COMPILATION OF GROUND-WATER-QUALITY DATA IN PENNSYLVANIA

By James L. Barker

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FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply inch-pound units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	0.3048	meters (m)
gallons per minute (gal/min)	0.06308	liters per second (L/s)
gallons per day (gal/d)	0.003785	cubic meters per day (m^3/d)

COMPILATION OF GROUND-WATER-QUALITY DATA IN PENNSYLVANIA

By James L. Barker

ABSTRACT

The U.S. Geological Survey's water quality file of 4,671 wells and springs in Pennsylvania provided ground-water-quality data for Pennsylvania. The data were assembled into computer-readable format and sorted into 15 major aquifer groups based on principal lithology, physiographic province, and age. Nineteen variables in each group were summarized by the Statistical Analysis Systems UNIVARIATE procedure to produce descriptive statictics including extreme values and quartiles.

The bulk of the water-quality data are in the important aquifers in the unconsolidated Coastal Plain sediments, the Triassic sedimentary rocks, the igneous and metamorphic rocks, and the carbonate rocks. On the other hand, water-quality data for aquifer groups in the Appalachian Plateau and Valley and Ridge Province are sparse. Statewide, only six wells provide sufficient long-term data for trend analyses.

Ground-water quality in Pennsylvania is highly diverse. High concentrations of dissolved solids, iron, manganese, sulfate, and nitrate are prevalent forms of natural and manmade contamination. The unconsolidated Coastal Plain aquifers have been most severely degraded. On the other hand, some of the best quality water is found in the quartzite, sandstone, and conglomerate rock units in the Cambrian and Precambrian rocks.

INTRODUCTION

The contamination of ground-water reservoirs has become an issue of major concern to users and water-supply managers at the local and national level. Recent problems such as toxic wastes at Love Canal in upstate New York, have focused attention on the need to develop methods to safely dispose of toxic waste and to educate the public about the vulnerability of ground water to contamination.

This investigation was part of a national assessment to inventory the existing ground-water-quality data on a state by state basis. Pennsylvania, because of its large data base, was one of four states selected.

This study was made possible through funds provided by the U.S. Geological Survey, Office of Hazardous Waste Hydrology. The information should be useful to water managers and the scientific community.

Purpose and Scope

This report presents the results of a study to (1) identify, screen for errors, and enter into the water-quality file all current ground-water-quality data for Pennsylvania; (2) summarize geology and selected important chemical data for the 15 geohydrologic units identified in Pennsylvania; (3) indicate where inadequacies in the data base may exist; and (4) identify areas and aquifer groups with existing or potential ground-water contamination.

The report presents the results of ground-water-quality data collected from 1925 to 1982. The data used represents the most recent listing of predominant constituents stored in the water-quality file (WATSTORE) for 4,671 wells and springs in Pennsylvania.

Acknowledgments

The ground-water data included in this report are a compilation of both U.S. Geological Survey and Pennsylvania Department of Environmental Resources files. The author is grateful to Mr. Larry Taylor of the Pennsylvania Geological Survey for his cooperation. A special thanks is also extended to Bernice Malione and Paula Kirsch, of the Susquehanna River Basin Commission, who did much of the coding of well data while working on assignment at the U.S. Geological Survey.

GROUND-WATER QUALITY IN PENNSYLVANIA

Natural Conditions

Precipitation is the source of nearly all water in Pennsylvania. The average annual precipitation is 41 inches but may range from 30 to 60 inches locally. Water from precipitation that does not run off replenishes the ground-water supply at the rate of 12 to 15 inches per year (fig. 1). Nearly all the water replenishes the ground water during the nongrowing season (October to April) when evapotranspiration is at its lowest.

Because precipitation in Pennsylvania is highly acidic (pH 3.5 to 4.5), it begins to dissolve soil and rock upon contact. As the water percolates through the earth's mantle or regolith, it is changed chemically by gains and losses of gases and ions. The amount and nature of change is proportional to the acidity of precipitation, residence time, and solubility of mineral constituents.

Pennsylvania is fortunate to have an abundant supply of ground water. Unfortunately it is not distributed evenly, nor is it all of the same good quality. The quality of natural water is determined by its suitability for the intended use. In general, total dissolved solids, total hardness, and iron are of most interest.

For domestic purposes, a water supply with a total dissolved solids content of less than 500 mg/L, a total hardness of less than 150 mg/L, and a dissolved iron content of less than 0.3 mg/L is generally satisfactory. For industrial purposes, acceptable concentrations depend upon the use.

Excessive dissolved iron, for example, causes staining problems for the paper products industry, while excessive hardness causes steam boiler scale.

Selected major constituents in drinking water, and the 1976 water-quality criteria published by the U.S. Environmental Protection Agency (EPA), are listed in table 1.

Natural ground-water quality in Pennsylvania is very diverse. Water flowing through limestone or dolomite will be high in pH, hardness, calcium, magnesium, and bicarbonate. Some of the shales and sandstones adjacent to limestone terranes yield small amounts of calcium and magnesium bicarbonate water that is not as high in pH or dissolved ions. Ground water in the sandstones and shales in southeastern, central, and northern Pennsylvania is composed predominately of the ions of calcium and bicarbonate where the dissolved solids are less than 300 mg/L and of calcium and sulfate where the concentration of dissolved solids is greater than 300 mg/L. The sandstones and quartzites in south-central and southwestern parts of the State are hydrologically similar to the Precambrian crystalline rocks in the southeastern part of the State. Water flowing from these rocks is low in dissolved solids and hardness (Dufor and Anderson, 1963).

Many wells, particularly those in the High Plateaus Section (fig. 2) intersect more than one water-bearing zone. If the lithology and, therefore, mineralogy differ between zones, the chemical character of the ground water in these zones also may differ, and the water from a well open to these zones may be a mixture of several hydrogeologic units.

Water of good quality in the Appalachian Plateau generally is a dilute calcium, magnesium, bicarbonate solution in the upper 300 feet of rock. Below the zone of fresh water is a zone of salty water, or connate water, that was trapped in the pore spaces when sediments that form the consolidated rocks settled to the ocean floor. Dissolved solids concentration in this connate water may exceed 200,000 mg/L.

Man's Influence on Water Quality

Pennsylvania's position as the fourth most populated State and as the second-ranking industrial State has placed considerable stress upon the natural resources, including ground-water supplies. Although only 11 percent of the 6.6 billion gallons that Pennsylvanians use daily comes from ground-water sources, 25 to 35 percent of the population depend on ground water for their personal needs.

Ground water is particularly susceptible to contamination by effluent from strip mines, underground mines, and land fills. Sewage-treatment facilities that apply sludge directly to the land surface can overload the soil and contaminate the ground water with nitrates. Waste disposal and liquid storage lagoons that use natural or artificial depressions over highly permeable formations are also high risks. Some aquifers have also been adversely affected by excessive applications of fertilizers and pesticides, the improper disposal of manure, and storage of silage.

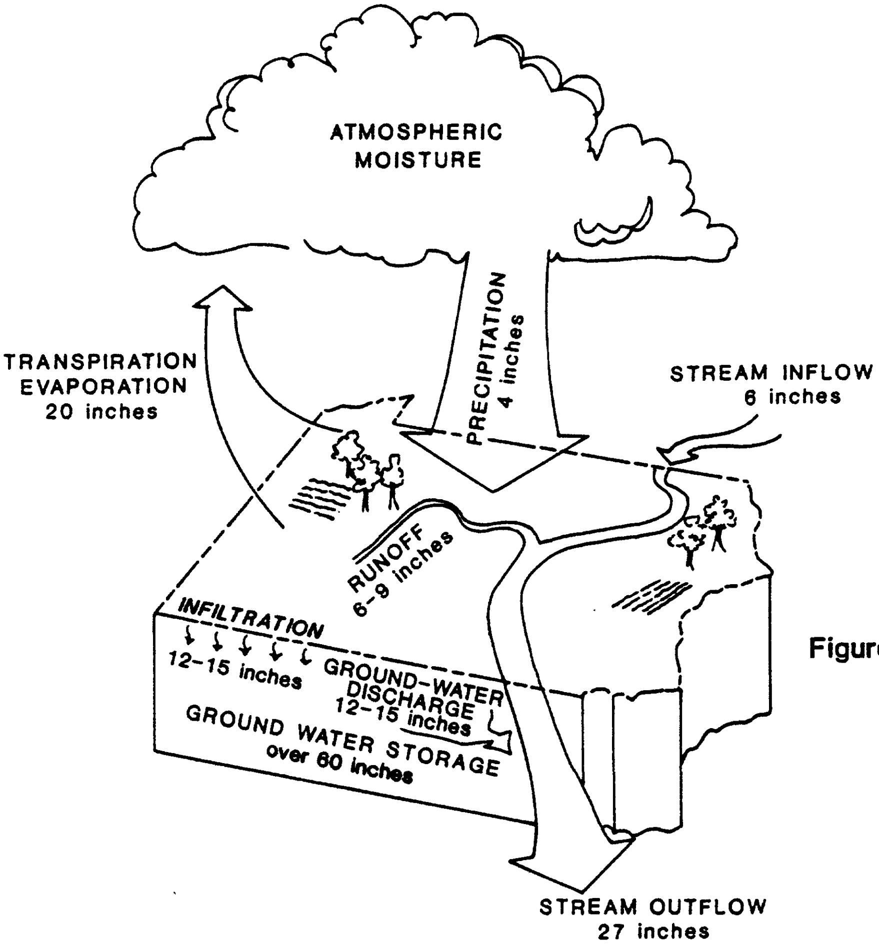

Figure 1.--The annual water cycle in Pennsylvania. (From Becher, 1970.)

Table 1.--Quality criteria for drinking water (U.S. EPA, 1976)

Constituent	Maximum concentration (milligrams per liter)
Lead (PB)	0.05
Nitrogen (N)	10 1/
Iron (FE)	.3
Manganese (MN)	.05
Chlorides (CL)	250
Sulfates (SO_4)	250
Dissolved Solids (D.S)	500

1/ Primary standard applies to both community and non-community water system.

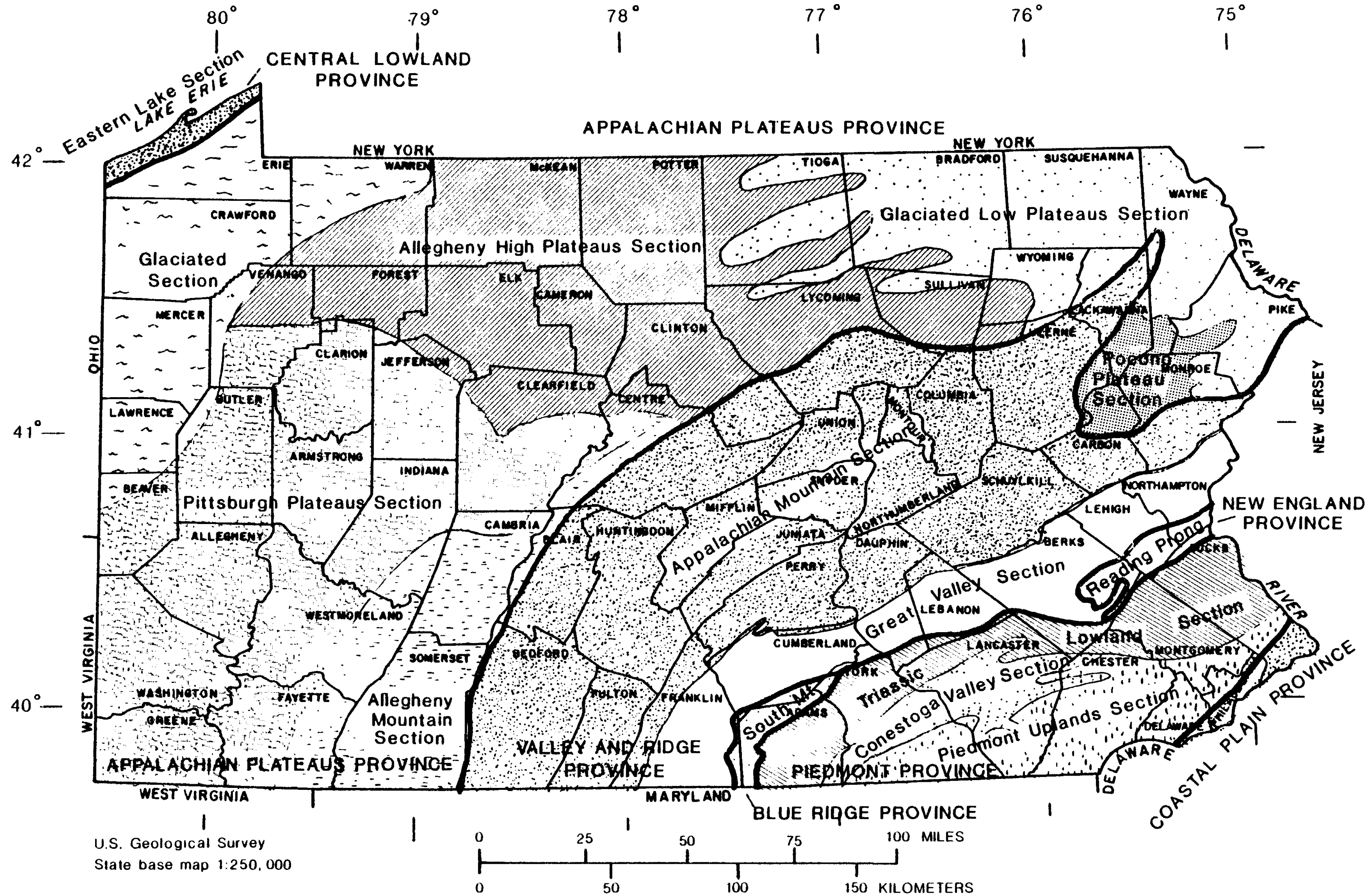

Figure 2.--Physiographic provinces of Pennsylvavania. (From Pennsylvania Department of Environmental Resources, 1979.)

One of the more serious problems of ground-water contamination is associated with the infiltration of synthetic organic compounds. The infiltration of organics generally can be traced to pesticides and herbicides, to industrial waste, or disposal sites, such as landfills. This problem has not been adequately documented to date but is known to be serious in some areas.

Acid-mine drainage from the coal fields of northeastern and western Pennsylvania may elevate acidity, sulfate, hardness, and total dissolved solids in ground water; some aquifers in the anthracite region are unfit as potable water supplies.

AVAILABLE GROUND-WATER-QUALITY DATA

The ground-water resources of Pennsylvania have been studied cooperatively by the U.S. Geological Survey and the Pennsylvania Department of Environmental Resources (PaDER) since 1925. Over the years there have been numerous investigations including landmark regional studies during the 1930's by Piper, Hall, Leggette, and Lohman. Continuing investigations through the U.S. Geological Survey's Federal-State Cooperative program have added water-quality analyses to the data base until there are presently 4,671 analyses stored in the National Computer System for Water Storage and Retrieval (WATSTORE). The locations of these wells and springs for which there are water-quality data are shown in figure 3.

As illustrated in figure 3, the areal distribution of chemical analyses is nonrandom. The data tend to be clustered in the populated valleys of southeastern Pennsylvania and in counties that have been studied geohydrologically.

Physical and chemical data for 3,850 wells and springs for 1925 through 1979 were published in three volumes by Koester and Miller (1980-82).

All analyses and well information from both U.S. Geological Survey and PaDER files have been entered into WATSTORE. Prior to entry into WATSTORE, the data from 885 wells sampled from 1979 through 1982 were scrutinized to remove discrepancies in the data. Data for wells were rejected if they did not have a chemical cationic/anionic balance within 20 percent or had other obvious errors, such as a misplaced decimal.

A potential source of error, particularly in the older data, is in the fact that the samples were analyzed by various agencies and laboratories, including several private laboratories, over a period of 58 years. Sampling and analytical methodologies have changed, and so has the quality control of the analytical work. Instrumentation is more sophisticated, and, in general, more accurate than in the past. Another potential source of error is in the coding and entering of data. No attempt was made to screen potential errors from the 3,850 analyses in WATSTORE prior to this study.

Because nearly all wells have been sampled only once, it is impossible to determine whether the older water-quality data are still valid, or whether they have changed because of manmade contamination.

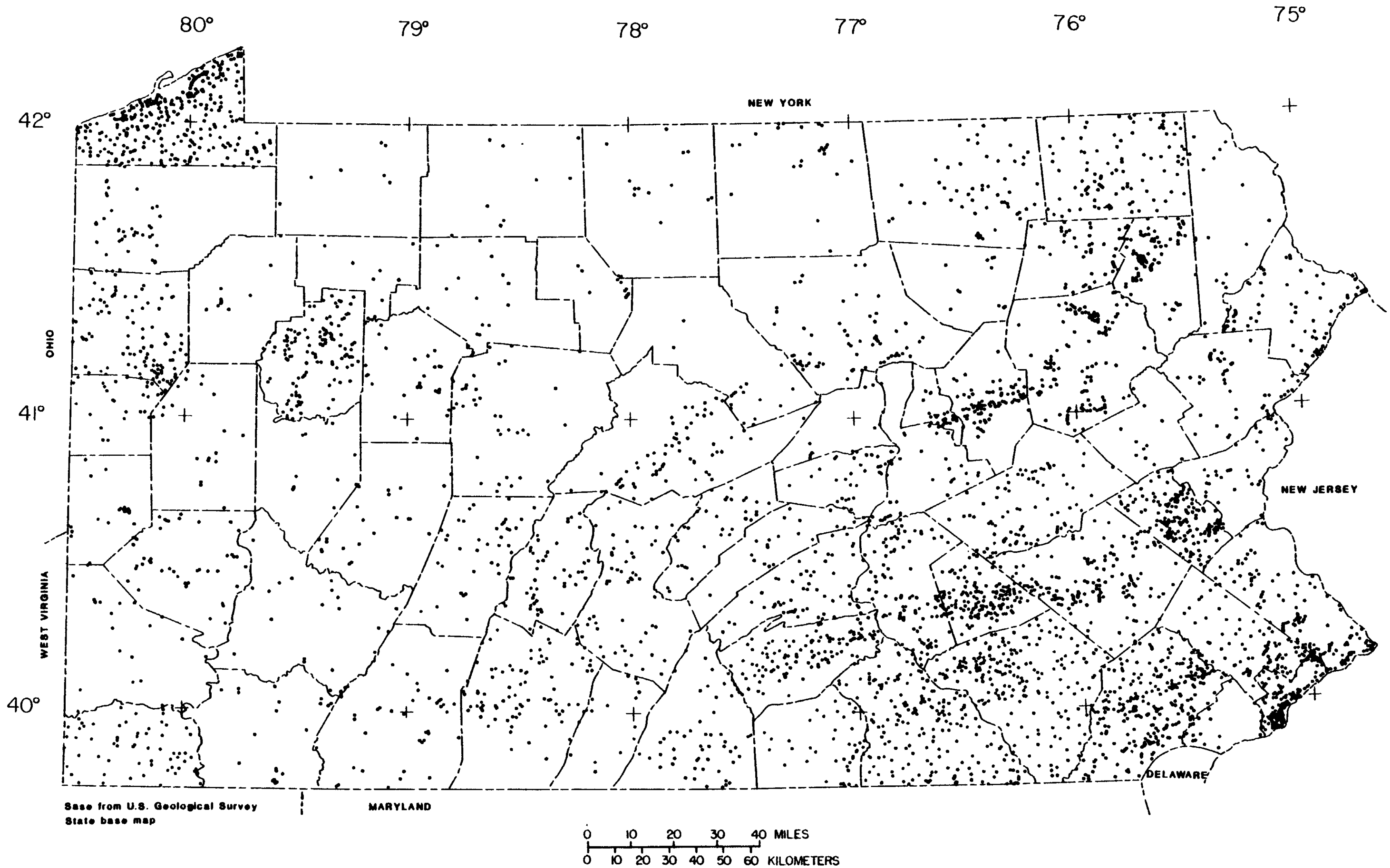

Figure 3.--Location of ground-water-quality sites in Pennsylvania.

The available data are almost exclusively restricted to inorganic analyses. Most microbiological and organic analyses are recent; therefore the data base for microbiological and organic analyses is insufficient for any kind of meaningful evaluation. Current studies are addressing these deficiencies on a limited scale.

METHODS OF STUDY

Grouping of Aquifers

Ground water in Pennsylvania is present in numerous rock formations. The formations, in general, rest upon one another from the most ancient (Precambrian) to the most recent (Pleistocene). The formations are extremely diverse in their origin, composition, texture, and in the quantity and quality of water they yield to wells and springs.

The geology of Pennsylvania is extremely complicated due to intense folding, uplifting, erosion, and the deposition associated with the advance of three great ice sheets from the north. As illustrated by the generalized geologic map (fig. 4), there are large deposits of the principal consolidated rock types--igneous, sedimentary, and metamorphic. Unconsolidated deposits, up to several hundred feet in thickness, cover large parts of the northern tier of counties and bottoms of the river valleys north and south of the southern extent of the ice.

The rock outcrops, which represent all geologic periods exept Jurassic, are mapped in more than 600 geologic units that have been coded, as proposed by the American Association of Petroleum Geologists (AAPG), for computer manipulation.

Because Pennsylvania's geologic history and structural evolution is complex, there are no major ground-water basins nor are there any major aquifers that cover large areas or have regional significance. For the purposes of this report, the chemical quality of Pennsylvania's ground-water supplies are defined in terms of groups of aquifers. In order to simplify the analyses and presentation of data, the more than 600 geologic units have been sorted by physiographic province, age, and principal lithology into 15 aquifer groups and named for the principal rock type(s). These groups, from oldest to most recent, are as follows:

1. Quartzite, sandstone, and conglomerate rocks
2. Igneous and metamorphic rocks
3. Carbonate rocks
4. Carbonate rocks interbedded with sandstone and shale rocks
5. Carbonate rocks and calcareous shale units containing evaporite minerals
6. Light gray and olive shale and siltstone rocks
7. Dark gray and black shale rocks
8. Devonian and Mississippian red shale and siltstone rocks
9. Bituminous coal-bearing Pottsville Group rocks
10. Anthracite-bearing rocks
11. Bituminous coal-bearing Conemaugh and Allegheny Group rocks
12. Bituminous coal-bearing Dunkard and Monongahela Group rocks

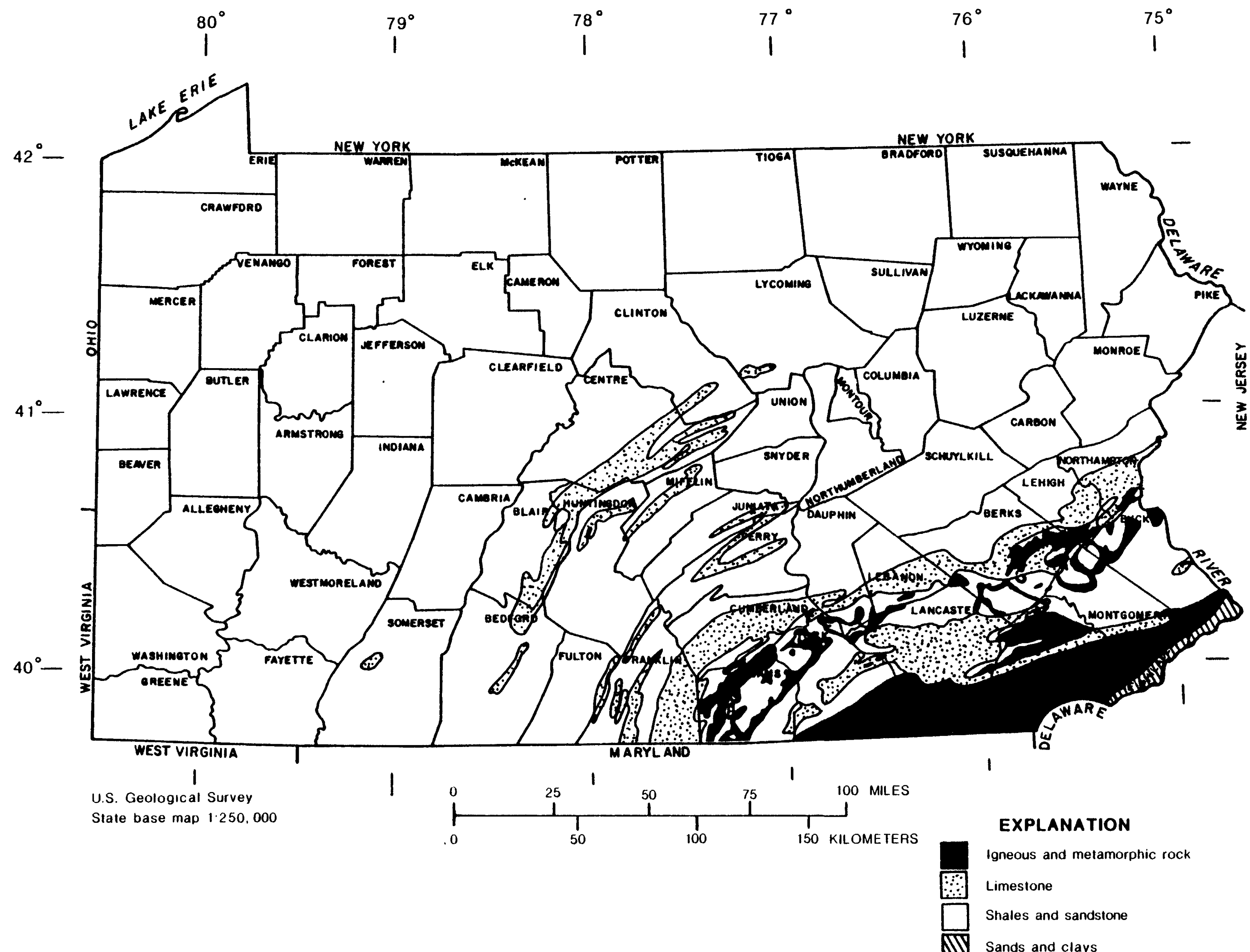

Figure 4.--Geology of Pennsylvania. (From Gray and others, 1979.)

13. Triassic sedimentary rocks
14. Unconsolidated Coastal Plain sediments
15. Unconsolidated glacial and alluvial deposits

Data Analysis Techniques

A brief description of each aquifer group is presented that includes information on the origin, age, physiographic province, location, composition, and texture of the principal rock material. Additional information may include notes on the terrane, water supply potential, and thickness of aquifers.

Following the retrieval and sorting of the most recent chemical data for each well and spring by geologic unit code and aquifer group, the data were analyzed using the Statistical Analyses System (SAS) UNIVARIATE program described in SAS Users Guide (SAS, 1979).

The UNIVARIATE program produces a host of simple descriptive statistics for each variable including detail on the extreme values, the median, 25th percentile, 75th percentile, and three plots to depict the frequency and probability distributions. The plots were not reproduced for the report.

The descriptive statistics were used to describe the chemical characteristics of the aquifer group. Anomalies within a geologic unit are considered to be the result of contaminants. Constituents and properties selected for statistical analyses are:

Depth of well, in feet
Calcium, dissolved
Sodium, dissolved
Magnesium, dissolved
Potassium, dissolved
Sodium plus potassium, dissolved, (as Na)
Chloride, dissolved
Sulfate, dissolved
Bicarbonate (as HCO_3)
Nitrate, dissolved (as NO_3)
Phosphate, ortho, dissolved (as PO_4)
pH (units)
Alkalinity (as $CaCO_3$)
Solids, dissolved @ 180°C
Specific Conductance (micromhos)
Iron, dissolved (μg/L)
Manganese, dissolved (μg/L)
Copper, dissolved (μg/L)
Lead, dissolved (μg/L)
Zinc, dissolved (μg/L)

In addition to the descriptive statistics, the springs and wells in each group were plotted on a county map to show their areal distribution. The areal extent of the various rock units could not be plotted accurately on the maps. Although some groups such as the igneous and metamorphic rock units and the Coastal Plain deposits are well defined, the rocks in the Valley and Ridge and the Plateau are discontinuous.

GEOLOGY AND WATER QUALITY OF AQUIFER GROUPS

Quartzite, Sandstone, and Conglomerate Rock Units

General Features

Quartzite rocks of unknown, Cambrian, and Silurian age crop out in the Piedmont, Blue Ridge, New England, and Valley and Ridge physiographic provinces in south-central and southeastern Pennsylvania (fig. 2). The chemically similar silica-rich sandstone and conglomerate rocks of Devonian and Mississippian age are scattered throughout the Valley and Ridge province and Appalachian Plateaus.

Yields from wells are generally small (5 to 20 gal/min) but are dependable and adequate for household or stock use. About 75 percent of the wells are less than 300 feet deep and the water is obtained from fractures.

Water Quality

Thirty two geologic units are included in this group. As indicated in table 2, only 14 units have wells with water-quality data. Most of the water-quality data are from wells in the Chickies and Pocono Formations. A total of 146 wells in the group have analyses. The location of these wells is shown in figure 5.

The water from wells in the quartzites, sandstones, and conglomerates generally does not contain large amounts of dissolved mineral matter. As indicated in table 3, of the 100 well samples analyzed for dissolved solids, only 25 contain more than 136 mg/L. These waters are the softest of any in the State. The minerals in this group, as illustrated in figure 6, consist mainly of calcium and bicarbonate. Other ions such as chloride, sulfate, or nitrate are only locally dominant.

Even comparatively small quantities of dissolved iron may be objectionable because iron is readily precipitated and may stain clothing washed in the water. The 1976 EPA criterion for domestic water supplies is 300 µg/L. Of the 144 water samples analyzed, 32 percent exceed the suggested criterion. The iron is from natural sources.

The waters in this group contain a wide range in nitrate concentrations; the range is from undetectable to 75 mg/L. Water from only one well exceeded 10 mg/L nitrate-nitrogen EPA drinking-water criterion.

Due to the mountainous terrane this group of aquifers is probably inadequately sampled. The wells in this group are scattered over a large area of the state; the small clusters of data in York and Chester Counties represent the Chickies Formation.

Table 2.--Gèologic names, codes and number of water-quality sites in quartzite, sandstone, and conglomerate rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Antietam Formation	377ANTM	17
Bald Eagle Formation	361BDEG	18
Bald Eagle Formation, Lost Run Member	361LSRN	0
Berry Run Member of Catskill Formation	341BRRN	0
Big Injun sand	337BGIJ	0
Chickies Formation	377CCKS	37
Chickies Formation, Hellam Member	377HLLM	2
Chilhowee Group	377CHLH	0
Clark Ferry Member of Catskill Formation	341CLKF	1
Fischer Ridge Member, Mahantango Formation	344FCRG	0
Hardyston Quartzite	377HRDS	14
Huntley Mountain Formation	337HNLM	0
Juniata Formation	361JUNT	10
Juniata and Bald Eagle Formation	361JBEG	0
Lackawanna Formation	341LCKX	0
Loudon Formation	377LUDN	0
Montalto Member, Harpers Formation	377MNTL	0
Montebello Sandstone Member, Mahatango Formation	344MNBL	2
Packerton Member of Catskill Formation	341PCKR	0
Pocono Formation	337POCN	46
Pocono Formation, Beckville Member	337BCKV	0
Pocono Formation, Burgoon Member	337BRGN	11
Pocono Formation, Mount Carbon Member	337MCRB	0
Potsdam Sandstone	371PSDM	0
Rockwell Formation	337RCKL	0
Shawangunk Formation	354SNGK	2
Shawangunk Formation, Middle Member	354SNGKM	0
Shawangunk Formation, Upper Member	354SNGKU	0
Spechty Kopf Member of Catskill Formation	337SPKP	0
Towamensing Member of Catskill Formation	341TMSG	3
Turkey Ridge Member of Marcellus Shale	344TKRG	0
Weverton Formation	377WVRN	1

1/ American Association of Petroleum Geologists

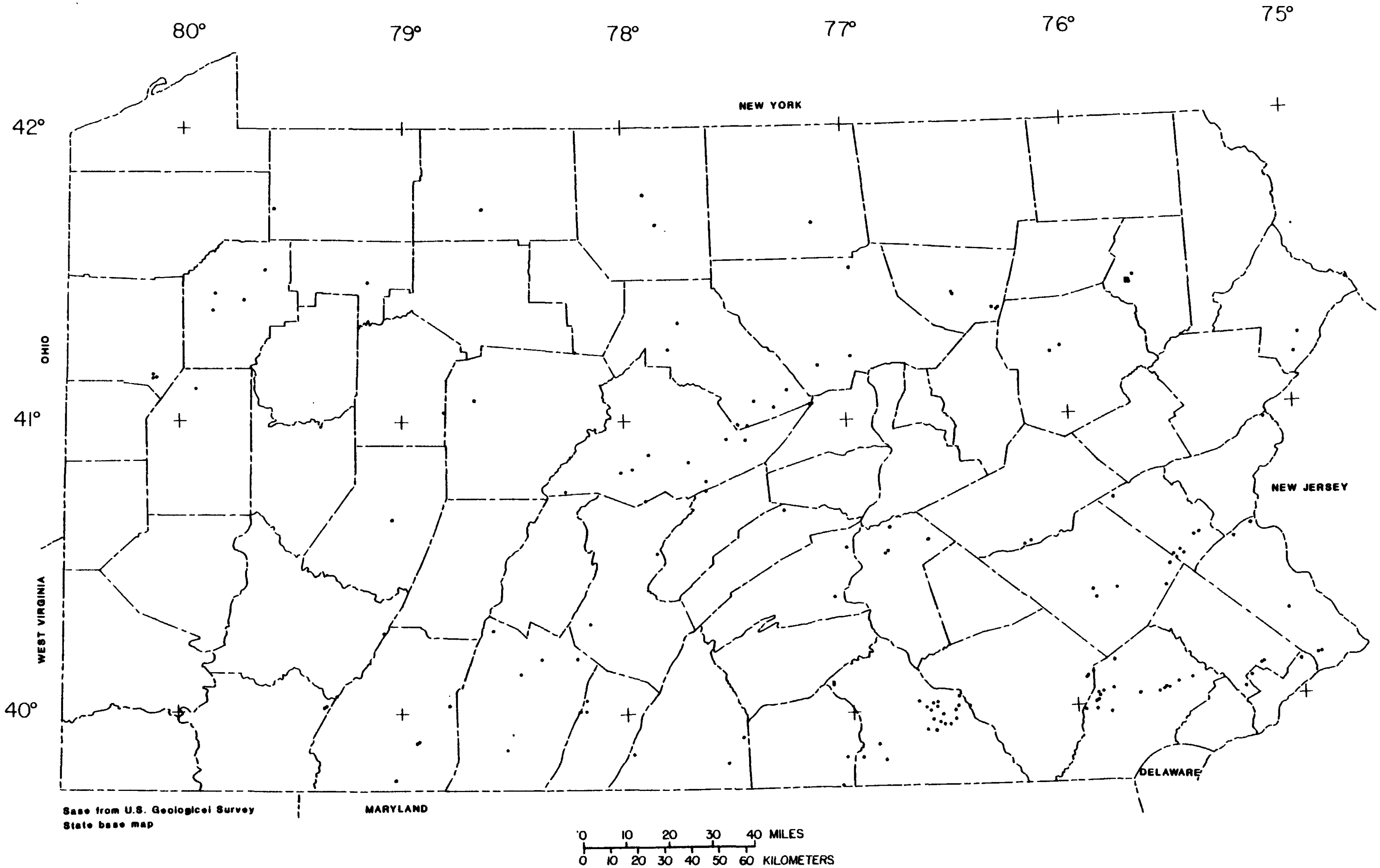

Figure 5.--Location of wells and springs in quartzite, sandstone, and conglomerate rock units.

Table 3.--Summary of chemical quality of ground water in quartzite, sandstone, and conglomerate rock units (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	104	190	750	310	120	52
Calcium	115	9.8	76.0	22.0	3.0	.5
Sodium	99	3.4	230.	6.2	1.4	.1
Magnesium	106	2.9	35.0	6.3	1.7	.4
Potassium	93	1.0	15.0	2.0	.7	.1
Chloride	146	3.0	400	8.0	1.5	0
Sulfate	143	8.0	178	15.0	5.0	.6
Bicarbonate as HCO_3	124	26	246	73	12	0
Nitrate (as NO_3)	142	1.2	75	4.9	.3	0
Phosphate, Ortho (as PO_4)	71	.06	1.20	.18	0	0
pH (units)	134	6.5	8.4	7.4	5.9	3.8
Alkalinity as $CaCO_3$	125	21	202	63	10	0
Solids, @ 180°C	100	63	478	136	34	11
Specific Conductance (micromhos)	113	117	6,000	212	52	17
Iron (µg/L)	144	120	80,000	657	40	0
Manganese (µg/L)	106	30	22,000	105	10	0
Copper (µg/L)	33	20	260	65	10	0
Lead (µg/L)	53	3	50	6	0	0
Zinc (µg/L)	53	40	5,600	105	20	0

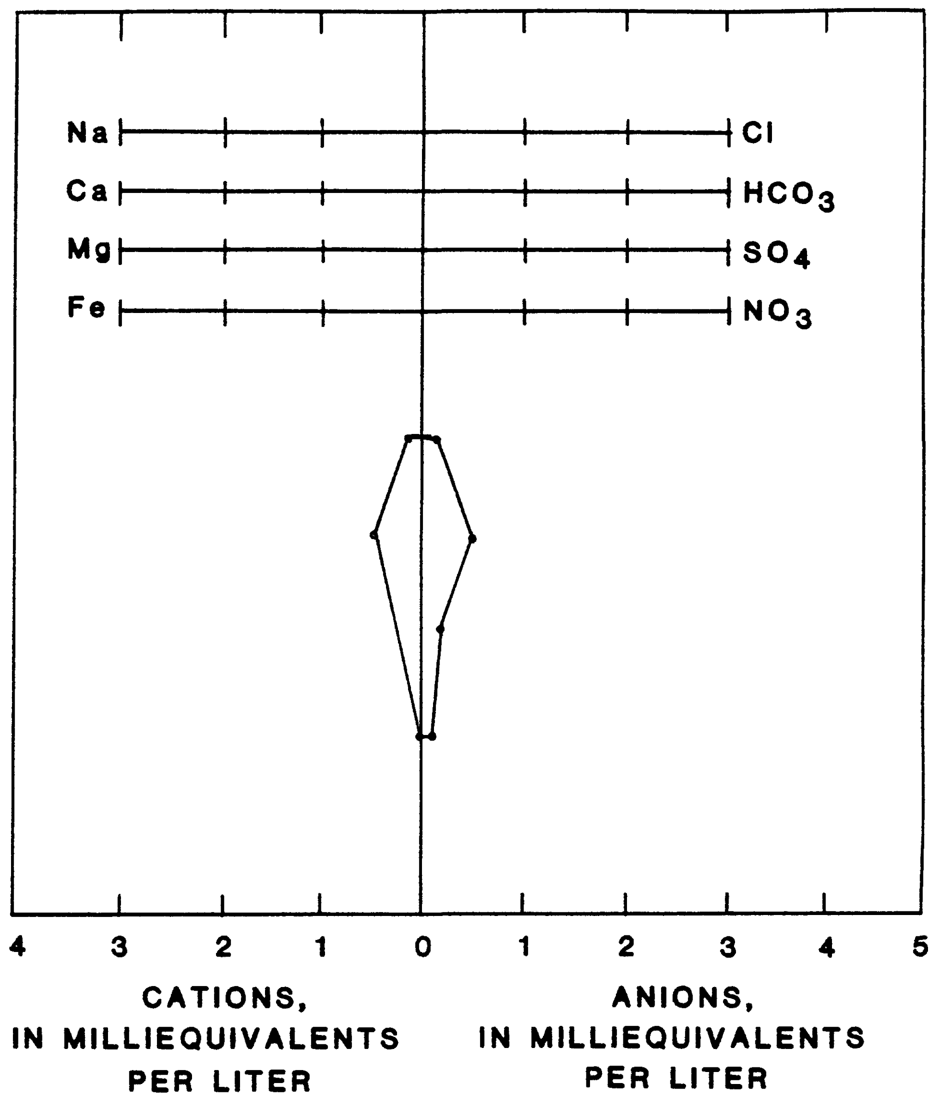

Figure 6.--Median concentrations of selected chemical constituents in quartzite, sandstone, and conglomerate rock units.

Igneous and Metamorphic Rock Units

General Features

The igneous and metamorphic rocks include the Triassic diabase dikes and sills and the Precambrian and lower Paleozoic intrusives, volcanics, and metasediments. These rocks are exposed in southeastern Pennsylvania in the area of the Reading Prong, South Mountain and in the Piedmont Uplands to the south and east. The diabase forms a series of ridges through the Triassic Lowland Section from the Maryland border northeastward to New Jersey (fig. 2). Their interlocking crystalline form and low solubility of their minerals make the igneous and metamorphic rocks resistant to weathering. Zones that yield significant quantities of water to wells are found only near the surface. The median depth of reported water-bearing zones is about 75 feet, and the median well depth is 135 feet.

Water Quality

Of the 49 geologic units included in this group (table 4), analyses are available for only 29 units. Complete or partial chemical analyses are available for 483 wells. Site locations are shown in figure 7.

The quality of water pumped from the igneous and metamorphic rocks is suitable for most uses. Median values for the identified water-quality constituents, listed in table 5, indicate the water of this group is among the best in the State. As illustrated in figure 8, the predominant ions are calcium, sulfate, and bicarbonate, and the water is generally slightly acidic.

Approximately 10 percent of the analyses had nitrate-nitrogen levels that exceeded the 1976 EPA drinking water standards, which state "water containing more than 10 mg/L nitrate-nitrogen is potentially dangerous when used in infant feeding." The health hazard is associated with methemoglobinemia, a reduction of the oxygen carrying capacity of the blood resulting from the bacterial conversion of ingested nitrate to nitrite.

Concentrations of iron and manganese exceed the recommended standards (table 1) in 35 percent of the ground-water samples analyzed. These metals are natural constituents in the parent rock.

Table 4.--Geologic names, codes, and number of water-quality sites in igneous and metamorphic rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Amphibolite	000AMPB	0
Amphibolite	400AMPB	0
Baltimore Gneiss	400BLMR	21
Basalt	231BSLT	0
Byram Gneiss	400BYRM	12
Cardiff Metaconglomerate	360CRDF	0
Diabase dikes and sills	231DIBS	37
Felsic gneiss	400FLGC	0
Gabbro and gabbro gneiss	000GBBR	25
Glenarm Series	300GLRM	0
Granite	000GRNT	0
Granite gneiss	000GRGS	19
Granodiorite	000GRDR	17
Granulite gneiss, felsic	400GRLGF	0
Granulite gneiss, mafic	400GRLGB	0
Graphitic gneiss	000GRPC	13
Harpers Formation	377HRPR	22
Hornblende gneiss	000HBLD	2
Losee diorite gneiss	400LOSE	0
Marburg Schist	300MRGB	15
Metabasalt	000MBSL	2
Metadiabase	000MDBS	0
Metarhyolite	000MTRL	5
Moravian Heights Formation	400MRVN	1
Octoraro phyllite	300OCRR	0
Peach Bottom slate	360PCBM	3
Pegmatite	000PGMT	0
Peters Creek Schist	300PRCK	30
Pickering Gneiss	400PCKG	1
Pochuck Gneiss	400PCCK	10
Setters Formation	300STRS	6
Serpentinite	000SPRN	10
Springfield granodiorite	400SPGF	0
Quartz monzonite	000QZMZ	8
Wissahickon Formation	300WSCK	37
Wissahickon albite chlorite schist	300WSCKA	19
Wissahickon oligoclase mica schist	300WSCKO	132
Wissahickon metavolcanics	300WSCKV	2
Wissahickon boulder gneiss	300BLDR	0
Wissahickon metaconglomerate	300MCGM	0

Table 4.--Geologic names, codes, and number of water-quality sites in igneous and metamorphic rock units--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
Wissahickon metagraywacke	300MGCK	0
Wissahickon pelitic schist	300PLTCL	0
Wissahickon pelitic schist	300PLTCU	0
Wissahickon Formation informal subunit WAS-1	300WSCK1	5
Wissahickon Formation informal subunit WAS-2	300WSCK2	6
Wissahickon Formation informal subunit WAS-3	300WSCK3	20
Wissahickon Formation informal subunit WAS-4	300WSCK4	1
Wissahickon Formation informal subunit WAS-5	300WSCK5	0

1/ American Association of Petroleum Geologists

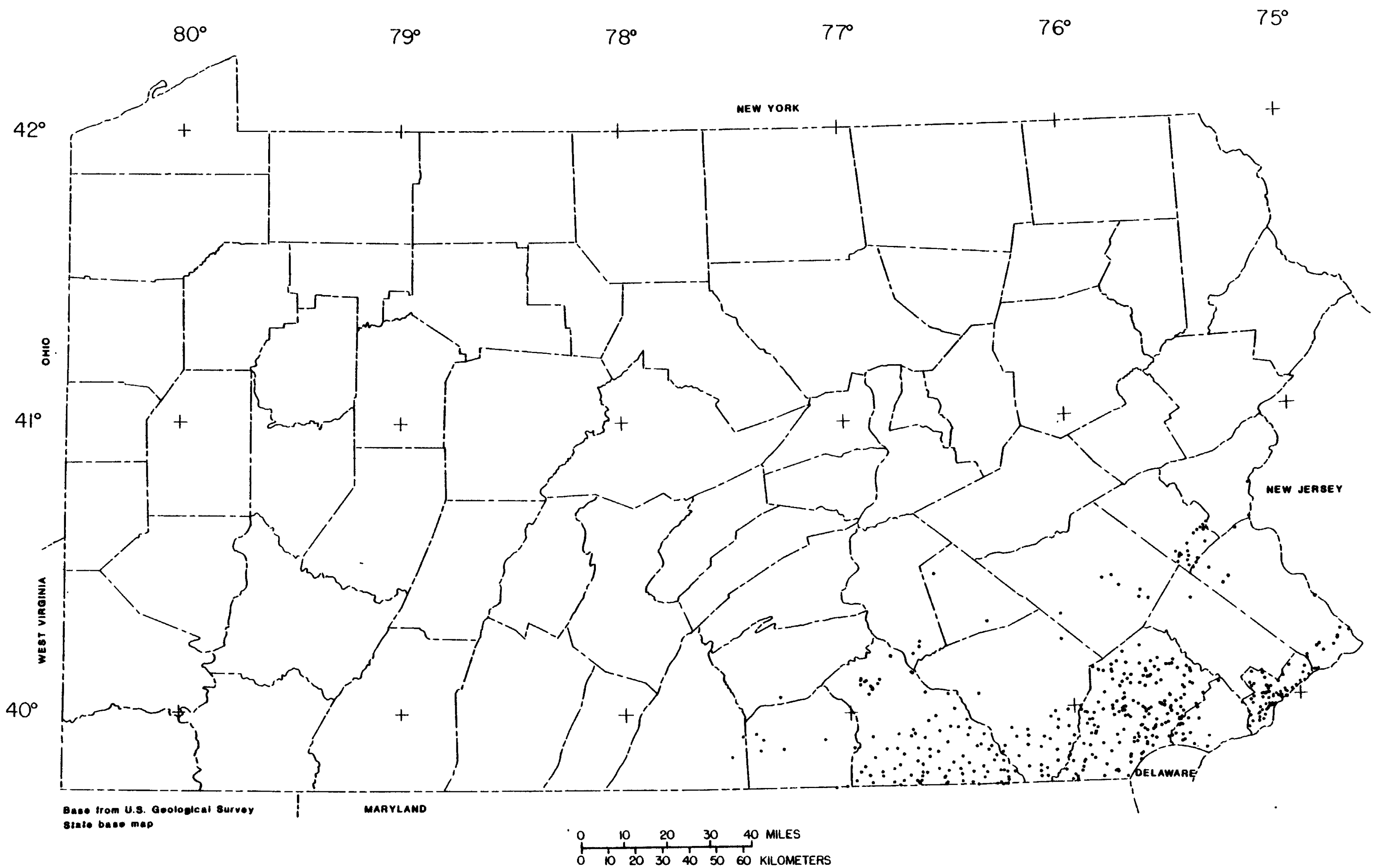

Figure 7.--Location of wells end springs in igneous and metamorphic rock units.

Table 5.--Summary of chemical quality of ground water in igneous and metamorphic rock units
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	372	135	1,040	249	80	6
Calcium	361	15	365	29	6.8	.2
Sodium	328	7	330	12	4	1
Potassium	327	1.3	41	2.9	.8	.1
Magnesium	361	5.8	210	11	3.2	0
Chloride	450	9.0	1,260	25	5.0	.5
Sulfate	446	15	918	37	5.0	0
Bicarbonate (as HCO_3)	396	41	404	80	23	0
Nitrate (as NO_3)	453	11	177	26	2.2	0
Phosphate, Ortho (as PO_4)	206	.06	6.1	.15	.01	0
pH (units)	437	6.4	9.2	7.1	6.0	2.7
Alkalinity (as $CaCO_3$)	397	34	331	66	19	0
Solids, @ 180°C	340	129	3,350	230	85	19
Specific Conductance (micromhos)	39	211	4,080	372	129	13
Iron (µg/L)	453	120	72,000	710	40	0
Manganese (µg/L)	350	20	8,700	70	10	0
Copper (µg/L)	129	20	890	66	10	0
Lead (µg/L)	201	2	6,900	6	0	0
Zinc (µg/L)	198	55	50,000	130	30	0

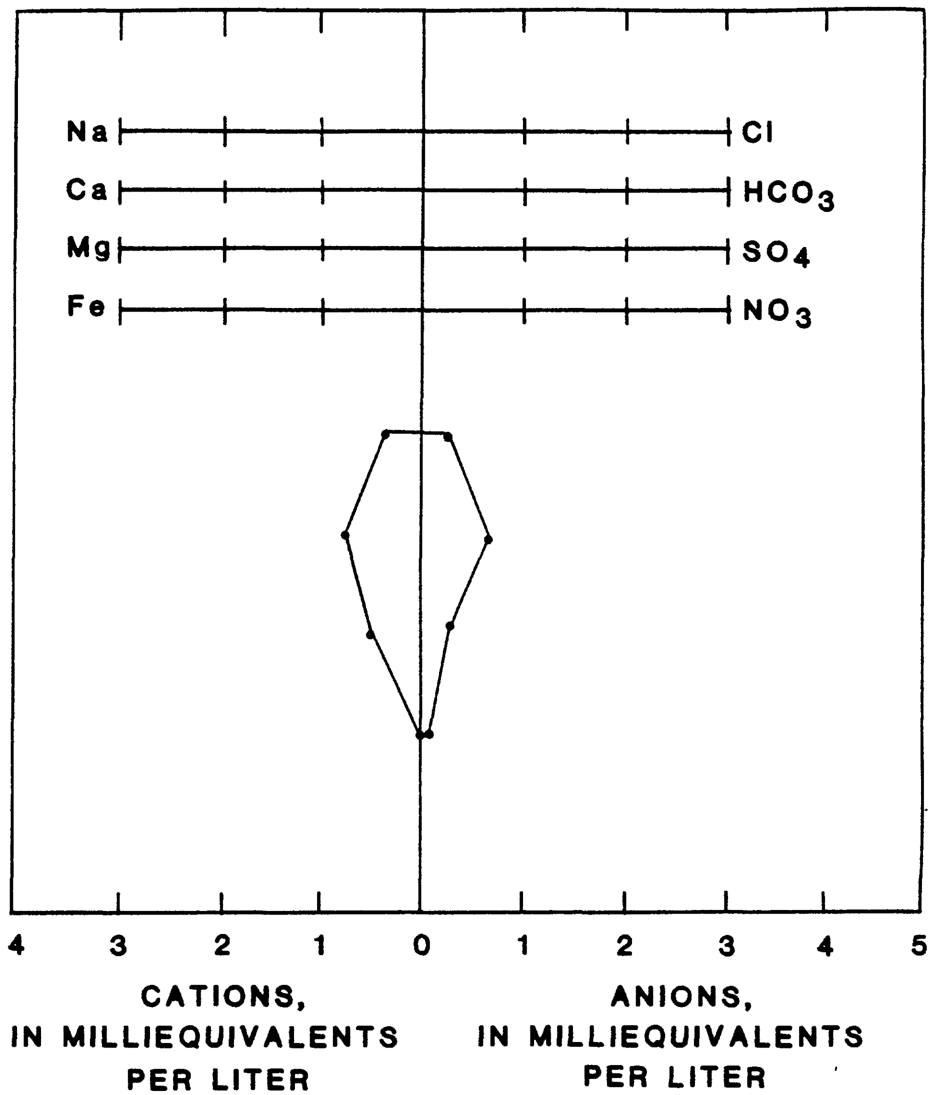

Figure 8.--Median concentrations of selected chemical constituents in igneous and metamorphic rock units.

Carbonate Rock Units

General Features

Limestone and dolomite rocks, collectively referred to as carbonate rocks are chiefly of Cambrian and Ordovician age. The carbonate rocks are present primarily in the Piedmont and Valley and Ridge provinces.

The carbonate aquifers are among the most important water-bearing formations in Pennsylvania. In addition to producing some of the best agricultural soils in the State, the carbonate rocks are the source of water for about one-half of the 196 important springs in Pennsylvania. Discharge and water-quality data for the important springs have been tabulated by Flippo (1974).

Carbonate rocks are unique because of their solubility in the presence of carbon dioxide. With the passing of time, small cracks and fissures may enlarge and eventually store and transmit large quantities of water. This characteristic also makes the carbonate aquifers close to the surface very susceptible to contamination from landfills, mines, quarries, and impoundments. The numerous depressions and sinkholes that characterize carbonate rock terrane, provide easy access for contaminants. Because of these secondary openings, contamination may move rapidly for considerable distances.

Water Quality

Of the 107 geologic units in this group (table 6), chemical analyses are available for just 61 units. The major aquifers have been adequately sampled but many thin units have not been sampled. Chemical analyses are available for 657 wells and springs; the locations of these wells and springs are shown in figure 9.

Ground water in the carbonate rocks is a calcium-bicarbonate type as illustrated in figure 10. The major cations in order of abundance are calcium, magnesium, sodium, and potassium. The major anions in order of abundance are bicarbonate, sulfate, nitrate, and chloride. The median, maximum, minimum, 75th and 25th percentiles of 19 chemical constituents are given in table 7.

Water quality of the carbonate aquifers is highly diverse. Where uncontaminated, the water quality is acceptable for most uses except that it may cause scale buildup in steam boilers and excessive soap use because of high concentrations of calcium and magnesium.

Nitrate is the most widespread contaminant in the carbonate aquifers. Thirteen percent of the 619 wells and springs analyzed had water containing more than 10 mg/L nitrate-nitrogen. The nitrate comes from manure, cesspools, septic drainfields, and barnyards.

Table 6.--Geologic names, codes, and number of water-quality sites in carbonate rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Albright Limestone	321ALBG	0
Allentown Formation	371ALNN	40
Allentown Formation, Maiden Creek Member	371MDCK	7
Allentown Formation, Muhlenberg Member	371MLBG	6
Allentown Formation, Tuckerton Member	371TCKR	3
Ames Limestone	321AMESN	0
Annville Formation	364ANVL	3
Axemann Formation	367AXMN	1
Axemann, Bellefonte Formations, undifferentiated	367BFAX	2
Barton Limestone	321BRTN	0
Beekmantown Group	364BKMN	58
Bellefonte Formation	367BLFN	17
Benner Formation	364BNNR	0
Benner Formation, Snyder Member	364SNDR	0
Benner Formation, Stover Member	364STUR	0
Benner, Hatter, Snyder, Loysburg Formations, undifferentiated	364BSHL	1
Benwood Limestone	321BNWD	0
Black River Formation	365BKRV	0
Brush Creek Limestone	321BRCK	3
Buffalo Springs Formation	374BSPG	12
Cambridge Limestone	321CMBG	1
Carlim Limestone	367CRLM	0
Chambersburg Formation	364CBBG	5
Coburn Formation	364CBRN	2
Coburn, Salona, Nealmont Formations, undifferentiated	364CBSN	3
Clarksburg Limestone	321CKBG	0
Cockeysville Marble	300CCKV	17
Conestoga Limestone	367CNSG	46
Conococheague Group	371CCCG	16
Curtin Limestone	364CRTN	2
Deer Valley Limestone	331DRVL	0
Elbrook Formation	371ELBK	41
Epler Formation	367EPLR	33
Ewing Limestone	321EWNG	0
Fishpot Limestone	321FSPT	0
Franklin Marble	400FRKL	0
Franklindale Limestone	341FKLD	0
Gatesburg Formation	371GBRG	11
Gatesburg Formation, Mines Member	371MINS	2
Gatesburg Formation, lower sandy member	371GBRGL	0
Gatesburg Formation, upper sandy member	371BGRGU	2

Table 6.--Geologic names, codes, and number of water-quality sites in carbonate rock units--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
Gatesburg Formation, Ore Hill Member	371ORHL	0
Gatesburg Formation, Stacy Member	371STCY	0
Greenbrier Limestone	331GRBR	0
Hatter Formation	364HTTR	2
Hatter Formation, Eyer Member	364EYER	0
Hatter Formation, Grazier Member	364GRZR	0
Hatter Formation, Hostler Member	364HSLR	0
Hershey Limestone	364HRSY	9
Hunter Group	364HNTR	0
Irondale Limestone	321IRDL	0
Jacksonburg Limestone	364JKBG	21
Jacksonburg Formation, cement limestone	364JKBGC	3
Jacksonburg Formation, cement rock	364JKBGR	6
Johnstown Limestone	324JNSN	1
Kittanning Limestone	324KNNGN	0
Larke Dolomite	367LRKE	0
Lavansville Limestone	321LVVL	0
Ledger Dolomite	377LDGR	33
Leithsville Formation	374LSVL	20
Linden Hall Formation	364LDHL	5
Lowville Limestone	364LULL	1
Loyalhanna Limestone	337LLNN	1
Loysburg Formation	367LBRG	0
Loysburg Formation, Clover Member	367LLVR	0
Loysburg Formation, Milroy Member	367MLRY	0
Milbach Formation	371MLBC	9
Mines Dolomite	371MINS	2
Myerstown Limestone	364MRSN	4
Nealmont Formation	364NLMN	3
Nealmont Formation, Oak Hill Member	364OKHL	0
Nealmont Formation, Rodman Limestone Member	364RDMN	1
Nealmont Formation, Center Hall Member	369CRHL	0
Nineveh Limestone	317NNVHN	0
Nittany Dolomite	367NTTN	14
Nittany, Larke Dolomites, undifferentiated	367NNLK	2
Ontelaunee Formation	364ONLN	15
Pine Creek Limestone	321PCRK	0
Pinesburg Station Formation	367PBGS	7
Pittsburg Limestone, Lower	321PBRGN	0
Redstone Limestone	321RDSNN	1
Richland Formation	371RCLD	15
Rickenback Formation	367RCKB	4
Rockdale Run Formation	367RKR	29

Table 6.--Geologic names, codes, and number of water-quality sites in carbonate rock units--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
St. Paul Group	364STPL	14
Salona Formation	364SLON	0
Schaefferstown Formation	371SCFR	3
Shadygrove Formation	371SDGV	6
Snitz Creek Formation	371SZCK	10
Stonehenge Formation	367SNNG	27
Stoufferstown Formation	367SFRS	0
Tomstown Formation	377TMSN	14
Trenton Limestone	364TRNN	1
Trough Creek Limestone Member of Mauch Chunk Formation	331TGCK	0
Uniontown Limestone	321UNNNN	0
Curtin Formation, Valentine Member	364VLNN	0
Curtin Formation, Valley View Member	364VLLN	0
Vanport Limestone	324VNPR	4
Vintage Formation	377VNTG	12
Wakefield Marble	300WKFD	1
Warrior Limestone	371WRRR	1
Wellersburg Limestone	321WLBG	0
Whiteport Dolomite Member of Rondout Formation Formation	347WTPR	0
Woods Run Limestone Bed of Glenshaw Formation	321WDST	0
Wymps Gap Limestone Member of Mauch Chunk Formation	331WPGP	0
Zooks Corner Formation	374ZKCR	9
Zullinger Formation	371ZLGR	13

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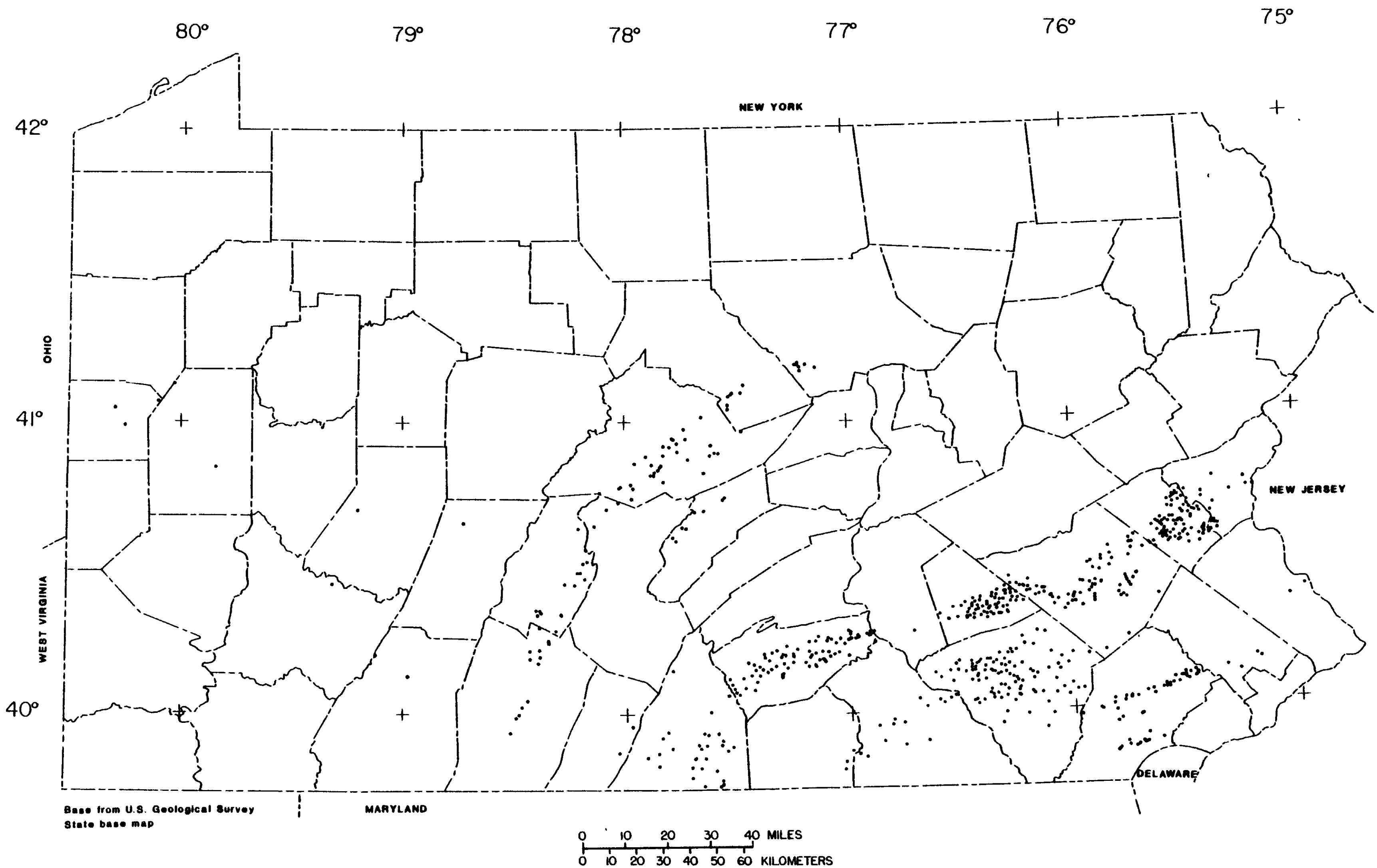

Figure 9.--Location of wells and springs in carbonate rock units.

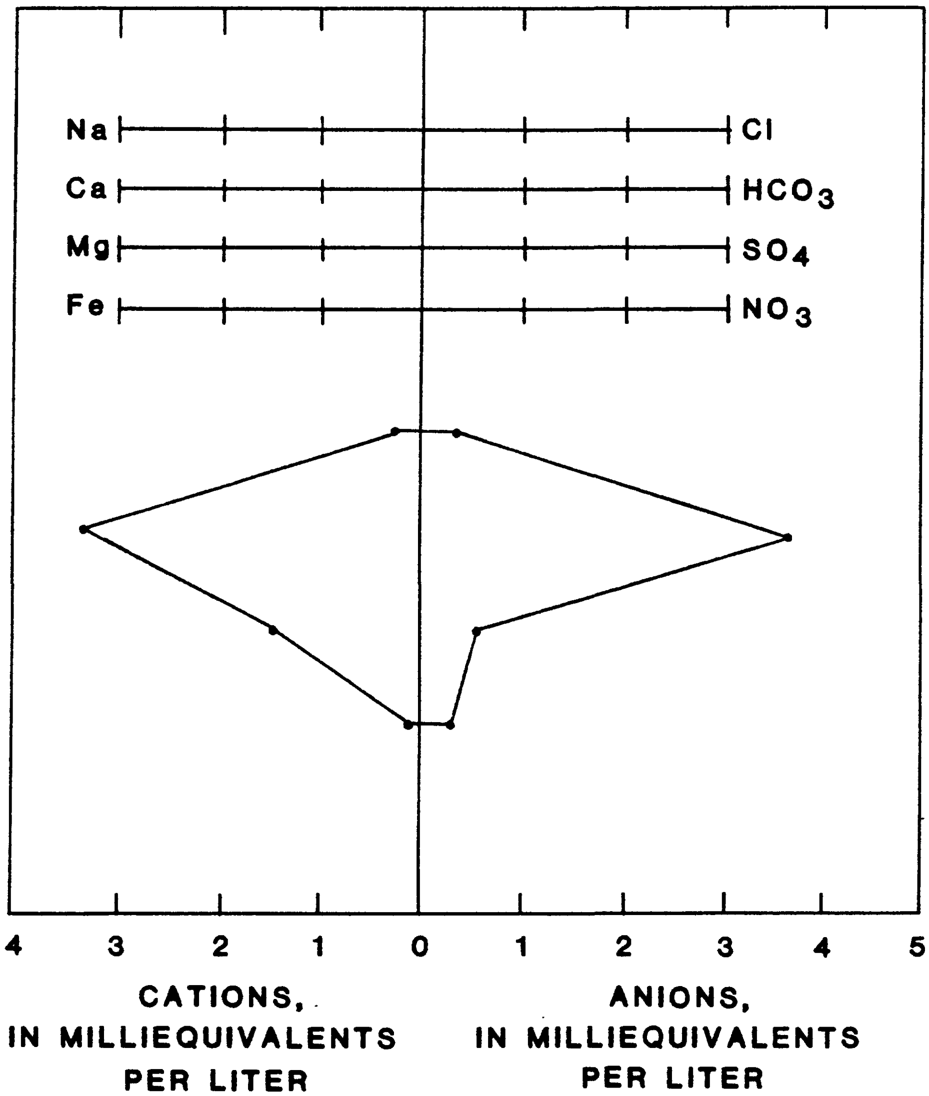

Figure 10.--Median concentrations of selected chemical constituents in carbonate rock units.

Table 7.--Summary of chemical quality of ground water in carbonate rock units
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	476	161	1,013	264	97	13
Calcium	532	70	170	92	48	1.6
Sodium	462	6.0	5,700	11	3.0	0
Magnesium	530	18	110	26	12	.5
Potassium	453	2.0	5,700	3.8	1.2	0
Chloride	626	12	440	21	6.0	.2
Sulfate	596	28	680	50	16	.4
Bicarbonate as HCO_3	512	231	976	280	165	6
Nitrate (as NO_3)	619	18	212	34	7	0
Phosphate, Ortho (as PO_4)	285	.01	12	.6	0	0
pH (units)	587	7.5	8.9	7.8	7.2	5.2
Alkalinity as $CaCO_3$	524	189	801	230	138	5
Solids, @ 180°C	433	325	1,070	400	240	30
Specific Conductance(micromhos)	541	527	2,060	658	393	51
Iron (µg/L)	557	60	38,000	140	20	0
Manganese (µg/L)	463	10	4,700	20	0	0
Copper (µg/L)	50	3.5	170	20	0	0
Lead (µg/L)	130	3	1,200	5	1	0
Zinc (µg/L)	150	40	6,000	120	20	0

Carbonate Rocks Interbedded with Sandstone or Shale Rock Units

General Features

The sedimentary rocks in this group are of Cambrian, Ordovician, Silurian, and Devonian age. The rocks are found throughout the Valley and Ridge province (fig. 2) and are associated with other carbonate rocks.

Two important aquifers dominate this group. The Hamburg sequence is a large shale unit that surfaces along the north side of the Great Valley Section in Cumberland, Dauphin, Lebanon, and Berks Counties. The other large unit in this group in the Mahantango Formation--a marine shale and siltstone exposed along the Delaware River from Matamoras to Stroudsburg and westward.

Water Quality

Of the 70 geologic units included in this group (table 8), water-quality analyses are available for just 31 units. Most of the 384 water samples were collected from the Hamburg sequence and Mahantango Formation. Many of the other rock units are thin layers or are areally insignificant. Location of the wells and springs with chemical analyses are shown in figure 11.

Water from wells and springs in this group is generally very acceptable for most uses. Like the carbonate rocks, the major cations are calcium and magnesium and the major anions are bicarbonate and sulfate. The median concentrations of the major constituents are illustrated in figure 12. The median dissolved solids content is 167 mg/L or about half that of the Carbonate Group.

As indicated in the summary of chemical quality in table 9, a few wells have water containing high concentrations of sulfate, chloride, iron, and nitrate. These ions are largely from natural sources.

Table 8.--Geologic names, codes, and number of water-quality sites in carbonate rocks interbedded with sandstone or shale rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Andreas Red Beds, Keyser Formation	347ADRS	0
Becraft Limestone	347BCRF	0
Bloomsburg, Mifflintown Formations, undifferentiated	351BBGM	4
Bloomsburg Formation	351BMBG	35
Bloomsburg Formation, Bridgeport Member	351BDGP	2
Bossardville Limestone	351BDVL	0
Buttermilk Falls Limestone	344BMKF	3
Cayuga Group	351CYUG	0
Clinton Formation	354CLNN	12
Coeymans Limestone (or Formation)	347CMNS	0
Coeymans Formation, Depue limestone Member	347DEPU	0
Decker Formation	351DCKR	0
Decker Formation, Wallpack Center Member	351WPKC	0
Devonian, Middle	344DVNNM	0
Esopus Formation	344ESPS	1
Hamburg sequence	364HMBG	103
Hamburg sequence, subunit 2A	364HMBGA	1
Hamburg sequence, subunit 2B	364HMBGB	0
Hamburg sequence, subunit 1	364HMBG1	11
Hamburg sequence, subunit 2	364HMBG2	2
Hamburg sequence, subunit 3	364HMBG3	3
Hamburg sequence, subunit 4	364HMBG4	3
Hamburg sequence, subunit 5	364HMBG5	2
Hamburg sequence, subunit 6	364HMBG6	4
Hamburg sequence, subunit 7	364HMBG7	1
Hamburg sequence, subunit 8	364HMBG8	0
Hamburg sequence, subunit 9	364HMBG9	0
Hamilton Group	344HMLN	13
Helderberg Group	347HDBG	11
Kalkberg Limestone	347KKBG	0
Kinzers Formation	377KZRS	12
Little Gap zone	344LLGP	0
Mahantango Formation	344MNNG	90
Mahantango Formation, Centerfield Zone	344CFLD	0
Mahantango Formation, Dalmatie Member	334DLMT	0
Mahantango Formation, Kinkletown Zone	344KNKL	0
Mandata Member of Heldeberg Formation	347MNDT	0
Martinsburg Formation, basal limestone	361MRBGN	0
McKenzie Formation	354MCKZ	6
Mifflintown Formation	354MFLN	8
Mifflintown Formation, Rochester Member	354RCSR	0

Table 8.--Geologic names, codes, and number of water-quality sites in carbonate rocks interbedded with sandstone or shale rock units--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
Minisink Limestone	347MNSK	0
New Scotland Limestone (or Formation)	347NSCD	0
New Scotland Formation, Flatbrookville Member	347FBKV	0
New Scotland Formation, Maskenozha Member	347MSKZ	0
Nis Hollow Streets Member of Mahantango Formation	344NSHL	0
Old Port Formation	347OLDP	14
Onondago, Old Port Formations	344ODOP	2
Onondago Limestone	344ONDG	18
Oriskany Group	347ORSK	6
Palmerton Sandstone	347PLMR	0
Peters Valley Member of Coeymans Formation	347PRVL	0
Pleasant Hill Limestone	374PLHL	0
Port Ewen Shale	347PREN	0
Poxono Island Formation	351PXID	2
Rondout Formation	347RNDT	0
Rondout Formation, Mashipacong Member	347MPCG	0
Rondout Formation, Puttonville Member	347DNVL	0
Ridgeley Sandstone	347RDGL	7
Schoharie Formation	347SCHR	0
Schoharie, Esopus Formations	344SCEP	0
Selinsgrove Member of Onondago Limestone	344SLGY	0
Shawee Island Member of Coeymans Formation	347SILD	0
Sherman Ridge Formation	344SMRG	1
Shriver Chert	347SRUR	2
Schochary Sandstone	361SCRY	1
Sparrow Bush Formation	344SPRB	0
Coeymans Formation, Stormville Member	347SMVL	0
Tully Limestone	344TLLY	1
Waynesboro Formation	377WSBR	3

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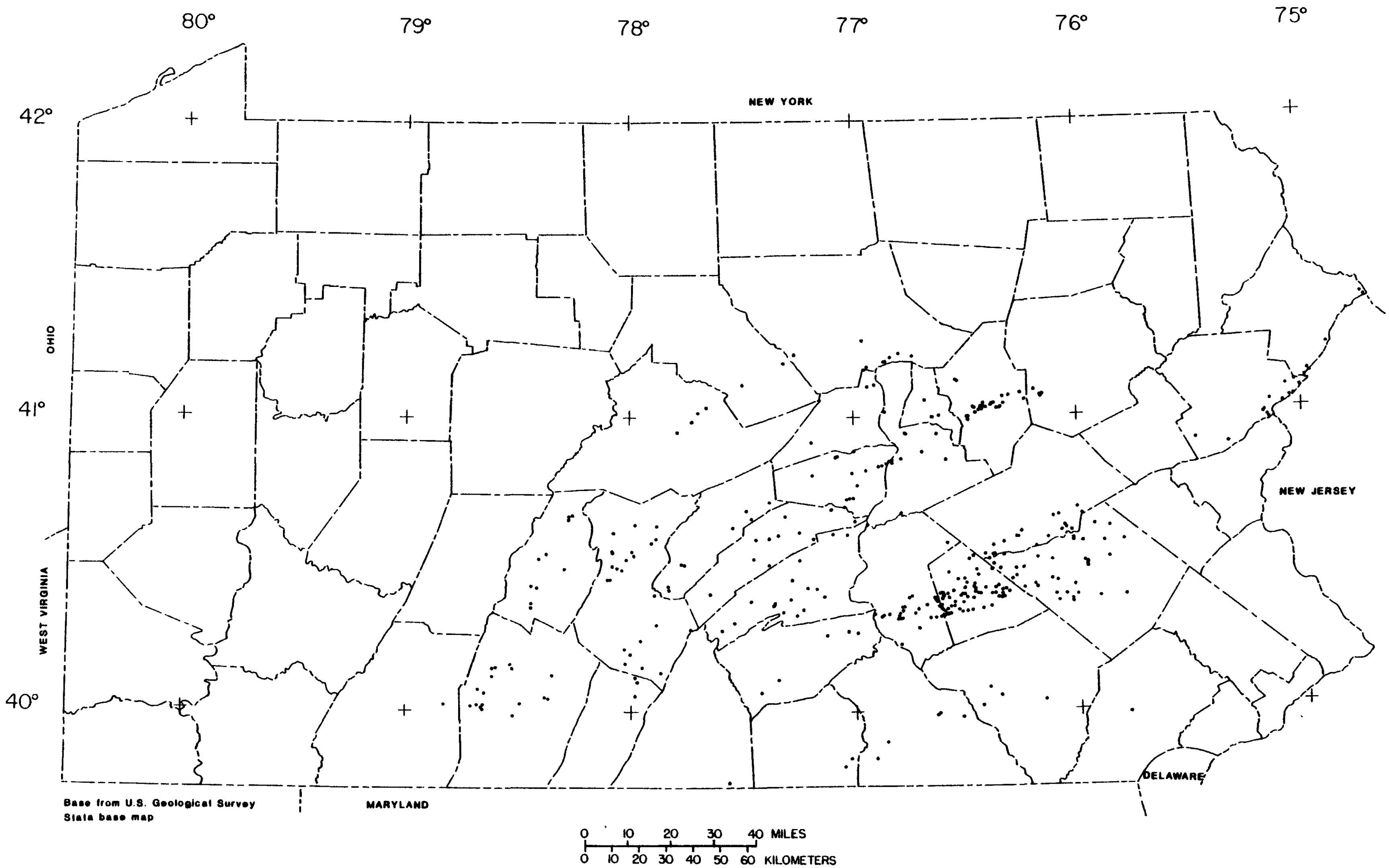

Figure 11.--Location of wells and springs in carbonate rocks, interbedded with sandstone or shale rock units

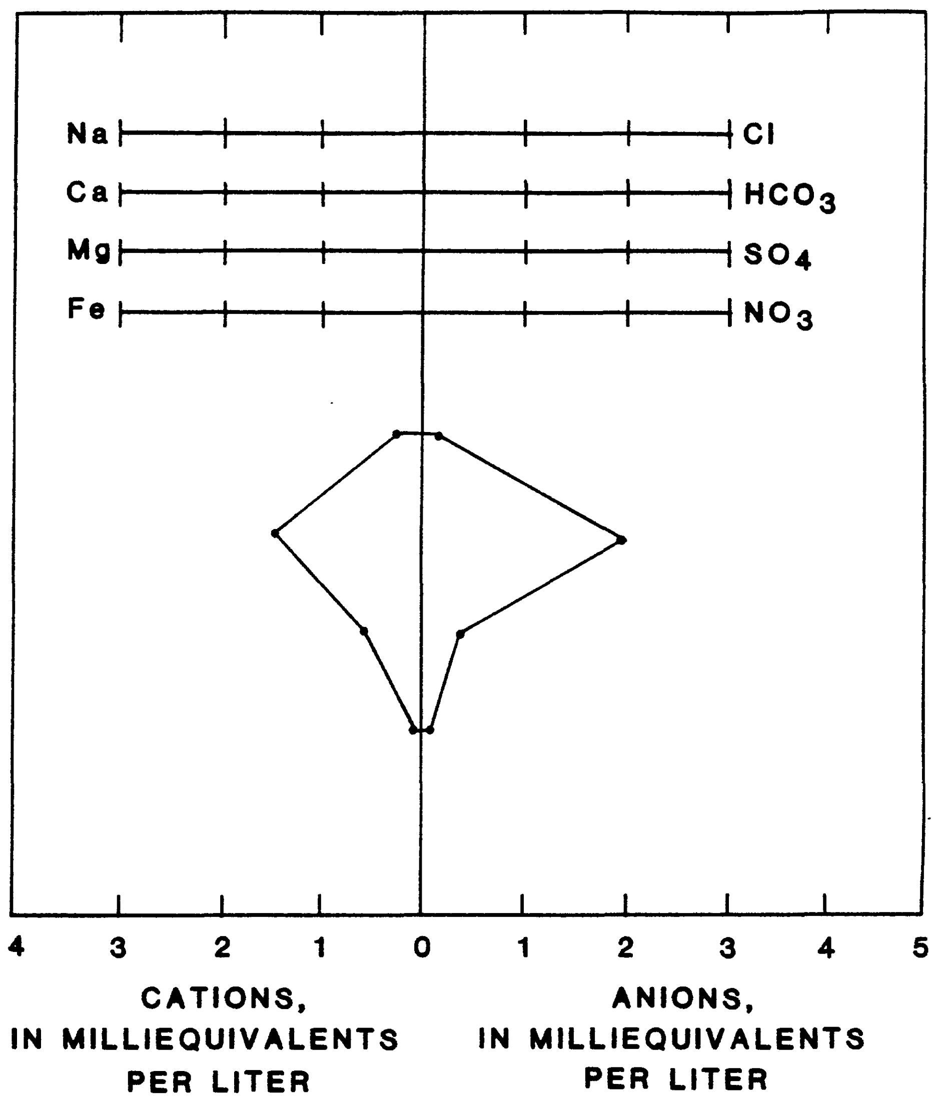

Figure 12.--Median concentrations of selected chemical constituents in carbonate rocks interbedded with sandstone or shale rock units.

Table 9.--Summary of chemical quality of ground water in carbonate rocks interbedded with sandstone or shale rock units.
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	253	160	804	260	100	10
Calcium	333	31	558	49	17	1.1
Sodium	297	6	8,400	10	4	0
Magnesium	326	7	160	11	5	.1
Potassium	293	1	1,200	1	0	0
Chloride	371	5	1,500	12	2	.5
Sulfate	360	18	1,764	30	10	0
Bicarbonate as HCO_3	190	124	394	166	64	4
Nitrate (as NO_3)	324	1.6	155	8.8	.2	0
Phosphate, Ortho (as PO_4)	120	.06	4.30	.15	.01	0
pH (units)	216	7.4	8.6	7.7	6.9	5.0
Alkalinity as $CaCO_3$	196	102	323	136	52	3
Solids, @ 180°C	165	167	2,530	247	110	22
Specific Conductance (micromhos)	294	244	4,450	362	170	32
Iron (µg/L)	348	130	29,000	410	50	0
Manganese (µg/L)	308	30	6,500	108	10	0
Copper (µg/L)	43	20	350	35	1	0
Lead (µg/L)	139	3	480	5	1	0
Zinc (µg/L)	179	20	5,000	50	20	0

Carbonate and Calcareous Shale Units Containing Evaporite Minerals

General Features

This group of rocks consists of Silurian and Devonian limestone and interbeds of calcareous shale, siltstone, sandstone, shaley limestone, and dolomite; these interbeds also contain evaporite minerals. The eight geologic units in this group are in the central and southern Appalachian Mountains Section of the Valley and Ridge province (fig. 2).

The Wills Creek Shale and Tonoloway Limestone dominate this group. The Wills Creek consists chiefly of thin fissile, calcareous, gray shale with thin layers of limestone near the base and at intermediate horizons. The thickness of the formation ranges from 400 to 500 feet in its western and southern outcrops and from 400 to 750 feet in its central outcrops.

The Tonoloway Limestone overlies the Wills Creek Shale and consists of thin beds to laminated beds of limestone and calcareous shale. It is 400 to 600 feet thick in most places but thins out to 200 feet or less in Perry County.

Water Quality

Of the eight units in this group, only six have water-quality data. As indicated in table 10, most of the data are from the Tonoloway Limestone and the Wills Creek Shale. Locations of the 120 wells and springs for which water-quality data are available are shown in figure 13.

The water is generally free of contamination. Concentrations of calcium, magnesium, sulfate, and bicarbonate are dominant as illustrated in figure 14. The median dissolved solids content is 292 mg/L. Some wells in the Wills Creek Shale contain up to 1,000 mg/L dissolved solids because of the presence of calcium sulfate derived from gypsum in the rocks.

A few wells in Bedford, Mifflin, and Huntingdon counties have dissolved concentrations of sodium, nitrate, potassium, and chloride that are excessive due to natural sources. Most of the water is unfit for many industrial uses. A summary of the chemical data are presented in table 11.

Table 10.--Geologic names, codes, and number of water-quality sites in carbonate and calcareous shale units containing evaporite minerals

Lithologic type	AAPG[1]/Code	No. of Sites
Keyser, Tonoloway Formation, undifferentiated	347KRTL	8
Keyser Formation	347KYSR	14
Keyser, Tonoloway, Wills Creek, Bloomsburg, Mifflintown Formations, and Clinton Group, undifferentiated	347KTWC	0
Keyser, Tonoloway, Wills Creek, Bloomsburg, Mifflintown Formations, undifferentiated	347KTWM	0
Tonoloway Limestone	351TNLY	37
Wills Creek Formation	351WLCK	41
Wills Creek Formation, lower member	351WLCKL	9
Wills Creek Formation, upper member	351WLCKU	11

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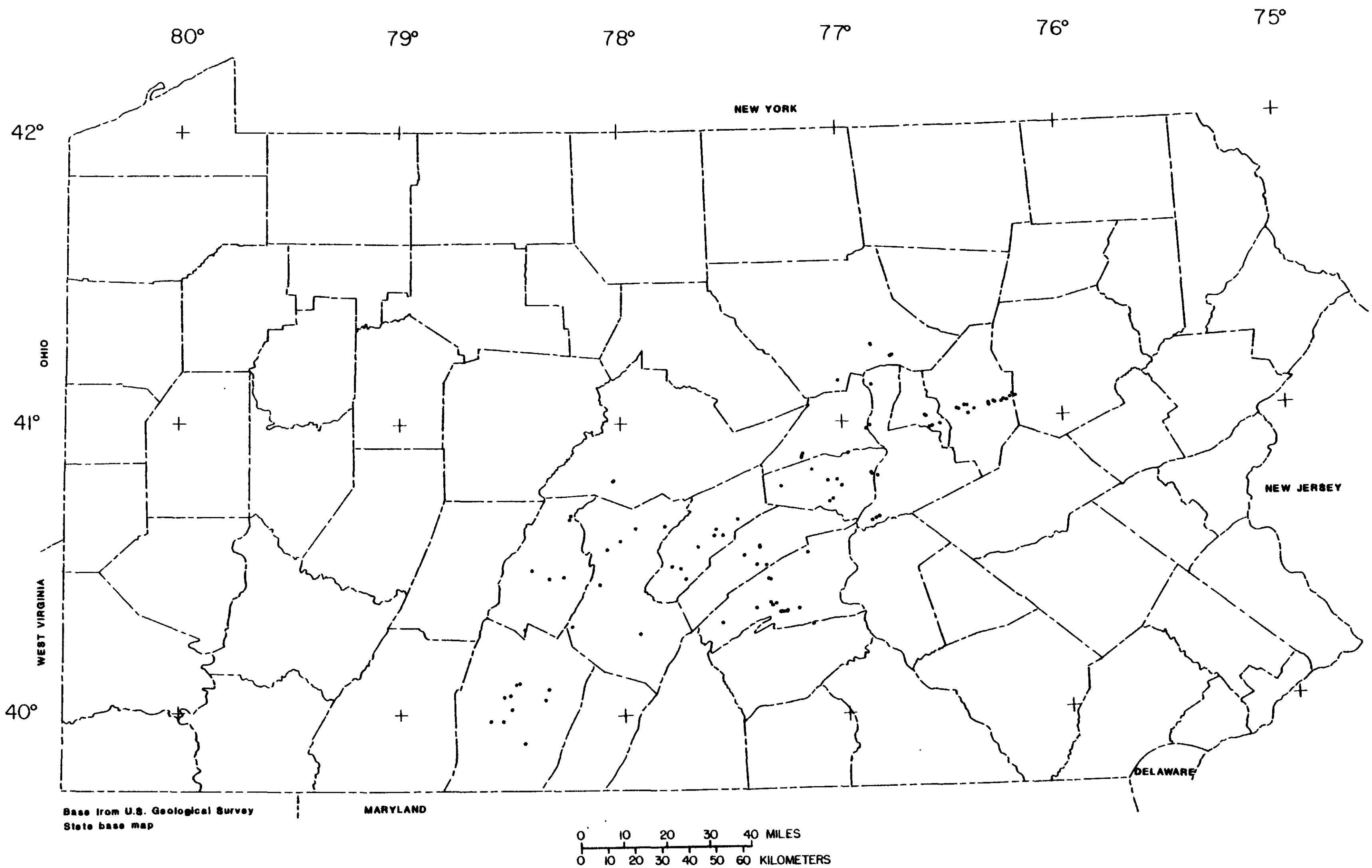

Figure 13.--Location of wells and springs in carbonate and calcareous shale units containing evaporite minerals.

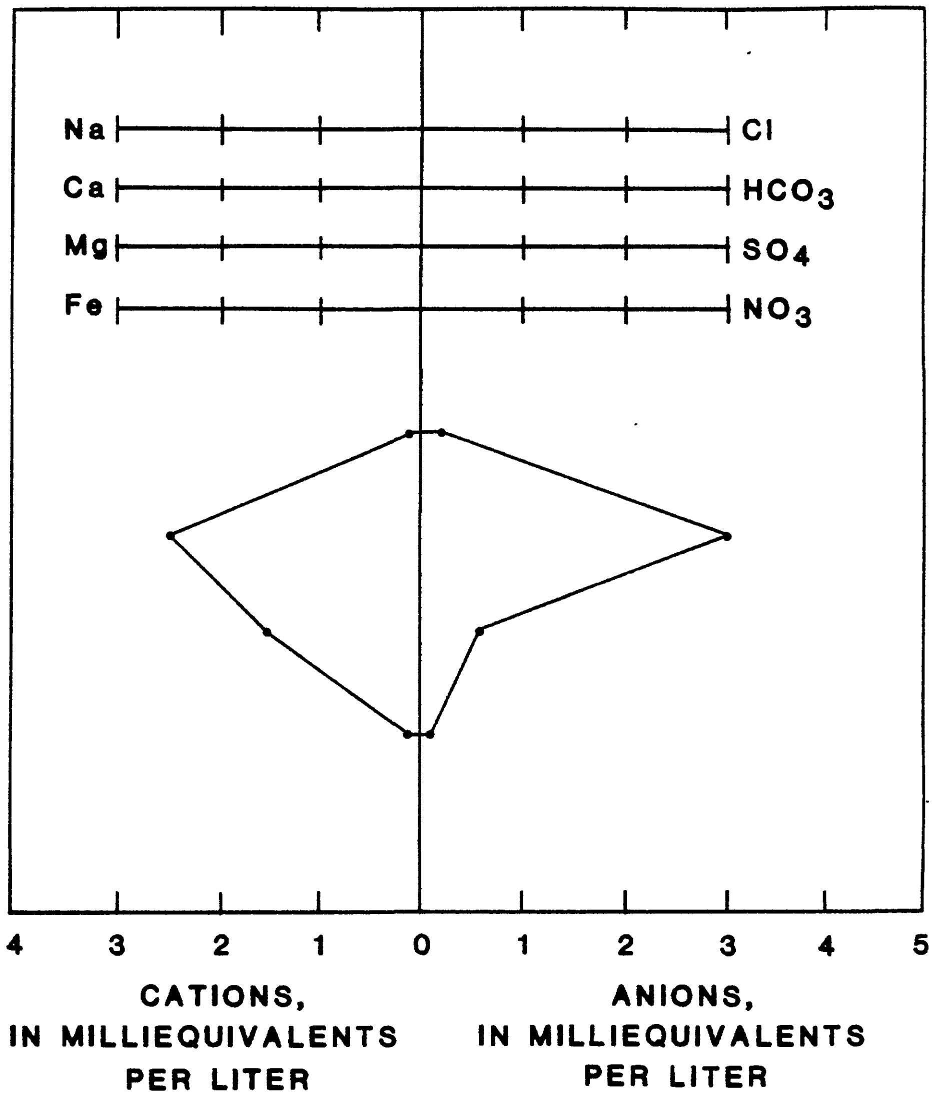

Figure 14.--Median concentrations of selected chemical constituents in carbonate and calcareous shale units containing evaporite minerals.

Table 11.--Summary of chemical quality of ground water in carbonate and calcareous shale units containing evaporite minerals (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	98	155	699	260	100	18
Calcium	88	59	480	81	38	21
Sodium	74	3	5,400	11	1	0
Magnesium	87	18	121	26	10	1.6
Potassium	69	1	3,300	2	1	0
Chloride	119	9	200	22	4	.7
Sulfate	96	27	1,460	62	15	2.3
Bicarbonate as HCO_3	41	193	433	245	156	84
Nitrate (as NO_3)	101	7.5	115	18	.7	0
Phosphate, Ortho (as PO_4)	16	0.06	1.00	.18	.03	0
pH (units)	47	7.3	8.0	7.5	7.1	5.0
Alkalinity as $CaCO_3$	46	158	355	191	134	69
Solids, @ 180°C	31	292	1,020	429	219	83
Specific Conductance (micromhos)	65	410	2,100	538	305	139
Iron (µg/L)	92	90	2,000	238	20	0
Manganese (µg/L)	71	10	430	20	3	0
Copper (µg/L)	9	20	310	55	2	0
Lead (µg/L)	23	4.0	50	6.0	2.0	1
Zinc (µg/L)	47	20	5,000	40	1.0	0

Light Gray and Olive Shale and Siltstone Rock Units

General Features

Light gray and olive colored shale, sandstone and siltstone of Mississippian, Upper Devonian, and Silurian age are exposed over a wide area of the Appalachian Plateaus and Valley and Ridge provinces (fig. 2). Much of the region is forested and sparsely populated.

Water Quality

Of the 71 geologic units included in this group (table 12), chemical analyses are available for 34 units. Most of the 379 wells for which there are data are located in the Chadokoin, Canadaway, Chemung, Cussewago, Lock Haven, and Trimmers Rock Formations. The locations of all wells in this group are shown in figure 15.

The water quality in this group is acceptable except where contaminated with brine solutions. As indicated in table 13, about 25 percent of the wells contain water with a dissolved chloride content in excess of 30 mg/L. The chloride is derived from connate water in the Chemung marine beds.

As shown in figure 16, the water is basically a calcium-bicarbonate type that is quite variable in composition due to brines in the deeper wells (300 to 400 feet). The median dissolved solids content is 223 mg/L and ranges from 13 to 77,500 mg/L. Twenty-three percent of the wells contain water that exceeds 500 mg/L total dissolved solids.

Table 12.-- Geologic names codes, and number of water-quality sites in light gray and olive shale, sandstone, and siltstone rock unit

Lithologic type	AAPG[1]/Code	No. of Sites
Amity Shale Member Cattaraugus Formation	341AMTY	0
Berea, Bedford, Cussewago, Riceville Formations, undifferentiated	337BBCR	5
Berea, Bedford, Cussewago, Venango Formations, undifferentiated	337BCRV	8
Berea Sandstone	337BERE	2
Beaverdam Run Member of Catskill Formation	341BVMR	0
Brallier Formation	341BRLR	19
Brallier, Harrell Formations, undifferentiated	341BLHL	3
Canadaway Formation	341CNDY	44
Cattaraugus Formation	341CRGS	0
Chadakoin Formation	341CDKN	44
Chemung Formation	341CMNG	31
Chemung Formation, Marine Beds	341CMNGB	7
Chemung Formation, Fall Creek Member	341FLCK	0
Chemung Formation, Piney Ridge Member	341PRDG	0
Chemung Formation, Allegrippis Member	341ALGP	0
Conewango Formation	341CNNG	6
Conneaut Formation	341CNNT	11
Corry, Bedford, Cussewago, Riceville Formations, undifferentiated	337CBCR	7
Corry Sandstone	337CRRY	0
Cussewago Sandstone	337CSSG	26
Cuyahoga Formation	337CYHG	1
Delaware River Formation	341DLVR	0
Dunkirk Formation	341DKRK	0
Foreknobs Formation	341FRKB	0
Gardeau Formation	341GRDU	1
Girard Formation	341GRRD	10
Harrell Shale	341HRRL	4
Hempfield Shale	337HMPF	0
Keefer Sandstone Member of Clinton Formation	354KEFR	0
Knapp Formation	337KNPP	0
Lock Haven Formation	341LKHV	42
Meadville Shale	337MDVL	2
Middlesex Formation	341MDLX	0
Millrift Formation	341MLRF	0
Murrysville Formation	337MRVL	0
Myers Shale	337MYRS	0
Northeast Shale	341NRTS	7
Nunda Formation	341NUND	0
Orangeville Shale	337OGVL	1

Table 12.-- Geologic names codes, and number of water-quality sites in light gray and olive shale, sandstone, and siltstone rock unit--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
Oswayo Formation	341OSWY	4
Patton Shale	337PTTN	0
Pinkerton Sandstone	337PNKR	0
Pipe Creek Formation	341PPCK	0
Rhinestreet Formation	341RNSR	0
Riceville Formation	341RCVL	1
Riddlesburg Shale Member of Pocono Formation	337RDBG	0
Rose Hill Formation	354RSHL	8
Rose Hill Formation, lower member	354RSHLL	12
Rose Hill Formation, middle member	354RSHLM	0
Rose Hill Formation, upper member	354RSHLU	5
Sherman Ridge Member of Rose Hill Formation, Cabin Hill Member	354CBHL	0
Sherman Ridge Member of Rose Hill Formation, center member	354CNTR	0
Rush Formation	341RUSH	1
Rush Formation, Burket Member	341BRKT	0
Salamanca Formation	341SLMC	0
Scherr Formation	341SCRR	3
Sharpsville Sandstone	337SPUL	6
Shenango Formation	337SNNG	11
Shenango Formation, lower member	337SNNGL	0
Shenango Formation, upper member	337SNNGU	1
Shellhammer Hollow Formation	337SLMH	0
Sherman Ridge Member of Mahantango Formation	344SMRG	0
Sloat Brook Formation	341SLBK	0
Sonyea Formation	341SONY	0
Squaw sand	337SQUW	1
Trimmers Rock Formation	341TMRK	42
Trimmers Rock, Harrel Formations, undifferentiated	341TRKH	3
Towanda Formation	341TWND	0
Walton Group	341WLTN	0
Wiscoy Formation	341WSCY	0
Woodmont Shale	341WDMN	0

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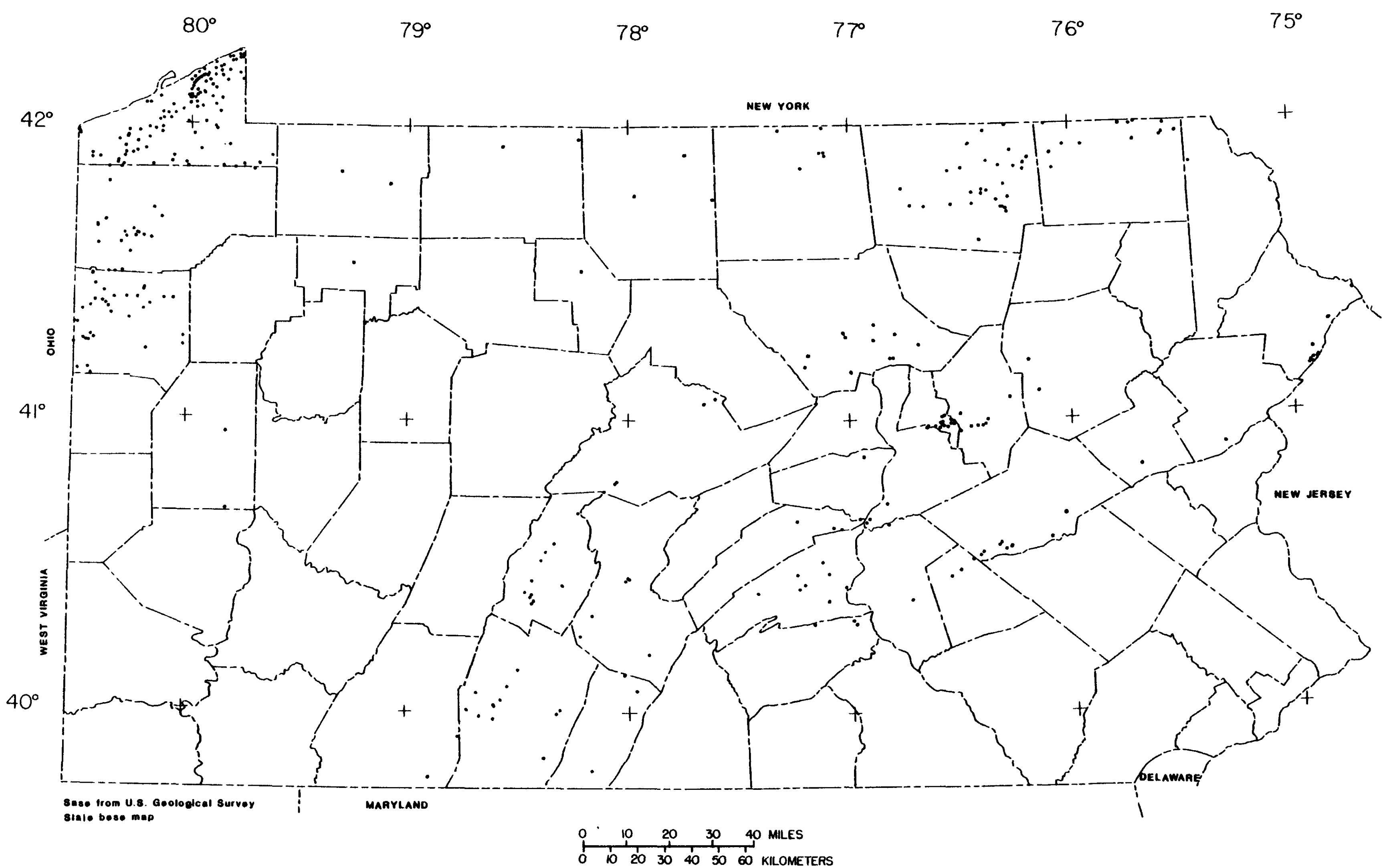

Figure 15.--Location of wells and springs in light grey and olive shale and siltstone rock units.

Table 13.--Summary of chemical quality of ground water in light gray and olive shale, sandstone, and siltstone rock units
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	346	97	850	200	55	12
Calcium	235	20	660	36	11	0
Sodium	215	13	22,000	74	5	0
Magnesium	228	7.5	1,860	12	4.4	.1
Potassium	203	2	3,600	4	1	0
Chloride	380	7.8	79,000	30	3.0	.4
Sulfate	256	11.5	307	20	5.0	0
Bicarbonate as HCO_3	132	167	3,340	257	80	0
Nitrate (as NO_3)	218	.4	49	1.5	.1	0
Phosphate, Ortho (as PO_4)	62	.04	5.50	.11	0	0
pH (units)	218	7.4	9.4	7.8	7.1	5.2
Alkalinity as $CaCO_3$	143	131	2,740	204	73	6
Solids, @ 180°C	118	223	77,500	413	110	13
Specific Conductance (micromhos)	329	348	91,000	533	212	13
Iron (µg/L)	308	160	52,000	638	50	0
Manganese (µg/L)	221	60	4,800	160	20	0
Copper (µg/L)	26	13	170	45	0	0
Lead (µg/L)	49	2	200	50	2	0
Zinc (µg/L)	116	20	24,000	48	10	0

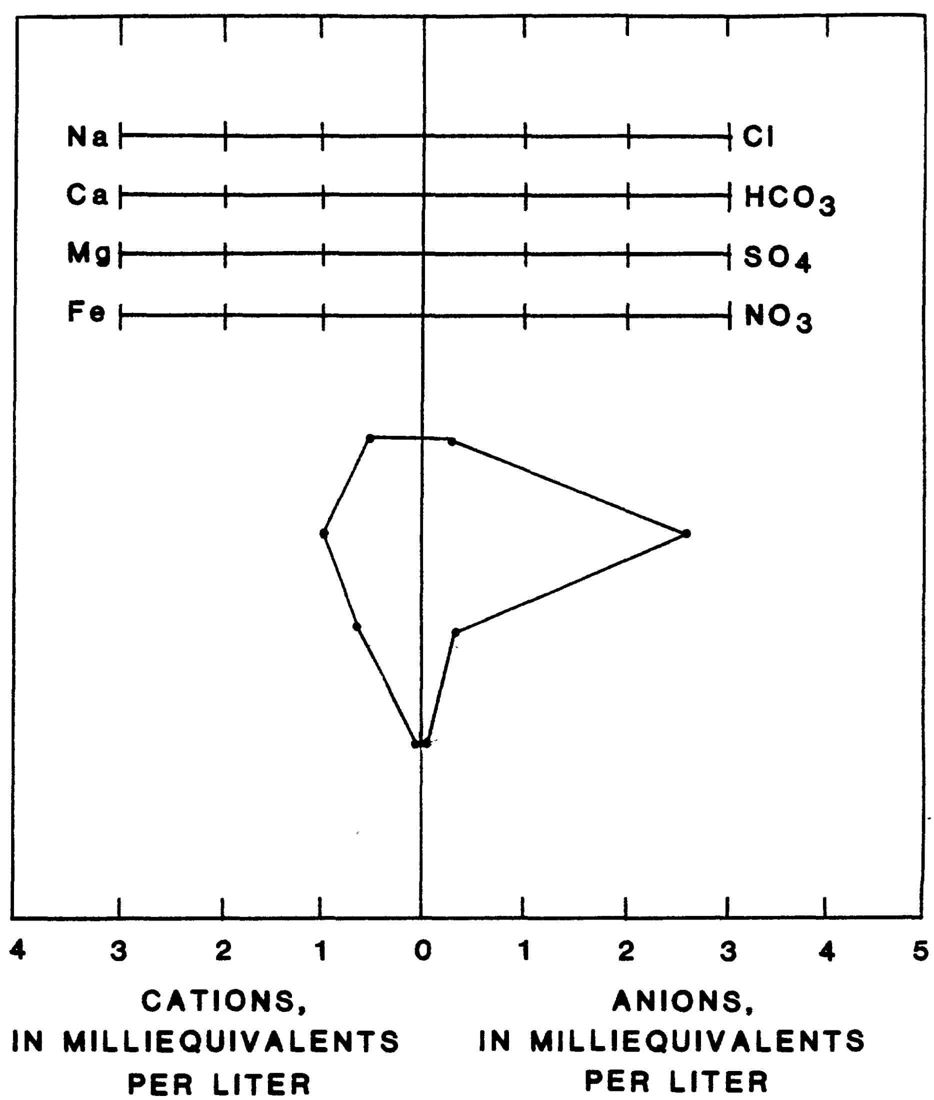

Figure 16.--Median concentrations of selected chemical constituents in light gray and olive shale and siltstone rock units.

Dark Gray and Black Shale Rock Units

General Features

This group of rock units consists primarily of Ordovician shales distributed in the Valley and Ridge province (fig. 2). The dominant unit in this group is the Martinsburg Shale. It is an extensive unit that comprises a large part of the Great Valley.

The Martinsburg Shale ranges in thickness from 2,000 feet in the western part of the State to 3,000 feet in the eastern part of the State. In eastern Pennsylvania, a dark carbonaceous, fissle shale has been metamorphosed to slate.

Water Quality

Of the 17 geologic units included in this group (table 14), chemical-quality data are available for only 12 units. Quality data are available for 172 wells and springs in this group; nearly all of the data are for the Martinsburg Shale. Locations of the wells and springs are shown in figure 17.

A summary of the chemical analysis for the wells and springs developed in this group is presented in table 15. The water is quite diverse in mineral content but generally of acceptable quality. As illustrated in figure 18, the water is a calcium-bicarbonate type.

Manmade contamination has not adversely affected ground water in this group. Just 2 percent of the wells contained nitrate-nitrogen concentrations in excess of the 10 mg/L EPA drinking-water criteria.

Natural sources of iron and manganese caused 36 and 58 percent, respectively, of the wells and springs to exceed the EPA drinking-water criteria for these constituents. Of the 108 water supplies tested for dissolved solids, only 5 percent were found to exceed the proposed criterion of 500 mg/L. The waters are generally lower in dissolved solids than the carbonates and higher than the quartzites.

Table 14.--Geologic names, codes, and numbers of water-quality sites in dark gray and black shale rock units

Lithologic type	AAPG[1/] Code	No. of Sites
Antes Formation	364ANTS	1
Cocalico Shale	361CCLC	5
Cocalico phyllite	361CCLCP	1
Marcellus Shale	344MRCL	19
Martinsburg Shale	361MRBG	39
Martinsburg Shale, C unit	361MRBGC	1
Martinsburg Shale, lower member	361MRBGL	42
Martinsburg Shale, middle member	361MRBGM	25
Martinsburg Shale, upper member	361MRBGU	18
Martinsburg Shale, Bushkill Member	361BSKL	3
Martinsburg Shale, Pen Argyl Member	361PAGL	2
Martinsburg shale, Ramseyburg Member	361RMBG	0
Needmore Shale	344NDMR	0
Needmore Shale, Beaver Dam Shale Member	344BVDM	0
Reedsville Shale	361RDVL	16
Romney Shale	344RMNY	0
Upper Ordovician shale	361SHLE	0

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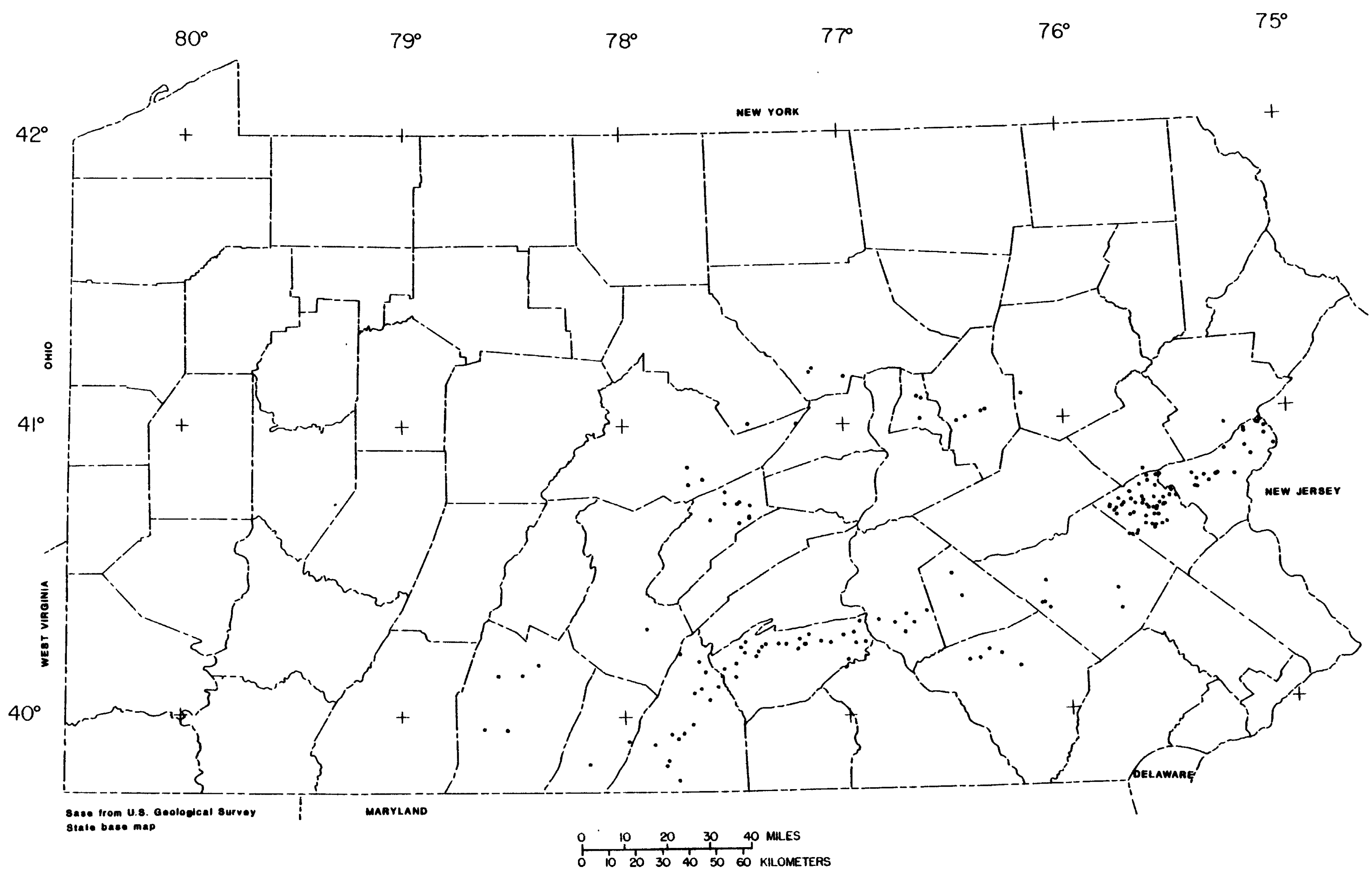

Figure 17.--Location of wells and springs in dark gray and black shale rock units.

Table 15.--Summary of chemical quality of ground water in dark gray and black shale units
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	133	180	800	300	100	12
Calcium	134	30	160	46	21	1.2
Sodium	122	7	3,700	12	5	0
Magnesium	130	8.0	40	13	5.7	.4
Potassium	123	7.6	860	2	0	0
Chloride	168	6	280	13	3	.2
Sulfate	161	30	760	52	15	1
Bicarbonate as HCO_3	125	85	340	44	60	9
Nitrate (as NO_3)	162	1.1	109	11	.1	0
Phosphate, Ortho (as PO_4)	56	.03	1.6	.14	0	0
pH (units)	140	7.5	8.9	7.7	7.1	5.8
Alkalinity as $CaCO_3$	129	71	279	1 18	49	7
Solids, @ 180°C	108	182	935	48	130	11
Specific Conductance (micromhos)	132	278	2,400	58	206	16
Iron (µg/L)	146	145	9,000	423	60	0
Manganese (µg/L)	130	45	1,600	223	10	0
Copper (µg/L)	14	6	130	33	1.5	0
Lead (µg/L)	39	3	50	5	1	0
Zinc (µg/L)	49	20	790	75	20	0

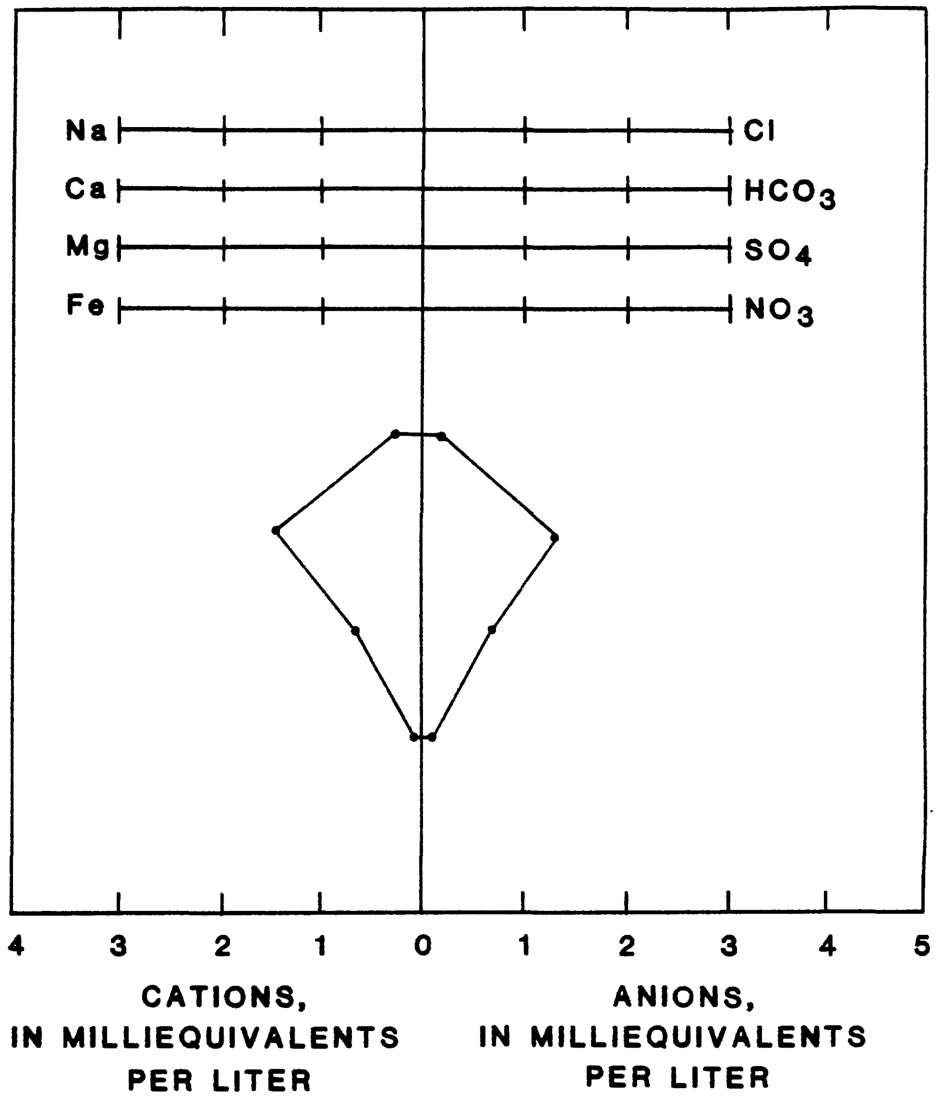

Figure 18.--Median concentrations of selected chemical constituents in dark gray and black shale rock units.

Devonian and Mississippian Red Shale and Siltstone Rock Units

General Features

The red shale, siltstone, and minor amounts of sandstone of Devonian and Mississippian age are exposed over a wide area of the Appalachian Plateaus and Valley and Ridge provinces. Two important geologic units--the Mauch Chunk and the Catskill--are included in this group. They are important because of their wide areal distribution and the large number of wells that they contain. Both units are among the most productive water-bearing formations in northeastern Pennsylvania.

The sedimentary rocks of the Catskill group range in thickness from about 1,800 feet in Susquehanna County to about 6,000 feet in Carbon County (Lohman, 1937). The Mauch Chunk Shale, which surrounds nearly all the anthracite fields, is 2,000 to 3,000 feet thick on the south side of the Southern Anthracite field and 200 to 300 feet thick on the north side of the Northern Anthracite field.

Water Quality

Of the 27 geologic units included in this group (table 16), analyses are available for wells developed in just 15 units. Chemical analyses are available for 619 wells in this group; 500 are in the Catskill Formation, and 119 are in the Mauch Chunk Formation, Susquehanna Group, and Venango Formation. The locations of the wells in this group are shown in figure 19.

Water quality is generally acceptable for all uses. As shown in figure 20, the water is a calcium-bicarbonate type that is low in dissolved solids. The median concentration of dissolved solids is 129 mg/L, and the median concentration of dissolved iron is 80 μg/L. A summary of chemical data is given in table 17.

Manmade contamination of ground water is not a serious problem in this group. However, a few wells in Bedford County, have high concentrations of sodium and nitrate that are believed due to contamination from agricultural drainage or septic waste.

Table 16.--Geologic names, codes, and number of water-quality sites in Devonian and Mississippian Age red shale and siltstone rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Catskill Formation	341CSKL	419
Catskill Formation, lower member	341CSKL	2
Catskill Formation, upper sandstone member	341CSKL	1
Catskill Formation, upper redbeds member	341CSKL	4
Catskill Formation, Buddys Run Member	341BDSR	3
Catskill Formation, Cherry Ridge Member	341CRDG	0
Catskill Formation, Duncannon Member	341DNCN	5
Catskill Formation, Irish Valley Member	341IRVL	23
Catskill Formation, Kings Mill Member	341KGML	0
Catskill Formation, Long Run Member	341LNGR	4
Catskill Formation, Poplar Gap Member	341PLGP	0
Catskill Formation, Sawmill Run Member	341SMLR	0
Catskill Formation, Shermans Creek Member	341SMCK	39
Catskill Formation, Walcksville Member	341WCKV	0
Hampshire Formation	341HMPR	0
Catskill Formation, Honesdale Member	341HSOL	0
Jennings Formation	341JNGS	0
Mauch Chunk Formation	327MCCK	75
Mauch Chunk Formation, upper member	327MCCKU	3
Mauch Chunk Formation, middle member	331MCCKM	8
Mauch Chunk Formation, lower member	331MCCKL	4
Mauch Chunk Formation, Saxton Member	341SXTN	0
Mount Pleasant Formation	341MPLS	0
New Milford Formation	341NMFD	0
Catskill Formation, Shohola Member	341SHHL	0
Susquehanna Group	341SSQN	4
Venango Formation	341VNNG	25

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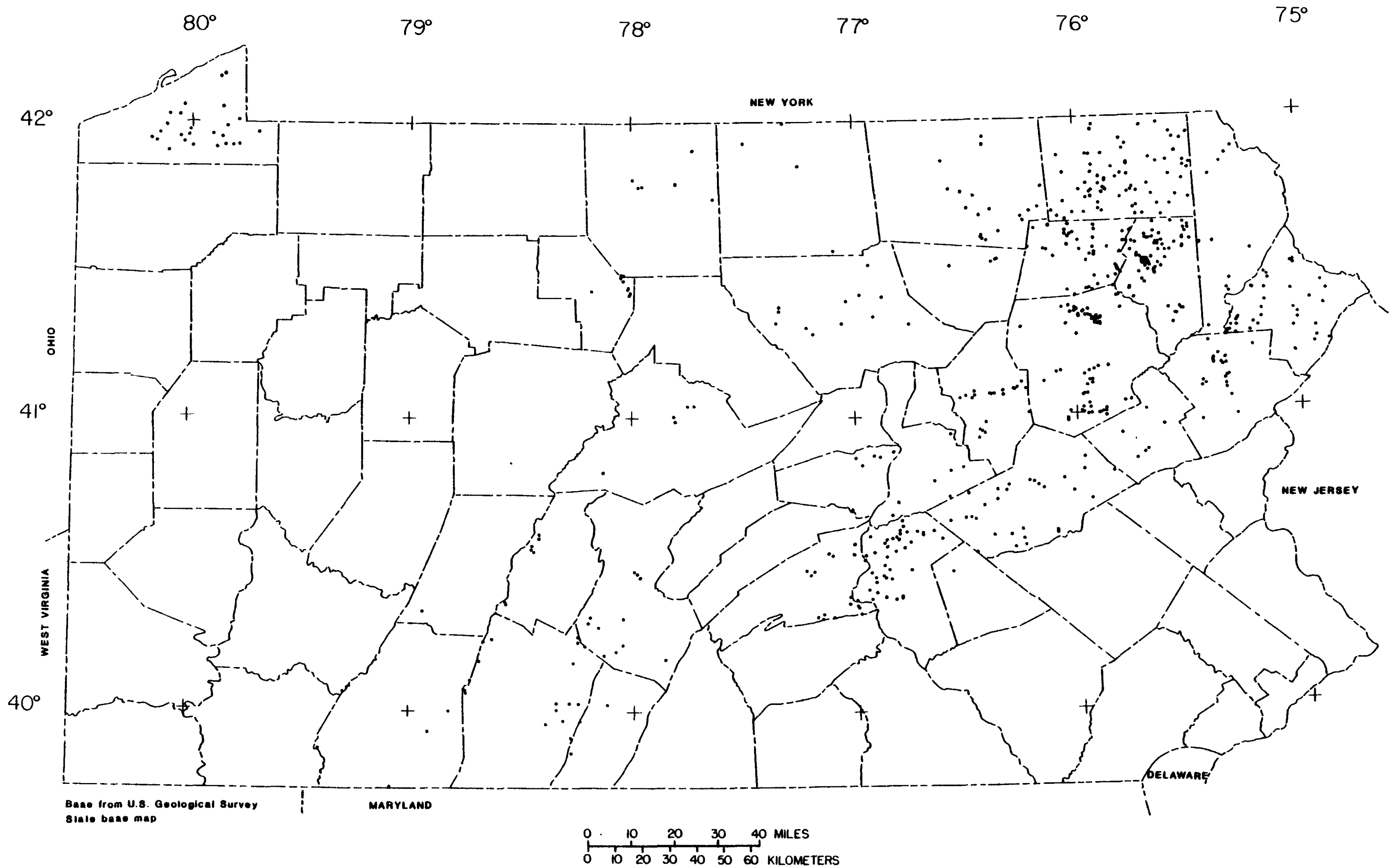

Figure 19.--Location of wells and springs in Devonian and Mississippian red shale and siltstone rock units.

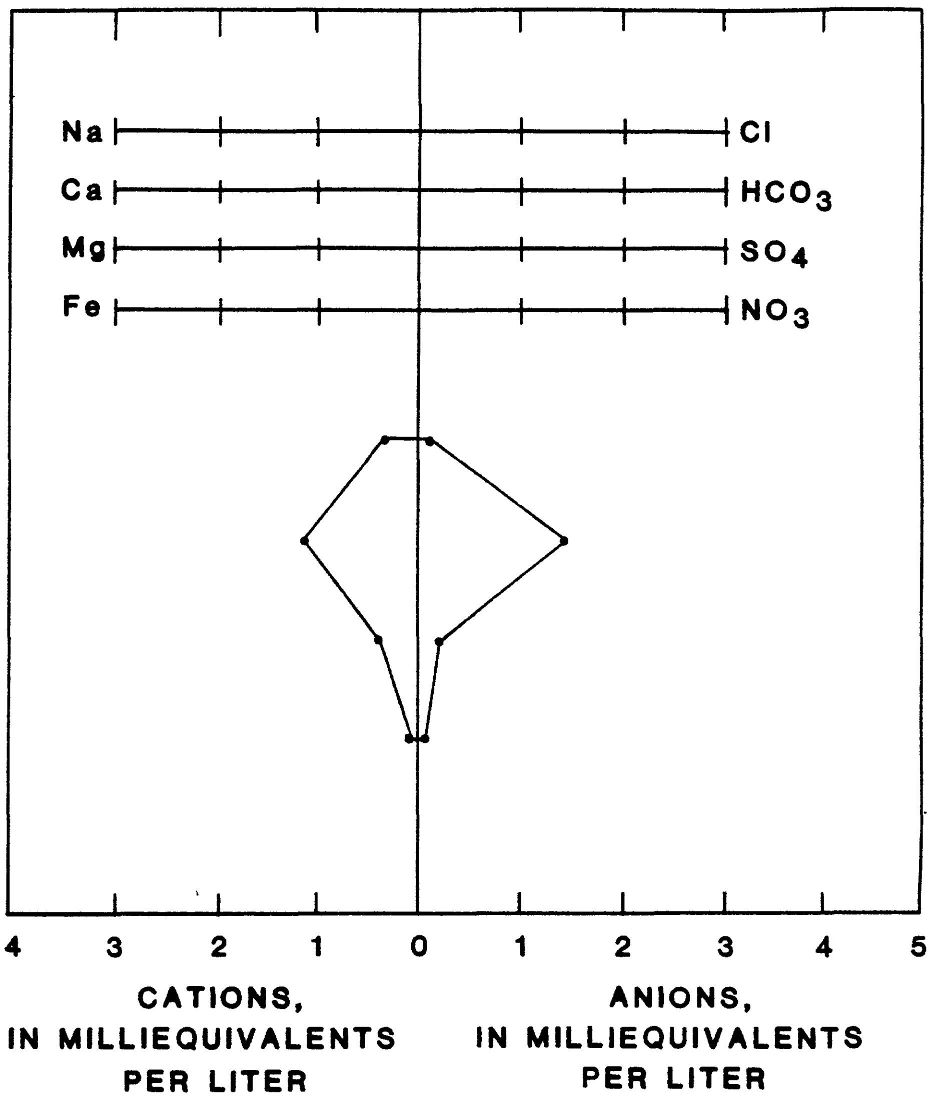

Figure 20.--Median concentrations of selected chemical constituents in Devonian and Mississippian red shale and siltstone rock units.

Table 17.--Summary of chemical quality of ground water in Devonian and Mississippian age red shale and siltstone units (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	507	210	1,000	323	140	4
Calcium	458	23	230	35	12	.1
Sodium	416	8	8,600	14	4	0
Magnesium	438	4.8	88	7.1	2.8	0
Potassium	374	1	1,400	2	1	0
Chloride	600	5	2,800	15	2	0
Sulfate	546	10	313	15	5	0
Bicarbonate as HCO_3	290	93	238	126	43	2
Nitrate (as NO_3)	503	2	204	6.2	.3	0
Phosphate, Ortho (as PO_4)	170	.09	5.5	.12	.06	0
pH (units)	412	7.2	9.4	7.6	6.7	4
Alkalinity as $CaCO_3$	293	76	195	104	32	2
Solids, @ 180°C	210	129	4,380	174	81	15
Specific Conductance (micromhos)	431	220	8,500	310	147	9
Iron (µg/L)	575	80	47,500	220	40	0
Manganese (µg/L)	486	20	4,600	80	10	0
Copper (µg/L)	127	30	1,800	50	20	0
Lead (µg/L)	207	2	244	5	0	0
Zinc (µg/L)	360	40	11,000	98	20	0

Bituminous Coal-Bearing Pottsville Group Rock Units

General Features

Geologic units of the Pottsville Group consist largely of hard sandstone, conglomerate, and shale that crop out or underlie nearly all the Appalachian Plateaus province. Some thin coal beds are associated with the Mercer Shale and Connoquenessing Sandstone. In the Valley and Ridge province, the group crops out only on high ridges. The Pottsville ranges in thickness from 130 feet in Cambria County to 375 feet in southern Somerset County. The distribution of coal-bearing rocks is shown in figure 21.

The sandstone members of the Pottsville are generally the most productive aquifers in the Appalachian Plateau province. The flow of some wells is as much as 40 gal/min. Pumped wells yield 100 gal/min and more. The Pottsville is largely unexploited in the Valley and Ridge province.

Water Quality

Of the 18 geologic units in this group (table 18), chemical analyses are available for only 7 units. There currently are 186 wells in this group for which there are chemical data in the WATSTORE file. The Pottsville Formation contains 142 wells. The other units are inadequately sampled. Locations of wells are shown in figure 22.

Water quality of wells in this group is generally unacceptable. Nearly three-fourths of the samples analyzed contained excess iron, individual analyses show concentrations as high as 500 mg/L. As shown in figure 23, the water is basically a calcium-bicarbonate type that is also high in sulfate. Dissolved solids exceed the 500 mg/L EPA drinking water criterion in more than 25 percent of the wells tested and reached a maximum concentration of 7,400 mg/L. Chemical data for wells in this group are summarized in table 19.

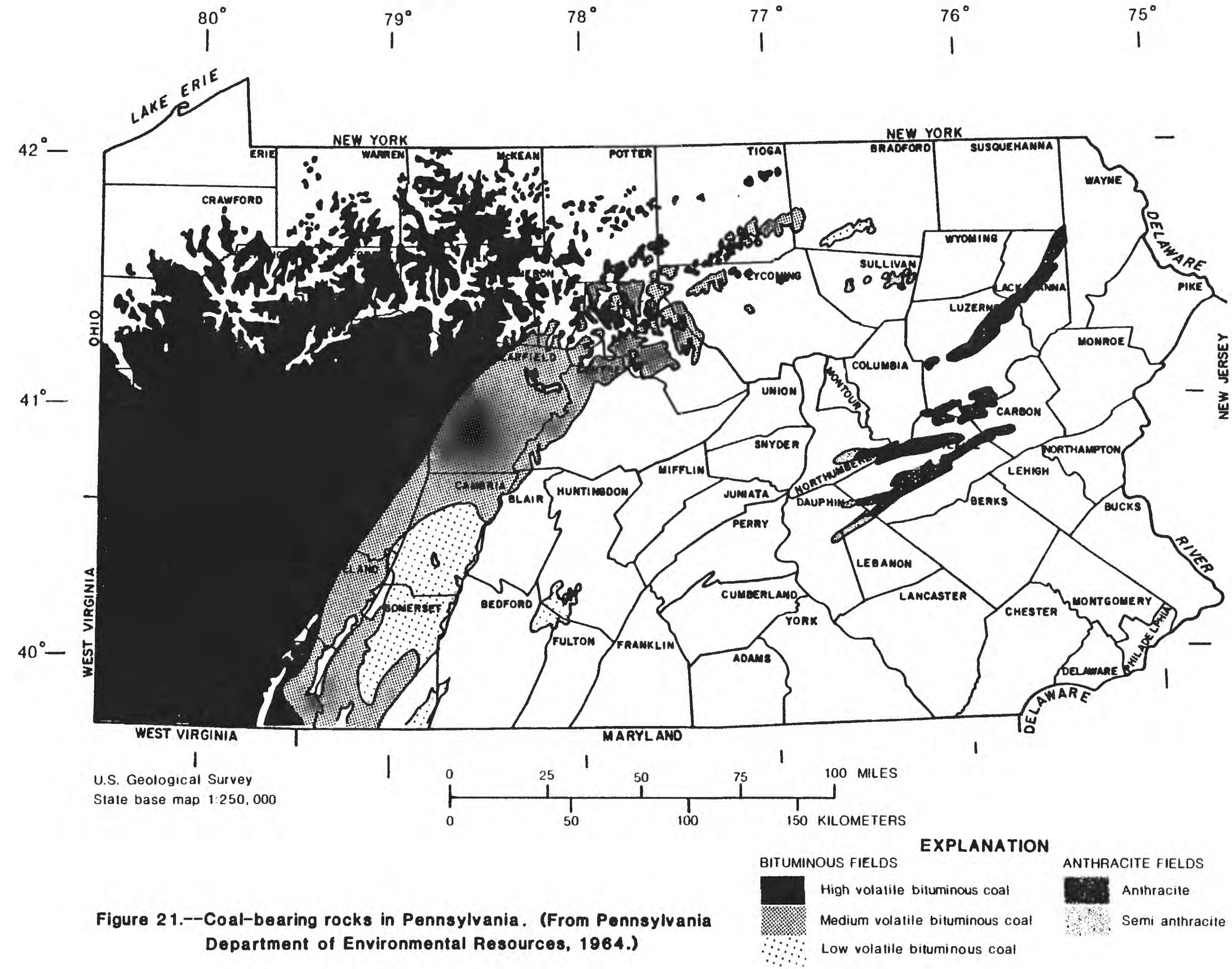

Figure 21.--Coal-bearing rocks in Pennsylvania. (From Pennsylvania Department of Environmental Resources, 1964.)

Table 18.--Geologic names, codes, and number of water-quality sites of the bituminous coal-bearing Pottsville Groups rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Connoquenessing Formation	327CQSG	35
Connoquenessing Formation, lower	327CQSGL	3
Connoquenessing Formation, middle	327CQSGM	0
Connoquenessing Formation, upper	327CQSGU	1
Connoquenessing Formation, Quakertown Member	327QKRN	0
Connoquenessing Formation, Quakertown Coal Bed	327QKRNC	0
Elliot Park Formation	327ELPK	0
Laurel Run Formation	324LRLR	1
Mercer Formation	324MRCR	3
Mercer coal group	324MRCRC	0
Millstone Run Formation	324MLSR	0
Mineral Springs Formation	324MSPG	0
New River Formation	327NRVR	0
New River Formation, Pineville Sandstone Member	327PNVL	0
Pottsville Formation	324PSVL	142
Pottsville Formation, Olean Sandstone Member	327OLEN	1
Sharon Formation	327SHRN	0
Sharon Conglomerate	327SHRNC	0

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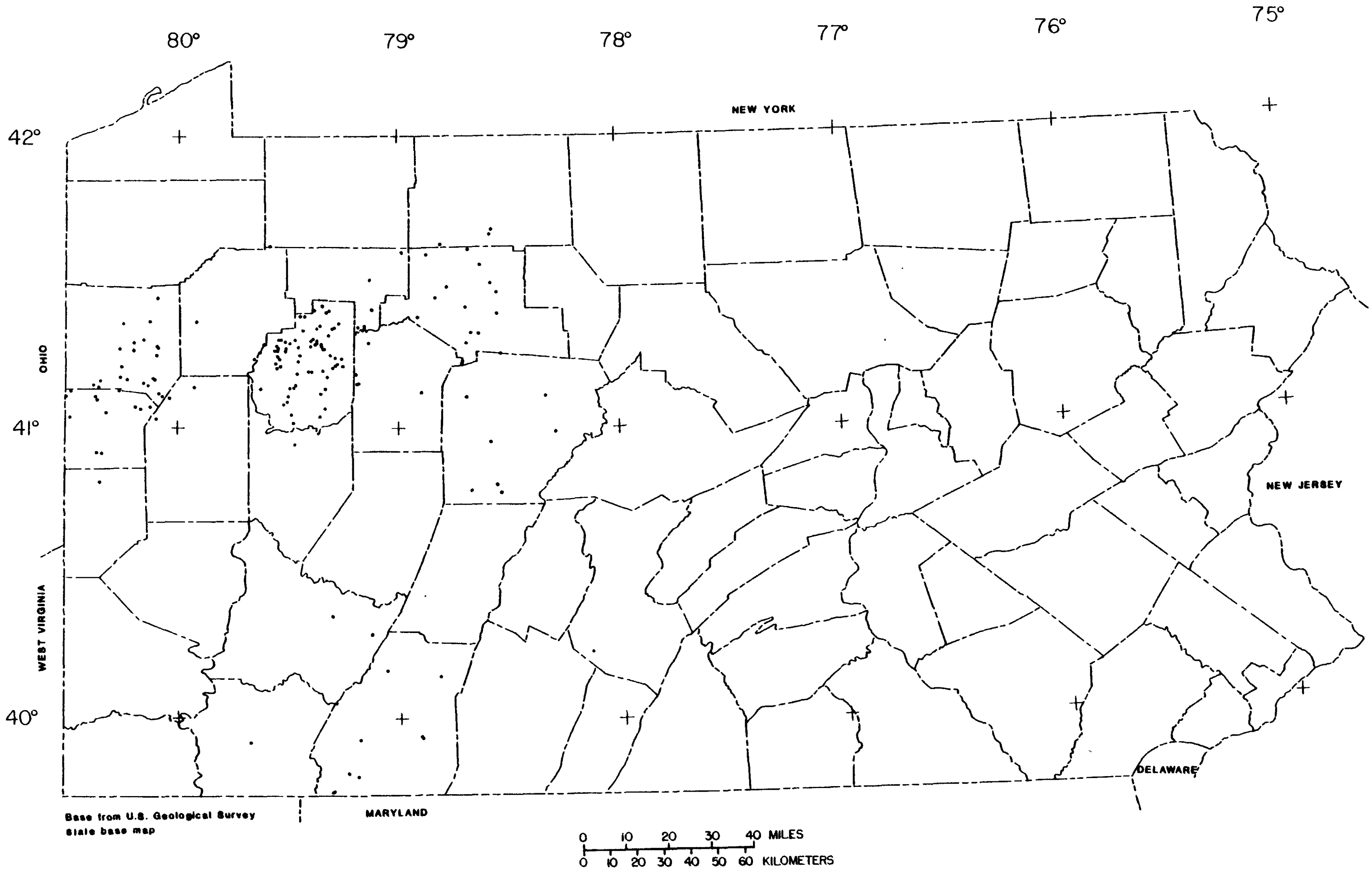

Figure 22.--Location of wells and springs in bituminous coal-bearing Pottsville Group rock units.

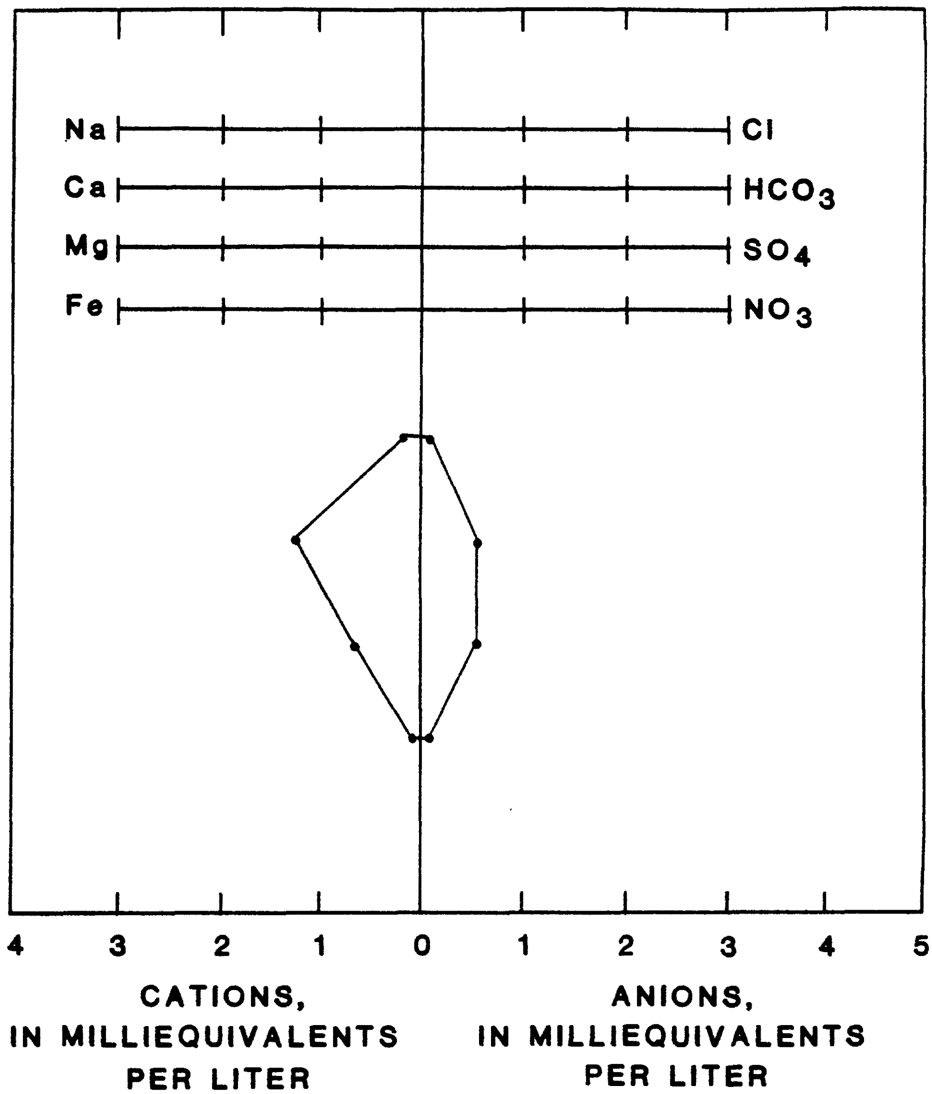

Figure 23.--Median concentrations of selected chemical constituents in bituminous coal-bearing Pottsville Group rock units.

Table 19.--Summary of chemical quality of ground water in bituminous coal-bearing Pottsville Group rock units (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of Well, feet	154	133	578	223	94	26
Calcium	98	25	357	64	9	1
Sodium	85	4	580	13	1	0
Potassium	82	2	18	4	1	0
Magnesium	92	8	984	17	4	1
Chloride	129	5	900	19	2	0
Sulfate	120	24	6,220	85	8	0
Bicarbonate as HCO_3	177	33	788	147	6	0
Nitrate (as NO_3)	101	.4	40	1.7	0	0
Phosphate, Ortho (as PO_4)	39	.03	.67	.09	0	0
pH (units)	154	6.4	8.2	7.2	5.6	2.7
Alkalinity as $CaCO_3$	177	27	646	120	5	0
Solids, @ 180°C	102	199	7,400	400	100	20
Specific Conductance (micromhos)	148	274	7,000	543	110	33
Iron (µg/L)	178	1,500	500,000	8,430	260	0
Manganese (µg/L)	156	300	280,000	1,000	70	0
Copper (µg/L)	18	48	270	120	19	0
Lead (µg/L)	16	5	40	5	0	0
Zinc (µg/L)	25	80	22,600	960	20	0

Anthracite-Bearing Rock Units

General Features

The Llewellyn and Pottsville Formations contain anthracite interbedded with sandstone, conglomerate, siltstone, and shale of Pennsylvanian age. The Llewellyn Formation is found in four synclinal basins (fig. 21) in northeastern Pennsylvania: (1) the Northern or Wyoming-Lackawanna Anthracite Field, which is the northeasternmost and is about 55 miles long and 6 miles wide at the center; (2) the Eastern Middle Anthracite Field, which is about 10 miles southwest of the Northern Anthracite field and comprises a number of small coal basins; (3) the Western Middle Anthracite Field, which joins the Eastern Middle Anthracite field on the southwest; and (4), the Southern Anthracite field, which is the largest (Lohman, 1937).

The Pottsville Formation consists mainly of hard, coarse conglomerate that directly underlies the Llewellyn Formation. The Pottsville forms a ridge around each of the coal basins. The Pottsville coal beds are large and valuable in the western end of both the Southern and the Western Middle Fields but decrease in size and number toward the east.

Water Quality

Water quality of these units is diverse. Potability of the supply is largely dependent upon proximity to acid-mine drainage; highly acidic water that results from the oxidation of pyrite in the coal precludes use of the Llewellyn Formation as a source of potable water in many areas. Wells away from mining operations that get their water from sandstones and conglomerates supply good quality water. The Pottsville Formation is an important water-bearing formation in parts of Luzerne and Schuylkill Counties, but in most of the other counties it crops out only on high, rugged ridges (Lohman, 1937).

Of the five geologic units included in this group (table 20), water analyses are available for only 62 wells developed in 4 units. Two of these four units are subdivisions of the Pottsville Formation. Of the 62 wells in this group 36 are in the Llewellyn and 26 are in the Pottsville. The locations of these wells are shown in figure 24.

Because of the acid-mine drainage, the water quality is generally unacceptable for a potable supply. As illustrated in figure 25, the water is dominated by ions of calcium, magnesium and sulfate. High concentrations of of dissolved solids and dissolved metals are evident in the water-quality summary in table 21.

EPA drinking water criteria are exceeded in 23 percent, 69 percent and 70 percent of the wells analyzed for sulfate, iron and manganese, respectively.

Table 20.--Geologic names, codes, and number of water-quality sites of anthracite-bearing rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Llewellyn Formation	321LLLN	36
Pottsville Formation	324PSVL	24
Pottsville Formation, Schuylkill Member	327SCLK	1
Pottsville Formation, Sharp Mountain Member	324SRPM	0
Pottsville Formation, Tumbling Run Member	327TBGR	1

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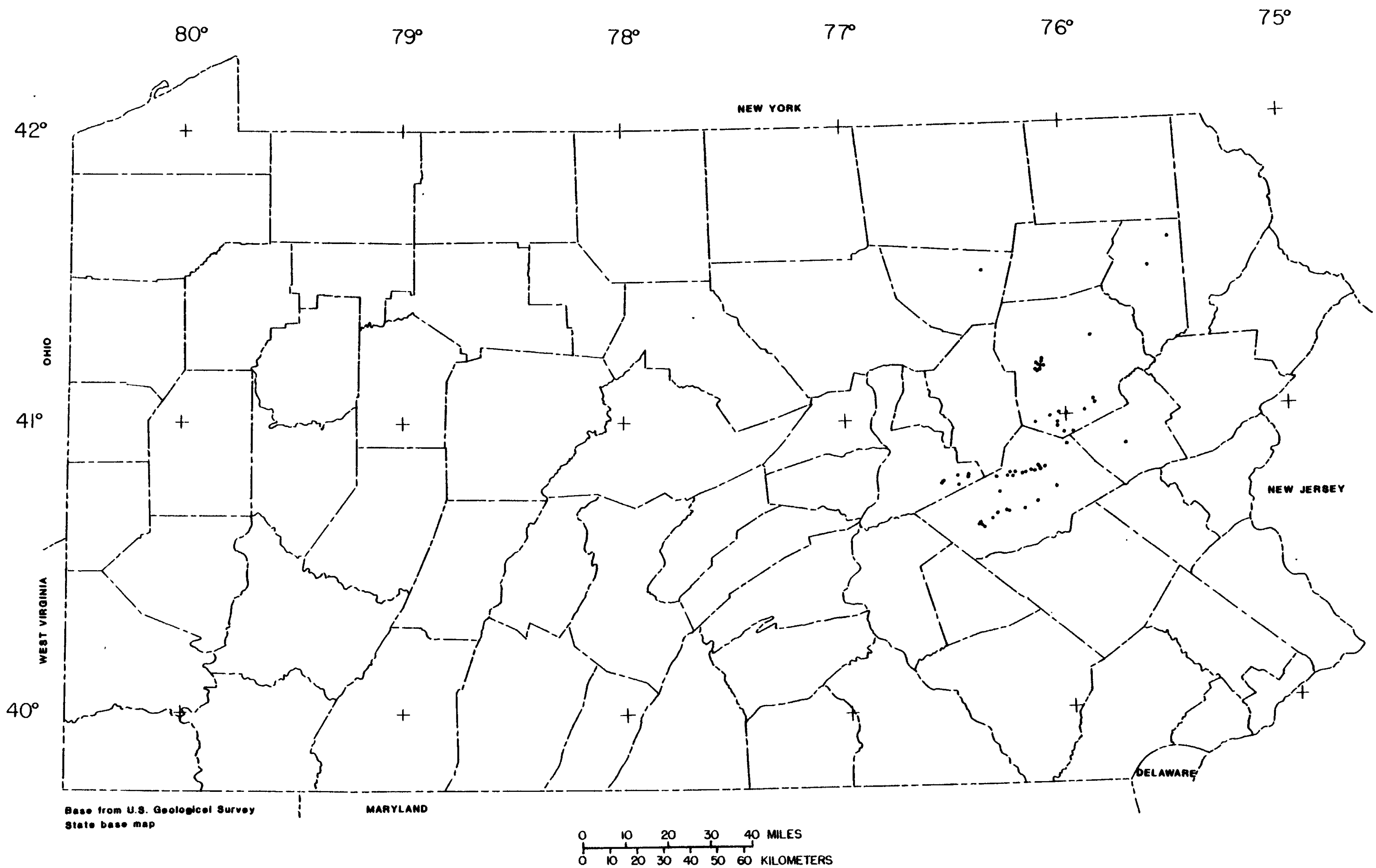

Figure 24.--Location of wells and springs in anthracite-bearing rock units.

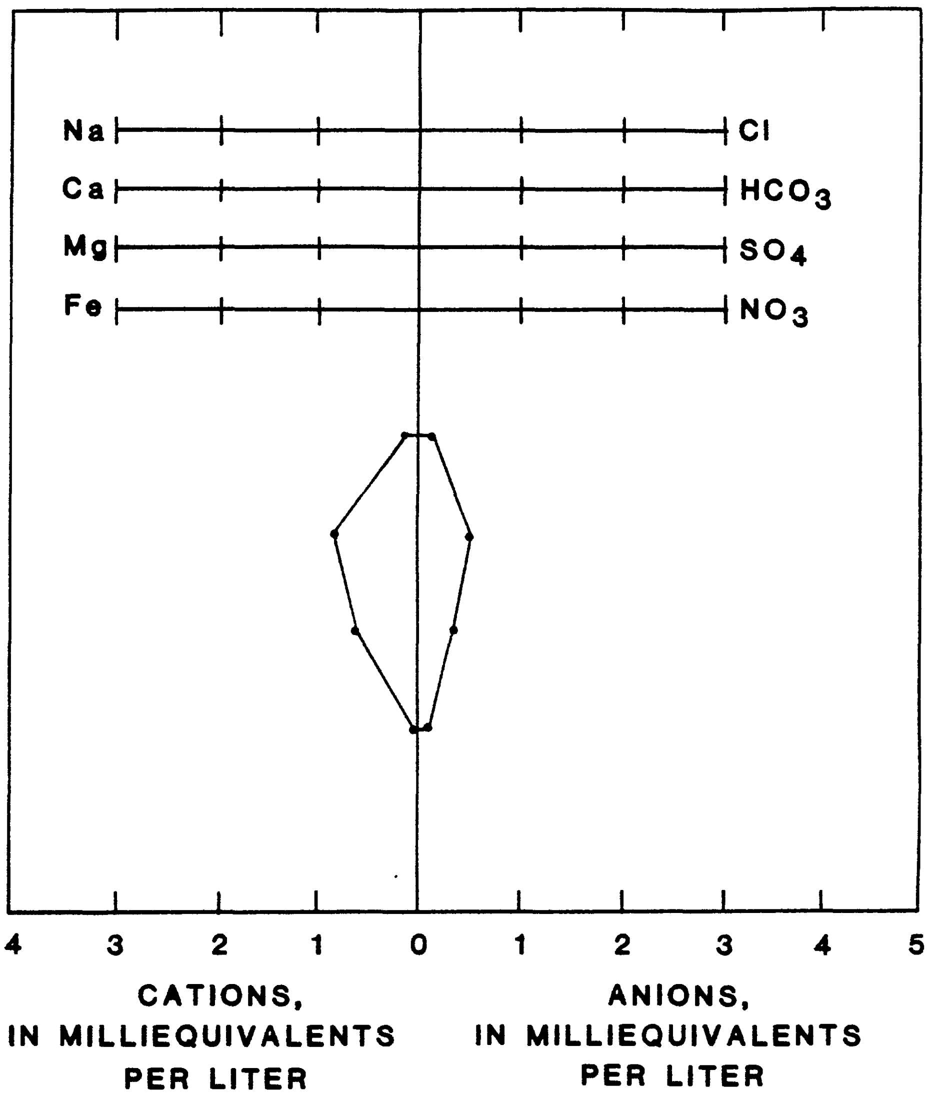

Figure 25.--Median concentrations of selected chemical constituents in anthracite-bearing rock units.

Table 21.--Summary of chemical quality of ground water in anthracite-bearing rock units (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	58	233	1,014	348	147	0
Calcium	29	18	320	24	6	2
Sodium	34	3.8	21	10.3	2.0	0.4
Potassium	28	1.7	8.2	2.8	.4	0
Magnesium	27	7.6	205	15	2.7	.5
Chloride	32	5.2	330	20.3	2.2	.7
Sulfate	54	14.5	2,670	233	6.1	2.6
Bicarbonate as HCO_3	31	30	608	68	10	2
Nitrate as (NO_3)	31	.36	16	1.3	.05	0
Phosphate, Ortho (as PO_4)	15	.09	1.2	.12	.03	0
pH (units)	55	6.1	9.5	6.9	5.5	2.6
Alkalinity as $CaCO_3$	31	25	499	56	8	2
Solids @ 180°C	27	84	1,860	148	45	13
Specific Conductance (micromhos)	43	317	2,700	792	126	25
Iron (µg/L)	60	1,350	95,000	13,000	92	10
Manganese (µg/L)	39	150	43,000	550	40	0
Copper (µg/L)	18	20	7,000	63	20	0
Lead (µg/L)	18	4	37	7	0	0
Zinc (µg/L)	24	55	5,100	220	22	0

Bituminous Coal-Bearing Conemaugh and Allegheny Group Rock Units

General Features

The geologic units in this group consist of numerous strata of bituminous coal interbedded with shale, sandstone, siltstone, and thin limestone. The units are exposed over a large part of the Appalachian Plateaus and the western edge of the Valley and Ridge provinces.

The Conemaugh Formation is, in general, an excellent source of water; its sandstone members being very productive over a wide area. Yields as high as 100 gal/min are found where coarse-grained zones lie below drainage level. Yields from shale members of the formation rarely exceed 5 gal/min, and more commonly are less than 1 gal/min (Piper, 1933).

The Allegheny Formation is highly diverse in lithology. The formation is mostly shale and sandstone with thin discontinuous limestone members and several beds of coal and fireclay of economic importance. The Allegheny formation supplies limited quantities of water; yields are generally less than 5 gal/min.

Water Quality

Sixty-four geologic units are included in this group. However, as indicated in table 22, chemical analyses are available for only 281 wells in 27 units. Locations of wells are shown in figure 26.

As shown by the diagram in figure 27, the water is basically a calcium-bicarbonate type that also contains a lot of magnesium and sulfate. Many wells are affected by acid-mine drainage. As shown by the summary in table 23, 50 percent of the wells tested had a dissolved-solids content between 164 and 448 mg/L and provide satisfactory supplies for domestic use. Excessive concentrations of dissolved iron and manganese were found in 55 percent and 70 percent of the wells, respectively.

Table 22.--Geologic names, codes, and number of water-quality sites in the bituminous coal-bearing Conemaugh and Allegheny group rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Allegheny Group	324ALGN	77
Allegheny Group, Kittanning Sandstone	324KNNGS	2
Bakerstown coal, lower	321BKRSL	0
Barton coal	321BRTNC	0
Birmingham red bed	321BMGM	0
Bolivar clay bed	324BLVR	0
Brookville coal	324BKLL	0
Brush Creek coal bed	321BRCKC	1
Allegheny Formation, Butler Sandstone Member	324BTLR	1
Conemaugh Group, Casselman Member	321CSLM	5
Clarysville coal	321CLVLC	0
Clarion Formation	324CLRN	16
Clarion coal, lower	324CLRNL	0
Clarion coal, upper	324CLRNU	0
Allegheny Formation, Clarion Sandstone Member	324CLRNS	2
Clearfield Creek Formation	324CFCK	0
Allegheny Formation, Columbiana Shale Member	324CLMB	0
Conemaugh Formation	321CNMG	50
Conemaugh Formation, Connelsville Sandstone Member	321CLVL	3
Conemaugh Formation, Mahoning Sandstone Member	321MNNG	16
Conemaugh Formation, Mahoning coal	321MNNGC	0
Conemaugh Formation, Mahoning Sandstone Member, lower	321MNNGL	1
Conemaugh Formation, Mahoning Red Bed	321MNNGR	0
Conemaugh Formation, Morgantown Sandstone Member	321MRGN	11
Conemaugh Formation, Mahoning Sandstone, Upper	321MNNGU	2
Conemaugh Formation, Buffalo Sandstone Member	321BFFL	4
Conemaugh Formation, Summerhill Sandstone Member	321SMRL	0
Corinth Sandstone	321CRNT	0
Curwensville Formation	324CRUL	0
Duquesne coal	321DQSN	1
Federal Hill coal	321FDLH	0
Franklin coal	321FRKL	0
Freeport Formation	324FRPR	10
Freeport Sandstone	324FRPRS	3
Conemaugh Formation, Friendsville Shale Member	321FDUL	0
Glenshaw Formation	321GLNS	17
Glen Richey Formation	324GLRC	1
Conemaugh Formation, Grafton Sandstone Member	321GRFN	0
Hoffman coal group	321HFMN	0
Homewood Formation	324HMWD	6
Homewood Sandstone	324HMWDS	16
Kittanning Formation	324KNNG	23

Table 22.--Geologic names, codes, and number of water-quality sites in the bituminous coal-bearing Conemaugh and Allegheny group rock units--(Continued)

Lithologic type	AAPG[1]/Code	No. of Sites
Kittanning Formation, lower	324KNNGL	0
Kittanning Formation, middle	324KNNGM	1
Kittanning Formation, upper	324KNNGN	0
Kittanning coal group, upper	324KNNGA	0
Kittanning coal group, middle	324KNNGB	1
Kittanning coal group, lower	324KNNGC	0
Little Pittsburgh coal	321LPBG	0
Lonaconing coal	321LNCG	0
Meyersdale Red Beds	321MRDL	0
Morgantown coal	321MRGNC	0
Niverton Shale	321NVRN	0
Conemaugh Formation, Saltsburg Sandstone Member	321SLBG	9
Scrubgrass coal	324SCBG	0
Thomas clay	321THMS	0
Thornton clay	321TRNN	0
Conemaugh Formation, Uffington Shale Member	321UFNG	0
Bakerstown coal, upper	321UPBK	0
Washingtonville Formation	324WGVL	0
Conemaugh Formation, Wellersburg coal member	321WLBGC	0
Allegheny Formation, Worthington Sandstone Member, Lower	324WRNGL	1
Allegheny Formation, Worthington Sandstone Member, Upper	324WRNGU	1
Allegheny Formation, Westernport Sandstone Member	324WRPR	0

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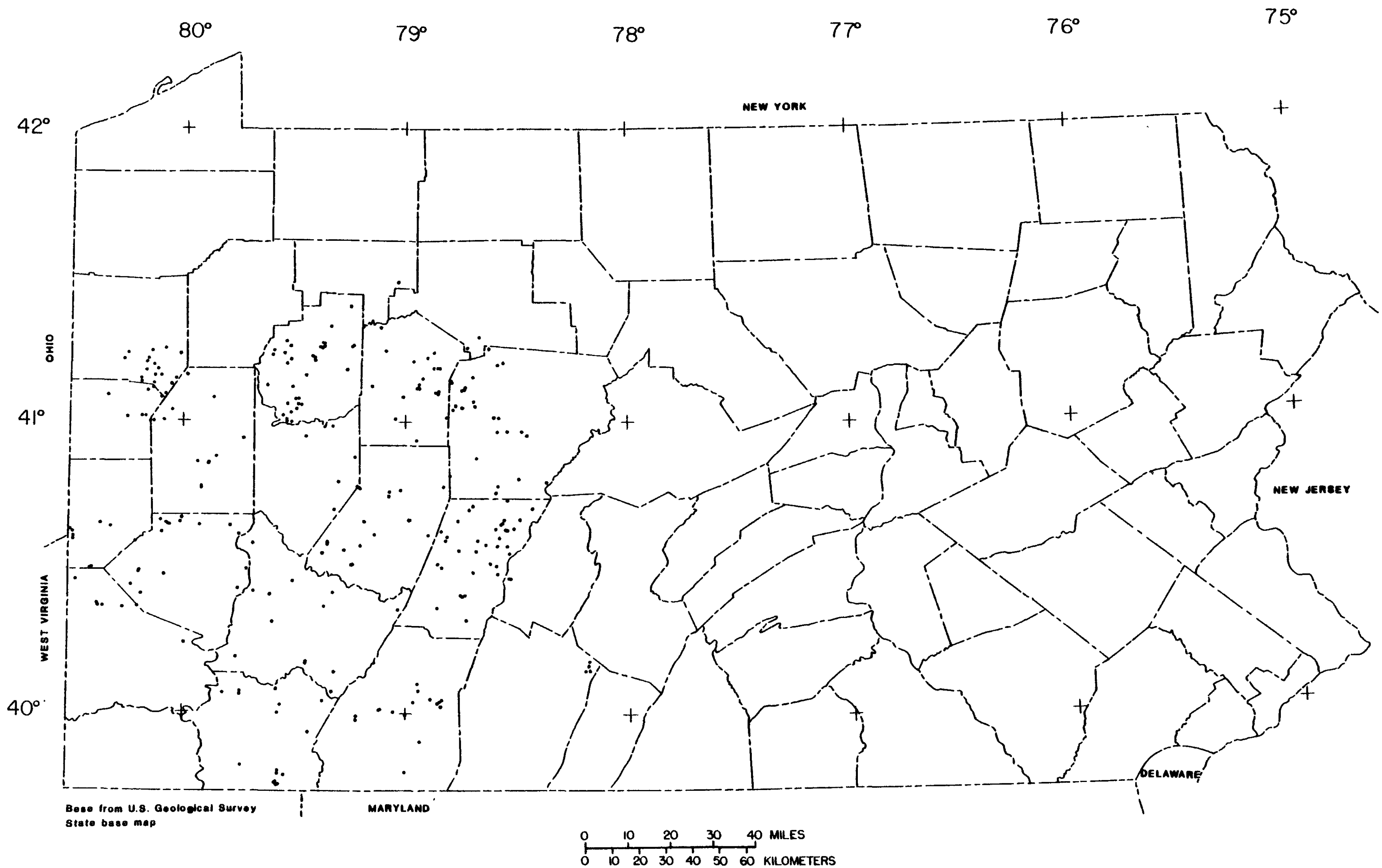

Figure 26.--Location of wells and springs in bituminous coal-bearing Conemaugh and Allegheny Group rock units.

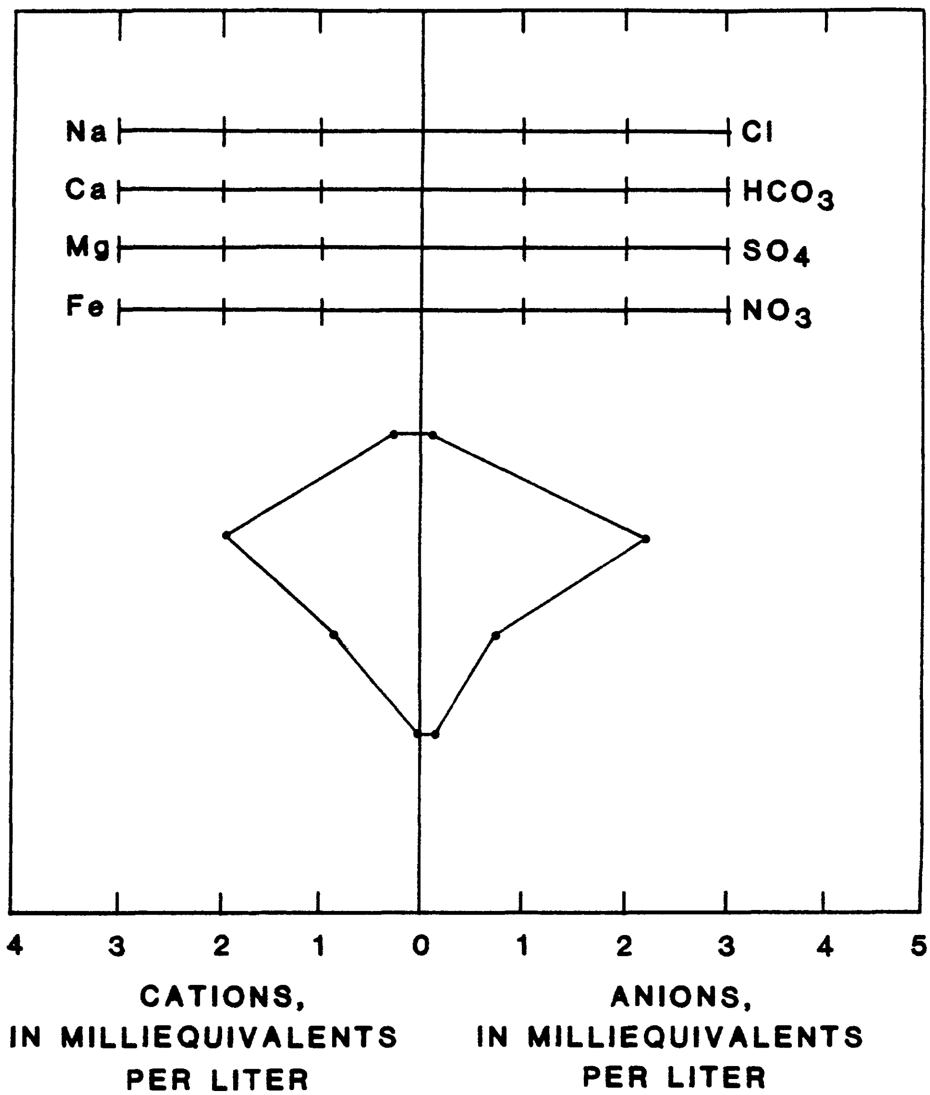

Figure 27.--Median concentrations of selected chemical constituents in bituminous coal-bearing Conemaugh and Alleheny Group rock units.

Table 23.--Summary of chemical quality of ground water in bituminous coal-bearing Conemaugh and Allegheny Group rock units (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	239	105	891	176	75	12
Calcium	186	40	506	63	18	1
Sodium	156	7	3,100	44	4	0
Magnesium	168	11	300	19	6	0
Potassium	154	2	24	3	1	0
Chloride	238	6	4,925	20	2	1
Sulfate	236	22	2,500	78	10	0
Bicarbonate as HCO_3	245	139	862	219	45	0
Nitrate (as NO_3)	199	.8	137	2.1	.2	0
Phosphate, Ortho (as PO_4)	45	.06	1.4	.30	.01	0
pH (units)	180	7.0	8.9	7.5	6.4	4
Alkalinity as $CaCO_3$	248	114	707	180	36	0
Solids, @ 180°C	178	254	9,130	448	164	19
Specific Conductance (micromhos)	171	325	16,000	507	177	31
Iron (µg/L)	256	550	110,000	2,380	160	0
Manganese (µg/L)	181	190	40,000	515	30	0
Copper (µg/L)	25	6	300	40	4	0
Lead (µg/L)	22	5	100	5	2	0
Zinc (µg/L)	50	60	2,000	193	20	0

Bituminous Coal-Bearing Dunkard and Monongahela Group Rock Units

General Features

The Dunkard Group and Monongahela Formation of Permian and Upper Pennsylvanian age, respectively, contain units of shale, sandstone, limestone, and bituminous coal. The units are exposed in southwestern Pennsylvania in Greene, Washington, Westmoreland, and Fayette Counties.

The Dunkard Group contains two subdivisions, the Greene Formation and the underlying Washington Formation. The Greene Formation is about 725 feet thick and yields small supplies of water from bedding planes. The Washington Formation ranges in thickness from 275 to 440 feet and yields up to 65 gal/min.

The Monongahela Formation lies just beneath the Washington and consists of 260 to 400 feet of thin beds of limestone, shale, sandstone and coal that yield up to 25 gal/min but, in general, is not a prominent source of ground water. The Pittsburgh and Waynesburg coals found in this formation are important commercially.

Water Quality

This group consists of 42 geologic units, however, as indicated in table 24, chemical analyses are available for only 13 units. Most of the 81 wells that have been analyzed are in the Greene, Washington, Waynesburg, and Monongahela Formations. Locations of wells in this group are shown in figure 28.

Water quality is diverse, depending upon the source strata. As indicated by the diagram of median concentrations (fig. 29), the waters are moderately high in dissolved solids.

Table 25 summarizes the chemical analyses for the group. Dissolved iron and manganese exceed the EPA drinking-water criteria in 22 and 21 percent of the wells tested, and dissolved solids exceed the criterion in 32 percent of the wells. A number of wells are contaminated with high dissolved solids because of drilling of gas wells.

Table 24.--Geologic names, codes, and number of water-quality sites in bituminous coal-bearing Dunkard and Monongahela Groups rock units

Lithologic type	AAPG[1]/Code	No. of Sites
Ames coal	321AMES	0
Arnoldsburg Sandstone	321ADBG	0
Waynesburg Formation, Cassville Shale Member	317CSVL	0
Dunkard Group	317DKRD	0
Monongahela Formation, Gilboy Sandstone Member	321GLBY	0
Greene Formation	317GREN	17
Jollytown coal	317JLTN	0
Little Washington coal	317LLWG	0
Little Waynesburg coal	321LWBG	0
Monongahela Group	321MNGL	12
Greene Formation, Nineveh Sandstone Member	317NNVHS	1
Pittsburgh Formation	321PBRG	1
Pittsburgh coal	321PBRGC	0
Pittsburgh Formation, Lower	321PBRGL	1
Pittsburgh Formation, Upper	321PBRGU	2
Pittsburgh Red Beds	321PBRGR	0
Pittsburgh Sandstone	321PBRGS	0
Pittsburgh Formation, Fishpot Member	321FSPT	0
Pittsburgh Formation, Fishpot coal	321FSPTC	0
Pittsburgh Formation, Redstone Member	321RDSN	0
Pittsburgh Formation, Redstone coal	321RDSNC	0
Pittsburgh Formation, Sewickley Member	321SCKL	1
Pittsburgh Formation, Sewickley coal	321SCKLC	0
Pittsburgh Formation, Sewickley sandstone	321SCKLS	0
Ten Mile coal	317TNML	0
Uniontown Formation	321UNNN	8
Uniontown coal	321UNNNC	0
Uniontown Formation, lower	321UNNNL	0
Uniontown Formation, upper	321UNNNU	0
Uniontown Sandstone	321UNNNS	0
Washington Formation	317WSNG	17
Washington Formation, lower	317WSNGL	0
Washington Formation, middle	317WSNGM	2
Washington Formation, upper	317WSNGU	0
Washington coal	317WSNGC	0
Waynesburg Formation	317WBRG	7
Waynesburg Formation, lower	317WBRGL	11
Waynesburg Formation, middle	317WBRGM	0
Waynesburg Formation, upper	317WBRGU	1
Waynesburg A coal	317WBRGA	0
Waynesburg B coal	317WBRGB	0

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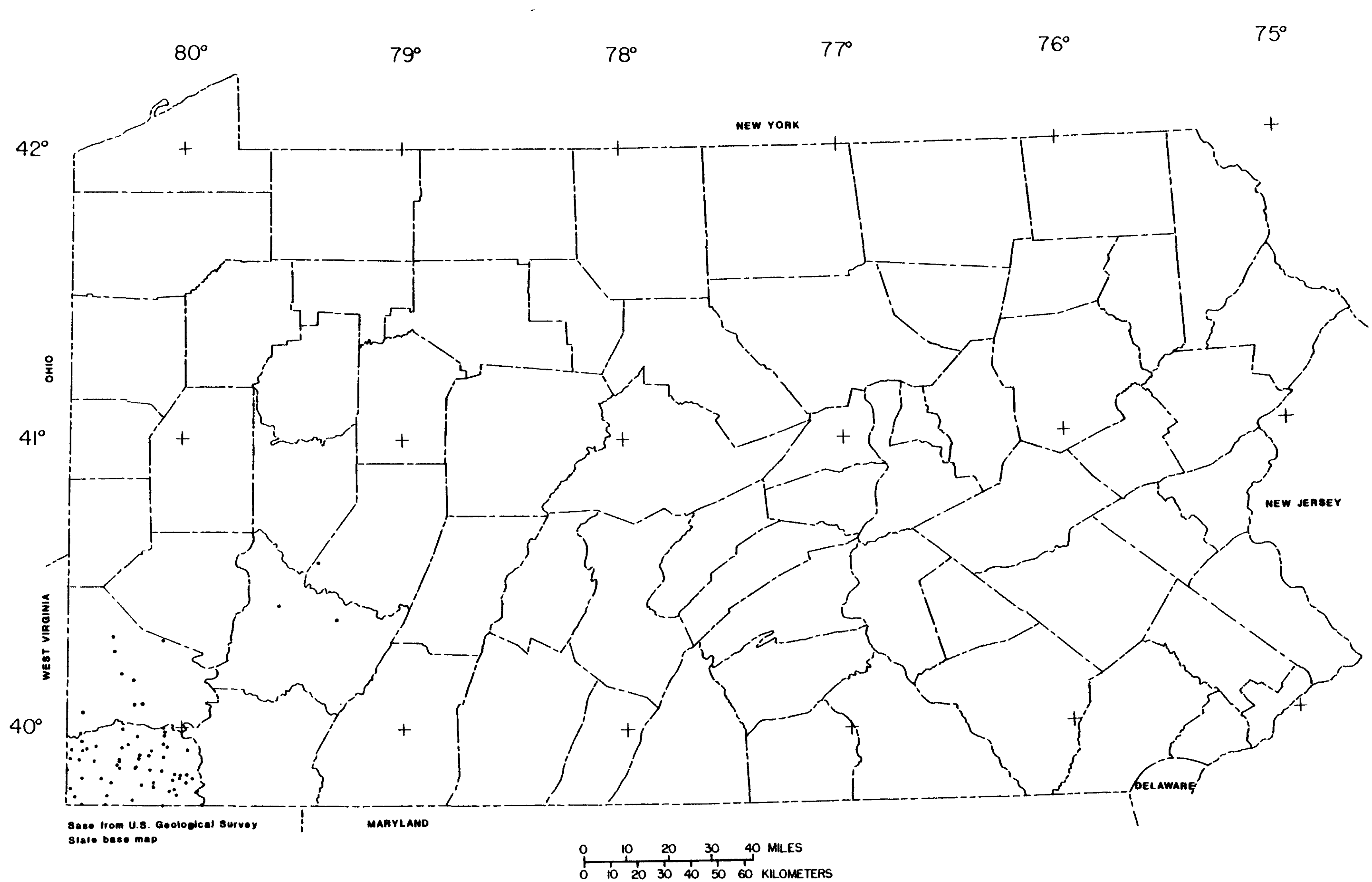

Figure 28.--Location of wells and springs in bituminous coal-bearing Dunkard and Monongahela Group rock units.

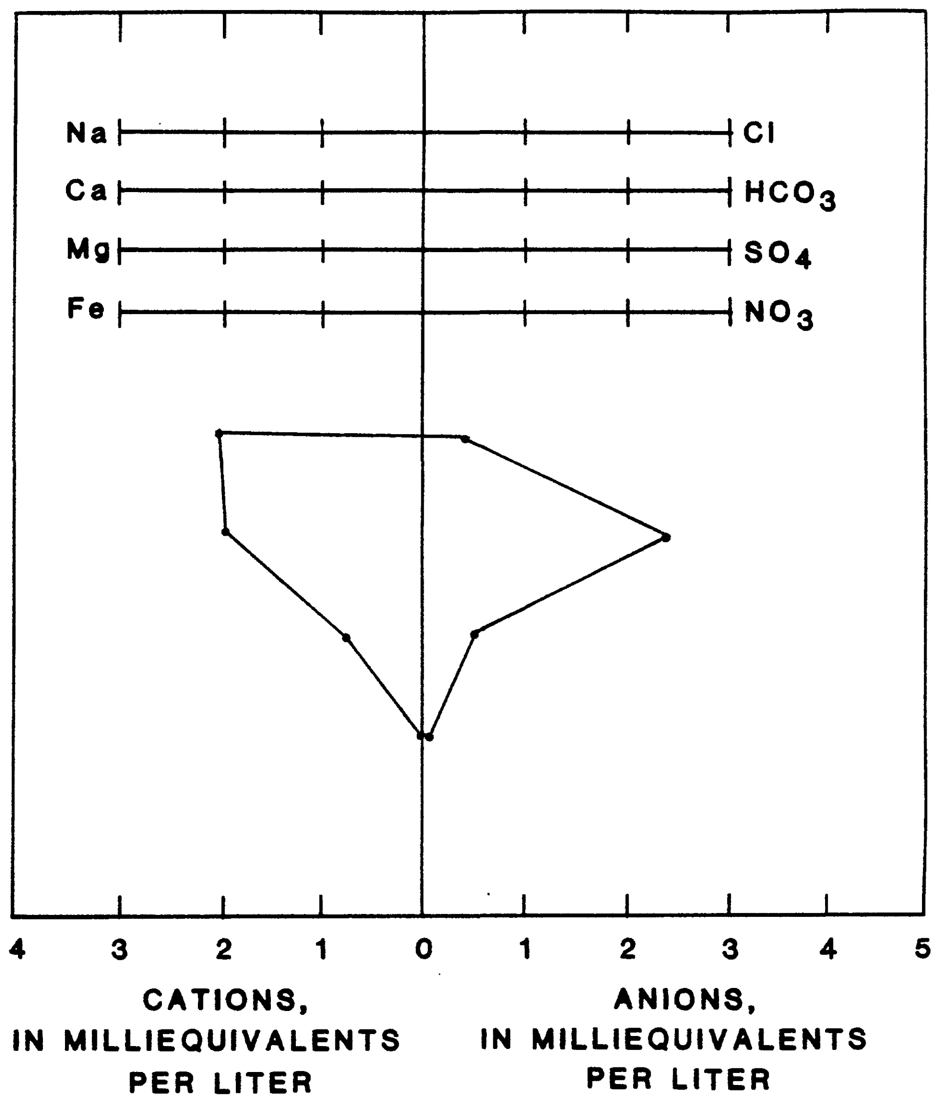

Figure 29.--Median concentrations of selected chemical constituents in bituminous coal-bearing Dunkard and Monongahela Group rock units.

Table 25.--Summary of chemical quality of ground water in bituminous coal-bearing Dunkard and Monongahela Group rock units (Constituents dissolved, except as noted.)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	66	103	630	162	63	13
Calcium	78	40	390	74	22	1
Sodium	76	48	2,700	158	9	3
Magnesium	78	10	370	17	4	.2
Potassium	75	2	17	4	1	0
Chloride	80	13.5	3,700	48	3.9	1
Sulfate	80	35	5,800	59	15	.9
Bicarbonate as HCO_3	77	270	1,000	450	180	0
Nitrate (as NO_3)	19	5.3	97	13	.8	0
Phosphate, Ortho (as PO_4)	32	.09	1.00	.39	.06	.03
pH (units)	65	7.6	9.3	8.2	7.1	2.8
Alkalinity as $CaCO_3$	79	223	830	370	150	0
Solids, @ 180°C	79	377	9,630	530	272	107
Specific Conductance (micromhos)	65	575	11,700	885	423	190
Iron (µg/L)	80	100	270,000	285	20	10
Manganese (µg/L)	65	20	260,000	70	10	1
Copper (µg/L)	14	3	50	11	1	0
Lead (µg/L)	14	1	7	5	0	0
Zinc (µg/L)	14	15	180	33	8	4

Triassic Age Sedimentary Rock Units

General Features

The Triassic sedimentary rock units consist of reddish-brown, interbedded sandstone, siltstone, shale, and some conglomerate. The rock strata occupy a belt from 4 to 32 miles wide that extends from the Delaware River southwest to the Maryland line near Gettysburg. The total thickness of the strata is reported to be about 23,000 feet (Hall, 1934).

The strata consist largely of large blocks bounded by faults that are tilted to the northwest. The primary direction of ground-water flow in the north dipping homocline is along the strike and down dip. High yields and vertical flow between stratigraphic horizons have been reported for wells that intercept faults (Delaware River Basin Commission, 1982).

According to Barksdale (1970), the Triassic aquifers are generally reliable sources of small to moderate (as much as 500 gal/min) quantities of water. Water is stored and transmitted primarily in fractures, inasmuch as the rocks are generally impermeable.

Water Quality

Chemical analyses are available for 449 wells in 9 of the 15 geologic units included in this group. As indicated in table 26, the number of analyses in any one unit ranges from 1 to 144. Most of the analyses are for wells in the Stockton, Gettysburg, Brunswick, and New Oxford Formations. The locations of the wells are shown in figure 30.

A summary of the chemical analyses for the wells developed in this group is presented in table 27. As illustrated by the diagram in figure 31, the water is a calcium-bicarbonate type that is quite diverse in dissolved-solid mineral content. The median dissolved-solids content is 238 mg/L and the range is 23 to 1,340 mg/L. Of the wells analyzed for dissolved iron and manganese, 16 percent had concentrations greater than 300 µg/L and 50 µg/L, respectively.

Manmade contamination of some shallow wells is a problem in rural areas. Nitrate-nitrogen that exceeds the 10 mg/L EPA drinking water criterion is found in about 5 percent of the wells.

Table 26.--Geologic names, codes, and number of water-quality sites in Triassic sedimentary rock units
(Constituents dissolved, except as noted)

Lithologic type	AAPG[1]/Code	No. of Sites
Brunswick Formation	231BRCK	86
Brunswick Formation limestone fanglomerate	231BRCKF	3
Brunswick Formation quartzite fanglomerate	231BRCKQ	14
Gettysburg Shale	231GBRG	93
Gettysburg Shale, Heidlersburg Member	231HDBG	1
Gettysburg Shale, lower member	231GBRGL	0
Gettysburg Shale, upper member	231GBRGU	0
Hammer Creek Formation	231HMCK	13
Lockatong Formation	231LCKG	17
New Oxford Formation	231NOXF	78
Stockton Formation	231SCKN	144
Stockton Formation, lower member	231SCKNL	0
Stockton Formation, upper member	231SCKNU	0
Upper Triassic Series	231TRSCU	0

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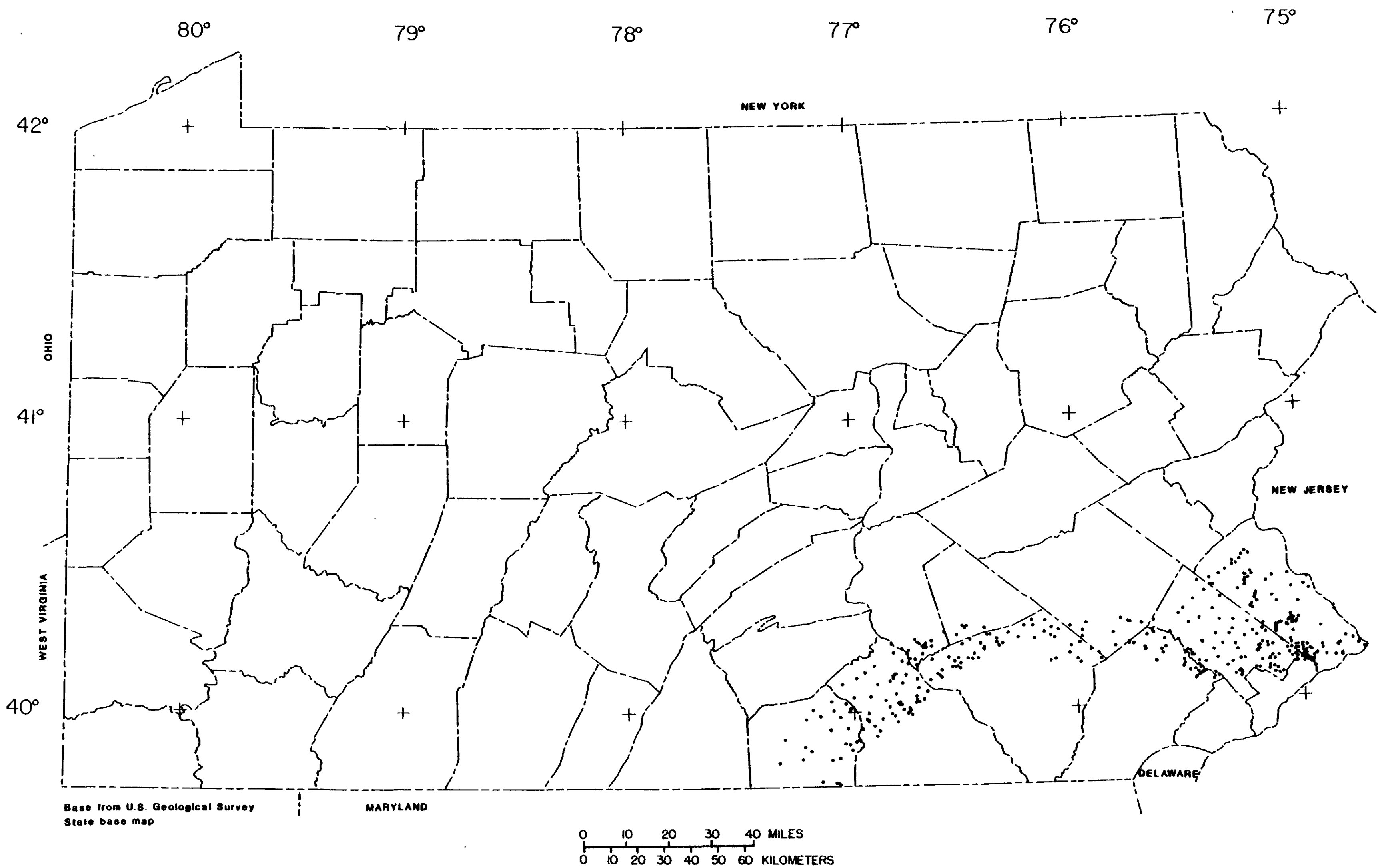

Figure 30.--Location of wells and springs in Triassic sedimentary rock units.

Table 27.--Summary of chemical quality of ground water in Triassic sedimentary rock units
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	389	270	916	401	124	17
Calcium	349	42	252	59	27	.7
Sodium	294	11	161	15	7	0
Magnesium	349	11	79	17	6.5	.6
Potassium	293	1	12	2	1	0
Chloride	433	10	173	17	6	1
Sulfate	420	28	788	51	15	0
Bicarbonate as HCO_3	372	135	384	176	94	5
Nitrate (as NO_3)	421	10	146	19	4	0
Phosphate, Ortho (as PO_4)	167	.06	.92	.18	.03	0
pH (units)	419	7.3	9.6	7.6	6.9	4.4
Alkalinity as $CaCO_3$	398	110	315	143	78	4
Solids, @ 180°C	366	238	1,340	324	177	23
Specific Conductance (micromhos)	318	360	1,660	472	260	47
Iron (μg/L)	429	80	22,000	180	40	0
Manganese (μg/L)	338	10	6,500	40	10	0
Copper (μg/L)	99	20	170	60	5	0
Lead (μg/L)	127	5	350	12	2	0
Zinc (μg/L)	108	50	3,300	160	23	6

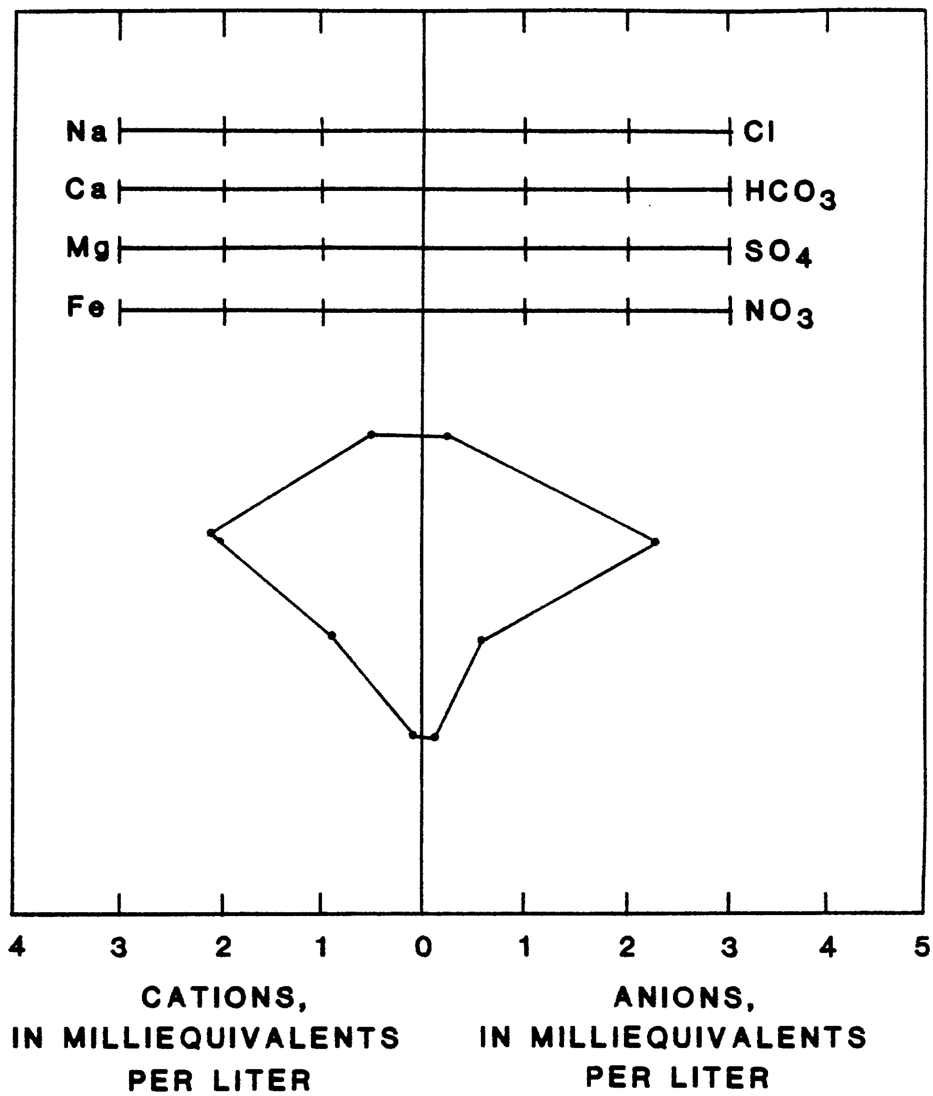

Figure 31.--Median concentrations of selected chemical constituents in Triassic sedimentary rock units.

Unconsolidated Coastal Plain Deposits

General Features

The Coastal Plain deposits and Delaware River gravels are areally limited but are important water-bearing formations of Cretaceous age. The deposits are alternating wedge shaped beds of sand, silt, clay, and gravel that thicken from a feather edge at the landward edge of the Coastal Plain province to about 300 feet beneath Delaware Bay.

The deposits are along the Delaware River from Bucks County to the Delaware State line (fig. 2) in Pennsylvania but are far more extensive along the eastern seaboard. The two aquifers of greatest interest to water users in the Coastal Plain are the Potomac-Raritan-Magothy (PRM) and the Trenton Gravel. The PRM and Trenton gravel aquifers are among the most productive in the State. Wells commonly yield 500 gal/min, and yields of 2,000 gal/min or more have been attained.

Water Quality

Of the 21 geologic units included in this group (table 28), analyses are available for wells developed in only 9 units. Nearly all the data are for the lower sand unit of the PRM aquifer system and Trenton Gravel. The locations of wells in this group are shown in figure 32.

Contamination is common in the Trenton Gravel and PRM aquifers. Increasing contamination due to induced recharge from the Delaware River and leakage from landfills, sewer lines, and industrial spills has placed many additional supplies in jeopardy. High concentrations of iron and manganese are common in water supplies in the Coastal Plain.

A summary of the chemical quality for 157 wells in this group is presented in table 29. The data indicate the water is chiefly a calcium-bicarbonate type that is high in nearly all the major ions. A diagram showing the median concentration of major ions is presented in figure 33.

An example of down-dip migration of contaminants in the PRM aquifer and its effect upon water quality is illustrated in figure 34 by the trends in long-term water-quality data at a well in Philadelphia County (PH-1) (Greenman and others, 1961). The well is at the U.S. Navy Shipyard near the Delaware River and was sampled an average of twice monthly between 1943 and 1957. Beginning in 1947, the concentrations of chloride, sulfate, and total dissolved solids showed increasing trends. By 1957, chloride had increased from 15 to 59 mg/L; sulfate, from 10 to 181 mg/L, and total dissolved solids, from 130 to 559 mg/L.

Table 28.--Geologic names, codes, and number of water-quality sites in unconsolidated Coastal Plain deposits

Lithologic type	AAPG[1]/Code	No. of Sites
Bryn Mawr Gravel	121BRMR	0
Cretaceous System	210CRCS	0
Lower Cretaceous Series	217CRCSL	0
Magothy Formation	211MRPA	0
Magothy-Raritan-Potomac Aquifer System	211MRPA	1
Magothy-Raritan-Potomac Aquifer System, lower sand unit	211MRPAL	78
Magothy-Raritan-Potomac Aquifer System, middle sand unit	211MRPAM	3
Magothy-Raritan-Potomac Aquifer System, upper sand unit	211MRPAU	3
Mesozoic Erathem	200MSZC	0
Patapsco Formation	217PPSC	0
Pensauken Formation	112PNSK	0
Pliocene Series	121PLCN	0
Terrace deposits	112TRRC	0
Tertiary System	120TRTR	0
Trenton Gravel	112TRNN	36
Trenton-Magothy-Raritan-Potomac Aquifer System	112TMRP	36
Upper Cretaceous Series	211CRCSU	0

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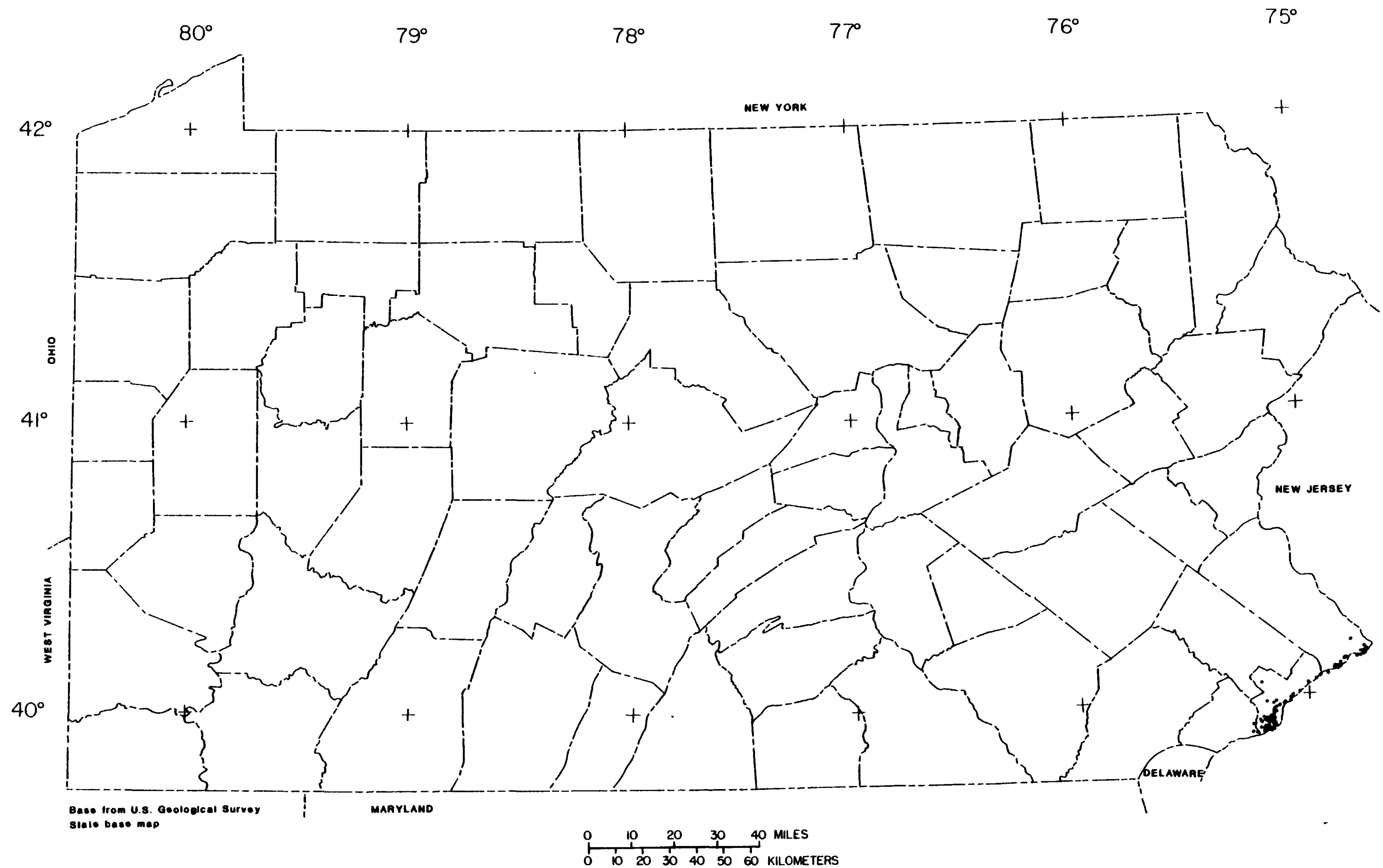

Figure 32.--Location of walls and springs in unconsolidated Coastal Plain deposits.

Table 29.--Summary of chemical quality of ground water in unconsolidated Coastal Plain deposits
(Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	153	81	270	160	50	10
Calcium	123	44	740	60	28	5
Sodium	83	37	420	57	22	3
Magnesium	123	23	195	36	13	2
Potassium	83	5	34	10	3	0
Chloride	148	46	625	77	23	3
Sulfate	152	93	2,200	160	43	1
Bicarbonate as HCO_3	148	141	744	251	58	0
Nitrate (as NO_3)	134	10	173	26	1	0
Phosphate, Ortho (as PO_4)	60	.08	13	.24	0	0
ph (units)	150	6.5	8.2	6.9	6.2	4
Alkalinity as $CaCO_3$	148	116	610	206	48	0
Solids, @ 180°C	123	423	4,480	600	231	77
Specific Conductance (micromhos)	146	700	3,500	950	416	26
Iron (µg/L)	136	1,750	292,000	7,430	190	0
Manganese (µg/L)	106	195	31,000	1,130	10	0
Copper (µg/L)	43	20	480	20	10	2
Lead (µg/L)	33	10	81	11	4	0
Zinc (µg/L)	43	40	4,600	90	10	4

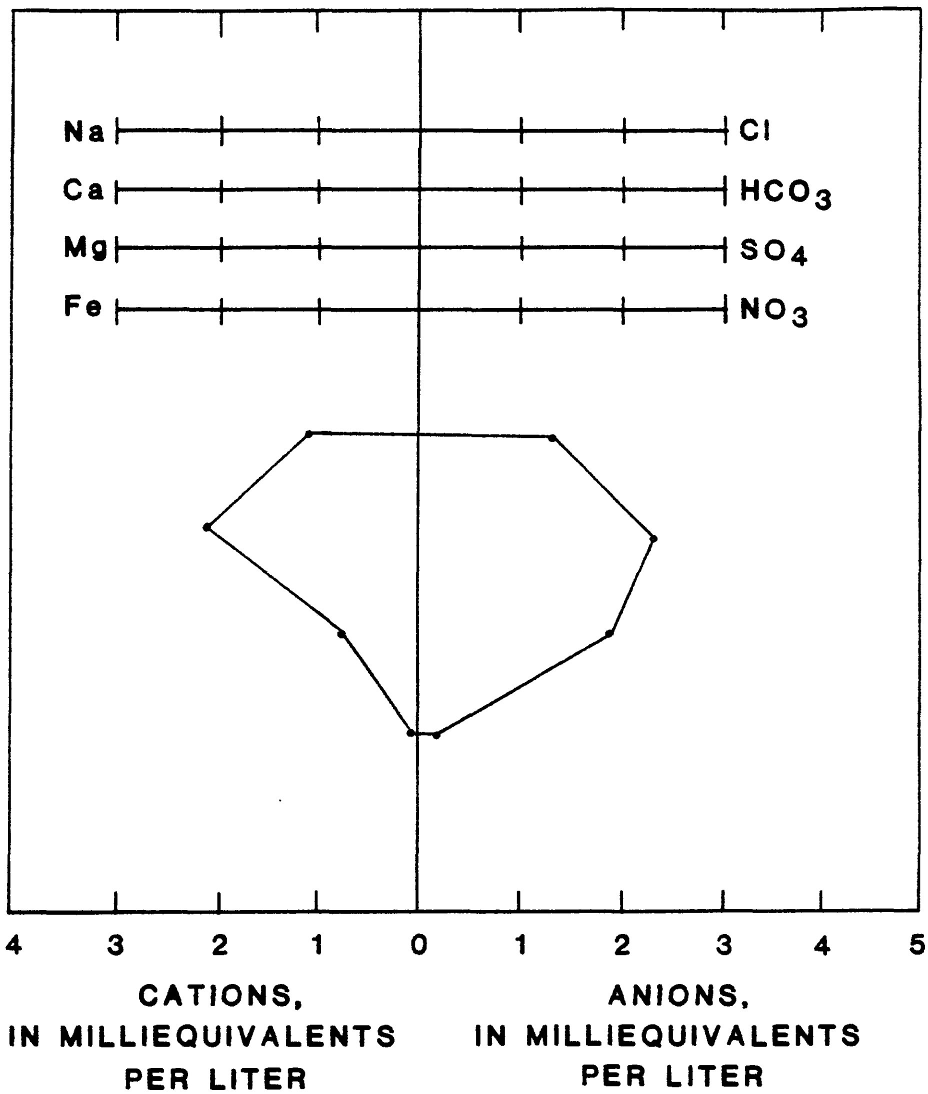

Figure 33.--Median concentrations of selected chemical constituents in unconsolidated Coastal Plain deposits.

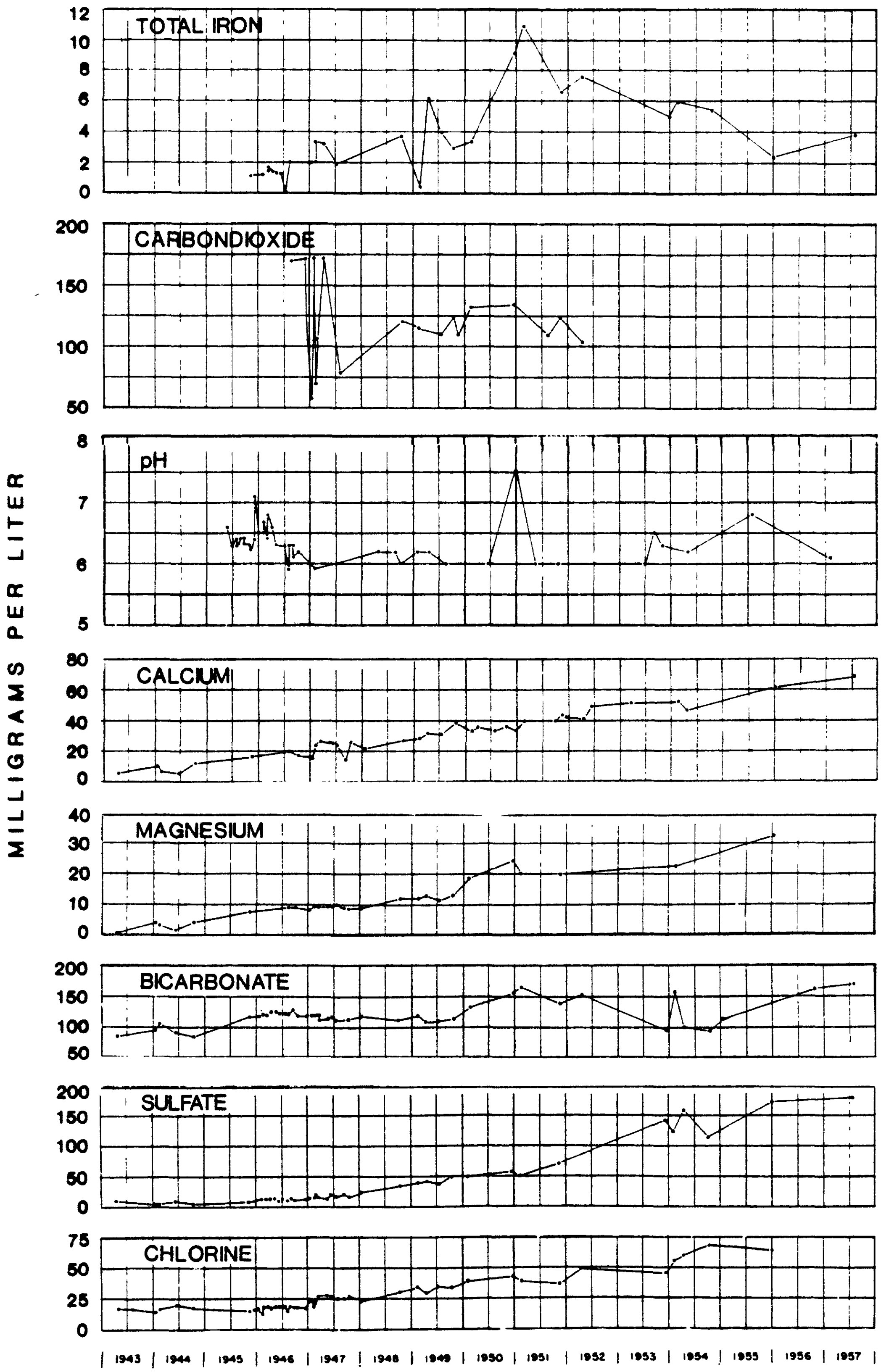

Figure 34.—Temporal variation of chemical constituents in water from well number pH-1 (1943-57). (From Greenman and others, 1961.)

Unconsolidated Glacial and Alluvial Deposits

General Features

Three successive ice sheets, which, in chronological order, were the Jersey, Illinoian, and Wisconsin covered northern Pennsylvania during the Pleistocene. The advancing ice sheets scraped and moved large quantities of soil and decomposed rock. During the retreat of the glaciers, the rock material was left scattered over the surface as a veneer of drift or in mounds known as moraines. The streams that flowed from the melting ice transported large quanties of material that partially filled many of the valleys, as illustrated in figure 35.

The sands and gravels laid down in glacial lakes and streams by the Illinoian and Wisconsin Glaciers are by far the most important water-bearing materials in the State. Yields of 1,000 gal/min are not uncommon, and some yield several thousand gallons per minute with little drawdown.

Water Quality

Twenty-eight geologic units are included in this group. However, as indicated in table 30, water-quality data are available for 479 wells in 15 of the units. Many of the deposits have limited areal extent or are not water-bearing and, therefore, have not been sampled. The locations of the wells are shown in figure 36.

If the locations of wells (fig. 36), with water-quality data are compared to the distribution of glacial deposits (fig. 35), it is obvious that many deposits have not been adequately sampled. Erie County, which was intensively sampled during county-wide studies in the 1950's and again in the late 1970's, is an exception.

Water quality of wells in this group is diverse. As illustrated in figure 37, the water is dominated by ions of calcium and bicarbonate but concentrations of sodium, chloride, magnesium, and sulfate also are high.

The data summarized in table 31 contain considerable evidence that many wells are contaminated with water high in chloride and sulfate, particularly in areas underlain by the Chemung Formation. Approximately 15 percent of the ground-water supplies have water with a specific conductance greater than 700 micromhos and 50 percent of the waters have a dissolved solids concentration in excess of 500 mg/L. About 4 percent of the wells have nitrate-nitrogen concentrations in the water that exceed the EPA drinking water criterion of 10 mg/L. Dissolved iron and manganese can be objectionable in parts of northwestern and north-central Pennsylvania.

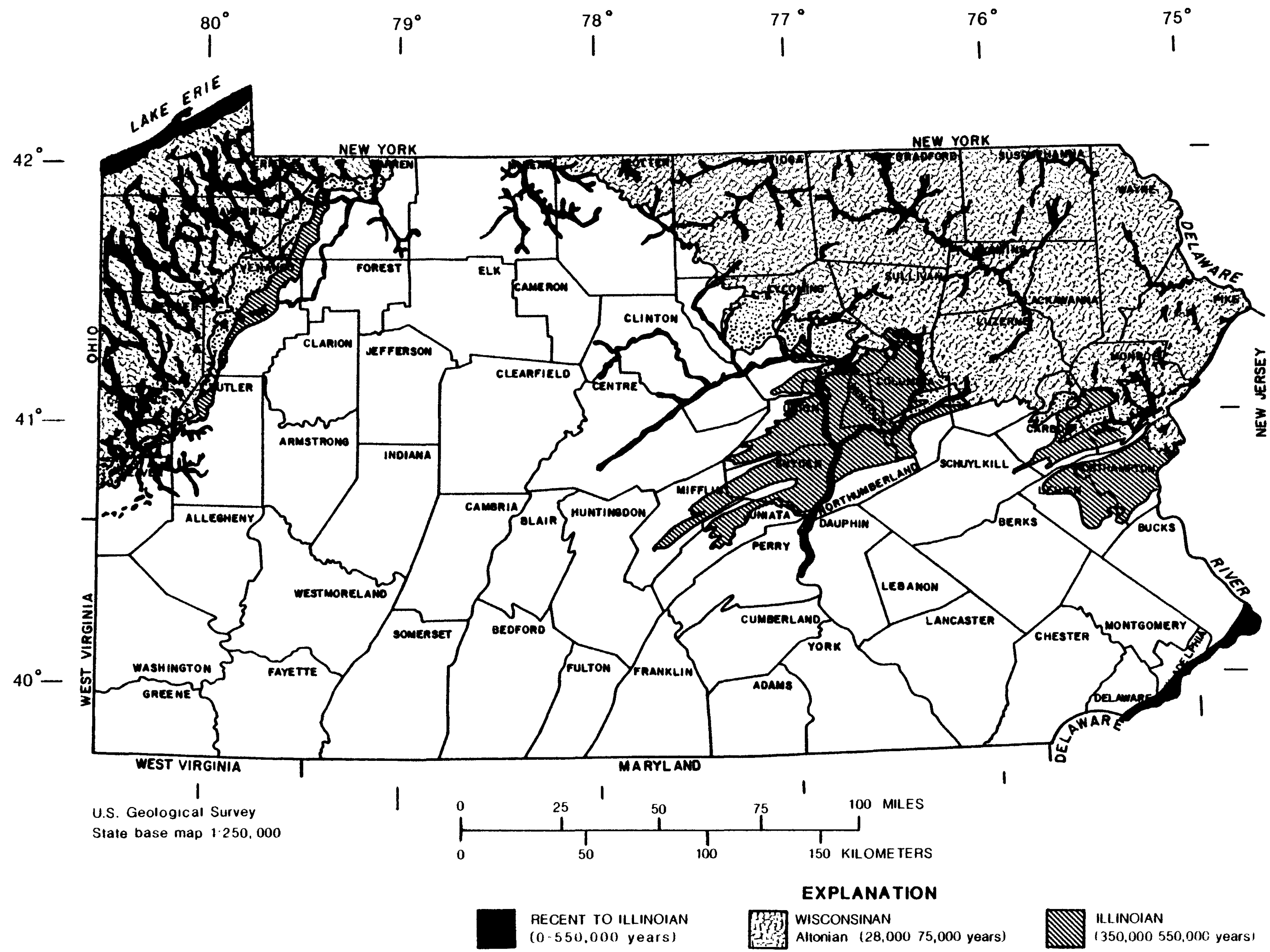

Figure 35 --Glacial deposits of Pennsylvania. (From Pennsylvania Department of Environmental Resources, 1981.)

Table 30.--Geologic names, codes, and number of water-quality sites in unconsolidated glacial and alluvial deposits

Lithologic type	AAPG[1]/Code	No. of Sites
Alluvium	111ALVM	41
Alluvium	112ALVM	30
Beach deposits	110BECH	0
Beach deposits	111BECH	2
Beach deposits	112BECH	63
Carmichaels Formation	112CMCL	3
Cenozoic Erathem	100CNZC	0
Colluvium	111CLVM	12
Drift	112DRFT	30
Drumlins	112DRML	0
Eskers	112ESKR	0
Fill	111FILL	0
Fluvial deposits	112FLVL	1
Holocene Series	111HLCN	0
Ice contact deposits	112ICCC	0
Kame deposits	112KAME	3
Kame terrace deposits	112KMTC	0
Lake deposits	112LAKE	0
Loess	112LOSS	0
Moraine deposits	112MORN	12
Outwash	112OTSH	201
Pleistocene Series	112PLSC	33
Stratified drift	112SFDF	2
Swamp deposits	111SWMP	0
Terminal moraine deposits	112TMLM	0
Terrace deposits	111TRRC	0
Till	112TILL	46

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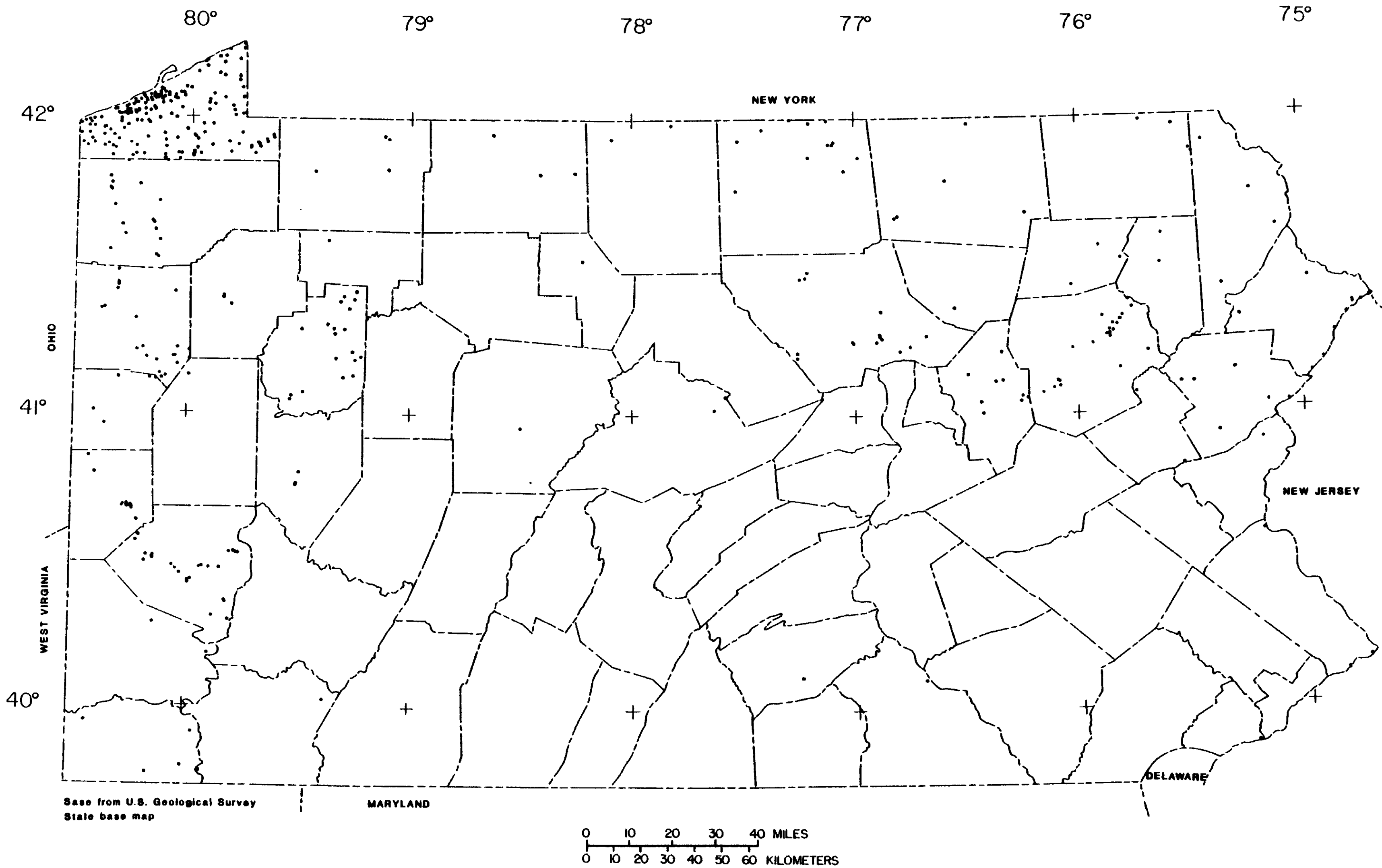

Figure 36.--Location of wells and springs in unconsolidated glacial and alluvial deposits.

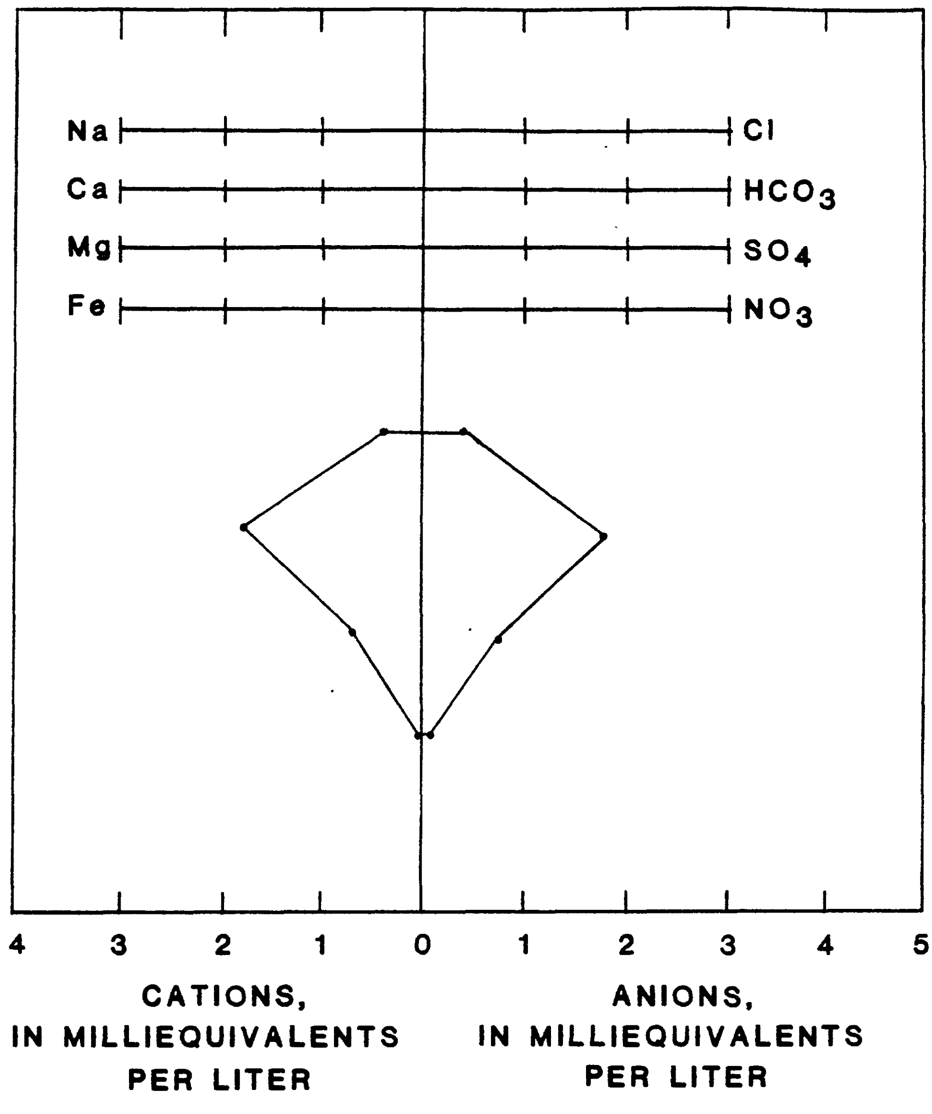

Figure 37.--Median concentrations of selected chemical constituents in unconsolitated glacial and alluvial deposits.

Table 31.--Summary of chemical quality of ground water in unconsolidated glacial and alluvial deposits (Constituents dissolved, except as noted)

Characteristic or property	No. of Wells	Median	Maximum	75th Percentile	25th Percentile	Minimum
		Concentrations in milligrams per liter, except as noted				
Depth of well, feet	432	52	305	75	30	6
Calcium	219	36	180	60	16	1
Sodium	166	10	480	20	4	1
Magnesium	192	8	72	14	4.4	0
Potassium	143	2	49	4	1	0
Chloride	467	15	1,200	37	5	0
Sulfate	301	37	786	80	14	0
Bicarbonate as HCO_3	289	109	392	185	44	0
Nitrate (as NO_3)	280	1.8	71	7.1	.4	0
Phosphate, Ortho (as PO_4)	100	.09	13	2.40	.01	0
pH (units)	286	7.2	9.5	7.6	6.6	3.6
Alkalinity as $CaCO_3$	318	92	610	157	37	1
Solids, @ 180°C	256	255	3,000	387	144	20
Specific Conductance (micromhos)	291	409	4,800	560	280	23
Iron (µg/L)	392	150	30,400	588	60	0
Manganese (µg/L)	208	60	19,000	270	10	0
Copper (µg/L)	63	20	330	50	3	0
Lead (µg/L)	66	5	680	18	2	0
Zinc (µg/L)	68	45	3,600	173	20	0

DATA BASE ADEQUACY

The adequacy of any data base is dependant upon the ultimate use of the data. If the goal is to delineate areas of ground-water contamination, the data is clearly inadequate. If, on the other hand, the goal is to obtain an overview of those areas of generally acceptable or unacceptable water quality, then the data is believed adequate.

As illustrated by the various maps of well and spring locations, the important aquifers in the unconsolidated Coastal Plain deposits, the Triassic sedimentary rocks, the igneous and metamorphic rocks, and most of the carbonate rocks have been extensively sampled. The limited areal coverage of the aquifer groups in the Appalachian Plateaus and Valley and Ridge province is suggestive of an inadequate data base. Long-term data collection for trend analyses is non-existent except for six wells in the Coastal Plain deposits.

The data base is also inadequate for the assessment of organic chemical and microbiological contamination. It has only been recently that ground water has been analyzed for organics and bacteria due to technological problems in sampling and identifying specific forms, and the high cost of analyses.

WATER-QUALITY PROBLEMS

Contamination occurs in all groups of aquifers. The contamination is generally confined to individual wells or springs and does not generally reflect a regional problem. However, areal contamination problems do exist in the Piedmont and Coastal Plain provinces, and in the anthracite fields.

The predominant ground-water quality problems identified to date are naturally occurring high levels of dissolved solids, iron, manganese, and calcium and magnesium hardness. Manmade problems are associated with high levels of nitrate-nitrogen, acid-mine drainage, industrial pollutants, fecal bacteria, and persistant organic chemicals.

Objectionable levels of dissolved solids, due in part to brines, can be found in the deeper wells throughout most of the Appalachian Plateaus province. The brines, which represent connate water in the sedimentary rocks, may be as shallow as 300 feet below ground level. Other areas with high dissolved solids are associated with mine drainage, carbonate waters, and industrial pollutants.

The U.S. Environmental Protection Agency Quality Criteria for Water (1976) recommends a maximum dissolved solids concentration of 500 mg/L. Of the 4,671 wells and springs analyzed 338 exceeded the recommended criteria. The locations of these wells and springs are shown in figure 38. Wells with high dissolved solids are mainly concentrated in Philadelphia County; somewhat smaller concentrations are in Erie, Mercer, Clarion, and Greene Counties.

Levels of dissolved iron responsible for problems with turbidity, taste, and staining of dishes and laundry are found in nearly all aquifer groups. As indicated in table 32, iron is most abundant in waters from the unconsolidated Coastal Plain sediments, anthracite rocks, and bituminous coal-bearing Pottsville Group rocks.

Hardness in natural waters is due primarily to the metallic ions of calcium and magnesium. Although most waters contain some hardness, it is generally only a problem in the carbonate aquifers. Natural sources of calcium and magnesium are limestone and dolomite, which are dissolved by percolating rainwater made acid by dissolved carbon dioxide. The metallic ions form scale in hot water boilers and increase the soap requirements needed for adequate lather.

Nitrate-nitrogen concentrations in ground water that exceed the 1976 EPA drinking-water criterion of 10 mg/L are reported in 183 of the 4,671 wells and springs. As shown in figure 39, nearly all the contaminated waters are in the Great Valley Section of the Valley and Ridge province, the Piedmont province, and the Coastal Plain province due to the highly permeable nature of much of the rock, intensive agricultural, and cultural development.

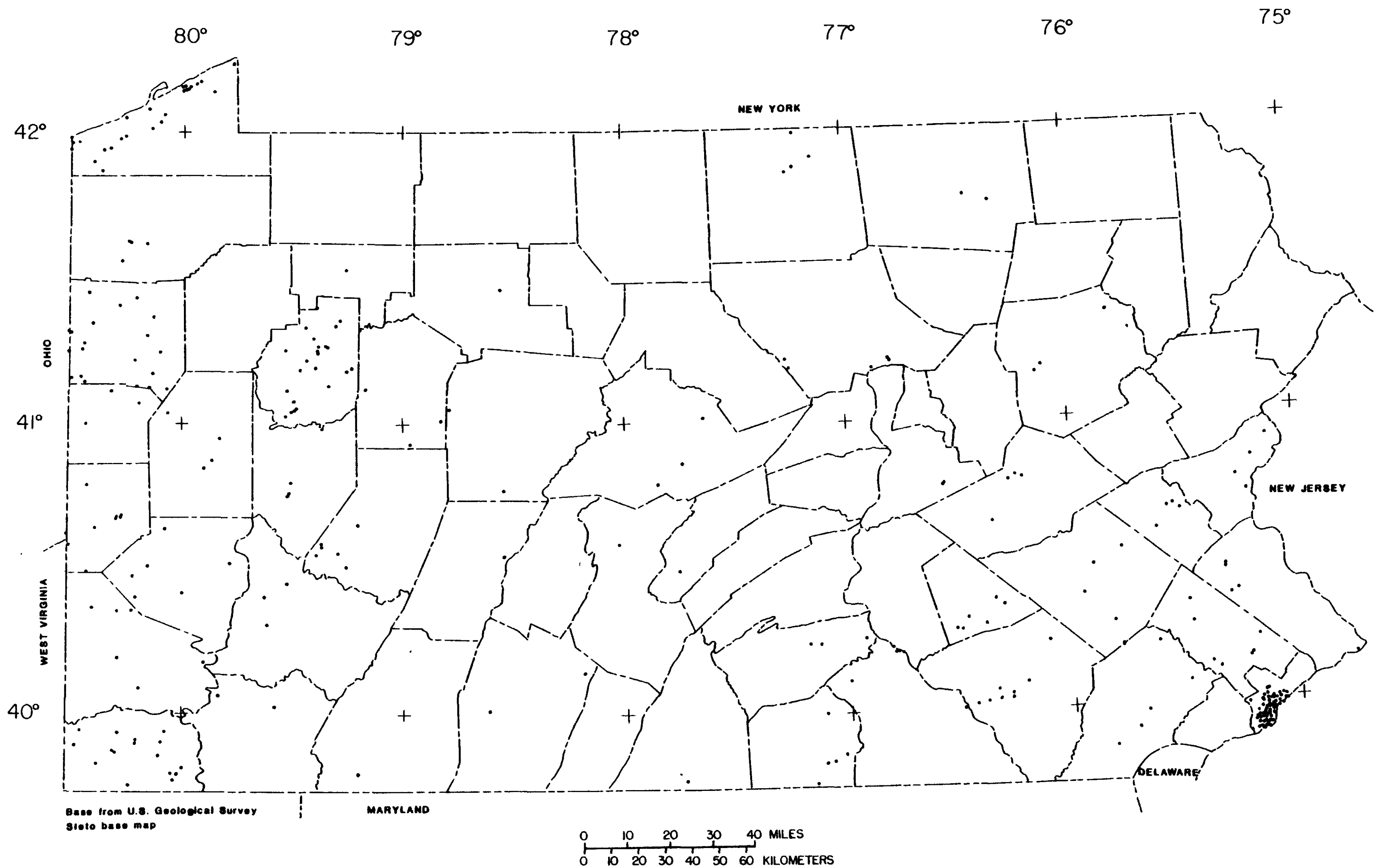

Figure 38.--Location of wells and springs with water containing dissolved solids greater than 500 milligrams per liter.

Table 32.--Summary of median values for selected chemical constituents in aquifer groups

(Concentrations of dissolved constituents in milligrams per liter, except as noted)

Aquifer Group	pH (units)	Specific conductance (µmhos)	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Chloride	Sulfate	Nitrate	Iron (µg/L)
Quartzite, sandstone, and conglomerate rocks	6.5	117	10	2.9	3	1	26	3	8	1.2	120
Igneous and Metamorphic rocks	6.4	211	15	5.8	7	1.3	41	9	15	11	120
Carbonate rocks	7.5	527	70	18	6	2	231	12	28	18	60
Carbonate rocks interbedded w/sandstone or shale	7.4	244	31	7	6	1	124	5	18	1.6	130
Carbonate rocks and calcareous shale w/evaporite minerals	7.3	410	59	18	3	1	193	9	27	7.5	90
Light gray and olive shale, sandstone and siltstone rocks	7.4	348	20	7.5	13	2	167	8	11	.4	160
Dark gray and black shale rocks	7.5	278	30	8	7	1	85	6	30	1.1	145
Devonian and Mississippian rocks	7.2	220	23	4.8	8	1	93	5	10	2	80
Bituminous Pottsville rocks	6.4	274	25	8	4	2	33	5	24	.4	1,500
Anthracite	6.1	317	18	7.6	3.8	1.7	30	5	14	.36	1,350
Conemaugh and Allegheny rocks	7.0	325	40	11	7	2	139	6	22	.8	550
Dunkard and Monongahela rocks	7.6	575	40	10	48	2	270	14	35	5.3	100
Triassic sedimentary rocks	7.3	360	42	11	11	1	135	10	28	10	80
Unconsolidated Coastal Plain deposits	6.5	700	44	23	37	5	141	46	93	10	1,750
Unconsolidated glacial and alluvial deposits	7.2	409	36	8	10	2	109	15	37	1.8	150

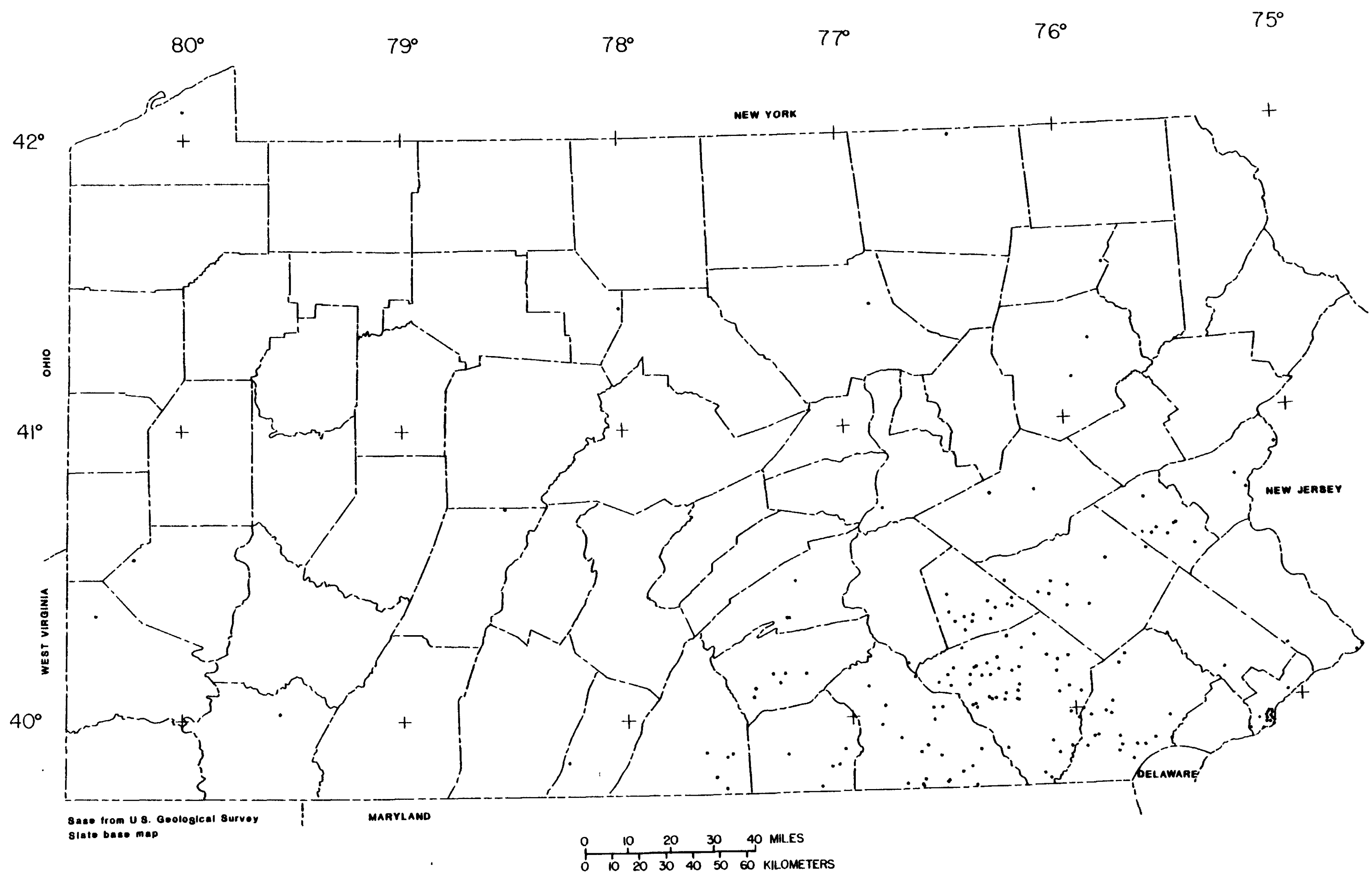

Figure 39.--Location of wells and springs with water containing dissolved nitrate-nitrogen greater than 10 milligrams per liter.

SUMMARY

The chemical quality of ground water in Pennsylvania is as diverse as the rocks and contaminants with which the water comes in contact. The geology of the State is complex. More than 600 geologic units are identified in Pennsylvania; these were sorted into 15 groups based upon similar lithology, age, or physiographic province.

The chemical quality of ground-water data in Pennsylvania was summarized by statistically analyzing the most recent data from 4,671 wells and springs currently in the U. S. Geological Survey Water-Quality file (WATSTORE). The data were analyzed with map plots and statistics.

Each group was characterized with respect to concentrations of major ions, the percentage of wells and springs considered to be contaminated, and the probable sources of contamination. The locations of wells and springs in each group were plotted on a county map. In addition, those wells and springs where concentrations of nitrate-nitrogen or dissolved solids exceed current EPA drinking-water standards were also located.

Approximately 280 of the major units of the more than 600 geologic unit codes are represented by one or more chemical analysis. Most unsampled units are either areally unimportant, the data are included in a more comprehensive unit, or the unit has been renamed.

Based on the map plots, the sampled wells and springs tend to be clustered in the populated valleys of southeastern Pennsylvania and in Erie, Clarion, and Greene counties where hydrologic studies have been done.

Although not tested statistically, the data base is believed adequate and representative of the important aquifers in the unconsolidated Coastal Plain sediments, the Triassic sedimentary rocks, the igneous and metamorphic rocks, and the carbonate rocks. Based upon limited areal coverage, the aquifer groups in the Appalachian Plateaus and Valley and Ridge province are probably inadequately sampled. Long-term data necessary to make trend analyses are inadequate except for the Coastal Plain deposits.

Examples of contaminated ground water can be found in all aquifer groups from either natural or manmade sources. The most prevalent contamination is due to high concentrations of dissolved iron and manganese, sulfate, nitrate, and total dissolved solids.

High concentrations of dissolved iron and manganese are a common problem throughout much of the State but particularly so in the anthracite-bearing rocks and in the unconsolidated Coastal Plain sediments. Dissolved sulfate is a problem that is generally limited to the western bituminous coal fields, northeastern anthracite, and some of the carbonate rocks that contain magnesium sulfate. Dissolved nitrate is generally a problem only in the shallow aquifers in the carbonate rocks, the igneous and metamorphic rocks, and the Coastal Plain sediments of southeastern Pennsylvania. Total dissolved solids commonly exceed 500 mg/L in the Coastal Plain sediments, the glacial deposits of Erie County, the bituminous coal fields of western Pennsylvania, and the carbonate rocks.

SELECTED REFERENCES

Becher, A. E., 1970, Ground Water in Pennsylvania, Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey, Educational Series No. 3, 42 p.

Delaware River Basin Commission, 1982, Basinwide Report and Executive Summary Special Ground-water Study, Delaware River Basin Commission, 147 p.

Dufor, C. N. and Anderson, P. W., 1963, Chemical Quality of Surface Waters in Pennsylvania, U. S. Geological Survey Water-Supply Paper 1619-W, 50 p.

Flippo, H. N., Jr., 1974, Springs of Pennsylvania, Pennsylvania Department of Environmental Resources Water Resources Bulletin No. 10, 46 p.

Gray, C. and others 1960, Geologic Map of Pennsylvania, 3d printing, Pennsylvania Department of Environmental Resources.

Greenman, David W., Rima, Donald R., Lockwood, L. M. N., and Meisler, Harold, 1961, Ground-water Resources of the Coastal Plain Area, Pennsylvania Geological Survey, 4th Series, Bulletin W-13, 375 p.

Hall, G. M., 1934, Ground Water in Southeastern Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-2, 255 p.

Koester, H. E. and Lescinsky, J., 1976, Selected Hydrologic Data, Clarion River and Redbank Creek Basin, Northwestern Pennsylvania — an interim report, U.S. Geological Survey Open-file Report 76-445, 164 p.

Koester, H. E. and Miller, D. R., 1980, Ground-Water Quality and Data on Wells and Springs in Pennsylvania, Vol. I -- Ohio and St. Lawrence River Basins, U.S. Geological Survey Open-file Report 80-1119, 95 p.

---- 1982, Ground-Water Quality and Data on Wells and Springs in Pennsylvania, Vol II — Susquehanna and Potomac River Basin, U.S. Geological Survey Open-file Report 81-329, 131 p.

---- 1982, Ground-Water Quality and Data on Wells and Springs in Pennsylvania, Vol III — Delaware River Basin, U.S. Geological Survey Open-file Report 81-330, 111 p.

Leggette, R. M., 1936, Ground Water in Northwestern Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-3, 215 p.

Lohman, S. W., 1937, Ground Water in Northeastern Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-4, 312 p.

---- 1938, Ground Water in South-central Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-5, 315 p.

---- 1939, Ground Water in North-central Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-6, 219 p.

Luzier, James E., 1980, Digital-simulation and Projection of Head Changes in the Potomac-Raritan-Magothy Aquifer System, Coastal Plain, New Jersey, U.S. Geological Survey Water Resources Investigation Report NTIS 80-11.

Pennsylvania Department of Environmental Resources, 1960, Geological Map of Pennsylvania: Pennsylvania Topographic and Geologic Survey.

---- 1980, Geological Map of Pennsylvania: Pennsylvania Topographic and Geologic survey

Piper, A. M., 1933, Ground Water in Southwestern Pennsylvania, Pennsylvania Geological Survey, 4th Series, Water Resources Report W-1, 406 p.

SAS Users Guide, 1979, SAS Institute Inc., Raleigh, North Carolina, 494 p.

Shope, W. G., Jr., 1982, WATSTORE User's Guide, Appendix, U.S. Geological Survey Open-file Report 75-426.

U. S. Department of Health, Education, and Welfare, 1962, Publication No. 956, p. 48-50.

U. S. Environmental Protection Agency, 1976, Quality Criteria for Water, 256 p.

White, D. E., Hem, J. D., and Waring, G. A., 1963, Data of Geochemistry - Sixth Edition, Chapter F, Chemical Composition of Sub-surface Waters, U.S. Geological Survey Professional Paper 440-F, 67 p.