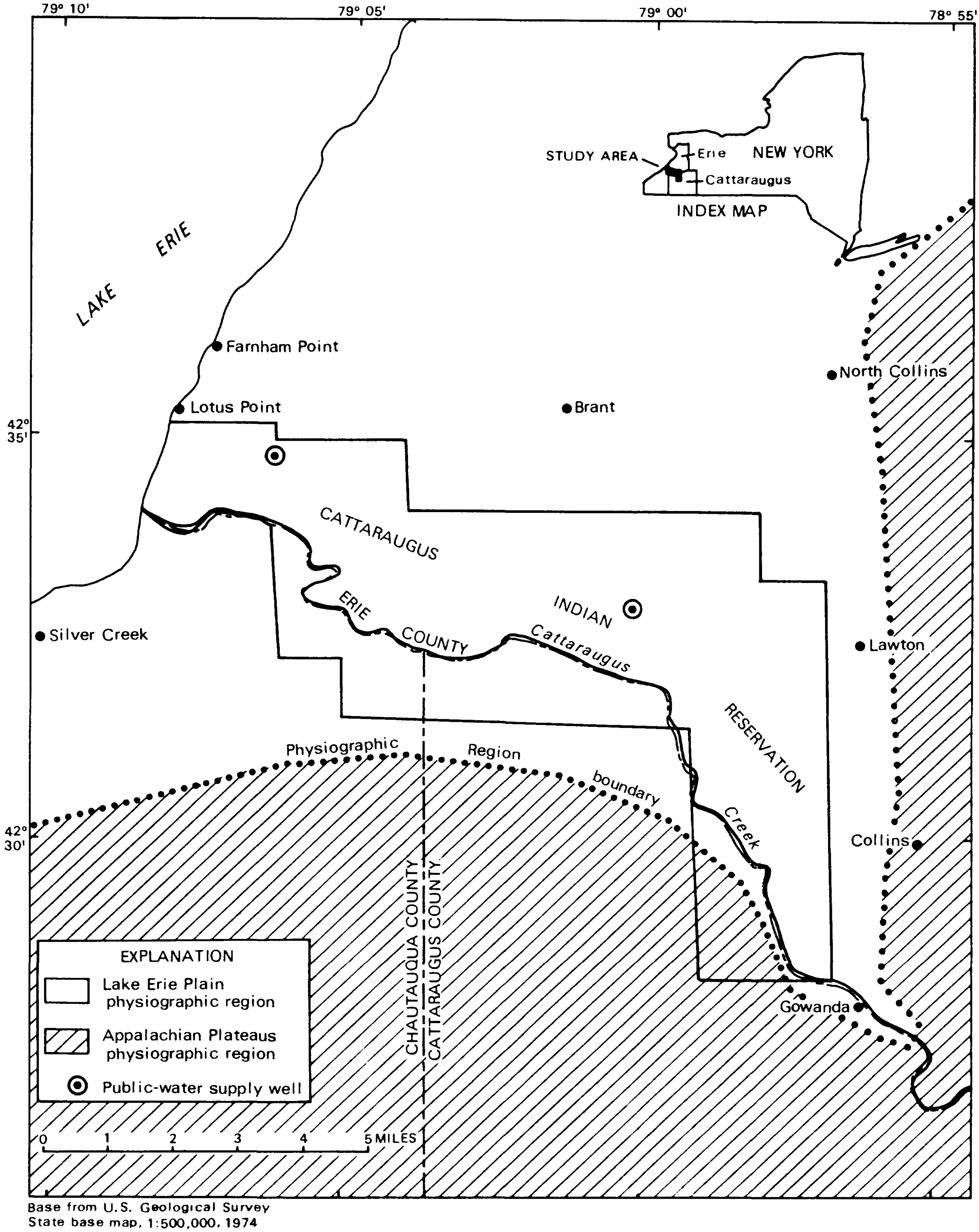


Figure 1.--Location and physiographic regions of the study area.

Purpose and Scope

This report describes the results of a study to obtain, from a single sampling of ground water from 100 representative wells and springs, information on the distribution and source of barium in ground water at the Cattaraugus Indian Reservation. The report also describes the geochemical processes involved in barium mobilization and presents detailed maps of the surficial and bedrock geology, including two geologic sections. Also included is a tabulation of water-quality and well data and geologic logs of two test holes.

Acknowledgments

This project was coordinated with the Seneca Nation of Indians through the Seneca Nation Planning Department. Supplemental data gathered for this study were provided by the Seneca Nation, local well drillers and consultants, and the residents of the Cattaraugus Indian Reservation. Thanks are extended to all of the above and to Sam Bradshaw of the Indian Health Service, Dr. Windsor Sung of the University of New Hampshire, and to other reviewers of this manuscript.

METHODS

The study entailed a literature search, compilation of available geohydrologic data, and a sampling program to test water from 100 wells and springs on the reservation for barium concentration. This approach was used on the assumption that the barium concentrations would be highest near or downgradient from the source(s) of the barium and that the distribution would indicate the location and nature of the source.

Water Sampling

Well-water samples generally were taken from household taps that were used frequently. If a tap was not used frequently, water was run for several minutes before sampling to remove all long-standing or stagnant water. Water from a few of the wells sampled had been treated by water softening; samples from those households were taken from taps yielding untreated water wherever possible.

All samples were collected in 100-mL acid-washed polyethylene bottles, acidified with nitric acid, and shipped to the U.S. Geological Survey Central Laboratory in Atlanta, Ga., where total barium content was determined by atomic absorption spectrometry. If available, data on well depth, well diameter, aquifer, well owner and driller, pH, and specific conductance also were compiled in the field for each well sampled. These data are tabulated in table 4 (at end of report).

Filtered and unfiltered samples also were collected from three wells known to have high barium concentrations to obtain more detailed information on the water chemistry. The filtered samples were analyzed for dissolved barium, calcium, chloride, fluoride, magnesium, nitrogen, potassium, silica, sodium, strontium, sulfate, and total alkalinity. The results (table 3) were then used as input for the WATEQF computer program (Plummer, Jones, and Truesdell, 1976) to determine the saturation level of the ground water with respect to common barium-containing minerals. The unfiltered samples were analyzed for total barium and total sulfide to determine whether barium is in the dissolved or suspended state.

GEOLOGY AND STRATIGRAPHY

Auger holes were drilled adjacent to the two wells from which the high barium concentrations were initially reported. Sediment and bedrock samples were collected from the auger holes to verify the stratigraphy near the wells. The logs of the auger holes are included in table 2 (p. 10).

Maps of the bedrock geology (pl. 1) and the surficial geology (pl. 2) of the area and two geologic sections (fig. 2) were drawn to delineate the geologic formations and surficial deposits and to identify their relationship to well locations and the distribution of barium.

PHYSIOGRAPHIC SETTING

The Cattaraugus Indian Reservation occupies 60 mi^2 of the Cattaraugus Creek valley southeast of Lake Erie (fig. 1). Cattaraugus Creek has a drainage area of about 450 mi^2 and flows westward to Lake Erie, draining several north-south-trending tributary valleys in the Appalachian Plateaus upland. This area has a continental climate with cold winters and warm summers. The mean annual precipitation is about 37 inches; the mean annual temperature is about 46° F (U.S. Department of Commerce, 1982).

The western and central parts of the reservation are within the Erie Lake Plain of the Central Lowlands, and the southeastern part is in the southern New York Uplands of the Appalachian Plateaus (Tesmer, 1975). The low-lying Erie Lake Plain is a relatively flat, gently sloping surface that rises eastward from Lake Erie to the base of the Appalachian Plateaus. The central part of the reservation is in an embayment of the Erie Lake Plain into the uplands (Muller, 1963); it is characterized by a relatively broad, flat valley bordered on the north and south by low-lying bedrock hills. The southeastern part of the reservation is at the base of the Appalachian Plateaus and is characterized by gently rolling hills.

Relief on the reservation ranges from 473 ft along the shore of Lake Erie to 1,040 ft in the uplands. The Erie Lake Plain occupies the area between 473 ft and 850 ft (Muller, 1963).

The bedrock that underlies the unconsolidated deposits consists of sedimentary rocks of the Canadaway and Java Formations and the West Falls Group of Devonian age (Buehler and Tesmer, 1963 and Tesmer, 1975). These strata are essentially undeformed and dip gently to the south-southeast. Plate 1 depicts the bedrock geology and includes a brief description of geologic units.

Unconsolidated deposits overlie bedrock both in the Cattaraugus Creek valley and along the hillside. The valley is partly filled with as much as 350 ft of lacustrine sediments of fine sand, silt, and clay that were deposited in ice-dammed lakes that preceded Lake Erie (fig. 2). After the lakes receded, Cattaraugus Creek deposited alluvial sand, gravel, and silt over the lacustrine deposits. The bedrock hills are covered in most places by a thin layer of till. A map of the surficial geology is shown in plate 2; the stratigraphy along two geologic cross sections is shown in figure 2.

HYDROGEOLOGY

Water supplies on the reservation are obtained primarily from two kinds of aquifers--confined bedrock and unconfined, unconsolidated sand and gravel deposits. A third type, consisting of scattered pockets or layers of sand and gravel buried beneath major confining units, may yield small quantities of water, but this type is not widely used in the area.

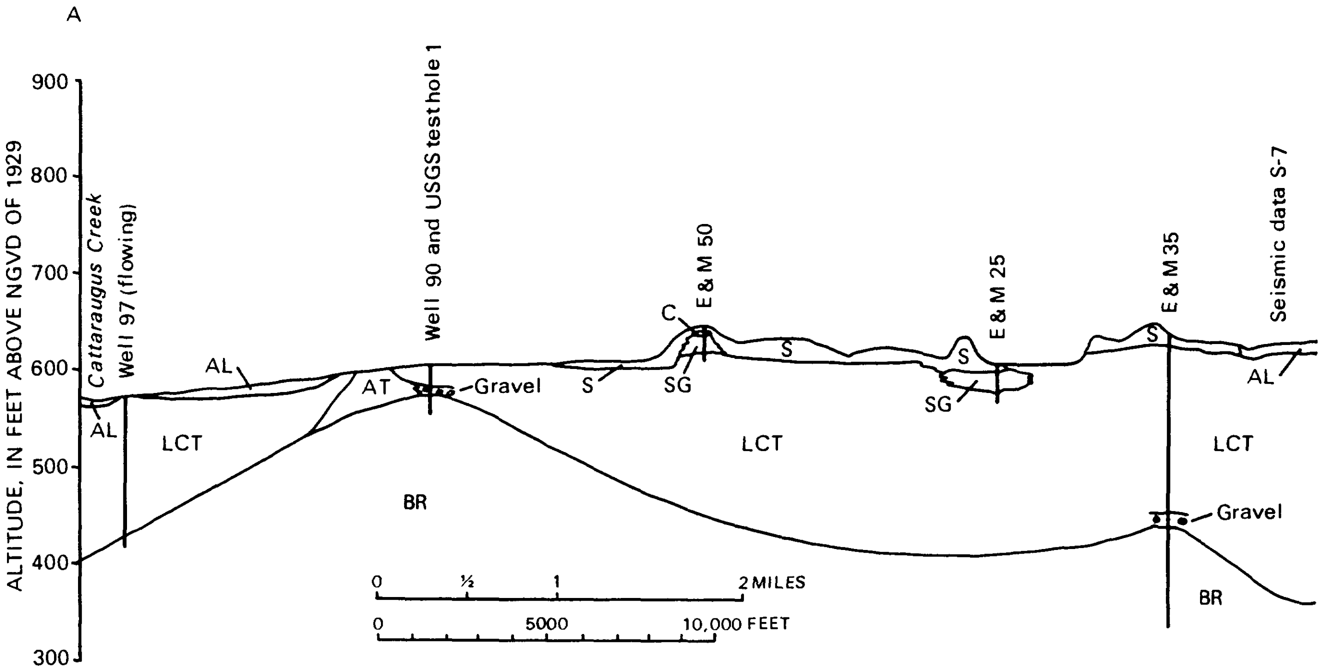
Bedrock Aquifer

The bedrock aquifer is recharged by rain and snowmelt on the surrounding hillsides, which in some areas extend beyond the reservation boundaries, and also along the valley axis by upward movement of deep ground water, which is of poorer quality than that from the hillsides. The bedrock aquifer discharges ground water upward into the surficial valley-fill deposits, as indicated by artesian heads along the valley axis. The bedrock is mostly confined by silt and clay deposits that formed in late-glacial ice-dammed lakes and were then reworked and redeposited as lodgment till by glaciers. These silt and clay deposits have low permeability and therefore limit the exchange of water between the bedrock and the surficial sand and gravel aquifer.

Few wells in the area extend more than 200 feet into the bedrock because the mineral content of the ground water increases beyond acceptable limits below that depth.

Unconsolidated Aquifer

The unconsolidated aquifer in the area is composed of saturated sand and gravel deposits at or near land surface that interfinger with or overlie the silt and clay layers (pl. 1 and 2). These unconsolidated deposits consist of deltaic sand and gravel in the southwestern part of the reservation, beach sand and gravel scattered locally throughout the reservation, and alluvial sand and gravel in low-lying areas near Cattaraugus Creek and other streams (pl. 2). These deposits are recharged by precipitation wherever they are exposed at land surface and locally from the upper bedrock aquifer.



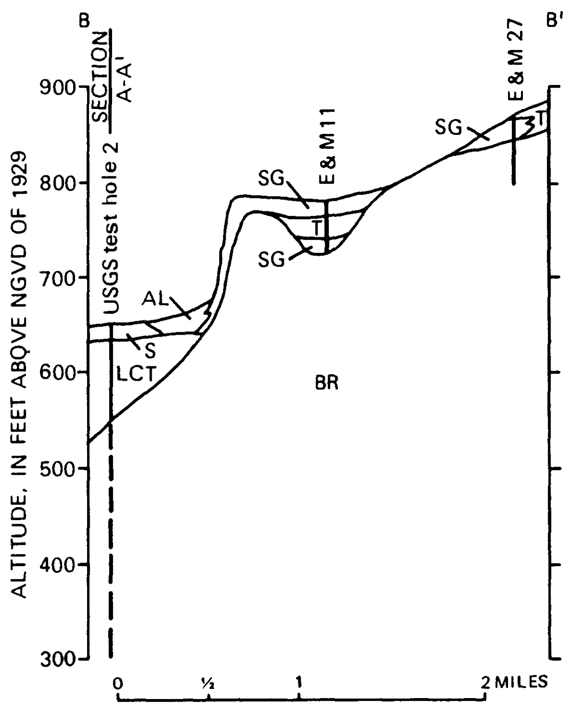
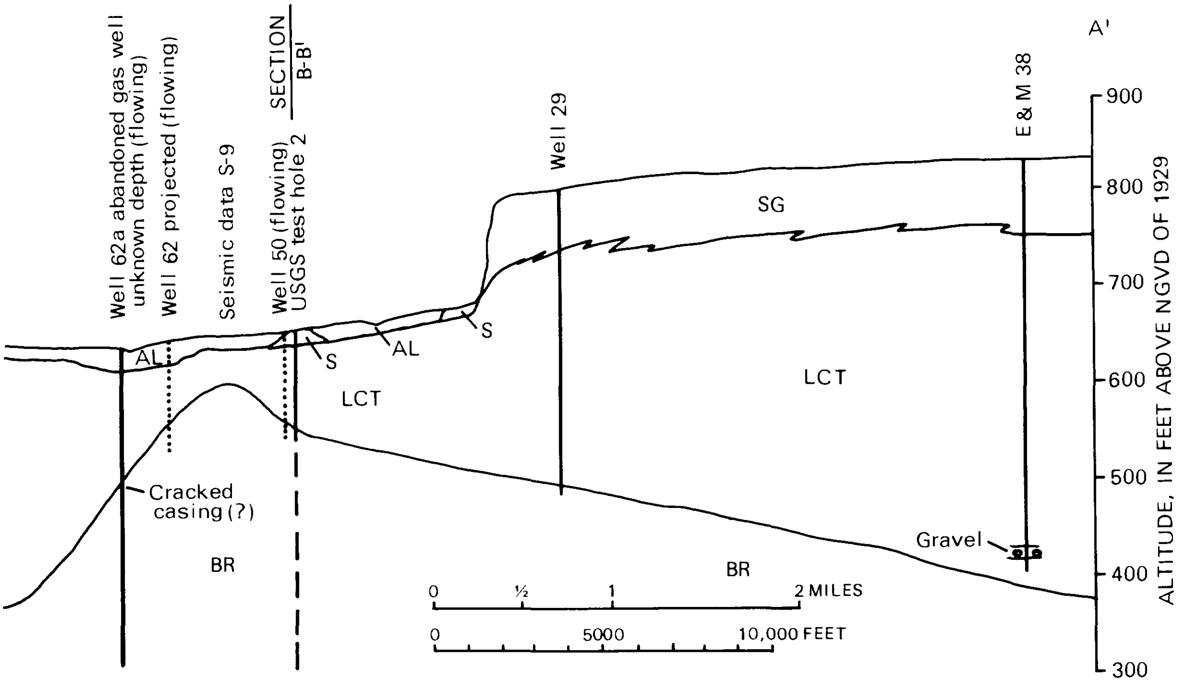


Figure 2.--Geologic sections through Cattaraugus Indian Reservation.



EXPLANATION

AL	Alluvium; deposited by streams; low permeability where silty, moderate permeability where sandy or gravely
SG	Sand and gravel; undifferentiated, high permeability
S	Sand, undifferentiated; high permeability
C	Clay; low permeability
LCT	Clay with silt; deposited in late-glacial ice-dammed lakes, partly reworked and redeposited as lodgment till; low permeability[1]
AT	Ablation till; low permeability where clayey, moderate permeability where sandy
T	Till, undifferentiated; low permeability where clayey, moderate permeability where sandy
BR	Bedrock undifferentiated; moderate permeability due to fractures near the upper bedrock surface

Well 29	Well -- number is from table 4
Well 50	Well of unknown depth and stratigraphy -- number is from table 4
USGS testhole 2	Test hole -- U.S. Geological Survey data on file with the USGS, Ithaca, N.Y.
E & M 38	Well -- number from Edwards and Moncreiff (1981 unpublished well report on file with the Seneca Nation Housing Authority)

[1] Localized layers of water-bearing gravel occur within or beneath this clay unit as labeled in section A-A'.

(Section locations are shown in pl. 2.)

DISTRIBUTION OF BARIUM

Ground Water

Barium concentration in samples from wells ranged from less than 0.5 mg/L to more than 23.0 mg/L. The highest barium concentration found during the study, 23 mg/L, was the highest reported to date from any natural ground-water system in the world. The second highest in the world, 19.4 mg/L, was in a ground-water sample from the Crimean Steppe zone of the Soviet Union (Terdovidov, 1971).

The areal distribution of barium as depicted on plate 1 indicates that wells with high barium concentrations are distributed randomly throughout the reservation. They are not clustered along Cattaraugus Creek nor around gas wells, nor are they limited to specific bedrock units.

The hydrologic, geologic, and chemical data on well and spring samples in table 4 (at end of report) indicate that:

(1) High barium concentrations are mainly in wells that penetrate the bedrock aquifer. Of the 28 wells with barium concentrations in excess of 0.5 mg/L, all are drilled wells, of which 12 were reported by the owners to penetrate bedrock. The remaining 16 are assumed to penetrate bedrock because they are either deep or near bedrock outcrops.

(2) Many of the wells with high barium concentrations also have a hydrogen sulfide odor.

(3) One well (site 65, pl. 1) having high barium concentrations taps a buried pocket of sand and gravel.

(4) The 26 wells and springs known to tap the surficial sand and gravel aquifer yield water with low barium concentrations (less than 0.5 mg/L).

Surface Water

The U.S. Geological Survey has collected water-quality samples regularly since November 1978 from Cattaraugus Creek at Gowanda, 1/2 mile upstream from the Reservation (fig. 1), at high, medium, and low flows. Results of the barium analyses of samples taken from November 1978 through September 1981 are summarized in table 1; the concentrations in all samples were low (less than 0.2 mg/L). Because no industries or other likely sources of barium are between the sampling point in Gowanda and the reservation, the barium concentrations measured in Gowanda are probably similar to those in Cattaraugus Creek where it passes through the reservation.

POSSIBLE SOURCES OF BARIUM

Several possible sources of the high barium levels in ground water were considered in this study; conclusions based on the results of the water-quality sampling are described in the following paragraphs.

Table 1.--Barium concentrations in water samples from Cattaraugus Creek at Gowanda, N.Y., November 1978 through September 1981.

[Data from U.S. Geological Survey, 1980, 1981, 1982. Location is shown in fig. 1. Dash indicates no data.]

Date (mo-day-yr)	Total recoverable barium (mg/L)	Dissolved Barium (mg/L)
11-09-78	0.10	0.10
1-10-79	.10	<.05
4-10-79	<.05	<.05
6-21-79	.10	.06
11-26-79	--	.05
1-22-80	.20	.07
4-29-80	<.05	.05
6-18-80	.10	.07
9-04-80	.10	.10
11-13-80	.10	.05
3-18-81	.10	.10
7-15-81	.10	.07
9-17-81	.10	.10

Cattaraugus Creek

If barium in ground water originates from seepage from Cattaraugus Creek and surface-water sources upstream from the reservation, high barium concentrations would be found in water samples from the creek and from wells adjacent to the creek wherever natural or induced recharge may occur. The distribution of barium shown in plate 1, however, does not indicate a clustering of high barium concentrations in wells near the creek, nor were high concentrations detected in samples from the creek (table 1). Therefore, Cattaraugus Creek is probably not the source.

Land Surface

If barium originates from the dumping of barium-rich substances on the land surface, large barium concentrations would be expected in shallow wells near the contaminated areas. Plate 1, however, indicates that the high barium concentrations are widespread, not localized in any specific area. Also, high barium concentrations were found in water from the deep wells, not the shallow wells, which are more vulnerable to contamination from surface sources. For example, wells 50, 51a, and 51b (table 4 and pl. 1) are close to one another but have considerably different barium concentrations. The deeper well (50) is the only one with a high concentration of barium (23 mg/L). This well penetrates more than 80 ft of relatively impermeable silt and clay, as determined from test boring 2 (table 2) before reaching the water-bearing unit (presumably bedrock). These observations seem to rule out surface contamination as the source of barium.

Table 2. Geologic logs of auger test holes.

[Locations are shown in pl. 2.]

TEST HOLE 1

Located 50 ft north of well 90. Log from sample study by R. B. Moore, U.S. Geological Survey.

0-6 ft	Clayey silt, brown, breaks apart, moist
6-15 ft	Clay, some silt, brown to gray, very pliable, saturated
15-26 ft	Till, mostly clay, pebbles and cobbles, gray, nearly dry
26.5 ft	Refusal

TEST HOLE 2

Located about 200 ft west of well 50. Log from sample study by R. B. Moore, U.S. Geological Survey.

0-13 ft	Gravel, some silt and cobbles, brown, saturated at 7 ft
13-88 ft	Clay, with silt, intermittent sand layers, gray, pliable, saturated
88 ft	Bottom of hole; no refusal

Barite Drilling Mud

If barium originates from barite drilling mud used during the drilling of gas and water wells, large barium concentrations would be expected only in wells in which barite drilling mud was used. However, several wells with high barium concentrations were constructed by procedures that did not use drilling mud (Frey Well Drilling, written commun., 1982, and Edwards and Moncriel, oral commun., 1982), which indicates that drilling mud is not the source.

Gas Wells Tapping Deep Bedrock

If deep ground water containing high barium concentrations were leaking upward into the aquifers along the casings of active or abandoned gas wells, large barium concentrations would be expected in water wells close to or downgradient from the gas wells. However, the wells with high barium concentrations were not clustered around gas wells nor were they aligned downgradient from them. Therefore, gas wells do not appear to serve as a conduit for barium contamination.

Upper Bedrock

Results of the water-quality sampling indicate high barium concentrations to be widespread among wells tapping the bedrock aquifer. Because no other source of barium has been identified, the high barium concentrations are probably derived from the dissolution of barium minerals in the upper bedrock.

Barite ($BaSO_4$) and witherite ($BaCO_3$) are the most common minerals containing barium and are, therefore, the most probable sources of barium; their solubilities are the most probable controls on barium concentrations in ground water.

BARIUM SOLUTION PROCESSES

In an attempt to verify the state of saturation of ground water with respect to barite and witherite, the WATEQF program (Plummer, Jones, and Truesdell, 1976) was used to relate the ion-activity products (IAP) of barite and witherite in waters from the three wells (table 3) having the highest barium concentration to the solubility products (KT) of the minerals. From the relationship, a value of log IAP/KT greater than zero indicates oversaturation, a value less than zero indicates undersaturation, and a value of zero indicates saturation. The log IAP/KT values obtained were:

	Well 50	Well 62a	Well 90
Barite ($BaSO_4$)	*	0.3	0.7
Witherite ($BaCO_3$)	-0.7	-1.8	-1.5

*Concentration of sulfate was less than the detection limit, therefore, the IAP could not be calculated.

Thus, water at all three wells was undersaturated with respect to witherite, and water in wells 62a and 90 was oversaturated with respect to barite, indicating that barium concentrations in the waters are probably controlled by the solubility of barite. This result and the reported occurrences of barite elsewhere in the same type of rocks that underlie the reservation (Hall, 1843) strongly suggest barite to be the barium source.

Additionally, if barite is the primary source of barium, one would expect the molar concentration of sulfate to be similar to that of barium from the 1:1 stoichiometric relationship expressed in the following equation:

$$BaSO_4 \rightleftharpoons Ba^{++} + SO_4^{=} \qquad (1)$$

Additional sources of sulfate such as gypsum would make the sulfate concentrations even greater. However, the concentrations of sulfate in the three wells having the highest barium concentrations were very low (table 3). A possible explanation of the low sulfate concentrations may be the action of sulfate-reducing bacteria. In an anaerobic environment, these bacteria use sulfate as an oxygen source for metabolizing organic material. In the process, sulfate is reduced to sulfide, as indicated in equation 2, and the sulfide may eventually escape from solution as hydrogen sulfide gas (Hem, 1970), as follows:

$$SO_4^{=} + CH_4 \longrightarrow HS^{-} + HCO_3^{-} + H_2O \qquad (2)$$

The odor of hydrogen sulfide gas was noted in many of the wells sampled, including those with high barium concentrations.

Additional observations support this explanation. Sulfate concentrations in the ground water of three wells were between <1 and 2 mg/L (table 3), whereas those in precipitation in the area range from 2 to 25 mg/L (Archer and others, 1968, p. 19). Because precipitation is the main source of recharge for ground water in the area, either sulfate concentrations in precipitation were less at the time of deposition or sulfate is being removed from the ground water. The organic compounds necessary to support the sulfide-reducing bacteria are common in most shale bedrock and have been observed in the Dunkirk shale (pl. 1) (Tesmer, 1975, p. 34). Also, natural gas produced by anaerobic bacteria that require an environment similar to that of sulfide-reducing bacteria has been reported to be emitted from several water wells in the area (table 4). Together, these observations lead to the conclusion that the bedrock in the area has the proper anaerobic environment and food source to support sulfate-reducing bacteria, which are, in fact, removing sulfate from the ground water.

This conclusion has chemical implications significant to this study. If sulfate is being removed from solution, equilibrium will shift to favor the dissolution of barite, which will increase the amount of barium in solution. This process would explain the unusually high concentration of barium measured in the ground water of the Cattaraugus Indian Reservation.

The high barium concentrations in the water can probably be reduced to more acceptable levels by standard water-treatment techniques. Because barium has the same positive (++) charge as calcium and magnesium, barium should be removed from solution by water softening or ion exchange. Water softening appeared to be effective in reducing the barium concentration of water from well 50. The barium concentration in well 50 decreased from 23 mg/L to 0.3 mg/L after treatment by water softening (table 4).

Table 3.--Chemical analyses of ground water from the three wells having high barium concentrations, Cattaraugus Indian Reservation, N.Y.

[Well locations are shown on plate 1. All concentrations are in milligrams per liter. Samples collected April 23, 1982].

Constituent or Property	Well Number		
	50	62a	90
pH (field)	7.2	7.1	6.8
Total alkalinity [as $CaCO_3$]	200	240	340
Barium, dissolved	23.0	2.5	6.9
Calcium, dissolved	28.0	36.0	64.0
Chloride, dissolved	9.8	110	74.0
Fluoride, dissolved	.3	.4	.3
Magnesium, dissolved	7.6	15.0	27.0
Nitrogen, dissolved	.1	.1	.1
Potassium, dissolved	2.4	1.8	3.2
Silica, dissolved	12.0	15.0	15.0
Sodium, dissolved	46.0	110	71
Strontium, dissolved	1.30	0.86	2.00
Sulfate, dissolved	<1.0	2.0	2.0
Sulfide, total	<.5	.5	<.5

SUGGESTIONS FOR FURTHER STUDY

If water-supply needs increase, it would be desirable to obtain more data on the quality and quantity of water available on the reservation and on the distribution of barium in various aquifers. Important questions to address are (1) whether barite minerals occur in the confining lodgment till and lake silts and clays that overlie the bedrock, and (2) whether increased development of the sand and gravel aquifers will draw barium-enriched water from the underlying bedrock. Future studies should also determine precisely the sulfate and sulfide concentrations in relation to the barium concentration in the ground water. Studies using the isotopes of sulfur (^{34}S and ^{32}S) in the ground water would be helpful in determining whether bacteria are indeed reducing sulfate to sulfide.

SUMMARY AND CONCLUSIONS

Ground water on the Cattaraugus Reservation contains dissolved barium concentrations as high as 23 mg/L. The high barium concentrations are primarily in water from the upper bedrock aquifer, although some are in water from isolated deep sand and gravel deposits. Water from the unconfined, unconsolidated deposits contains little or no barium. Results from a sampling of 100 wells and springs in the summer of 1982 indicate that the barium originates from dissolution of the mineral barite ($BaSO_4$) in the bedrock. The removal of sulfate by sulfate-reducing bacteria allows unusually high barium concentrations to be reached before the solubility of barite serves to control the barium concentrations. High barium concentrations could probably be decreased by water-softening treatment.

Treatment of water from wells with the high barium concentrations may be feasible because barium has the same positive (++) charge as calcium and could be removed by water softening or ion exchange.

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Table 4.--Well-inventory data and results of barium analysis, Cattaraugus Indian Reservation, Spring-Summer 1982.

Latitude-longitude	Local no.	Owner or resident	Source[1]	Driller	Date drilled or constructed	Type of well[2]	Well depth (ft)	Casing diam. (in)	Aquifer type[3]	pH	Spec. cond.[4]	Total barium (mg/L)	Remarks by resident or owner
423132 0785628	1	--------------	S	---	---	---	---	---	---	6.8	456	<0.1	-----
422816 0785733	2	Douglas Fox	S	---	1962	---	---	---	---	6.9	344	<.1	Good quality & supply
422818 0785734	3	--------------	S	---	----	---	---	---	---	7.1	157	.1	-----
422827 0785753	4	Rita Silverheels	W	Ehmke	1975	Drl	---	8	---	7.0	380	<.1	Sometimes goes dry
422828 0785824	5	Ronald White	W	Dolly	----	Drl	76	10	Bedrock	7.1	180	<.1	Good quality & supply
422840 0785819	6	Milburn White	S	Dale	----	Dug	6	24	Gravel	6.6	284	<.1	-----
422843 0785749	7	Carol Henhock	W	Ehmke	1980	Drl	---	---	---	8.1	281	<.1	Poor quality-particulates-sampled after softener
422851 0785838	8	Fleeta Twoguns	W	Ehmke	1979	Drl	42(?)	6	---	8.3	237	.1	Cloudy gray water
422856 0785650	9	John Thomas	W	---	----	Dug	---	---	S & G	6.5	220	<.1	Good supply
422903 0785659	10	Natalie Thompson	W	Owner	1950s	Dug	20	---	S & G	6.6	284	<.1	Good quality
422930 0785710	11	Marshal Schindler	W	---	1925	Drl	37	---	S & G	6.7	320	.1	Good quality
422951 0785729	12	Calvin Lay	W	Stevens	1977	Drl	51	---	S & G	7.0	540	.1	Good quality & supply
422958 0785720	13	Suzanne Cooper	W	---	----	---	9.5	8	S & G	7.0	300	.1	Good quality & supply
423001 0785656	14	Beatrice Renaud	W	---	----	---	---	---	S & G	6.8	275	<.1	Good quality & supply
422958 0785643	15	Sharon Jimerson	W	Ehmke	1968	Drl	50	---	S & G	6.9	284	.2	Good quality & supply
423015 0785738	16	Ernest Mohawk	W	Johnson	----	Drl	45	6	S & G	7.4	206	.1	Iron & 5 gal/min max
423020 0785748	18	Frank Paterson	W	Owner	1937	Dug	40	36	S & G	6.9	325	<.1	Good quality & supply (hard)
423026 0785759	19	Mohawk	S	---	----	---	---	---	S & G	7.1	244	.1	Good quality
423037 0785757	20	Scott Patterson	W	---	1960s	---	---	---	S & G	6.9	274	.2	Good quality & supply
423053 0785806	21	Paul Twoguns	W	Ehmke	1963	Drl	47	7	S & G	6.9	307	.1	Good quality 17.5 gal/min
423057 0785833	23	Donald Bray	W	Gillis	1975	Drl	38	6	S & G	6.9	228	<.1	Good quality & supply
423101 0785807	25	Marion Hill	W	Ehmke	----	Drl	46	---	S & G	6.7	255	.1	Good quality & supply
423133 0785826	27	Windsor Pierce	W	Ehmke	1980	Drl	48	6	S & G	6.7	280	.1	Good quality & supply
423141 0785838	28	Harry Lavis	W	Burkett	1979	Drl	62	6	S & G	6.7	477	.1	Rust & sometimes goes dry
423151 0785839	29	Doris Seneca	W	Gas Co.	----	Drl	315	---	Bedrock	7.2	216	1.2	Hydrogen sulfide odor, poor taste, good supply
423200 0785911	30	Howard Mayber	W	---	----	---	---	---	---	6.1	272	.1	Good quality and supply
423153 0785903	31	--------------	S	---	----	---	---	---	S & G	7.5	400	.1	------
423236 0785817	33	Elsie Jimerson	W	Frey	1979	Drl	115	6	---	6.3	464	.1	1/2 gal/min
423226 0785758	34	Brenda Paterson	W	Owner	----	Dug	---	36	S & G	5.4	203	<.1	Sometimes goes dry
423221 0785731	35	Sue Thompson	W	Stevens	----	Drl	56	6	---	7.0	258	.9	Hydrogen sulfide odor, good supply
423202 0785656	36	Ivan Lee	W	Johnson	1981	Drl	99	6	---	7.0	216	3.8	Iron
423219 0785703	38	Eugene Lay	W	Johnson	1962	Drl	35	---	---	6.8	210	3.4	Cloudy gray, good supply
423235 0785719	39	Thomas Laird	W	Johnson	1956	Drl	45	6	---	6.7	210	.1	Hydrogen sulfide odor, 3/4 gal/min
423242 0785722	40	Dana Kenyon	W	Stevens	----	---	---	---	---	7.1	140	.1	-----
423303 0785719	41	Ronie Cook	W	---	----	Drl	---	6	---	6.0	394	.2	Rust and poor taste
423356 0785851	42	Kevin Brooks	W	---	----	Dug	---	24	S & G	5.4	191	<.1	-----
423331 0785854	43	Loretta Warrior	W	Ehmke	----	Drl	---	---	---	6.9	365	.6	Hydrogen sulfide odor, iron stains
423306 0785905	44	Elsie Jacobs	W	---	----	Dug	24	36	---	6.4	158	<.1	Hydrogen sulfide odor
423317 0785845	45	William Harris	W	Johnson	1965	Drl	35-40	6	---	6.2	119	.1	Iron
423318 0785957	46	Blair Maybee	W	Ehmke	----	Drl	70	8	---	6.8	170	.3	Good quality

1 W = well, S = spring
2 Drl = drilled
3 S & G = sand and gravel
4 Specific conductance, in μmho/cm at 25°C
-- Indicates data are unavailable

Table 4.--Well-inventory data and results of barium analysis, Cattaraugus Indian Reservation, Spring-Summer 1982 (continued).

Latitude-longitude	Local no.	Owner or resident	Source[1]	Driller	Date drilled or constructed	Type of well[2]	Well depth (ft)	Casing diam. (in)	Aquifer type[3]	pH	Spec. cond.[4]	Total barium (mg/L)	Remarks by resident or owner
423308 0785855	48	-----	W	-----	----	Dug	--	24	S & G	6.0	217	.1	-----
423300 0785847	49	Morris Jimerson	W	Johnson	1950s	Drl	53	--	-----	6.4	146	.5	Good quality
423230 0790001	50	Seneca Nat. Housing	W	-----	----	Drl	--	--	-----	7.2	162	23.0	Hydrogen sulfide odor, USGS test= 0.3 mg/L after softener
423240 0790000	51a	Seneca Nation	W	-----	----	Dug	--	120	S & G	6.8	250	.1	-----
423246 0785957	51b	Seneca Nation	W	-----	----	Dug	--	120	S & G	6.8	250	.1	-----
423203 0785927	52	May W. Lay	W	-----	----	Dug	--	--	S & G	6.6	250	.1	-----
423153 0785915	53	Sady Pierce	W	-----	----	Drl	--	--	-----	7.4	180	<.1	Sampled after softener
423129 0785916	54	Raymond Jimerson	S	-----	----	---	--	--	-----	6.8	207	<.1	Good quality
423121 0785938	55	Elizabeth John	W	Dolly	1967	Drl	60	--	S & G	6.9	180	.1	-----
423132 0785946	56	Nelson Huff	S	-----	----	---	--	--	S & G	6.5	123	<.1	Spring gets low, never dry
423150 0790003	57	Basil Williams	W	Ehmke	1954	Drl	70	6	Bedrock	7.0	215	.6	Hydrogen sulfide odor
423154 0790035	58	Doris Paterson	S	-----	----	---	10	--	-----	6.2	115	<.1	Good supply & quality
423139 0790058	59	Deborah John	W	Ehmke	1974	Drl	--	10	-----	7.3	160	.8	Good supply & quality
423121 0790100	60	Paul Williams	W	Stevens	1972	Drl	45	10	-----	7.0	480	1.6	Good quality but hard
423222 0790017	61	William Preischel	W	-----	1957	Drl	25	6	S & G	6.6	490	.2	Good supply, sampled after softening
423224 0790013	61a	Betty Gornflow	W	Dolly	1960	Drl	12	6	Sand	6.3	409	.1	Good supply, hard
423230 0790049	62	Stephen Ashcroft	W	-----	----	Drl	--	6	Bedrock	7.1	240	7.3	Iron artesian
423233 0790057	62a	-----	-	-----	----	Drl	--	--	Bedrock	7.1	317	2.5	Gas well artesian
423301 0790102	63	Twylah Nitsch	W	Owner	----	Dug	20	18	S & G	6.5	197	.1	Good quality
423317 0790108	64	Martin Seneca	W	Ehmke	----	Drl	35	8	-----	7.0	195	1.0	Iron, good supply
423339 0790007	65	Deborah Sanford	W	Frey	1979	Drl	49	--	Gravel below till	6.6	258	2.3	Iron, 11 gal/min
423348 0790029	66	Edith John	W	Owner	1980	Dug	12	36	Sand	6.9	130	<.1	Good quality
423351 0790049	67	R. Sanford	W	-----	----	---	26	--	S & G	7.2	147	<.1	Good quality
423301 0790227	68	Suzanna Seneca	W	-----	----	Dug	14	24	S & G	6.5	75	<.1	Iron
423346 0790130	69	Ruth Kenjockeqi	W	Stevens	1977	Drl	42	6	Bedrock	6.5	402	.2	Hydrogen sulfide odor
423343 0790129	69a	-----	Pond	-----	----	---	--	--	-----	7.2	124	<.1	-----
423331 0790146	70	Marilyn Godzik	W	-----	----	Drl	--	--	-----	7.0	344	.7	Hydrogen sulfide odor
423241 0790118	71	Marguerite Haring	W	-----	----	Driven	15	--	S & G	7.2	135	<.1	-----
423234 0790100	71a	Florence Lay	W	Ehmke	----	Drl	20	6	S & G (?)	6.4	203	.2	Good quality except after floods
423238 0790139	72	Terry Nephew	W	Stevens	1970	Drl	21	8	S & G	6.9	190	.1	Good quality
423241 0790210	73	Sady Bennett	W	Owner	----	Dug	14	36	S & G	6.7	154	<.1	Good quality, limited supply
423241 0790230	74	Robert Kenjockety	W	-----	1974	Drl	15	12	-----	7.0	143	<.1	Good quality, limited supply
423241 0790245	75	Edna Parker	W	Stevens	1971	Drl	146	--	-----	7.2	515	6.5	Gas, iron, 9 gal/min (filtered)
423245 0790312	76	Kathryn Betton	W	Owner	----	Driven	14	3	-----	6.5	175	.1	Good supply & quality
423252 0790346	77	Alton Van Aernm	W	Frey	----	Drl	29	10	S & G	6.6	153	<.1	Iron, good quality
423301 0790312	78	Annabelle Jimerson	W	Ehmke	----	Drl	--	--	-----	7.2	1465	9.1	Seltzer taste
423308 0790339	79	C. Mohawk	W	-----	1977	Drl	140	6	-----	7.4	845	16.0	Hydrogen sulfide odor, iron jelly forms in tanks
423223 0790523	81	James Snyder	W	-----	----	---	35	12	-----	6.7	292	.1	Hydrogen sulfide odor, dark color
423236 0790536	82	Grace Loomis	W	-----	----	Dug	20	6 ft.	S & G	6.8	171	<.1	-----
423305 0790431	83	Donald Train	W	-----	----	Drl	--	6 in.	-----	6.9	187	<.1	Hydrogen sulfide odor, iron problems

Table 4.--Well-inventory data and results of barium analysis, Cattaraugus Indian Reservation, Spring-Summer 1982 (continued).

Latitude-longitude	Local no.	Owner or resident	Source[1]	Driller	Date drilled or constructed	Type of well[2]	Well depth (ft)	Casing diam. (in)	Aquifer type[3]	pH	Spec. cond.[4]	Total barium (mg/L)	Remarks by resident or owner
423322 0790415	84	Gloria Nephew	W	-----	----	Drl	--	6	----	7.0	865	2.9	Salty
423344 0790517	85	Arthur Nephew	W	-----	----	Drl	126	6	----	7.3	574	8.8	Gas, seltzery
423354 0790540	86	Aby Brooks	W	-----	----	Dug	12	--	S & G	6.3	263	.1	-----
423356 0790543	87	Aby Brooks	W	Dolly	----	Drl	119	6	-----	6.9	839	4.8	Hydrogen sulfide odor, black color
423421 0790621	88	Leonard Williams	Town Water	-----	----	---	--	--	-----	6.4	75	<.1	Silver Creek town water
423448 0790617	90	Seneca Nation	W	Ehmke	----	Drl	--	--	Bedrock	6.8	835	6.9	Hydrogen sulfide odor
423443 0790520	91	Roland Barreno	W	Stevens	----	Drl	--	12	-----	7.4	587	.2	Hydrogen sulfide odor
423429 0790432	92	Melvin Pierce	W	-----	----	Drl	50-55	6	Bedrock	6.9	254	3.1	Limited supply
423456 0790413	93	Ruth Abrams	W	Wills	----	Drl	60	6	-----	6.8	560	<.1	-----
423424 0790718	95	Philip Waterman	W	Ehmke	----	Drl	50	8	Bedrock	7.0	269	2.8	Iron but good quality
423442 0790714	96	Clifton Rice	W	-----	1974	Drl	38	6	Bedrock	6.9	186	1.5	Hydrogen sulfide odor
423444 0790714	96a	Robert Kennedy	W	Gillis	1976	Drl	35	6	-----	7.2	191	.2	Hydrogen sulfide odor, iron
423402 0790751	97	Robert Porter	W	Burkett	----	Drl	149	6	Bedrock	7.0	267	3.1	Artesian, iron, depth to bedrock 143 ft.
423436 0790756	98	Jeff Dietrich	W	Owner	1980	Drl	53	6	Bedrock	7.0	211	1.4	Hydrogen sulfide odor, 1.5 gal/min
423457 0790753	99	Edward Redmond	W	Stevens	1978	Drl	51	6	Bedrock	6.6	320	.1	Some iron, 3/4 gal/min
423504 0790718	100	Kevin Seneca	W	Ehmke	1972	Drl	65-70	6	Bedrock	6.9	556	1.7	Hydrogen sulfide odor, hard, 10 gal/min
423137 0790411	101	Norman Tall Chief	W	Owner		Dug	--	--	S & G	6.3	124	.2	-----

1 W = well, S = spring
2 Drl = drilled
3 S & G = sand and gravel
4 Specific conductance, in µmho/cm at 25°C
-- Indicates data are unavailable