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GEOCHEMICAL AND HYDROLOGIC DATA FOR WELLS AND SPRINGS IN THERMAL-SPRING AREAS OF THE APPALACHIANS

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The report presents data collected during a one-year reconnaissance study of 9 thermal spring areas of the Appalachians from New York to Georgia. Maps show locations of selected wells, warm springs, and cold springs in the areas. Physical tables list hydrologic and geologic information on the springs and wells. The chemical tables include dissolved gas concentrations (oxygen, nitrogen, argon, methane, carbon dioxide and helium), isotope contents (tritium, carbon-13 and oxygen-18), some trace and minor element chemical data, and concentrations of the major chemical constituents. Methods of collection and analysis are described.

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By W. A. Hobba, Jr., J. C. Chemerys
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ABSTRACT

Current interest in geothermal potential of thermal-spring areas in the Appalachians enhances the value of data on thermal springs and wells in these areas. This report presents maps showing locations of selected springs and wells and tables of physical and chemical data pertaining to these wells and springs. The chemical tables show compositions of gases (oxygen, nitrogen, argon, methane, carbon dioxide, and helium), isotope contents (tritium, carbon-13, and oxygen-18), trace and minor element chemical data, and concentrations of the major chemical constituents.

INTRODUCTION

The U.S. Geological Survey has completed a reconnaissance of the ground-water hydrology and chemistry of thermal spring areas in the Appalachians. This report presents data collected for the study, including the preliminary data in Hobba and others (1976). An interpretative report is in preparation, but these data are being released in the present form because of current interest in geothermally related data.

The stratigraphic nomenclature used in this report was determined from several sources and may not necessarily follow the usage of the U.S. Geological Survey.

HYDROLOGIC TECHNIQUES

During the summer of 1975, a reconnaissance of 10 thermal-spring sites in the Appalachians was carried out. Much of the spring and well data given here were obtained by canvassing homeowners. However, some of the data for Virginia and New York were obtained from well drillers' files, and some of the data for Pennsylvania were obtained from drillers' records on file at the Pennsylvania Geological Survey.

After the wells and springs were inventoried, some were selected for sampling. Generally, ground water was sampled at three or more sites in the vicinity of each warm spring: the warm spring itself, a

well or spring tapping the rock units adjacent to the rock unit from which the thermal spring issues, and a well or spring in the recharge area for the thermal spring, as nearly as it could be determined. These sites were sampled in the fall of 1975 when ground-water levels were low, and some were sampled again the following spring when levels were higher.

ANALYTICAL TECHNIQUES

Field Procedures

Samples were field-filtered, using pressurized nitrogen, through 0.20μm (micrometer) membrane filters, for all laboratory determinations except dissolved gases and stable carbon isotope analyses. Samples for cation analyses were acidified with hydrochloric acid. Specific conductance was measured in the field with field model conductivity meters and electrodes. Temperatures were measured with a 12-inch mercury-in-glass thermometer having a range of 0 to 50 degrees Celsius with markings every 0.2 degrees.

Sampling devices for the dissolved-gas analyses consisted of 500 ml (milliliter) glass flasks with evacuated side arms. In use, water was pumped into the flask to fill it, and an additional 2 liters of sample was pumped through the flask in order to flush adsorbed gases from the glass wall. After the sampler was filled and flushed, the inlet and outlet stopcocks were closed to the supply and to the atmosphere, respectively, then opened to the previously evacuated side chamber. The samplers were then returned to the laboratory for analysis of the vapor phase.

Samples for stable carbon isotope ratio measurement were fixed in the field to prevent loss of dissolved carbonate as gaseous CO_2. (Gleason, Friedman, and Hanshaw, 1969). The samples were collected with minimum aeration in 1-quart (0.946 liters) glass bottles. To each sample was added, by pipet, 50 mL of a strontium hydroxide solution, prepared by dissolving 1 lb (453.6 g) of reagent grade $SrCl_2 \cdot 6H_2O$ in a 5-pint (2.37 L) bottle of reagent grade concentrated (30 percent) NH_4OH. This solution raised the pH of the sample, so that all the dissolved carbonate was present as the carbonate (CO_3) ion, which then combined with the strontium to precipitate $SrCO_3$. Samples for stable oxygen isotope ratio analyses and tritium were collected in glass bottles with minimum aeration and exposure to the atmosphere.

pH, Alkalinity

pH measurements were made in the field when the samples were collected. Commercial pH meters, electrodes, and liquid buffers were used. The combination electrode was immersed in a bath through which the sample water flowed. This bath also served to maintain the pH buffers at the sample temperature. The meter and electrode were standardized with pH 7 and pH 4 buffers at the observed sample temperature, and the sample pH was then determined.

Alkalinities of freshly drawn samples were determined by the electrometric titration method described in Brown, Skougstad, and Fishman (1970, p. 42-43).

Dissolved Oxygen and Sulfide

A commercial kit (Hach Chemical Co., Mdl. OX-2P*) was used for determinations of high dissolved oxygen concentrations. Concentrations of dissolved oxygen less than 2mg/L (milligrams per liter) were determined more precisely by the modified Winkler method (Brown, Skougstad, and Fishman, 1970, p. 126). A Hach Model HS-6 sulfide kit (based on the methylene blue method) was used for determinations of sulfide in those samples containing less than 1 mg/L dissolved oxygen. Lower detection limit for sulfide by this method is about 0.02 mg/L.

Laboratory Procedures

Appropriate analytical techniques described in Brown, Skougstad, and Fishman (1970) were used for the analyses of dissolved chemical constituents, except the following:

1) Ammonia was separated in a micro-Kjeldahl still. In this device, high pH for distillation (achieved by making samples 0.1 normal in sodium hydroxide) is necessary for quantitative removal of the ammonia. Hydrolysis of reactive organic nitrogen compounds may introduce positive errors in this procedure.

2) Nitrate was determined by the phenoldisulfonic acid method as described by Rainwater and Thatcher (1960, method D:25b-1).

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*The use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

3) Arsenic and selenium were analyzed by a graphite furnace atomic absorption technique. Standards were acidified with doubly distilled nitric acid to provide acid concentrations equal to that of the field-fixed samples. No additional matrix modifications were needed for these relatively dilute samples. Electrodeless discharge lamps were used as radiation sources. Times and temperatures used for drying, charring, and atomization were the same as those suggested by Kunselman and Huff (1976).

Bromide analyses were done by the Atlanta Central Laboratory of the U.S. Geological Survey.

Dissolved Gases

Dissolved gases were analyzed chromatographically. The system used to obtain quantitative determinations of the gases consists of stainless steel columns packed with porous polymer beads, a hot wire thermal conductivity bridge detector, and electronic integration of the detector response to the individual eluted gases. Standard gas mixtures were used to calibrate the chromatograph response.

Argon was used as the carrier gas for helium analyses; a helium carrier was employed for the other determinations. Nitrogen, oxygen, and argon were separated on a 45-foot Porapak** QS column in a dry ice-isopropanol bath (Porapak** Brochure). Methane and carbon dioxide were separated from each other and from the major atmospheric gases on a Porapak** QS-Porapak** R column maintained at 50°C. Use of this combined column was suggested by Wilhite and Hollis (1968). Helium separations were made on a Porapak** QS column in an ice-water bath.

Sample flasks are attached to the chromatograph inlet with short lengths of plastic tubing. Tubing, inlet, and calibrated chromatograph sample loop are evacuated, then the flask stopcock is opened to admit gases to the loop. The analytical sequence is started by actuating a valve-switching arrangement, which diverts carrier gas flow through the loop to the column. Volumes of the sampler side tube, plastic tubing, inlet system, and sample loop are known, so that total amounts of individual gases in the vapor phase can be calculated. From these data, together with the known volumes of the sampler water chambers and

** Registered trademark of porous polymer beads sold by Waters Associates, Framingham, Massachusetts.

published gas solubility data, dissolved gas concentrations and partial pressures at sampling temperatures are determined.

Stable Isotopes

Stable isotope ratios were measured by a commercial laboratory using a mass spectrometer. Because it is difficult to measure absolute values of isotope ratios with any precision, such ratios are measured and reported relative to arbitrary but widely used standards. The measurements are reported in the δ notation, where:

$$\delta\ (o/oo) = \left(\frac{R_{sample}}{R_{standard}} - 1\right) X\ 1000\ .$$

R_{sample} and $R_{standard}$ are the isotope ratios ($^{13}C/^{12}C$, $^{18}O/^{16}O$) in the sample and standard, respectively. The standard to which the carbon isotope ratios reported here are referred is the PDB standard (Craig, 1957), whereas the oxygen isotope ratios are referred to the SMOW standard (Craig, 1961). The precision of the analyses reported here is considered to be ± 0.1 o/oo.

The 1-quart samples treated in the field to precipitate all the carbonates as $SrCO_3$ were filtered under nitrogen and the $SrCO_3$ precipitate thoroughly rinsed and dried. This carbonate was then reacted with 100 percent H_3PO_4 to produce the CO_2 gas required for the mass spectrometric analysis of $^{13}C/^{12}C$ ratios (McCrea, 1950).

$^{18}O/^{16}O$ ratios were measured on a second CO_2 gas sample. This gas was prepared in the laboratory by equilibrating CO_2 with the water samples collected for that purpose. The $^{18}O/^{16}O$ ratio of the water is calculated from the $^{18}O/^{16}O$ ratio of the gas equilibrated with it.

The tritium analyses were made in the U.S. Geological Survey Laboratory, Reston, Virginia, by liquid scintillation counting after electrolytic enrichment of the sample by a factor of about 17. Tritium concentrations are given in tritium units (TU). One TU corresponds to a concentration of 1 tritium atom per 10^{18} hydrogen atoms and equals 3.2 picocuries per liter. The analytical errors reported are based on the statistics of counting random radioactive decay events and are 1 standard deviation (1σ) errors.

SUMMARY

Figure 1 shows the locations of the warm spring areas that were sampled in the Appalachian Mountains. Tables 1A, 1B, and 2 list the springs and wells sampled and show the results of chemical, dissolved gas and isotope analyses. Figures 2-8 show the locations of springs and wells in the warm springs areas. Tables 3-9 give the data for the springs and wells shown on the location maps.

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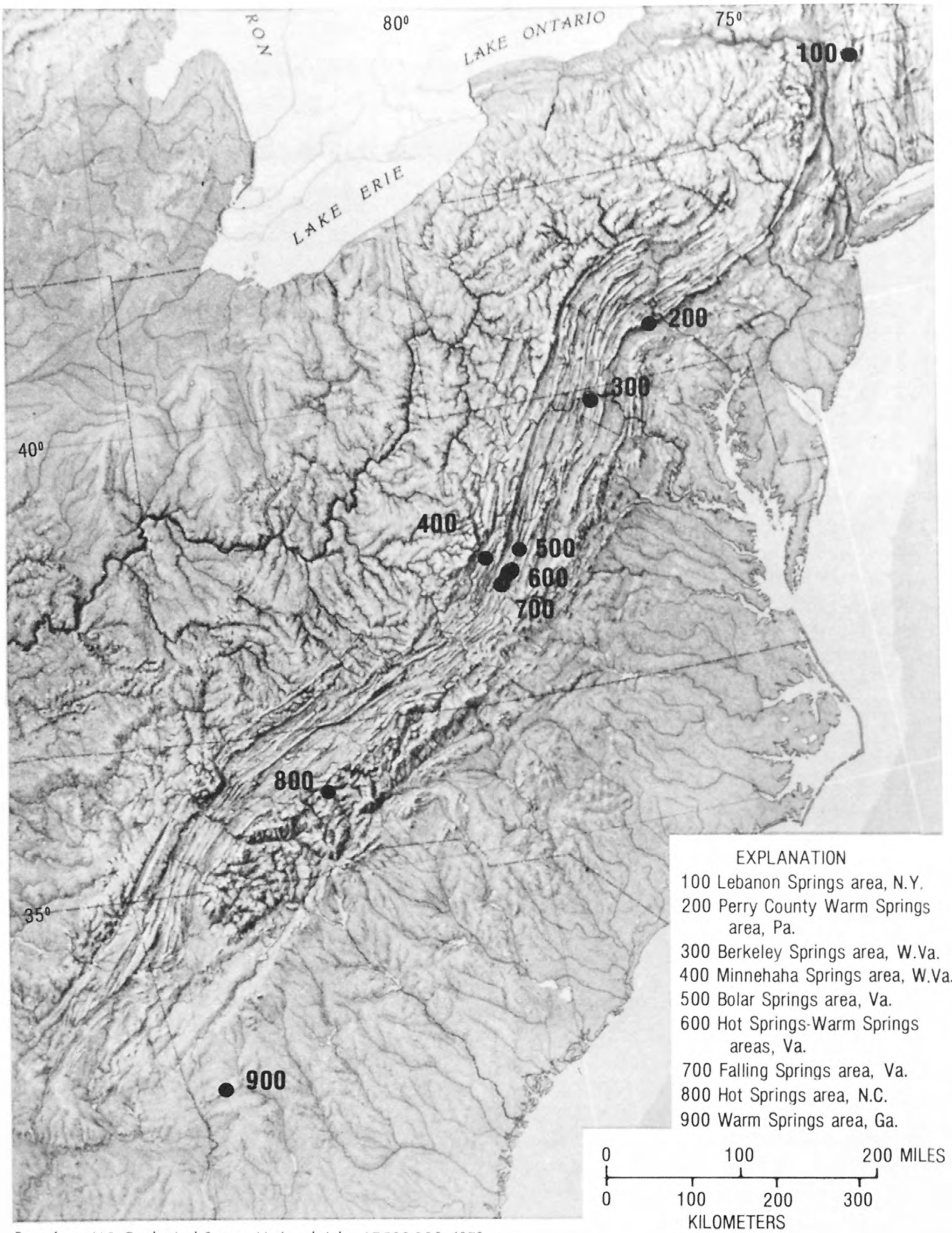


Base from U.S. Geological Survey National Atlas 1:7,500,000, 1972

Figure 1.--Locations of sampled thermal spring areas in the Appalachians.

Table 1A.--Results of chemical analyses of waters from Appalachian warm springs areas

[Concentrations of dissolved constituents in milligrams per liter (mg/L)]

Sample number	Owner or name	Date	Temperature (°C)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)
						NEW YORK - LEBANON SPRINGS AREA									
101	Lebanon Spring	10-75	21.9	7.60	12	35	16	0.4	6.9	1.2	166	25	6.5	1.1	0.3
101		5-76	18.7	7.72	9.0	40	14	.2	5.5	1.0	170	20	5.2	1.2	.2
109	John Koepp	10-75	14	7.60	11	31	17	.4	7.0	1.3	168	23	6.4	.4	.3
109		5-76	12.2	8.00	11	31	15	.3	7.3	1.3	158	22	6.7	.2	.3
114	B. Schell	10-75	10.9	7.20	6.0	133	12	2.4	28	.8	186	328	.8	.5	.5
116	F. Amlaw	10-75	10.4	7.55	14	49	22	.1	2.8	.4	241	21	1.1	.2	.3
						PENNSYLVANIA - PERRY COUNTY WARM SPRINGS AREA									
201	Warm Spring	10-75	17.8	7.2	9.0	38	3.3	.3	1.6	.5	135	8.3	.8	.1	.1
201		5-76	17.7	7.62	7.4	40	2.8	.2	1.8	.5	133	6.3	.9	.1	.1
202	Lloyd Hetrick	10-75	12	6.85	4.2	25	1.4	.1	.6	.6	82	.4	1.4	.1	.1
216	Stambaugh	10-75	12.8	6.50	7.3	17	2.1	.1	1.4	.6	58	6.3	1.1	.5	.1
218	Morris Loy	10-75	12.0	7.20	5.9	65	5.9	.4	3.1	.9	176	29	14	6.9	.2
						WEST VIRGINIA - BERKELEY SPRINGS AREA									
301	Berkeley Springs	10-75	22.2	6.99	9.5	45	5.6	.5	4.1	1.0	168	17	6.4	.5	.1
301		5-76	21.9	7.46	9.0	47	4.8	.4	4.3	.9	165	15	1.8	.1	.1
302	F. Wachter	10-75	13.0	6.8	20	80	11	.4	6.2	.6	254	55	1.1	.2	.2
302		5-76	12.8	7.07	17	83	9.7	.3	6.8	.6	246	52	1.0	.2	.2
303	F. Wachter	9-75	13.9	7.30	18	55	20	1.0	17	.4	226	42	23	.1	.2
307	H. Hovermale	10-75	16	6.97	7.8	106	24	1.7	3.8	.7	410	25	10	6.5	.2
						WEST VIRGINIA - MINNEHAHA SPRINGS AREA									
401	Minnehaha Spring	11-75	20.1	7.88	8.4	39	6.0	.4	2.2	.8	116	38	.8	.1	.2
401		6-76	20.3	7.90	8.1	38	5.3	.4	2.2	.8	114	38	.8	.1	.1
402	Camp Minnehaha	11-75	11.6	7.30	14	61	15	.4	4.2	.4	230	37	.8	.1	.2
402		6-76	13.2	7.30	13	64	13	.5	3.9	.4	230	37	.8	.3	.1
403	A. T. White	11-75	13.3	7.20	6.8	36	.7	.1	1.2	.8	84	2.8	3.4	23	.1
406	F. Davis	11-75	10.3	7.63	5.0	36	1.3	.0	.4	.8	113	5.9	.8	.1	.1
407	R. Shinaberry	11-75	10.8	5.50	6.8	14	1.2	.0	2.6	1.5	20	1.6	5.3	27	.1
410	T. Rose	6-76	13.8	7.68	7.2	129	38	9.1	1920	12	272	22	3240	--	.2
						VIRGINIA - BOLAR SPRING AREA									
501	Bolar Spring	12-75	22.2	7.48	11	58	14	.3	1.6	2.3	205	29	.8	.9	.3
501		6-76	20.2	7.42	8.1	54	10	.3	1.6	2.0	185	24	1.0	1.1	.3

Table 1A.--Results of chemical analyses of waters from Appalachian warm springs areas--Continued

Sample number	Owner or name	Date	Temperature (°C)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)
						VIRGINIA - HOT SPRINGS - WARM SPRINGS AREAS									
602	Boiler Spring	11-75	39.9	6.65	21	132	40	1.3	7.0	13	454	130	2.6	.1	1.1
602		6-76	40.0	6.55	20	126	35	1.4	6.9	14	452	128	2.7	.1	1.1
605	Cold Magnesia	11-75	15.2	7.20	8.2	60	9.7	.3	1.7	2.9	174	35	9.5	.8	.3
605	Spring	6-76	14	7.15	7.0	53	7.5	.4	1.5	2.5	163	32	1.8	1.0	.2
a607A	Homestead Hot Well	11-75	19.6	7.15	15	113	34	1.1	2.9	5.8	364	114	2.4	.1	.6
b607B		2-76	17.9	7.6	7.2	53	18	.4	2.6	3.0	192	37	2.8	.4	.4
c607C		2-76	19.5	6.9	14	119	35	1.1	4.9	11	392	116	2.3	.1	.9
d607D		2-76	32.2	--	19	123	37	1.4	5.6	13	400	132	2.4	.1	1.0
619	M. Dunn Spring	11-75	15.8	7.32	8.9	80	14	.5	2.1	2.6	196	85	2.2	2.4	.5
619		6.76	14.4	7.42	7.2	73	9.2	.7	1.8	2.1	179	64	2.4	2.3	.4
625	Valley View Cottages	11-75	12.0	7.30	6.0	60	16	.5	1.5	1.2	248	14	.7	.1	.4
627	T. H. Bonds	11-75	10.5	7.48	5.4	96	7.6	.1	5.7	.6	300	10	10	10	.1
631	Warm Springs	11-75	35.4	7.32	21	112	28	1.9	3.7	7.4	197	232	1.5	.1	1.4
631	(Childrens pool)	6-76	35.4	7.20	20	119	25	1.9	3.7	6.9	194	227	1.6	.0	1.4
633	Ingalls Airport	12-75	9.1	4.50	3.8	.5	.2	.0	.4	.2	--	.4	.6	.5	.0
						VIRGINIA - FALLING SPRINGS AREA									
701	Falling Spring	12-75	25.0	7.32	18	158	30	2.4	3.8	16	315	289	2.5	1.3	1.2
701		6-76	20.8	7.32	12	117	21	1.7	3.1	10	250	189	2.4	2.4	.9
702	H. D. Webb	11-75	27.2	7.15	24	234	55	3.5	6.6	2.5	423	507	4.3	.1	2.4
						NORTH CAROLINA - HOT SPRINGS AREA									
801	Hot Spring	12-75	39.3	7.50	31	135	29	3.8	10	10	126	369	3.8	.1	1.4
801		5-76	41.4	7.50	33	144	25	3.9	9.6	9.8	119	369	3.9	.0	1.3
803	City Well	12-75	15.2	6.75	25	13	10	.1	6.6	4.5	114	9.3	5.9	.1	.2
803		5-76	15.2	6.88	27	11	8.8	.1	6.9	4.3	109	9.1	6.1	.0	.1
804	Fairview Water	12-75	12.5	7.10	7.4	4.9	3.4	.0	.9	1.5	29	4.8	.8	1.4	.1
805	Bubbling Springs	12-75	13.2	7.75	11	19	11	.0	.3	2.2	108	1.8	.5	.4	.2
810	P. Lovin	5-76	15.0	8.1	5.2	23	14	.0	1.8	1.3	136	4.2	2.2	7.8	.0

a Sample pumped from 215 foot depth.
b Sample collected at 335 foot depth with sampling tube on logger.
c Sample collected at 400 foot depth with sampling tube on logger.
d Sample collected at 745 foot depth with sampling tube on logger.

Table 1A.--Results of chemical analyses of waters from Appalachian warm springs areas--Continued

Sample number	Owner or name	Date	Temperature (°C)	pH	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Alkalinity (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Fluoride (F)
							GEORGIA - WARM SPRINGS AREA								
901	Warm Springs	12-75	30.9	7.40	20	22	13	.1	1.2	3.8	122	7.1	1.9	.3	.1
901		5-76	31.6	6.95	18	20	11	.1	1.2	3.7	118	6.7	1.7	.3	.1
905	South Spring	12-75	17.7	4.00	7.5	.3	.2	.0	.9	.6	--	.4	1.2	.2	.0
905		5-76	17.8	4.90	6.5	.2	.1	.0	.8	.5	2	.4	1.4	.3	.0
907	J. Phillips	12-75	33.8	6.42	21	12	8.4	.0	1.0	4.0	64	5.7	1.2	.1	.1
909	A. Baxley	12-75	17.0	7.02	31	19	3.4	.1	10	3.5	94	6.3	1.8	.1	.3

Table 1B.--Results of chemical analyses of waters from Appalachian warm springs areas
[Concentrations of dissolved constituents in milligrams per liter (mg/L) or micrograms per liter (μg/L) as noted]

Sample number	Date	Hydrogen sulfide (H_2S) mg/L	Ammonium as NH_4 mg/L	Phosphorus as PO_4 mg/L	Aluminum (Al) μg/L	Arsenic (As) μg/L	Boron (B) mg/L	Bromide (Br) mg/L	Copper (Cu) mg/L	Iron (Fe) mg/L	Lithium (Li) mg/L	Manganese (Mn) mg/L	Selenium (Se) μg/L	Zinc (Zn) mg/L
						NEW YORK - LEBANON SPRINGS AREA								
101	10-75	--	0.05	0.03	14	0.2	0.02	0.056	0.00	0.00	0.00	0.00	<1	0.00
101	5-76	--	--	.04	<1	.2	.01	--	.00	.00	.01	.00	<1	.00
109	10-75	--	.04	.02	14	.2	.02	.043	.00	.01	.00	.00	<1	.00
109	5-76	--	--	.04	<1	.2	.01	--	.00	.02	.01	.00	<1	.01
114	10-75	--	.09	.01	<1	.8	.03	.012	.00	.01	.01	.11	<1	.00
116	10-75	--	.03	.03	31	<.2	.00	.015	.00	.01	.00	.00	<1	.11
						PENNSYLVANIA - PERRY COUNTY WARM SPRINGS AREA								
201	10-75	--	.08	.10	<1	.2	.00	.012	.00	.01	.00	.00	<1	.00
201	5-76	--	--	.10	<1	.2	.00	--	.00	.00	.00	.00	<1	.01
202	10-75	--	.02	.62	<1	<.2	.00	.016	.00	.02	.00	.00	<1	.00
216	10-75	--	.09	1.2	14	.2	.00	.030	.00	.00	.00	.00	<1	.00
218	10-75	--	.06	.15	<1	<.2	--	.043	.00	.00	.00	.00	<1	.00
						WEST VIRGINIA - BERKELEY SPRINGS AREA								
301	10-75	--	.03	.13	24	.2	.02	.023	.00	.00	.00	.00	<1	.00
301	5-76	--	--	.14	<1	.2	.02	--	.00	.00	.00	.00	<1	.01
302	10-75	--	.22	.02	34	<.2	.03	.018	.00	.96	.03	.10	<1	.11
302	5-76	--	--	.02	<1	<.2	.01	--	.00	.47	.04	.16	<1	.08
303	9-75	<0.02	.38	.07	<1	<.2	.03	.086	.03	1.4	.04	.08	<1	.00
307	10-75	--	.05	.02	7	<.2	.02	.063	.05	.00	.00	.00	<1	.00
						WEST VIRGINIA - MINNEHAHA SPRINGS AREA								
401	11-75	--	.04	.24	<1	.2	.01	.006	.00	.00	.00	.00	<1	.00
401	6-76	--	--	.07	17	<.2	.02	--	.00	.00	.01	.00	--	.01
402	11-75	<.02	.18	.14	<1	<.2	.01	.016	.00	.25	.02	.19	<1	2.8
402	6-76	<.02	--	.02	3	--	.04	--	.00	.19	.02	.14	--	2.4
403	11-75	--	.01	.65	6	<.2	--	.020	.00	.00	.00	.00	<1	.04
406	11-75	--	.11	.14	<1	<.2	.00	.010	.00	.00	.00	.00	<1	.00
407	11-75	--	.10	.11	<1	<.2	--	.018	.07	.03	.00	.00	<1	.05
410	6-76	.75	--	.02	3	.5	.67	--	.01	.06	2.8	.03	--	.02
						VIRGINIA - BOLAR SPRING AREA								
501	12-75	--	.12	.03	<1	<.2	.03	.011	.02	.00	.01	.00	<1	.00
501	6-76	--	--	.05	4	<.2	.01	--	--	.00	.00	.00	--	.02

Table 1B.--Results of chemical analyses of waters from Appalachian warm springs areas--Continued

Sample number	Date	Hydrogen sulfide (H_2S) mg/L	Ammonium as NH_4 mg/L	Phosphorus as PO_4 mg/L	Aluminum (Al) µg/L	Arsenic (As) µg/L	Boron (B) mg/L	Bromide (Br) mg/L	Copper (Cu) mg/L	Iron (Fe) mg/L	Lithium (Li) mg/L	Manganese (Mn) mg/L	Selenium (Se) µg/L	Zinc (Zn) mg/L
						VIRGINIA - HOT SPRINGS - WARM SPRINGS AREAS								
602	11-75	--	0.09	0.02	<1	0.5	0.03	0.029	0.00	0.17	0.05	0.00	<1	0.05
602	6-76	<0.02	--	.03	2	.5	.04	--	--	.17	.04	.00	--	.02
605	11-75	--	.06	.04	<1	<.2	.00	.031	.00	.00	.01	.00	<1	.03
605	6-76	--	--	.02	5	<.2	.00	--	--	.00	.01	.00	--	.01
607A	11-75	<.02	.08	.13	<1	1.5	.02	.024	.00	.16	.03	.08	<1	.39
607B	2-76	--	--	.13	--	--	.04	.024	.00	--	.01	.14	--	.07
607C	2-76	--	--	.11	18	--	.04	.028	.00	,34	.04	.27	--	1.0
607D	2-76	--	--	.13	29	--	.02	.025	.00	.04	.04	.04	--	.18
619	11-75	--	.05	.04	<1	<.2	.02	.018	.00	.00	.02	.00	<1	.04
619	6-76	--	--	.00	3	--	.02	--	--	.00	.01	.00	--	.01
625	11-75	<.02	.06	.00	<1	<.2	.01	.010	.00	.16	.03	.02	<1	.95
627	11-75	--	.10	.02	<1	<.2	--	.050	.00	.00	.00	.00	<1	.10
631	11-75	.75	.08	.01	<1	<.2	.02	.016	.00	.00	.04	.00	<1	.05
631	6-76	.75	--	.02	10	<.2	.02	--	.01	.00	.04	.00	--	.01
633	12-75	--	.05	.00	48	<.2	.01	.018	.00	.01	.00	.00	<1	.00
						VIRGINIA - FALLING SPRINGS AREA								
701	12-75	--	.10	.07	<1	.2	.02	.028	.00	.00	.17	.00	<1	.00
701	6-76	--	--	.04	4	.2	.02	--	.00	.00	.11	.00	--	.01
702	11-75	<.02	.08	.00	<1	.2	.04	.044	.00	.16	.30	.02	<1	.30
						NORTH CAROLINA - HOT SPRINGS AREA								
801	12-75	--	.07	.03	23	.2	.02	.049	.00	.00	.07	.00	<1	.05
801	5-76	--	--	.04	<1	.5	.05	--	.01	.00	.06	.00	<1	.00
803	12-75	--	.10	.38	<1	<.2	.01	.047	.00	12	.02	.62	<1	.25
803	5-76	<.02	--	.31	<1	<.2	.00	--	.00	11	.01	.61	<1	.54
804	12-75	--	.04	.12	<1	<.2	.00	.010	.00	.02	.00	.02	<1	.04
805	12-75	--	.08	.12	<1	.2	.01	.017	.00	.01	.00	.00	<1	.03
810	5.76	--	--	.00	2	<.2	.06	--	--	.00	.00	.00	<1	.25

Table 1B.--Results of chemical analyses of waters from Appalachian warm springs area--Continued

Sample number	Date	Hydrogen sulfide (H_2S) mg/L	Ammonium as NH_4 mg/L	Phosphorus as PO_4 mg/L	Aluminum (Al) µg/L	Arsenic (As) µg/L	Boron (B) mg/L	Bromide (Br) mg/L	Copper (Cu) mg/L	Iron (Fe) mg/L	Lithium (Li) mg/L	Manganese (Mn) mg/L	Selenium (Se) µg/L	Zinc (Zn) mg/L
						GEORGIA - WARM SPRINGS AREA								
901	12-75	--	0.04	0.08	<1	0.2	0.02	0.004	0.00	0.00	0.00	0.00	<1	0.00
901	5-76	--	--	.05	3	.2	.00	--	--	.01	.00	.00	<1	.03
905	12-75	--	.09	.00	15	<.2	.00	.011	.00	.00	.00	.00	<1	.00
905	5-76	--	--	.01	8	<.2	.00	--	--	.00	.00	.00	<1	.00
907	12-75	--	.05	.04	<1	<.2	.00	.013	.00	.00	.00	.00	<1	.00
909	12-75	<.02	.08	.13	<1	.2	.02	.017	.00	.10	.00	.07	<1	.03

Table 2.--Results of dissolved-gas and isotope analyses of waters from Appalachian warm springs areas

Sample number	Date	Gases (concentrations in mg/L): Field dissolved oxygen (O_2)	Lab dissolved oxygen (O_2)	Nitrogen (N)	Argon (Ar)	Methane (CH_4)	Carbon dioxide (CO_2)	Helium (He)	Isotope results: Tritium T.U.	Tritium ±1σ	$\delta^{13}C_{PDB}$ ‰	$\delta^{18}O_{SMOW}$ ‰
						NEW YORK - LEBANON SPRINGS AREA						
101	10-75	4.5	4.3	24	.96	<0.01	6.4	Tr<.002	11.6	±1.0	-11.9	-9.9
101	5-76	5.2	5.8	27	1.04	<.03	7.1	.0010	19.9	±1.3	-11.9	-10.7
109	10-75	3.0	2.4	24	.90	<.01	3.7	<.002	1.0	±1.4	-13.1	-10.0
109	5-76	2.0	(a)	(a)	(a)	<.04	3.9	.0013	-.4	±.5	-11.1	-9.8
114	10-75	7.2	7.3	20	.78	<.01	6.6	<.002	.3	±.9	--	--
116	10-75	.8	(a)	(a)	(a)	<.01	9.8	<.002	.6	±1.0	-11.5	-9.4
						PENNSYLVANIA - PERRY COUNTY WARM SPRINGS AREA						
201	10-75	6.0	7.2	23	.91	<.01	9.0	<.002	6.0	±1.0	-13.4	-7.7
201	5-76	4.0	(a)	(a)	(a)	<.03	7.4	<.0005	8.3	± .6	-12.6	-8.2
202	10-75	6.5	(a)	(a)	(a)	<.01	9.6	<.002	55.6	±3.0	--	--
216	10-75	8.0	8.5	19	.78	<.01	21	<.002	15.5	±1.4	-12.9	-8.8
218	10-75	10	8.7	18	.68	<.01	8.5	<.002	78.1	±4.1	-12.3	-7.5
						WEST VIRGINIA - BERKELEY SPRINGS AREA						
301	10-75	4.5	3.6	22	--	<.01	25	<.002	2.7	±.8	-15.2	-8.7
301	5-76	5.0	(a)	(a)	(a)	<.03	29	<.0005	2.6	±.6	-13.9	-8.6
302	10-75	10	8.8	19	--	<.01	21	--	36.2	±2.4	-15.5	-7.9
302	5-76	3.0	.2	27	1.16	.02	39	<.0005	40.2	±2.1	-15.5	-8.2
303	9-75	<.1	1.4	26	.89	.02	15	<.002	45.3	±2.6	--	--
307	10-75	6.2	(a)	(a)	(a)	<.01	55	<.002	71.8	±3.7	-15.2	-7.8
						WEST VIRGINIA - MINNEHAHA SPRINGS AREA						
401	11-75	3.5	3.2	19	.80	<.01	2.7	Tr<.0001	2.5	±.9	-11.4	-8.5
401	6-76	3.0	(a)	(a)	(a)	.04	3.4	<.0003	1.3	±.6	-11.4	-8.6
402	11-75	<.1	.26	28	1.06	.006	16.6	<.0001	41.0	±2.4	-14.4	-8.1
402	6-76	.12	.19	31	1.25	<.02	21	<.0003	--	--	--	--
403	11-75	9.0	--	--	--	--	--	--	--	--	--	--
406	11-75	11	10.3	19	.73	<.01	3.3	<.0001	62.9	±3.6	-13.1	-7.2
407	11-75	10	8.9	22	.78	<.01	67	<.0001	87.6	±4.5	-22.9	-8.0
b410	6-76	<.1	<.03	4.9	.25	24	4.4	<.0014	.3	±.6	2.1	-7.6

Tr Trace present.

a Air contaminated sample.

b Contains 0.10 mg/L ethane.

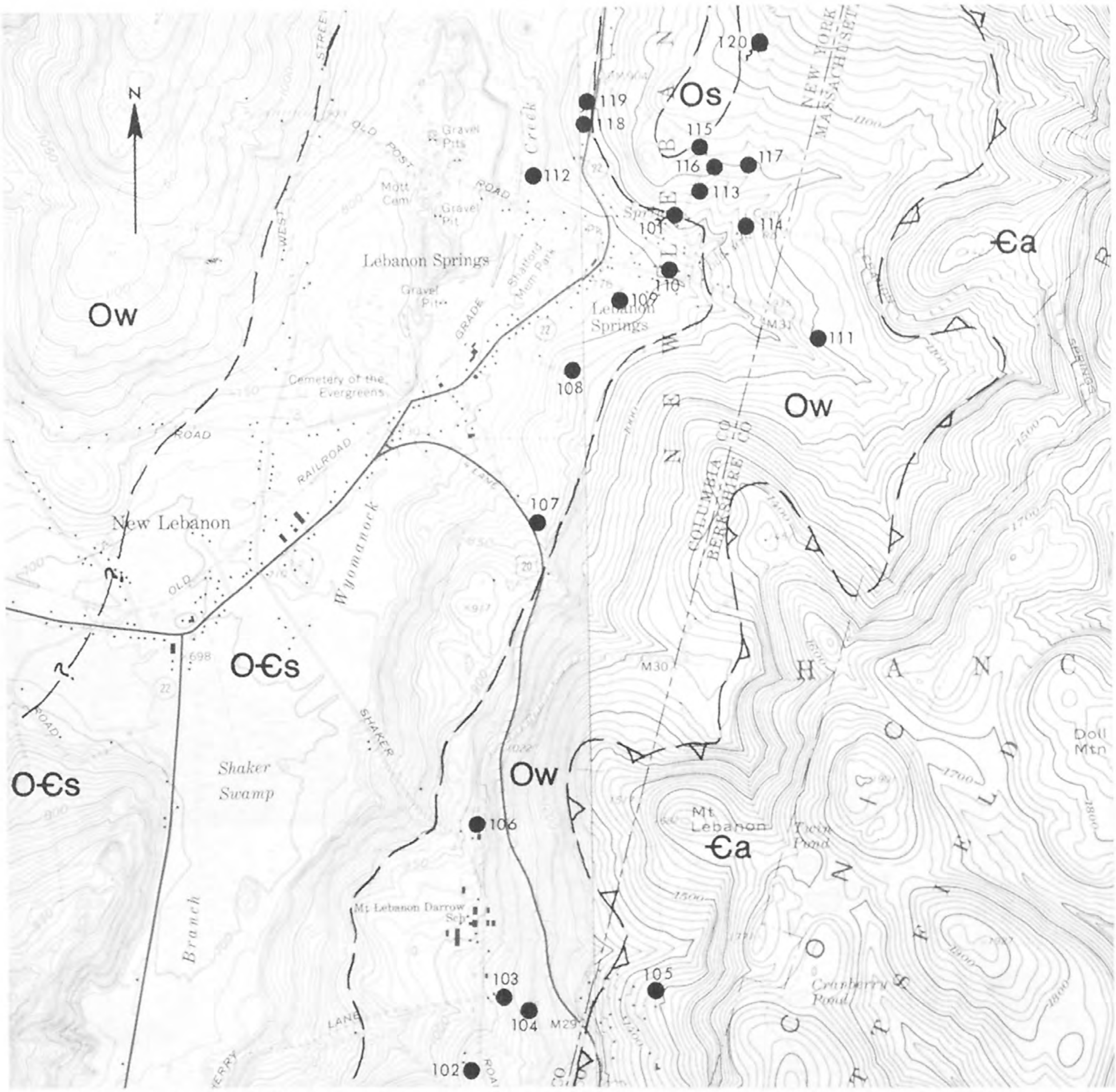
Table 2.--Results of dissolved-gas and isotope analyses of waters from Appalachian warm springs areas--Continued

Sample number	Date	Field dissolved oxygen (O_2)	Lab dissolved oxygen (O_2)	Gases (concentrations in mg/L): Nitrogen (N_2)	Argon (Ar)	Methane (CH_4)	Carbon dioxide (CO_2)	Helium (He)	Isotope results: Tritium T.U.	Tritium ±1σ	$\delta^{13}C_{PDB}$ °/oo	$\delta^{18}O_{SMOW}$ °/oo
VIRGINIA - BOLAR SPRING AREA												
501	12-75	5.0	4.9	22	0.82	<0.005	16	Tr<0.0002	24.4	±2.0	-9.2	-8.0
501	6-76	6.0	(a)	(a)	(a)	Tr<.03	11	<.0003	27.2	±1.6	-10.1	-8.1
VIRGINIA - HOT SPRINGS - WARM SPRINGS AREAS												
602	11-75	2.0	.62	17	.72	Tr<.006	136	.0007	-3.1	±1.8	-5.6	-7.4
602	6-76	.4	(a)	(a)	(a)	Tr<.03	114	.0003	.7	± .5	-5.8	-8.3
605	11-75	9.2	8.5	19	.72	<.01	14.4	<.0001	41.0	±2.4	-8.8	-7.9
605	6-76	--	--	--	--	--	--	--	43.5	±2.2	-9.8	-9.1
607A	11-75	.5	.36	25	.96	<.01	115	.0010	2.4	±2.3	-7.5	-7.8
619	11-75	8.0	7.1	19	.74	<.007	13.4	Tr<.0002	36	±2.8	-10.4	-7.7
619	6-76	6.0	5.7	14	.63	<.015	12	<.0003	34.2	±2.0	-7.4	-8.3
625	11-75	1.7	.16	30	1.13	Tr<.02	15.5	<.0001	4.9	±1.8	-7.7	-7.9
627	11-75	7.0	7.1	26	.89	<.007	31	<.0001	64.6	±3.5	--	--
631	11-75	.1	<.01	16	.79	Tr<.006	21	.0001	.9	±.9	-8.2	-7.9
631	6-76	.2	<.02	16	.81	Tr<.03	20	<.0003	1.6	±.6	-8.8	-8.5
633	12-75	8.5	8.0	19	.78	<.005	50	<.0001	68.3	±3.4	--	--
VIRGINIA - FALLING SPRINGS AREA												
701	12-75	7.0	7.2	15	.66	<.005	33	<.0003	24.4	±2.2	-6.8	-7.7
701	6-76	8.0	7.8	18	.70	<.015	30	Tr<.0003	32.6	±1.9	-8.4	-7.8
702	11-75	.1	(a)	(a)	(a)	Tr<.03	140	.0020	10.9	±1.0	-8.0	-7.9
NORTH CAROLINA - HOT SPRINGS AREA												
801	12-75	3.2	3.5	15	.61	<.005	7.9	.0007	-.2	±2.0	-9.5	-6.3
801	5-76	3.5	4.7	32	.86	<.02	4.5	.0004	-.5	±.7	-9.2	-6.4
803	12-75	1.4	<.02	25	.84	.06	38	<.0001	40.6	±2.4	-19.3	-6.2
803	5-76	<.1	1.3	28	.96	.06	41	<.0001	33.3	±1.9	-19.2	-7.0
804	12-75	10	10.5	22	.82	<.005	3.0	<.0001	52.2	±3.0	-12.0	-5.9
805	12-75	10	9.3	21	.79	<.005	2.7	<.0001	6.0	±1.0	-13.4	-6.2
810	5-76	--	--	--	--	--	--	--	48.9	±2.4	-12.4	-6.8

Tr Trace present.
a Air contaminated sample.

Table 2.--Results of dissolved-gas and isotope analyses of waters from Appalachian warm springs areas--Continued

Sample number	Date	Gases (concentrations in mg/L)							Isotope results			
		Field dissolved oxygen (O_2)	Lab dissolved oxygen (O_2)	Nitrogen (N_2)	Argon (Ar)	Methane (CH_4)	Carbon dioxide (CO_2)	Helium (He)	Tritium T.U.	Tritium ±1σ	$\delta^{13}C_{PDB}$ ‰	$\delta^{18}O_{SMOW}$ ‰
GEORGIA - WARM SPRINGS AREA												
901	12-75	7.0	6.6	20	0.81	<.005	11	<0.0001	0.8	0.9	-13.7	-4.5
901	5-76	6.5	--	--	--	--	--	--	.8	.5	-14.5	-5.0
905	12-75	8.2	7.9	14	.58	<.005	55	<.0002	34.6	2.4	-30.1	-4.4
905	5-76	9.2	5.3	21	.44	<.02	34	<.0001	30.3	1.7	-24.3	-5.2
907	12-75	7.0	5.6	23	.58	<.01	14	<.0001	-1.0	2.2	-16.4	-4.3
909	12-75	.4	<.02	25	.84	<.01	17	<.0002	15.1	1.4	-20.0	-4.2



Base from U.S. Geological Survey Canaan 1:24,000, 1973 and Pittsfield West 1:24,000, 1973

1 ½ 0 1 Mile

1 .5 0 1 Kilometer

CONTOUR INTERVALS 10 AND 20 FEET DATUM IS MEAN SEA LEVEL

EXPLANATION

Ow — Walloomsac Slate — ORDOVICIAN

O€s — Stockbridge Limestone

€a — Austerlitz Phyllite — CAMBRIAN

Geologic Contact

Fault

Spring

Well

(Geology modified after unpublished maps by D.W. Fisher, 1960, 1970. Modifications based on well driller's logs.)

FIGURE 2.--GEOLOGY AND SPRING AND WELL LOCATIONS IN NEW YORK--LEBANON SPRINGS AREA.

Table 3.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Casing depth (ft)	Well diameter (in)	Date drilled	Altitude (feet above mean sea level)	Water level (land surface, ft)	Date measured	Yield (gal/min)	Specific conductance (micromhos at 25°C/cm)	Temperature (°C)	Date sampled	pH	Topographic situation	Geologic formation
								NEW YORK-LEBANON SPRINGS AREA									
4228500732211.1	*101	Lebanon Spring	P	--	--	--	--	910	--	--	105	260	21.9	10- 4-75	7.6	S	Stockbridge Limestone
				--	--	--	--	--	--	--	145	290	18.7	5-20-76	7.72		
4226460732254.1	102	D. McDonald		332	82	6	1946	1080	r50	--	4	--	--	--	--	S	Walloomsac Slate
4226570732247.1	103	Darrow School	T	132	26	6	1962	1075	r16	10- -62	15	340	13.5	9-18-75	7.3	S	Do.
4226550732243.1	104	.....do.......	U	258	32	6	1965	1125	e15	--	10	--	--	--	--	S	Do.
4226570732218.1	105	Shaker Hts. Inc. Assoc.	P	400	--	6	--	1470	--	--	--	320	--	9-16-75	8.0	S	Austerlitz Phyllite[b]
4227220732252.1	106	Darrow School	T	338	20	6	1965	970	r15	8-25-65	6	--	--	--	--	S	Walloomsac Slate
4228050732239.1	107	Ed Blomgren	H	96	--	6	--	825	--	--	e<10	--	--	--	--	T	Stockbridge Limestone
4228270732232.1	108	Donald Kline	H	--	--	6	--	840	--	--	10	360	14.6	9-16-75	8.0	S	Do.
4228380732223.1	*109	John Koepp	H	111	70	6	1970	785	a+1.8	--	10+	260	14.6	9-16-75	7.6	V	Do.
										--		255	12.2	5-21-76	8.0		Do.
4228420732212.1	110	E. Arcouet	H	137	38	6	1967	805	a+1.2	--	8	340	12.0	9-18-75	8.0	T	Do.
4228330732144.1	111	M. Ahlert	H	20	20	48	1700's	1000	e15	10- 3-75	--	--	--	--	--	S	Walloomsac Slate
4228560732238.1	112	F. Cummings	H	144	7	6	1967	775	0.0	9-16-75	16	235	11.1	9-16-75	8.0	T	Stockbridge Limestone (?)
4228530732206.1	113	S. Stouter	H	123	120	6	--	960	30.1	10- 4-75	--	--	--	--	--	S	Do.
							--		30.07	5-20-76	20+	--	--	9-18-75	7.7		Do.
4228480732157.1	*114	B. Schell	H	155	155	6	--	950	73.7	9-17-75	6	825	14.2	9-17-75	7.2	S	Stockbridge Limestone-Walloomsac Slate
4228590732206.1	115	K. Duffy	H	140	138	6	1961	1025	--	--	6	370	12.1	9-17-75	7.8	S	Stockbridge Limestone
4228570732203.1	*116	F. Amlaw	H	184	151	6	1968	1005	78.0	9-17-75	10	380	13.2	9-17-75	7.5	S	Do.
4228570732156.1	117	W. Weigan	U	--	--	36	--	1000	e5	9-18-75	--	--	--	--	--	S	Walloomsac Slate
4229030732229.1	118	G. W. Winquist	H	180?	--	6	--	880	<20	9-18-75	--	260	10.6	9-18-75	8.0	S	Stockbridge Limestone
4229070732228.1	119	R. Francher	H	272	--	6	--	885	0.0	9-18-75	good	260	--	9-18-75	8.0	S	Do.
4229150732154.1	120	F. Amlaw	S	--	--	--	--	1150	--	--	e5	110	12.2	9-17-75	5.8	S	Till (?)

* Sampled for chemical analysis.
e Estimated.
r Reported.
a Above land surface.
b Nomenclature not adopted by U.S. Geological Survey.

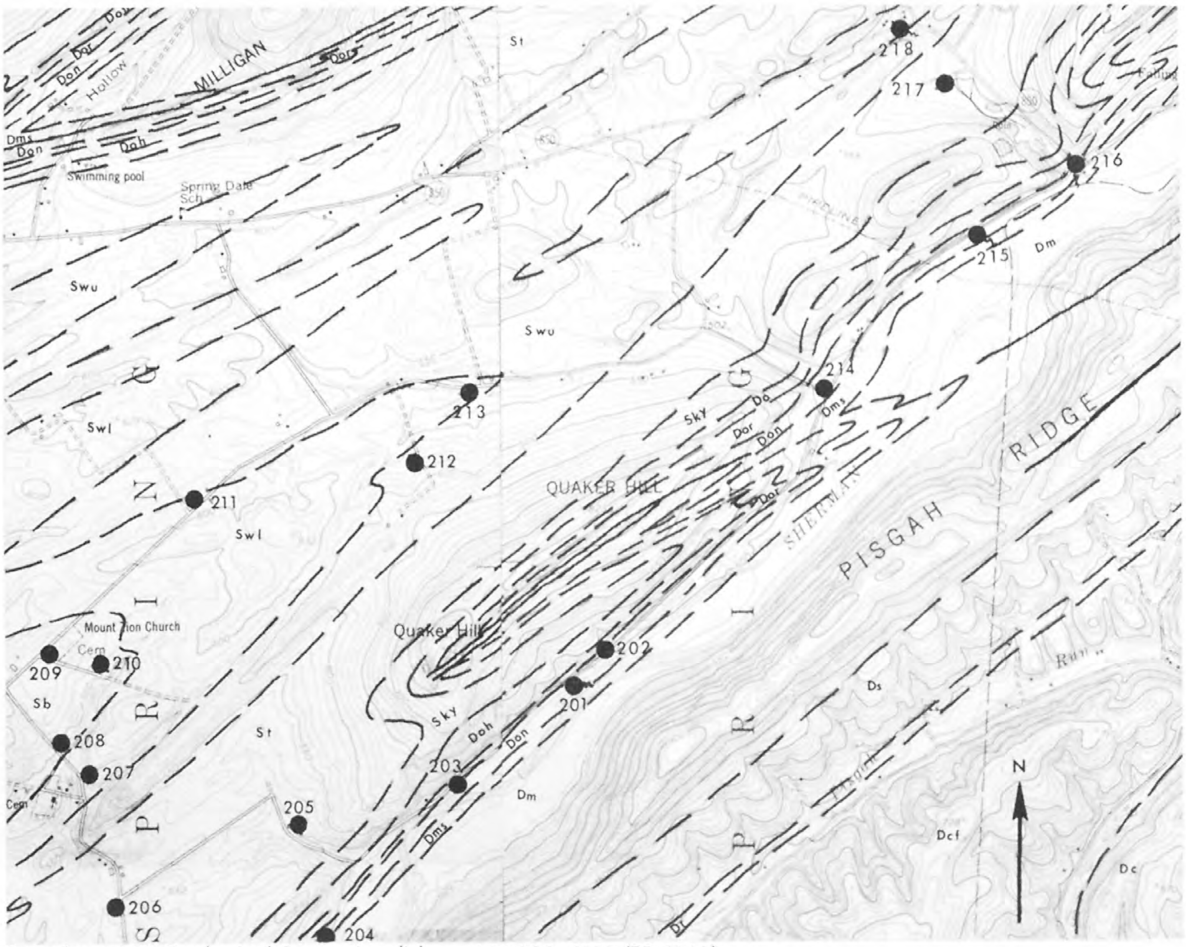
Explanation

Use

P - Public
T - Institutional
U - Unused
H - Household
S - Stock

Topographic situation

S - Hillside
T - Terrace
V - Valley



Base from U.S. Geological Survey Landisburg 1:24,000, 1952 (PR 1969)
and Shermans Dale 1:24,000, 1952 (PR 1968 and 1973)

1 ½ 0 1 Mile

1 .5 0 1 Kilometer

CONTOUR INTERVAL 10 FEET DATUM IS MEAN SEA LEVEL

EXPLANATION

DEVONIAN

- Dc — Catskill Formation
- Dcf — Catskill and Fort Littleton Formations, undivided
- Dr — Rush Formation
- Ds — Sherman Ridge Formation
- Dm — Montebello Formation

DEVONIAN

- Dms — Shamokin Member of Montebello Formation
- Don — Onondaga Formation
- Dor — Ridgeley Member of Oriskany Formation
- Doh — Oriskany and Helderberg Formations, undivided
- Sky — Keyser Formation

SILURIAN

- St — Tonoloway Formation
- Swu — Upper Member of Wills Creek Formation
- Swl — Lower Member of Wills Creek Formation
- Sb — Bloomsburg Formation

- Fault
- Geologic Contact
- Spring
- Well

(Geology after Dyson, 1976, and J.T. Miller, 1961, in Johnston, 1970.)

FIGURE 3.--GEOLOGY AND SPRING AND WELL LOCATIONS IN PENNSYLVANIA--PERRY COUNTY WARM SPRINGS AREA.

Table 4.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Casing depth (ft)	Well diameter (in)	Date drilled	Altitude (feet above mean sea level)	Water level (land surface, ft)	Date measured	Yield (gal/min)	Specific conductance (micromhos at 25°C/cm)	Temperature (°C)	Date sampled	pH	Topographic situation	Geologic formation
PENNSYLVANIA - PERRY COUNTY - WARM SPRINGS AREA																	
4019430771447.1	*201	Perry County warm springs	C	--	--	--	--	460	--	10- 6-75	140	190	17.8	10- 6-75	7.2	V	Oriskany Formation
				--	--	--	--		--	5-19-76	165	200	17.7	5-19-76	7.6		
4019480771441.1	*202	Lloyd Hetrick	H	123	123	6	1973	510	13.3	10- 6-75	--	--	--	--	--	S	Do.
									12.3	5-19-76	>10	125	12.0	10- 6-75	6.3		
4019300771508.1	203	Max Kretzing	U	--	--	--	--	460	--	--	--	170	15.1	9-11-75	6.2	V	Do.
4019090771532.1	204	.....do.......	U	83	0	6	1970	510	3.0	9-11-75	--	--	--	--	--	S	Do.
4019250771536.1	205	.....do.......	H	63	?	5	1969	510	16.6	10- 7-75	--	535	13.4	9-10-75	7.5	S	Tonoloway Limestone
4019130771609.1	206	Harry Crozer	H	43	20	6	1962	515	16	4- -62	25	630	--	4- -62	--	V	Do.
4019320771614.1	207	Paul Crozer	H	75	29	6	1963	545	15	5- -63	25	--	--	--	--	S	Wills Creek Formation
4019360771620.1	208	Banks Scheibly	U	400	40	15	--	550	a+	3- -65	--	--	--	--	--	S	Bloomsbury Formation
4019490771621.1	209	Mt. Zion Church	T	80	31	6	1956	590	37	10- -56	15	180	--	10- -56	--	H	Do.
4019470771612.1	210	Banks Scheibly	H	61	25	6	1957	560	12	9- -57	8	--	--	--	--	S	Do.
4020100771555.1	211	C. A. Shope	H	70	53	6	1957	595	40	7- -57	10	--	--	--	--	S	Wills Creek Formation
4020140771515.1	212	Luther Snyder	H	96	74	6	1956	575	50	5- -56	10	370	--	5- -56	--	S	Do.
4020240771505.1	213	Bertram Shuey	H	104	?	6	1960	540	e25	9-10-75	--	425	12.6	9-10-75	8.0	S	Do.
4020240771401.1	214	W. A. Miller	H	93	50	6	1973	435	e12	9- -75	20	<50	13.2	9-11-75	5.7	T	Oriskany Formation
4020450771334.1	215	Spring	U	--	--	--	--	440	--	--	e25	--	13.4	9-10-75	--	V	Do.
4020540771316.1	*216	H. Stambaugh Spring	H	--	--	--	--	460	--	--	?	120	13.3	9-10-75	6.1	V	Do.
4021050771339.1	217	Morris Loy	H	63	30+	6	1963	505	r10	--	>40	440	14.2	9-10-75	7.3	S	Tonoloway Limestone
4021130771347.1	*218	.....do.......	U	--	--	--	--	525	--	10- 7-75	7.5	300	12.0	10- 7-75	--	S	Do.
4021490771324.1	219	Robert Miller	H	235	120	6	1975	645	61.3	9-11-75	12	--	--	--	--	S	Do.

*Sampled for chemical analysis.
e Estimated.
r Reported.
a Above land surface.

Explanation

Use	Topographic situation
C - Commercial	V - Valley
H - Household	S - Hillside
U - Unused	H - Hilltop
T - Institutional	T - Terrace

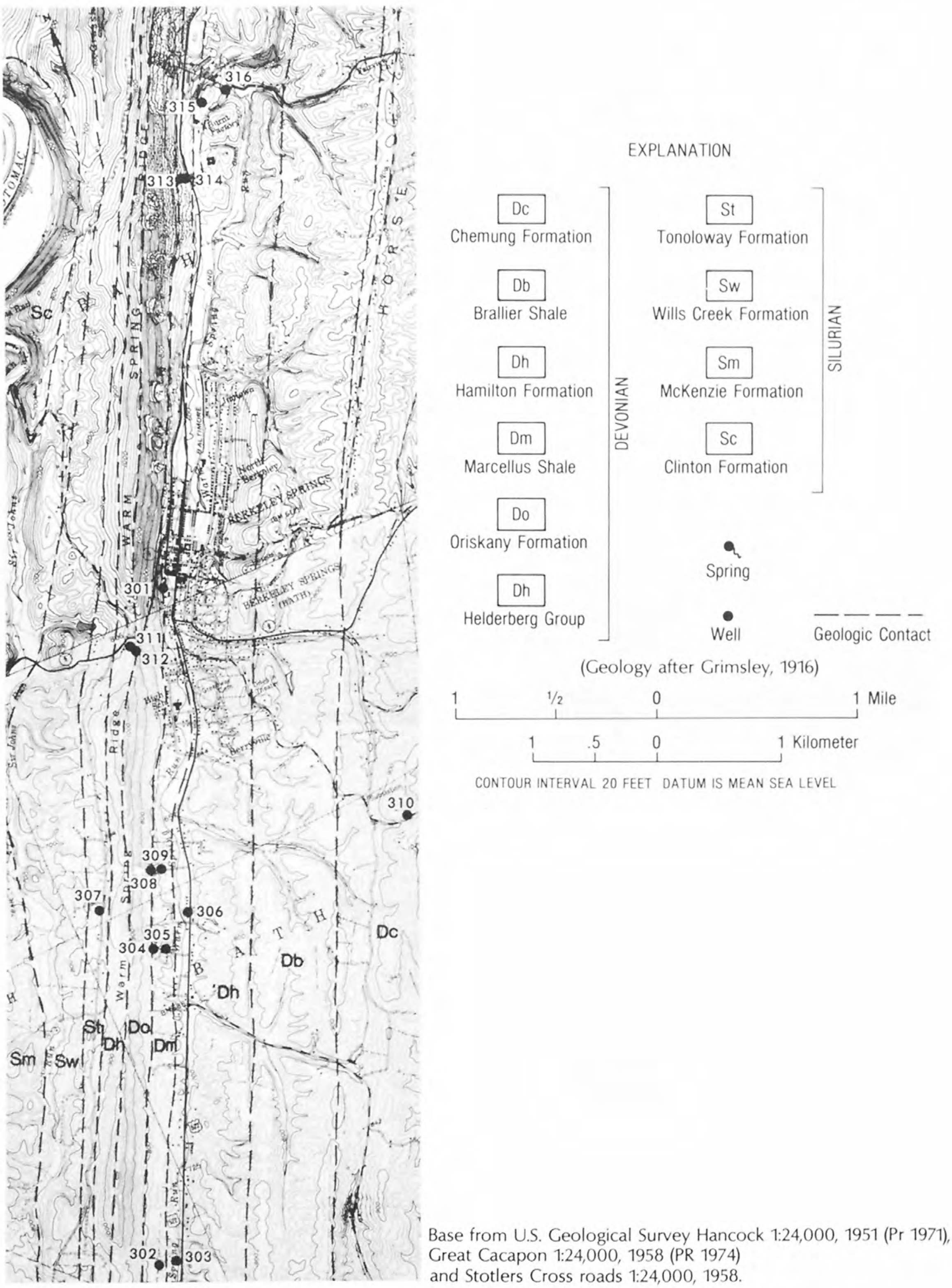


Figure 4.--Geology and spring and well locations in West Virginia--Berkeley Springs area.

Table 5.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Cas-ing depth (ft)	Well diam-eter (in)	Date drill-ed	Alti-tude (feet above mean sea level)	Water level (land sur-face, ft)	Date measured	Yield (gal/min)	Specific conduct-ance (micro-mhos at 25°C/cm)	Tem-per-a-ture (°C)	Date sampled	pH	Topo-graph-ic situa-tion	Geologic formation
								WEST VIRGINIA - BERKELEY SPRINGS AREA									
3937370781347.1	*301	Berkeley Springs	P	--	--	--	--	620	--	10- 2-75	1635	235?	21.8	10- 2-75	6.3	V	Oriskany Formation
				--	--	--	--		--	5-18-76	1715	250	22.2	5-18-76	7.0		
3934520781518.1	*302	Ford Wachter	U	398	62	6	1974	785	165	1-14-76	35	435	13.0	10-16-75	6.8	S	Marcellus Shale and Oriskany Formation
									164.5	5-17-76	--	645	12.8	5-17-76	7.1		
3934510781513.1	*303	.....do.......	H	198	136	7	1969	760	21.4	9-30-75	10	480	13.9	9-30-75	6.5	T	Marcellus Shale
3936090781438.1	304	WV Dept. of Highways	U	?	--	--	1974	705	dry	--	--		--	--	--	-	Oriskany Formation (?)
3936070781434.1	305	.....do.......	H	550	43	6	1974	695	25.1	8-20-75	8	--	--	--	--	-	Marcellus Shale
3936140781423.1	306	Bohler & McKoy	H	148	41	7	1969	670	9	8-22-69	15	340	--	8-22-69	7.0	T	Marcellus Shale and Hamilton Formation
3936230781449.1	*307	H. Hovermale	H	173	36	6	1967	840	48.4	10- 1-75	4	500?	16.6	10- 1-75	6.2	S	Tonoloway Formation
3936280781428.1	308	Kirkpatrick & Brown	U	150	--	6	1968	705	dry	--	--	--	--	--	--	S	Oriskany Formation
3636270781425.1	309	.....do.......	I	148	--	6	1968	680	.7	8-20-75	60	--	--	--	--	S	Marcellus Shale
3936150781302.1	310	Fred Unger	H	335	41	7	1969	950	e60	8-22-69	--	--	--	--	--	S	Chemung Formation[b]
3937240781404.1	311	R. Glass	H	147	20	6	1960	825	0	10-23-70	--	655	--	10-23-70	7+	H	Helderberg Group
3937220781404.1	312	.....do.......	U	180	20	10	1954	835	r140	-54	>30	--	--	--	--	H	Do.
3939110781244.1	313	Pa. Glass & Sand Co.	U	450	30	8	1969	660	115	3- -69	50	400	13.7	8-20-75	7.2	S	Marcellus Shale and Oriskany Formation
3939110781245.1	314	.....do.......	N	465	30	8	1969	660	115	5- -69	e50	--	--	--	--	S	Do.
3939280781220.1	315	.....do.......	N	360	--	6	1945	670	60-70	--	100	--	--	--	--	S	Oriskany Formation (?)
3939270781230.1	316	.....do.......	H	170	19	9	1957	600	--	--	12	--	--	--	--	S	Marcellus Shale (?)

*Sampled for chemical analysis.
e Estimated.
r Reported.
b Nomenclature not adopted by U.S. Geological Survey.

Explanation

Use	Topographic situation
P - Public supply	V - Valley
U - Unused	S - Hillside
H - Household	T - Terrace
I - Irrigation	H - Hilltop
N - Industrial	

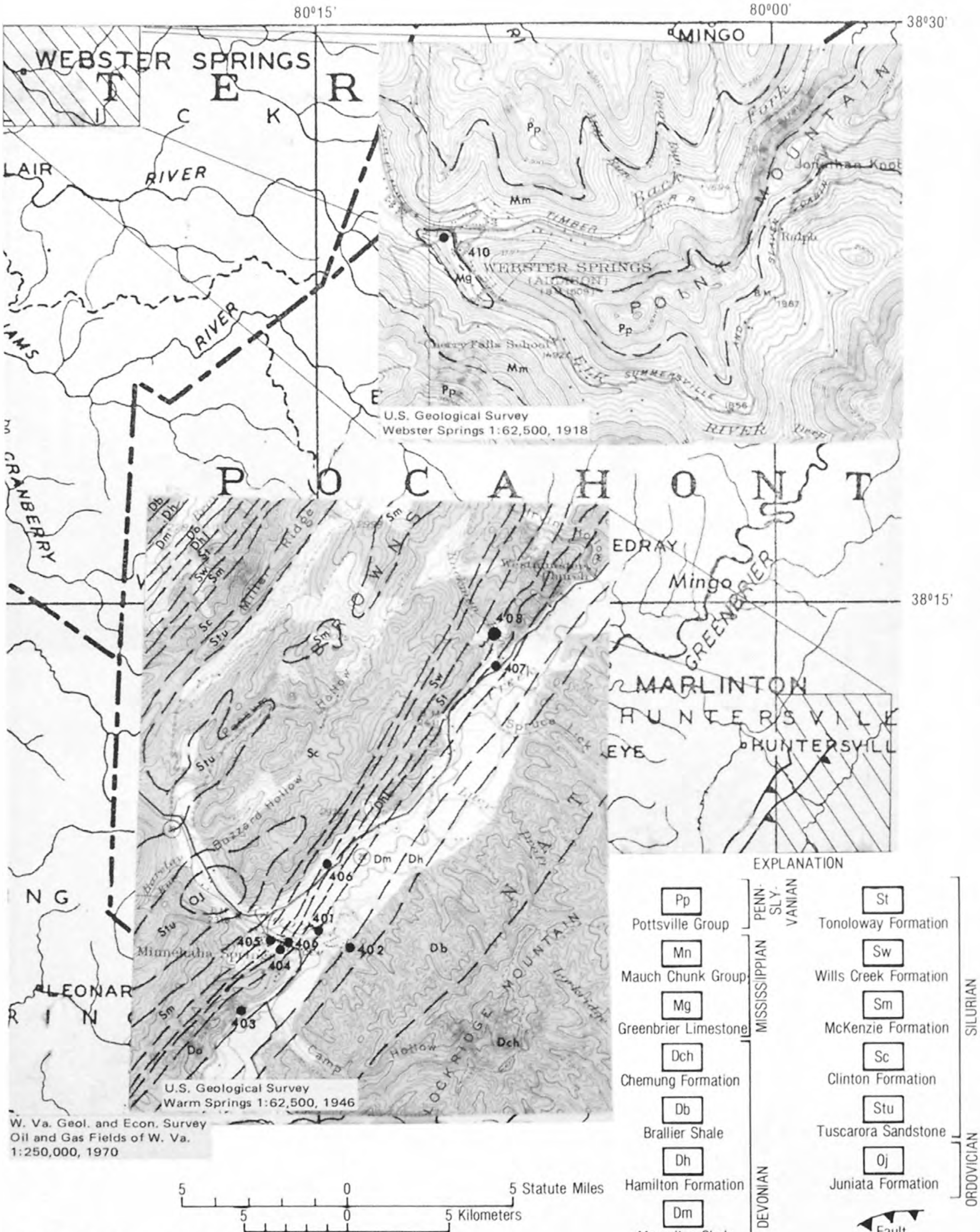


FIGURE 5.--GEOLOGY AND SPRING AND WELL LOCATIONS IN WEST VIRGINIA--MINNEHAHA SPRINGS AREA.

Table 6.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Casing depth (ft)	Well diameter (in)	Date drilled	Altitude (feet above mean sea level)	Water level (land surface, ft)	Date measured	Yield (gal/min)	Specific conductance (micromhos at 25°C/cm)	Temperature (°C)	Date sampled	pH	Topographic situation	Geologic formation
								WEST VIRGINIA - MINNEHAHA SPRINGS AREA									
3809500795829.1	*401	Minnehaha spring	R	--	--	--	--	2310	--	11-18-75	220	240	20.4	11-18-75	7.8	V	Oriskany Formation
										6- 9-76	480	285	20.3	6- 9-76	7.9		
3809450795814.1	*402	Camp Minnehaha	H	300	60	6	1971	2440	43.7	11-19-75	3	360	11.6	11-19-75	7.2	S	Hamilton (?) Formation
									p52.9	6-11-76	--	355	13.2	6-11-76	7.3		
3809180795907.1	*403	A. T. White	H	76	76	6	1953	2335	--	--	7.5	185	12.8	10-22-75	7.2	S	Oriskany Formation
3809430795848.1	404	J. Buzzard	H	46	27	6	1950	2355	r38	--	4.5	140	13.8	10-23-75	5.8	S	Do.
3809460795854.1	405	M. Buzzard	H	84	84	6	1958	2335	--	--	e20	80+	12.5	10-23-75	4.9	S	Do. (?)
3810170795826.1	*406	Floyd Davis	H	--	--	--	--	2320	--	--	e20	180	10.4	10-23-75	7.6	T	Tonoloway Formation
3811370795704.1	*407	R. Shinaberry	H	82	78	6	--	2365	37.9	10-22-75	9	110	13.5	10-22-75	5.5	T	Oriskany Formation
3811480795704.1	408	M. Workman	H	--	--	--	--	2435	--	--	e500	225	10.4	10-23-75	7.4	S	Tonoloway Formation
3809460795845.1	409	J. B. Worth	H	78	35	6	1976	2320	r2	--	6	--	--	--	--	-	Oriskany Formation
3828460802450.1	410	T. Rose	U	71	20?	6	1912	1460	2.5	6- 8-76	--	6100	13.8	6- 8-76	7.7	V	Greenbrier Limestone

*Sampled for chemical analysis.
e Estimated.
r Reported.
p Well pumped recently.

Explanation

Use
R - Recreational
H - Household
U - Unused

Topographic situation
V - Valley
S - Hillside
T - Terrace

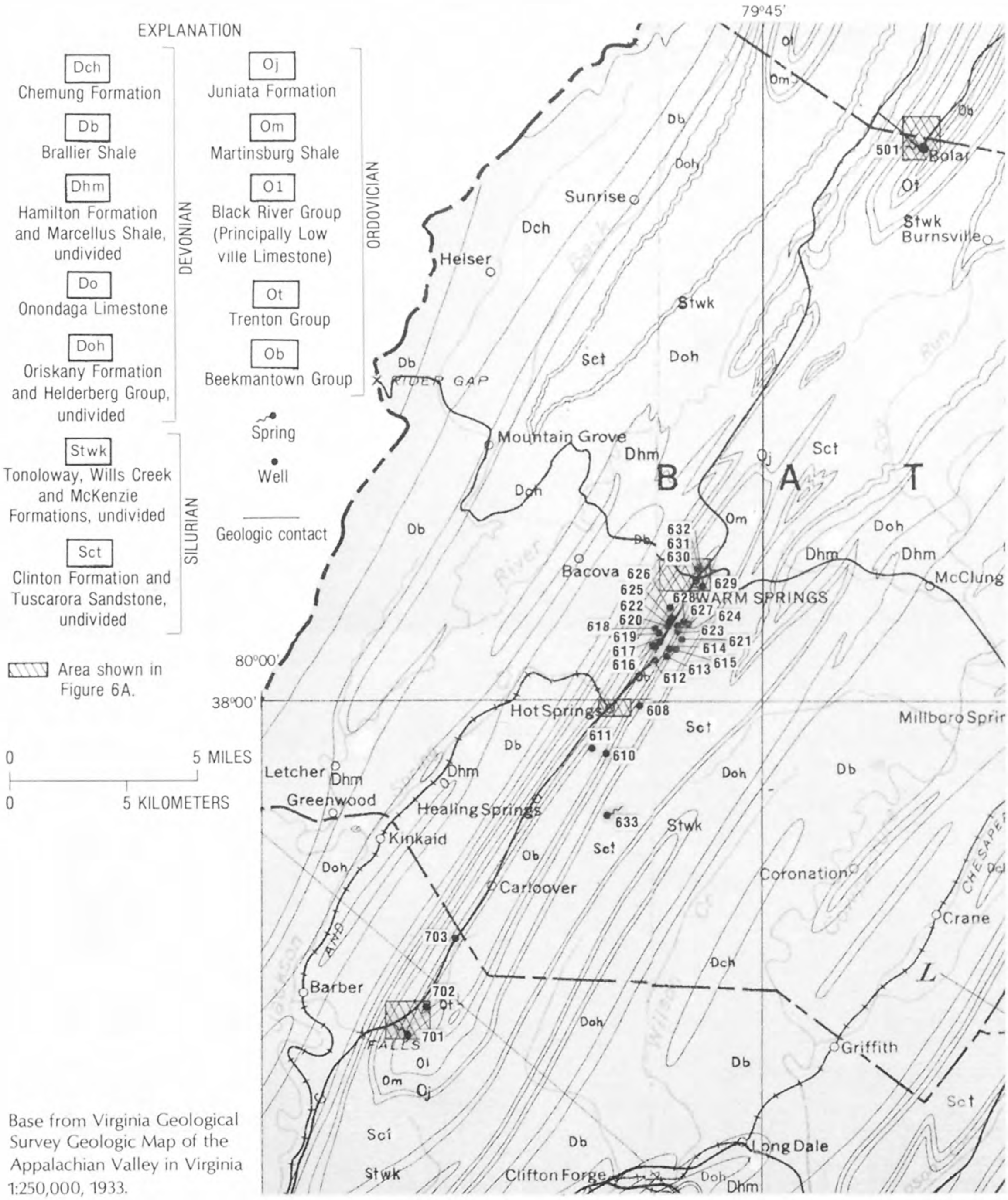


Figure 6.--Geology and spring and well locations in Virginia--Bolar Spring, Hot Springs-Warm Springs, Falling Springs areas.

Table 7.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Casing depth (ft)	Well diameter (in)	Date drilled	Altitude (feet above mean sea level)	Water level (land surface, ft)	Date measured	Yield (gal/min)	Specific conductance (micromhos at 25°C/cm)	Temperature (°C)	Date sampled	pH	Topographic situation	Geologic formation
VIRGINIA - BOLAR SPRINGS AREA																	
3812580794026.1	*501	Bolar Spring	R	--	--	--	--	2235	--	12-16-75	2065	325	22.2	12-16-75	7.5	C	Lowville Limestone
										6- 9-76	2600	335	20.2	6- 9-76	7.4		
VIRGINIA - HOT SPRINGS - WARM SPRINGS AREA																	
3759540794950.1	601	Octagon spring	R	--	--	--	--	2250	--	--	--	--	36.5	11-21-75	--	V	Do.
				--	--	--	--	--	--	--	--	--	36.8	6-10-76	--		
3759520794948.1	*602	Boiler spring	R	--	--	--	--	2275	--	11-21-75	60	700	39.9	11-21-75	6.6	V	Do.
				--	--	--	--	--	--	6-10-76	60	645	40.0	6-10-76	6.5		
3759520794947.1	603	Sulphur spring	-	--	--	--	--	2280	--	--	--	--	36.5	11-21-75	--	V	Do.
			-	--	--	--	--	--	--	--	--	--	35.2	6-10-76	--		
3759500794941.1	604	Magnesia spring	-	--	--	--	--	2305	--	--	--	--	16.2	11-21-75	--	V	Do.
			-	--	--	--	--	--	--	--	--	--	28.4	6-10-76	--		
3759490794940.1	*605	Cold Magnesia spring	-	--	--	--	--	2305	--	11-26-75	135	330	15.2	11-21-75	7.2	V	Do.
			-	--	--	--	--	--	--	6-10-76	320	265	14.0	6-10-76	7.2		
3759470794954.1	606	Soda spring	-	--	--	--	--	2280	--	--	--	--	13.4	11-21-75	--	V	Do.
3759560794921.1	*607	Homestead hot well	U	756	150	6	1974	2440	138	9- 4-75	220	420	19.6	11-20-75	7.2	S	Beekmantown[b] Group
3759490794904.1	608	Homestead well	U	341	101	6	1964	2650	r260	-64	15	--	--	--	--	S	Trenton and Black River[b] Groups
3759380794922.1	609	.....do.......	-	200?	--	--	--	2560	dry	--	--	--	--	--	--	S	Do.
3758430794952.1	610	.....do.......	-	808	367	5	1963	2840	r454	8- -75	--	--	--	--	--	S	Do.
3758470795022.1	611	Erwin Solomon	U	300?	--	6	--	2620	277?	12-17-75	--	--	--	--	--	S	Beekmantown[b] Group
3800460794841.1	612	Western Auto Store	C	235	205	6	--	2450	100+?	--	9	640	17.2	9- 4-75	7.0	S	Do.
3800490794818.1	613	R. Robertson	H	412	62	4	--	2610	r312	--	3	--	--	--	--	S	Trenton and Black River[b] Groups
3800540794819.1	614	Herbert Kriser	U	360	107	6	1970	2580	r284	-70	8	--	--	--	--	S	Do.
3800530794800.1	615	Unknown	-	212	116	--	--	2820	r83	10-11-73	20	--	--	--	--	S	Do.
3801020794848.1	616	J. Woodzell	H	100+	--	6	1957	2360	e93	9- 4-75	5	550	--	9- 5-75	--	S	Do.
3801020794837.1	617	R. Pampillonia	H	330	--	4	--	2370	--	--	12	--	--	--	--	S	Beekmantown[b] Group
3801290794850.1	618	T. K. Ellis	-	228	43	5	1962	2225	r15	--	42	--	--	--	--	S	Martinsburg Shale, Trenton and Black River[b] Groups
3801150794843.1	*619	M. Dunn	H	--	--	--	--	2290	--	11-24-75	1025	410	15.8	11-24-75	7.3	C	Trenton and Black River[b] Groups
				--	--	--	--					395	14.4	6-10-76	7.4		
3801350794815.1	620	T. K. Ellis	-	333	85	5	--	2400	r120	--	.5	--	--	--	--	S	Beekmantown[b] Group
3801260794751.1	621	Ramsay ?	-	?	--	--	--	2640	r dry	--	--	--	--	--	--	S	Trenton and Black River[b] Groups
3801410794816.1	622	T. K. Ellis	-	400	50	6	--	2340	r42	--	12	--	--	--	--	S	Beekmantown[b] Group

Table 7.--Records of springs and wells in the Appalachian warm springs areas--Continued

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Casing depth (ft)	Well diameter (in)	Date drilled	Altitude (feet above mean sea level)	Water level (land surface, ft)	Date measured	Yield (gal/min)	Specific conductance (micromhos at 25°C/cm)	Temperature (°C)	Date sampled	pH	Topographic situation	Geologic formation
VIRGINIA - HOT SPRINGS - WARM SPRINGS AREA--Continued																	
3801510794746.1	623	J. Oliver	-	350	--	--	--	2590	r dry	--	--	--	--	--	--	S	Trenton and Black River[b] Group
3801560794742.1	624	.....do.......	-	500	--	--	--	2580	r dry	--	--	--	--	--	--	S	Beekmantown[b] Group
3802010794807.1	*625	Valley View Cottages	P	761	64	5	1954	2500	r65	--	8	350	14.8	9- 4-75	--	S	Martinsburg Shale, Trenton and Black River[b] Groups
3802090794806.1	626	Unknown	-	125	--	--	--	2630	--	--	--	--	--	--	--	S	Martinsburg Shale
3801590794738.1	*627	T. H. Bonds	H	242	130+	6	--	2580	163.2	9- 5-75	5	455	13.0	9- 5-75	7.0	S	Trenton and Black River[b] Groups
3802070794743.1	623	Bath County High School	T	240	--	8	--	2540	r180	-55	12	360	11.9	9- 4-75	7.3	S	Do.
3802420794659.1	629	G. Gardner	H	200+	--	5	--	2495	--	--	13	275	16.4	9- 4-75	7.4	S	Do.
3803130794652.1	630	Warm Spring (ladies' pool)	M	--	--	--	--	2325	--	--	--	600	34.9	9- 3-75	7.1	V	Lowville Limestone
				--	--	--	--		--	11-25-75	185	--	34.8	11-25-75	--		
				--	--	--	--		--	6-10-76	410	--	35.1	6-10-76	--		
3803130794652.2	*631	Warm Spring (children's pool)	M	--	--	--	--	2325	--	--	--	600	35.3	9- 3-75	7.0	V	Do.
				--	--	--	--		--	11-25-75	180	640	35.4	11-20-75	7.3		
				--	--	--	--		--	6-10-76	185	580	35.4	6-10-76	7.2		
3803130794651,1	632	Warm Spring (mens' pool)	M	--	--	--	--	2325	--	--	--	600	35.2	9- 3-75	7.2	V	Do.
				--	--	--	--		--	11-25-75	450	--	35.0	11-25-75	--		
				--	--	--	--		--	6-10-76	410	--	35.4	6-10-76	--		
3757550794952.1	*633	Ingalls Airport "spring"	C	--	--	--	--	3690	e7	12-16-75	15	50	9.1	12-16-75	4.5	H	Clinton Formation
VIRGINIA - FALLING SPRINGS AREA																	
3752090795600.1	*701	Falling Spring	U	--	--	--	--	2195	--	12-15-75	3240	800	25.0	12-15-75	7.3	C	Lowville Limestone
				--	--	--	--		--	6-11-76	4640	530	20.8	6-11-76	7.3		
3752580795539.1	*702	H. D. Webb	S	167	?	6	1973	2235	?	--	good	1050	27.2	11-26-75	7.15	V	Beekmantown[b] Group
3753580795416.1	703	Va. Polytech.	U	1000	1000	2	1975	2451	125	1-15-76	--	--	--	--	--	S	Do.

* Sampled for chemical analysis.
e Estimated.
r Reported.
b Nomenclature not adopted by U.S. Geological Survey.

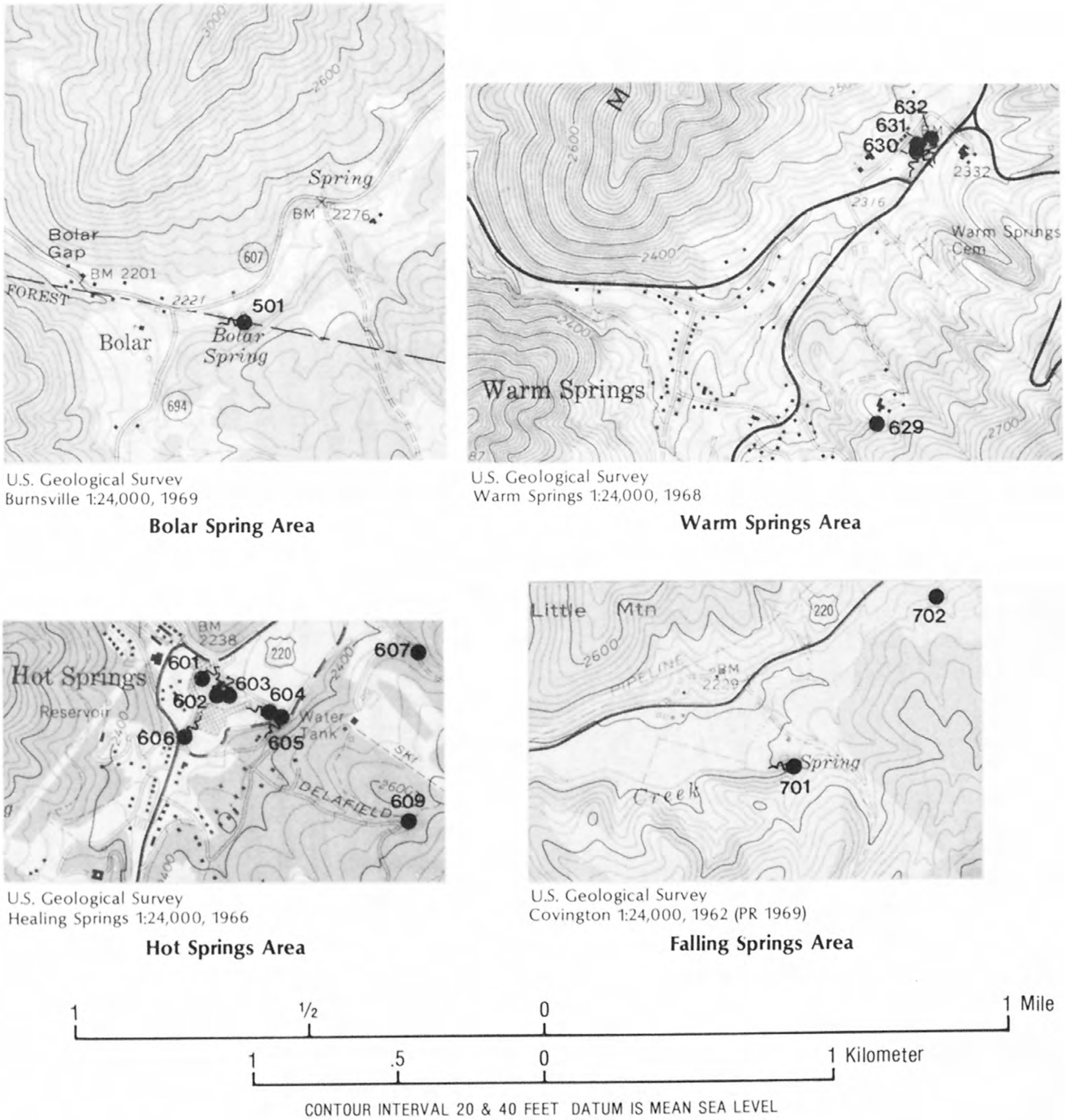
Explanation

Use

P - Public supply
H - Household
T - Institutional
M - Medicinal
C - Commercial
U - Unused
S - Stock
R - Recreational

Topographic situation

S - Hillside
V - Valley
H - Hilltop
C - Stream channel

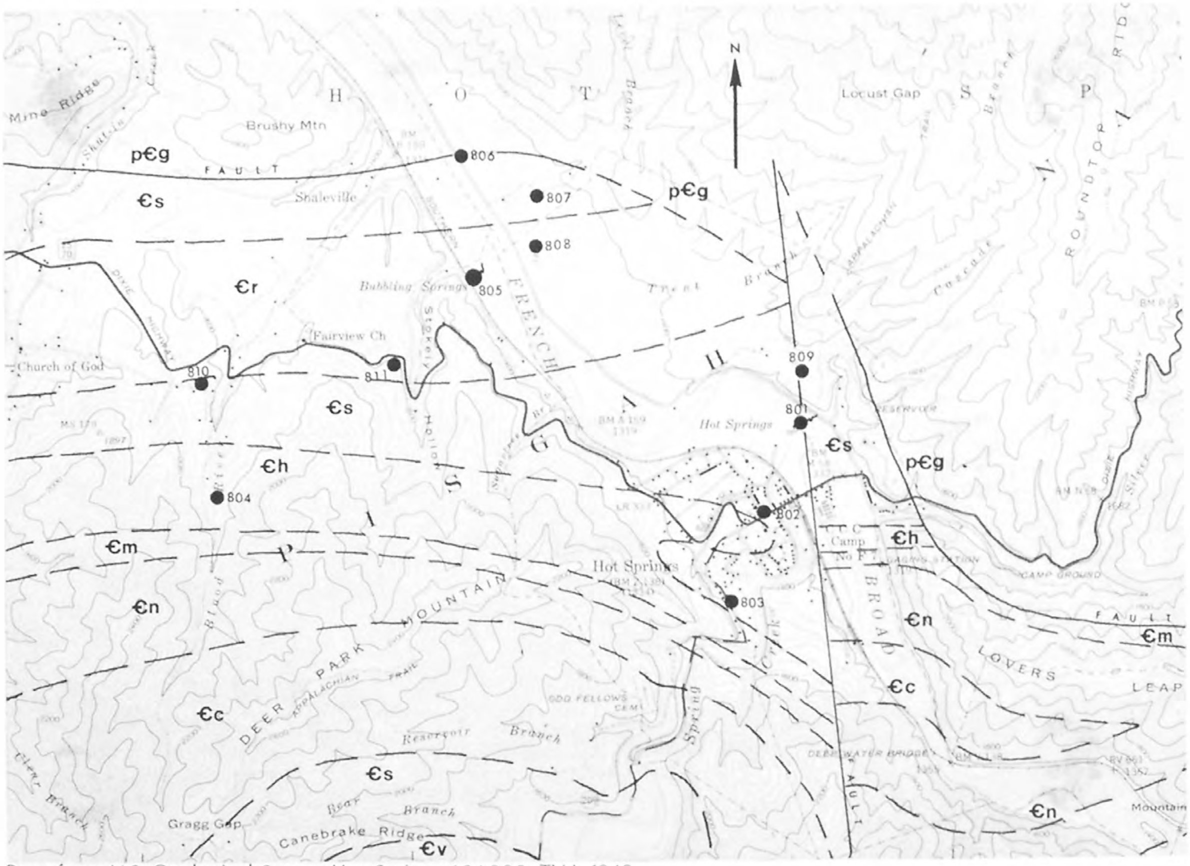


EXPLANATION

Spring

Well

Figure 6A.--Detailed maps showing warm springs and well locations in Virginia.



Base from U.S. Geological Survey Hot Springs 1:24,000, TVA 1940

1 ½ 0 1 Mile

1 .5 0 1 Kilometer

CONTOUR INTERVAL 40 FEET WITH 20 FOOT CONTOURS SHOWN BY BROKEN LINE

EXPLANATION

CAMBRIAN

€r	Rome Formation
€s	Shady Dolomite
€h	Hesse Quartzite
€m	Murray Shale
€n	Nebo Quartzite
€c	Cochran Quartzite
€s	Sandsuck Shale
€v	Vann Quartzite

PRECAMBRIAN

p€g	Great Smoky Quartzite

Fault

Spring

Well

Geologic Contact

(Geology based on map by Arthur Kieth and revised by Stose and Stose, 1947)

FIGURE 7.--GEOLOGY AND SPRING AND WELL LOCATIONS IN NORTH CAROLINA--HOT SPRINGS AREA.

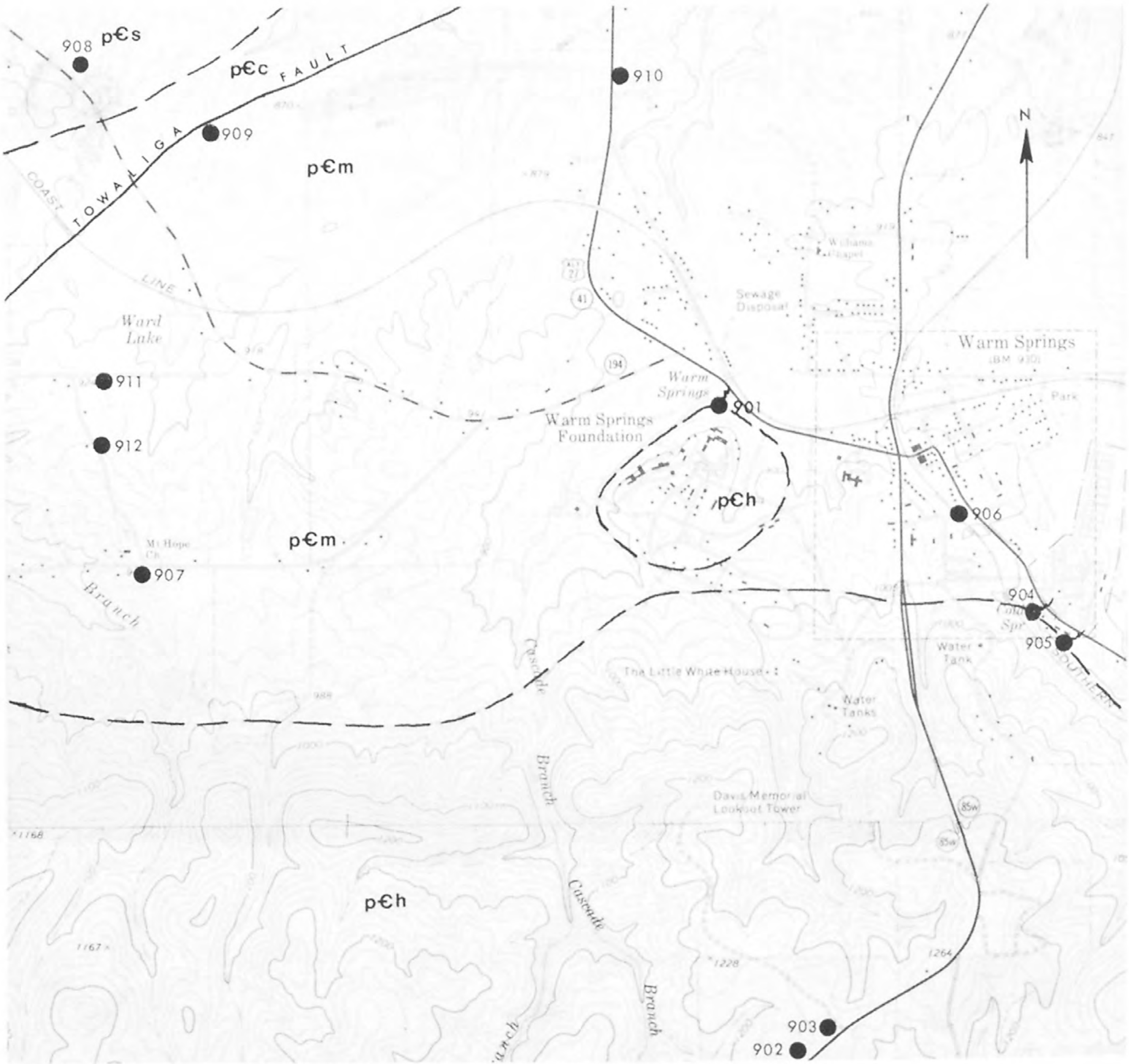
Table 8.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Cas-ing depth (ft)	Well diam-eter (in)	Date drill-ed	Alti-tude (feet above mean sea level)	Water level (land sur-face, ft)	Date measured	Yield (gal/min)	Specific conduct-ance (micro-mhos at 25°C/cm)	Tem-per-a-ture (°C)	Date sampled	pH	Topo-graph-ic situa-tion	Geologic formation
NORTH CAROLINA - HOT SPRINGS AREA																	
3553500824933.1	*801	Hot Spring	U	--	--	--	--	1315	8.85	12- 6-75	8.5	710	39.3	12- 6-75	7.5	V	Shady Dolomite
				--	--	--	--		8.86	5- 3-76	6.8	830	41.4	5- 3-76	7.5		
3553330824941.1	802	J. R. Henderson	U	11	11	48	--	1335	dry	11- 1-75	--	--	--	--	--	T	Alluvium
3553170824948.1	*803	City Well	P	385	22	6	1966	1380	25.2	10-31-75	50	200	15.2	12- 6-75	6.7	T	Murray Shale
												220	15.2	5- 3-76	6.8		
3553370825143.1	*804	Fairview Water Assoc.	P	320	178	5	1972	1730	100	10-31-75	22	65	13.2	11- 1-75	5.5	S	Hesse Quartzite
3554150825446.1	*805	Bubbling Springs	P	--	--	--	--	1315	--	12- 5-75	480	165	13.2	12- 5-75	7.75	V	Rome Formation
3553360825143.1	806	Kail Graham	H	140	--	6	--	1310	--	--	--	--	--	--	--	T	Great Smoky[b] Quartzite
3554300825031.1	807	W. Gorneflo	H	210	--	6	--	1350	--	--	--	--	--	--	--	T	Shady Dolomite
3554210825032.1	808	R. Williamson	H	160	30	6	1970	1320	r10	--	6	285	13.6	10-31-75	8.0	T	Rome Formation
3553590824933.1	809	W. Ramsey	U	200+?	--	6	--	1520	--	--	--	--	--	--	--	T	Shady Dolomite
3553570825146.1	*810	Paul Lovin	I	245	200	4	1966	1630	r200	--	12	245	15.0	5- 3-76	8.1	S	Do.
3554000825103.1	811	Burlin Shetley	U	238	196	6	1956	1610	r138	--	60	--	--	--	--	S	Do.

* Sampled for chemical analysis.
e Estimated.
r Reported.
b Nomenclature not adopted by U.S. Geological Survey.

Explanation

Use	Topographic situation
U - Unused	V - Valley
P - Public supply	T - Terrace
H - Household	S - Hillside
I - Irrigation	



Base from U.S. Geological Survey Warm Springs 1:24,000, 1971 and Shiloh 1:24,000, 1971

1 ½ 0 1 Mile

1 .5 0 1 Kilometer

CONTOUR INTERVAL 20 FEET DATUM IS MEAN SEA LEVEL

EXPLANATION

PRECAMBRIAN: p€m Manchester Schist; p€h Hollis Quartzite

PRECAMBRIAN: p€s Snelson Granite; p€c Carolina Gneiss

Fault

Well

Spring

Geologic Contact

(Geology after Hewett and Crickmay, 1937)

FIGURE 8.--GEOLOGY AND SPRING AND WELL LOCATIONS IN GEORGIA--WARM SPRINGS AREA.

Table 9.--Records of springs and wells in the Appalachian warm springs areas

Latitude-longitude number	Spring or well number	Owner or name	Use	Well depth (ft)	Cas-ing depth (ft)	Well diam-eter (in)	Date drill-ed	Alti-tude (feet above mean sea level)	Water level (land sur-face, ft)	Date measured	Yield (gal/min)	Specific conduct-ance (micro-mhos at 25°C/cm)	Tem-per-a-ture (°C)	Date sampled	pH	Topo-graph-ic situa-tion	Geologic formation
GEORGIA - WARM SPRINGS AREA																	
3253330844126.1	*901	Warm Springs	M	--	--	--	--	845	--	12-11-75	885	182	30.9	12-10-75	7.40	V	Hollis Quartzite[b]
				--	--	--	--		--	5- 5-76	h1085	210	30.5	5- 5-76	6.95		
3251550844111.1	902	E. Neely	U	184	--	5	--	1225	65.7	12-11-75	--	--	--	--	--	H	Do.
					--		--		69.5	5- 5-76	--	--	--	--	--		
3251590844106.1	903	Butts	U	66	--	48	1924	1225	61.7	12-11-75	--	--	--	--	--	H	Do.
					--				65.1	5- 5-76	--	--	--	--	--		
3253010844029.1	904	Cold Spring	P	--	--	--	--	885	--	12- 8-75	e800	--	--	--	--	S	Do.
3252560844023.1	*905	South Spring	N	--	--	--	--	880	--	12- 8-75	270	<50	17.7	12- 8-75	4.0	S	Do.
				--	--	--	--		--	5- 5-76	245	<50	17.8	5- 5-76	4.9		
3253160844042.1	906	Ellerson	U	<20	--	--	--	920	13.9	12-13-34	--	--	--	--	--	S	Manchester (?) Schist
3253080844308.1	*907	James Phillips	H	240	240	6	1965	945	81.2	12-10-75	100	100	33.8	12-10-75	6.42	S	Do.
3254240844316.1	908	B. Jewett Barnes	H	98	80	6	1955	890	r20	--	35	<50	17.6	12-10-75	--	H	Snelson Granite
3254130844258.1	*909	Andy Baxley	H	106	2	6	1975	840	6	- -75	--	158	17.0	12-11-75	7.02	S	Carolina[b](?) Gneiss
3254220844141.1	910	Chic Sports Wear	N	<100	--	--	--	855	--	--	--	50	--	5- 6-76	--	H	Manchester Schist
3253370844312.1	911	B. J. Harring-ton	H	45	--	--	--	920	--	--	--	80	--	5- 6-76	--	S	Do.
3253270844313.1	912	W. L. Pritt	H	40	--	--	--	940	--	--	--	100	--	5- 6-76	--	S	Do.

* Sampled for chemical analysis.
e Estimated.
r Reported.
h This measurement erroneously high because of stored water draining from reservoir.
b Nomenclature not adopted by U.S. Geological Survey.

Explanation

Use	Topographic situation
M - Medicinal	V - Valley
U - Unused	H - Hilltop
P - Public supply	S - Hillside
N - Industrial	
H - Household	

Table 10 -- FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The following factors may be used to convert the English units published herein to the International System of Units (SI).

Multiply English units	By	To obtain SI units
	Length	
inches (in)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
square miles (mi^2)	2.590	square kilometers (km^2)
	Volume	
gallons (gal)	3.785	liters (L)
	3.785	cubic decimeters (dm^3)
	3.785×10^{-3}	cubic meters (m^3)
million gallons (10^6gal)	3785	cubic meters (m^3)
	3.785×10^{-3}	cubic hectometers (hm^3)
cubic feet (ft^3)	28.32	cubic decimeters (dm^3)
	.02832	cubic meters (m^3)
	Flow	
cubic feet per second (ft^3/s)	28.32	**liters per second (L/s)
	28.32	cubic decimeters per second (dm^3/s)
	.02832	cubic meters per second (m^3/s)
gallons per minute (gal/min)	.06309	liters per second (L/s)
	.06309	cubic decimeters per second (dm^3/s)
	6.309×10^{-5}	cubic meters per second (m^3/s)
million gallons per day (Mgal/d)	43.81	cubic decimeters per second (dm^3/s)
	.04381	cubic meters per second (m^3/s)

**The unit liter is accepted for use with the International System (SI). See NBS Special Bulletin 330, p. 13, 1972 edition.