Hydrogeology and Geochemistry of the Peters Mountain Aquifer, Monroe County, WV

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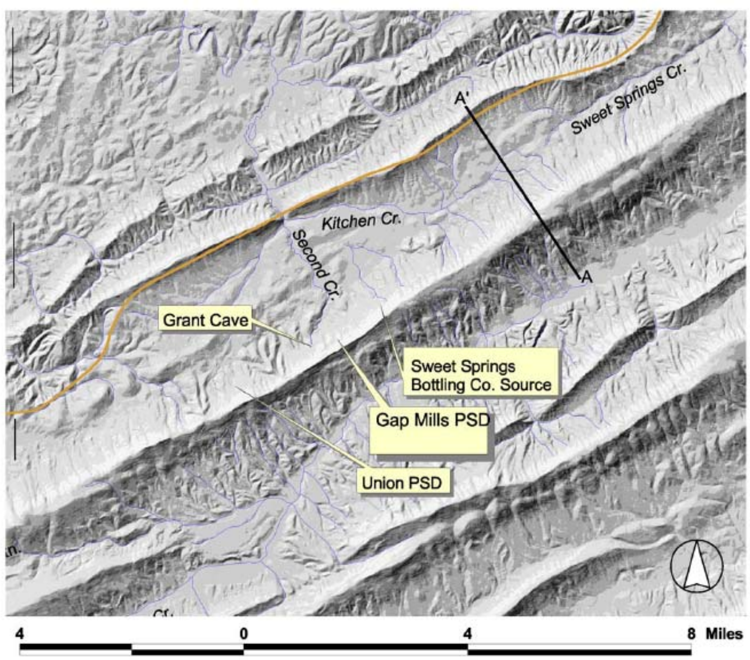
Study Area

The study examined groundwater occurrence in Peters Mountain between the towns of Centennial and Zenith.

Peters Mountain lies on the leading edge of the Allegheny front thrust fault complex and forms the VA-WV border for several miles. The area has abundant groundwater and relatively little current use. The groundwater is very high in chemical quality, supporting a public service district, bottled water company, and local communities. The remote mountain recharge setting means water is relatively pristine and not currently subject to risk of contamination.



Water uses and surface water systems of Peters Mt. near Gap Mills, WV

Purpose

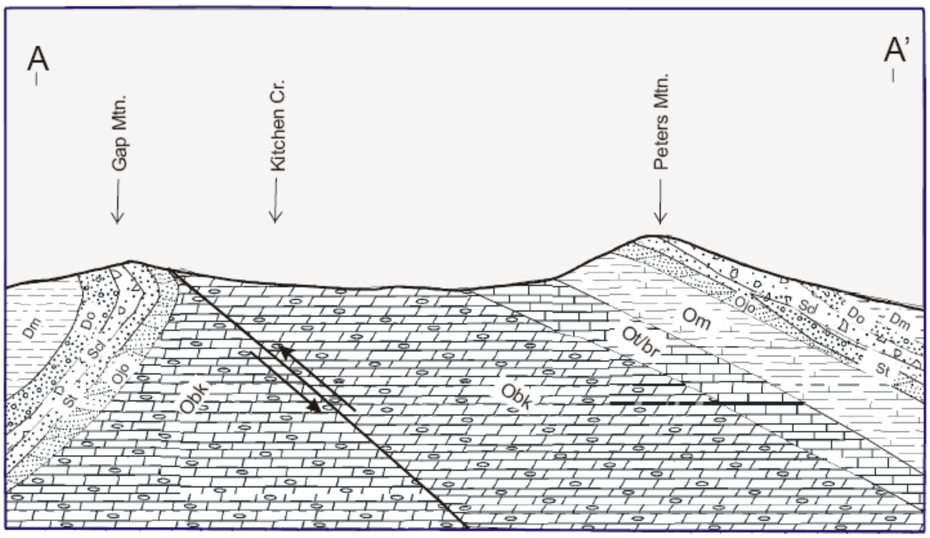
To test the hypothesis that there are systematic differences in groundwater chemistry within a karst flow regime that can be interpreted to reflect the source of aquifer lithology, structure, and stratigraphy.

General Method

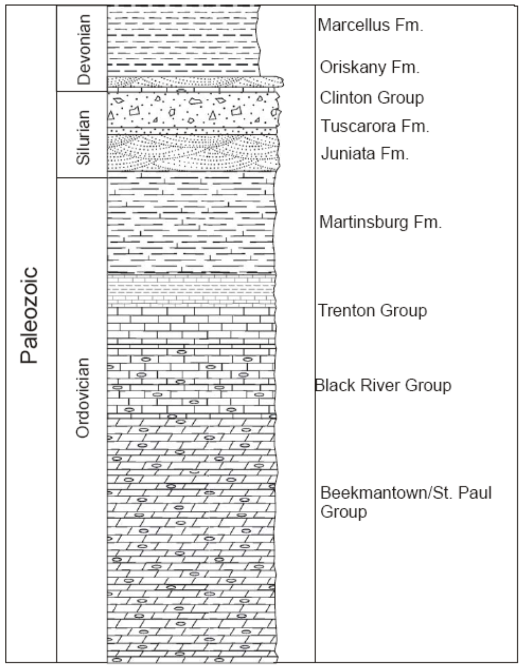
Springs were mapped in the field, and then classified according to surface geology. Springs were also sampled for water chemistry. Statistical analyses were then performed to test the hypothesis.

Objectives

1. Locate and map groundwater discharge points (springs).
2. Delineate major hydrologic zones along Peters Mt.
3. Perform spring reconnaissance and quantify equilibrium geochemistry.
4. Apply statistical analyses to the chemical variables illustrating similarities and differences between aquifer group.
5. Interpret how the variability influences groundwater chemistry.



Geologic cross section of Hanging Rock adapted from Reger (1927).



Columnar section measured near Hanging Rock, Peters Mt. after the description in Reger (1926).

Methodology

Spring reconnaissance and mapping

From May-Aug 2004, 221 springs were located; 76 were measured for pH, temp., and specific conductance. Discharge was estimated.

In July-Aug 2004, samples were collected at 22 springs for analysis of major ion chemistry.

Springs were located and mapped.

Sampling and chemical analysis

Springs were selected for chemical analysis to be representative of 3 main aquifer types in the area. Alkalinity, pH, and spec. conductance were measured in the field. Major ion chemistry was analyzed in Morgantown (NRCCE lab).

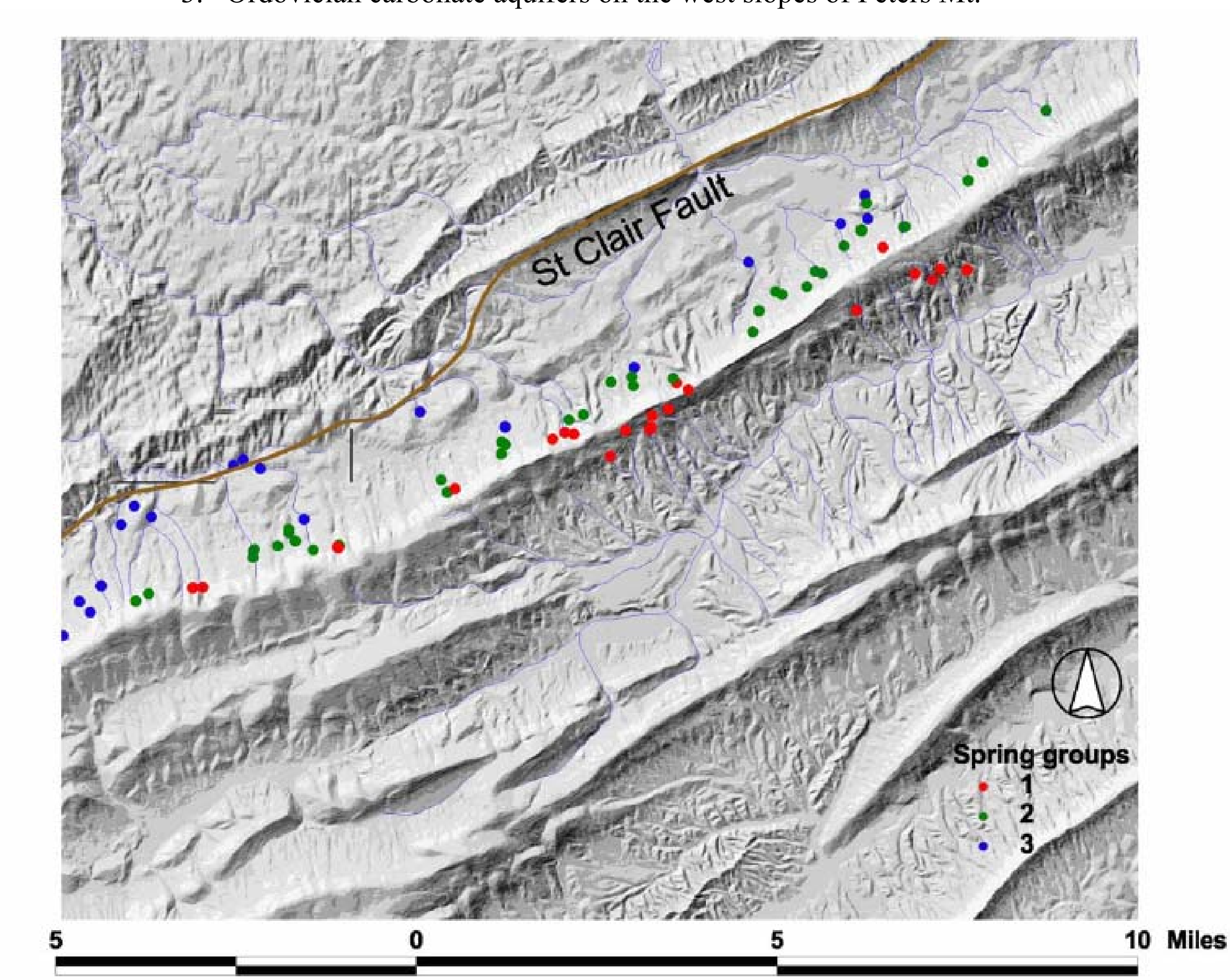
Analysis of results

The equilibrium partial pressure of carbon dioxide and saturation indices with respect to calcite and dolomite was calculated for each water sample. The contrasts in these results were then interpreted to be different aquifer groups. All spring locations and geology were placed in a GIS format. Statistical analyses were then performed to test for significant differences between aquifer groupings.

Outcomes

Springs and seeps within the Second Creek and Indian Creek Watersheds were identified and classified into one of three groups based on surface geology:

1. Silurian/Devonian clastic rocks on the east slopes of Peters Mt.
2. The Martinsburg Fm near the top of Peters Mt.
3. Ordovician carbonate aquifers on the west slopes of Peters Mt.



Spring groups

Group 1: Silurian/Devonian clastic rocks on east slopes of Peters Mt.

Springs occurred all up and down the east side of the mountain. Chemical signatures were similar to regional precipitation. Springs were widely scattered and relatively low in discharge.

Group 2: Martinsburg Fm near top of Peters Mt.

Springs occurred at high elevation. There were significantly higher concentrations of dissolved solids than group 1 which were similar to regional precipitation. Springs were much more frequent, relatively low in discharge, and occur in cluster on upper slopes. These springs are controlled mainly by stratigraphy.

Group 3: Ordovician carbonate aquifers on the west slopes of Peters Mt.

Springs occurred at low elevation. They had significantly higher concentrations of dissolved solids than did group 1 which were similar to regional precipitation. Springs were few in number, widely scattered, and of generally high discharge. These springs are believed to be influenced by conduit zones in the Cambro-Ordovician, possibly in some cases by fault location. Springs are controlled by structure/faulting.

Significance

This study provides a basis for local government and organizations to understand and classify their groundwater resources. Insight is provided into which aquifers yield:

- The most desirable water quality (Group 2)
- The highest quantity of water (Group 3)
- The most vulnerable groundwater to protect from contamination (Group 3)

Interpretations

- Dominant modes of pH are at 5.8 and 7.3; this delineates two basic types of groundwater from Peters Mt:
  - Low-alkalinity waters derived from clastic materials and
  - More strongly alkaline waters derive from aquifers containing carbonate materials

- Dominant modes of specific conductance are 0-50 and 125
  - Waters with low SC (<50 µS/cm) have few dissolved solids
  - Waters with higher SC have Ca or Mg dominating from the dissolution of carbonate minerals.

- Alkalinity… non-normal and negatively skewed
  - Low end represents groundwater flowing thru clastic rock; alkalinity being a function of availability
  - Moderate alkalinities of group 2 springs have source aquifer with calcareous shales and limestones
  - More strongly alkaline waters derive from aquifers with limestone and dolomite

- Ca concentrations are strongest in waters flowing exclusively thru limestones
- Ca concentrations are low in water discharging from clastic rocks
- Mg in groundwater is believed to be dissolution of dolomite
- Only 4 locations have appreciable Mg concentrations of 4x to 10x that of other springs

	Q	pH	SC	Alk	Ca	Mg	Na	K	Si	Cl	SO_4	pCO_2	SI_c	SI_d	elev
Q	1.00	0.18	0.22	-0.17	0.44	0.00	0.40	0.31	0.07	-0.08	0.33	0.17	0.17	0.16	**-0.56**
pH		1.00	**0.65**	0.12	0.19	0.21	0.24	0.41	-0.25	-0.03	0.19	0.01	-0.02	0.03	**-0.40**
SC			1.00	0.31	0.37	0.32	-0.01	0.21	0.06	-0.14	0.04	0.24	0.18	0.22	**-0.60**
Alk				1.00	**0.84**	**0.89**	-0.01	0.56	0.29	-0.09	0.47	**0.82**	0.62	**0.71**	-0.30
Ca					1.00	0.65	0.20	0.32	0.45	-0.05	0.30	**0.75**	**0.77**	**0.81**	-0.42
Mg						1.00	-0.21	0.63	0.09	-0.07	0.52	0.66	0.34	0.47	-0.42
Na							1.00	0.04	0.11	-0.09	-0.08	0.11	0.24	0.20	-0.16
K								1.00	-0.13	-0.06	0.47	0.57	-0.06	0.06	-0.58
Si									1.00	-0.17	-0.16	0.37	0.38	0.35	0.03
Cl										1.00	-0.26	-0.27	0.07	0.04	0.26
SO_4											1.00	0.35	-0.05	0.03	-0.32
pCO_2												1.00	0.49	0.56	-0.60
SI_c													1.00	**0.99**	-0.21
SI_d														1.00	-0.29
Elev															1.00

Correlations matrix for Datasets A and B (a = in red; b = in blue). Values of R exceeding tR (α=75%) are underlined, and those exceeding tR (α=95%) are highlighted in bold and also underlined.

- Notable differences occur in means between the 3 aquifer groups.
- Key differences are:
  - Alkalinity, Ca, Sic and Sid between Groups 1 and 2

- Alkalinity, Ca, Sic, Sid, and PCO2 between Groups 1 and 3
- Differences between Groups 2 and 3 versus Group 1 are due to carbonate dissolution
- Group 1 has no carbonates and is therefore lower in concentrations of the above variables
- Groups 2 and 3 have carbonate minerals that comprise aquifer materials and range from calcareous shales, calcite, and in some parts of Group 3, dolomite

Statistic	Groups	Alk	Ca	Mg	Na	K	Si	Cl	SO_4	Q	pH	SC	logPCO2	SIc	SId
n	1	5	4	4	4	4	4	4	4	22	22	22	2	2	2
n	2	9	9	9	9	9	9	9	9	39	39	39	9	9	9
n	3	12	9	9	9	9	9	9	9	18	18	18	9	9	9
mean	1	7.1	6.7	0.8	0.7	0.8	2.6	0.9	6.6	13.6	5.8	39.3	-2.8	-5.6	-11.5
mean	2	53.7	22.9	1.1	1.0	0.4	3.0	4.0	3.8	10.6	6.9	110	-2.6	-1.1	-3.3
mean	3	114	40.1	12.4	1.1	0.9	3.2	1.5	6.2	32.8	7.1	200	-2.2	-0.7	-1.9
std dev	1	6.35	5.42	0.22	0.31	0.16	0.73	0.02	0.68	21.5	0.85	62.0	0.17	0.03	0.06
std dev	2	8.84	5.68	0.18	0.58	0.18	0.45	9.13	1.69	12.2	0.70	90.7	0.23	0.31	0.51
std dev	3	57.2	9.59	13.0	0.65	0.32	0.67	0.63	4.33	38.4	0.26	113	0.20	0.34	0.99
alpha		0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
df		12	11	11	11	11	11	11	11	59	59	59	9	9	9
df		15	11	11	11	11	11	11	11	38	38	38	9	9	9
df		19	16	16	16	16	16	16	16	55	55	55	16	16	16
t_{obs}	1-2	**5.75**	**2.90**	1.78	0.63	1.82	0.74	0.39	1.90	0.18	1.46	0.87	1.03	**15.18**	**17.09**
t_{obs}	1-3	**2.17**	**3.86**	1.05	0.68	0.65	0.95	1.01	0.12	0.63	**2.05**	1.82	**2.98**	**15.57**	**10.23**
t_{obs}	2-3	1.36	**2.18**	1.23	0.11	1.94	0.45	0.38	0.73	0.94	0.41	0.91	1.70	1.31	1.77
t_{crit}	1-2	2.18	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.00	2.00	2.00	2.26	2.26	2.26
t_{crit}	1-3	2.13	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.02	2.02	2.02	2.26	2.26	2.26
t_{crit}	2-3	2.09	2.12	2.12	2.12	2.12	2.12	2.12	2.12	2.00	2.00	2.00	2.12	2.12	2.12

Parametric statistics and T-test results for Datasets A and B, broken into three groups (Group 1 and 2, Groups 1 and 3, and Groups 2 and 3.

Conclusions

1) Spring discharge on Peters Mt. has unique geochemical signatures related to surface geology at the springs.
2) Hydrochemistry of the groundwater appears to be strongly influenced by local lithology.
3) This results in groundwater that can be identified by the formation from which it discharges regardless of flow paths that may or may not cross lithologic boundaries.
4) Elevation, location, quantity, and chemistry of springs are all a function of structural and stratigraphic influences.
5) Group 1 springs emerge in the Silurian and Devonian clastics on the southern side of Peters Mt.
6) Discharges contain concentrations of dissolved solids and pH that are similar to rainwater, with very minor dissolution of calcite.
7) Group 1 springs may be ephemeral.
8) Group 2 springs discharge from the Ordovician Martinsburg Fm
9) Groundwater on this side of the mountain flows opposite to the direction of dip.

10) Clastic units intercalated with more soluble limestones are thought to produce multiple perched aquifer layers.
11) The groundwater has 2 chemical signatures:
    a) Springs from the clastics of the upper Martinsburg have lower alkalinities and lower concentrations of dissolved solids (similar to group 1)
    b) Groundwater flowing thru these perched aquifer layers commonly sinks and rises along a flow path and may be ephemeral.
12) Springs in the basal Martinsburg have higher alkalinities and solutes are derived almost exclusive from calcite dissolution
13) Group 3 springs discharge from the Ordovician dolomites lower in the valley at the western base of Peters Mt.
14) This aquifer is believed to be dominated by conduits and thought to receive recharge from sinking streams flowing down Peters Mt.
15) The St. Clair fault creates a structural boundary that may limit or preclude groundwater flow and appears to be the western extent of groundwater discharge.
16) Group 3 springs have two chemical signatures
    a) One group of springs flows entirely thru Ordovician limestones and have Ca/Mg. ratios varying from 12-20.
    b) The second group has more unified ratios of Mg to Ca which implies flow-paths are exclusively dolomitic.