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Water Quality and Inorganic Chemistry of Icewater Spring and Mount Le Conte Spring, Great Smoky Mountains National Park, Tennessee and North Carolina

by

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INTRODUCTION

In September 1998, the U. S. Geological Survey sampled waters from Mount Le Conte Spring and Icewater Spring in the Great Smoky Mountains National Park as part of an ongoing study aimed at understanding the geochemical controls on surface water chemistry associated with watersheds underlain by the Anakeesta Formation and related rock units (Seal and coworkers, 1998). The spring samples were collected as samples of regional ground waters for comparison with surface waters from the upper reaches of the West Prong of the Little Pigeon River, Tennessee and the Oconaluftee River, North Carolina. This report compares the inorganic chemistry of these springs to U.S.E.P.A. drinking water standards.

SITE DESCRIPTION

Mount Le Conte spring (35° 39.30′ N; 83° 26.44′W) is located in Tennessee near the crest of Mount Le Conte on the north side of the ridge at the Le Conte Lodge complex. Water was sampled directly from the well. Icewater spring (35° 37.81′N; 83° 23.22′W) is located in North Carolina near the crest of the Great Smoky Mountains on the southeast side of the ridge, approximately 3.9 km northeast of Newfound Gap along the Appalachian trail. Water was sampled from a flowing steel pipe.

GEOLOGICAL SETTING

Icewater and Mount Le Conte springs are typical of high elevation springs along the Appalachian Trail in Great Smoky Mountain National Park. In general, most of these springs have limited recharge areas and they flow from the base of thin colluvial accumulations. Mount Le Conte spring occurs at an elevation of approximately 1914 m (6280 feet) on a north-facing slope 215 m downslope from the ridge crest and about 45 m lower in elevation. The spring is in the center of a mountain hollow that eventually steepens to form the uppermost reach of Roaring Fork. Many of these north-facing hollows may be controlled by cross-joints (fractures) which are approximately perpendicular to erosion-resistant bedrock escarpments. At present, cobbles and boulders of metamorphosed sandstone and siltstone colluvium fill the hollow. The thickness of this material is unknown but in a few places along the trails near the spring, bedrock is exposed suggesting that the colluvium is on the order of 2 m or less thick. Soil in this area is very poorly developed. The spring is on an outcrop slope; bedding dips from 30 to 40 degrees to the southeast and strikes north-northeast. Although bedrock is covered in the area of the spring, the contact between Proterozoic age metamorphosed conglomerate and sandstone of the Thunderhead Sandstone and the metamorphosed siltstone and sandstone of the Anakeesta Formation probably passes close to, if not directly below the spring (Fig. 1). The change in rock type (lithology) at the contact may control the location of the spring. Upslope of the spring, lithologies are of the Anakeesta Formation which consist of light-gray metamorphosed siltstone and very fine-grained sandstone. Rocks of the Anakeesta near the spring are jointed and cleaved. The intersections of joints, cleavage and bedding form a boxlike pattern of fractures in outcrops of the Anakeesta siltstone and fine-grained sandstones upslope of the spring. These planar elements are spaced on the order of less than a meter apart and are probably conduits for groundwater flow. Massive conglomerate of the underlying Thunderhead Sandstone may retard ground water flow and channel it along the formation contact.

Icewater Spring occurs at 1804 m (5920 feet) on a east-facing slope, 245 m downslope and east of the crest of Mount Kephart at 1895 m (6217 feet) in elevation. The spring is on the southern edge of a small mountain hollow, at the contact of bedrock and a small boulder colluvial deposit. The boulders in the colluvium are lacking in finer material and consist of conglomerate of the Thunderhead Sandstone. Bedrock is of the same rock type which is exposed in the bottom of the trail near the spring. Soil is very poorly developed near the spring, both on bedrock and the colluvium. The colluvium is from 2 to about 3 m thick just upslope from the spring. Metamorphosed sandstone, siltstone and shale (slate) of the Thunderhead Sandstone and Anakeesta Formation occur upslope of the spring, and the contact between these formations is close to the spring (Fig. 1). The slope on which the spring occurs transects the north-northeast striking and southeast dipping bedrock. Thus, the bedding planes intersect the slope face and may be responsible, in part, for the location of the spring. Southeast dipping bedding planes up-dip and up-slope may recharge the spring that now flows along a colluvium-bedrock contact.

RESULTS

Analytical methods are summarized in Appendix 1; complete analyses of the springs are presented in Appendix 2. The inorganic chemical composition of both springs is similar. The waters are slightly acidic; pH values range from 5.3 to 5.7. The springs have low total dissolved solids (8.8 to 10.1 mg/L), low alkalinity (0.0 mg/L $CaCO_3$), and low hardness (3.3 to 4.3 mg/L $CaCO_3$). For both springs, calcium is the dominant cationic species and sulfate is the dominant anionic species. The waters are saturated with respect to dissolved oxygen.

Dissolved concentrations of cations in filtered and unfiltered splits of the springs compare favorably. The most significant discrepancy between the filtered (FA) and unfiltered (RA) splits is in the iron concentrations of Mount Le Conte Spring (LCLD-1-3). The unfiltered sample contains 17 µg/L, whereas the filtered sample contains less than 10 µg/L. This difference suggests that some of the iron in the unfiltered water is carried a particulate matter greater than 0.45 µm in diameter. Geochemical modeling of the water chemistry data using the computer program PHREEQC (Pankhurst, 1995) supports this conclusion and indicates the unfiltered concentration (17 µg/L) is supersaturated with respect to amorphous iron (ferric) hydroxide (the water would be at saturation with only 6.3 µg/L iron). Precipitation of ferric hydroxide can play an important role in suppressing the concentration of heavy metals such as copper, lead, zinc, cadmium, and arsenic. Regarding aluminum concentration, the Mount Le Conte Spring is undersaturated with respect to amorphous aluminum hydroxide, but supersaturated with respect other other aluminum-bearing compounds such as gibbsite, diaspore, and kaolinite, among others, all of which are unlikely to precipitate because of sluggish nucleation reactions. Mount Le Conte Spring is unsaturated with respect to all other common inorganic solids.

Geochemical modeling of the inorganic chemistry of Icewater Spring indicates that it is undersaturated with respect to amorphous iron (ferric) hydroxide and aluminum hydroxide, but supersaturated with respect to more crystalline iron (goethite, hematite) and aluminum (gibbsite, diaspore, and kaolinite, among others) that are unlikely to precipitate because of sluggish nucleation reactions. Icewater Spring is unsaturated with respect to all other common inorganic solids.

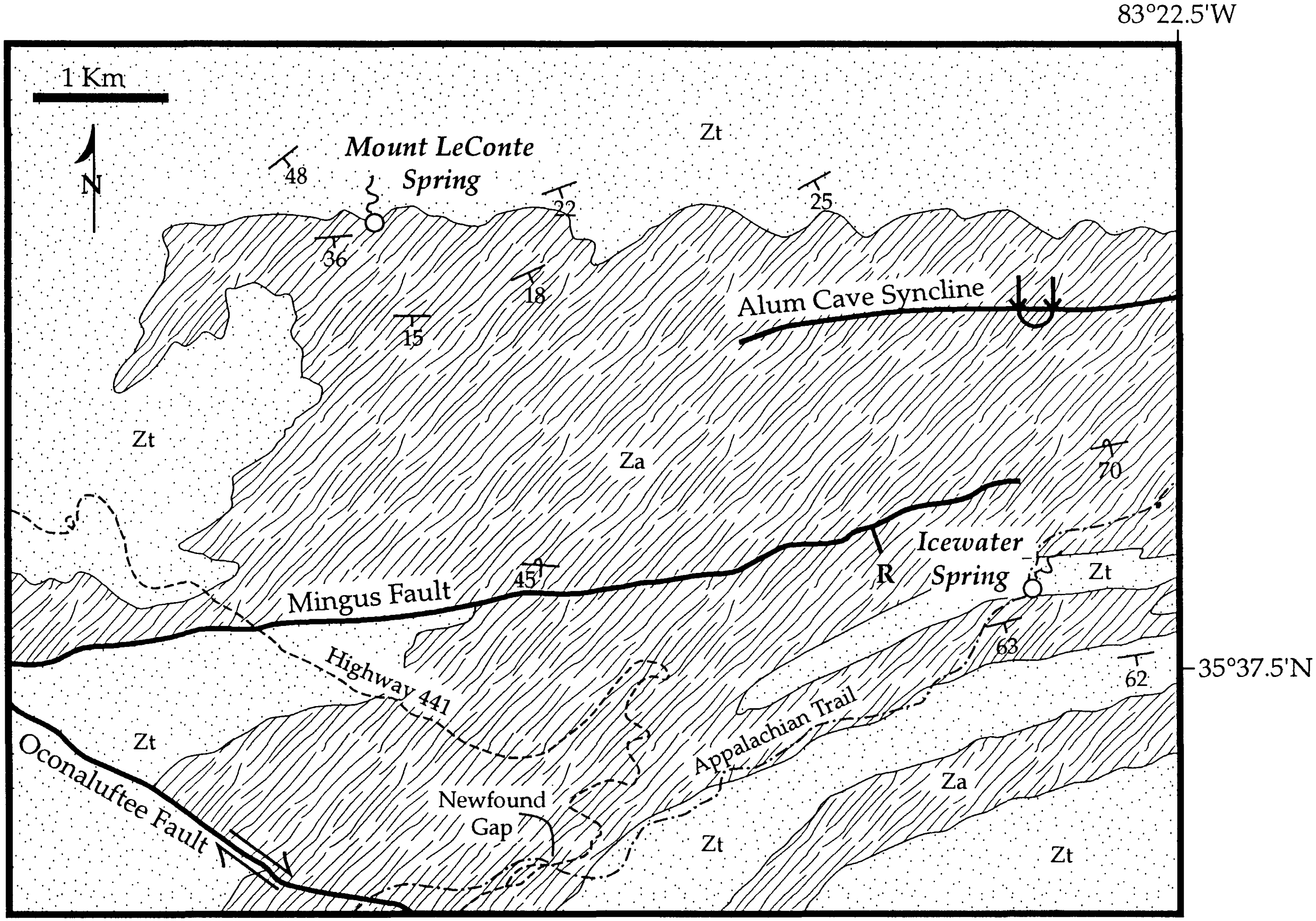

Figure 1. Geologic map showing the location of Mount LeConte and Icewater springs. Both springs are located near the contact of the Proterozoic Anakeesta Formation (Za; wavy pattern) and the Proterozoic Thunderhead Sandstone (Zt; stippled pattern). Modified from Schultz (1998).

COMPARISON WITH DRINKING WATER STANDARDS

The chemical composition of unfiltered samples of Mount Le Conte and Icewater springs are compared to U.S. EPA National Primary Drinking Water Regulations (Maximum Contamination Limits; MCL) in Table 1 and National Secondary Drinking Water Regulations in Table 2. National Primary Drinking Water Regulations are legally enforceable standards that apply to public water systems. National Secondary Drinking Water Regulations are non-enforceable standards that may cause cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, color, or odor) in drinking water. Neither Mount Le Conte Spring nor Icewater Spring exceed or approach the primary standards (MCL) for the compounds analyzed. However, regarding the secondary standards, Icewater spring (pH = 5.3) and Mount Le Conte Spring (pH = 5.7) are below the recommended pH range (6.5 to 8.5). (Note that carbonated drinks typically have a pH around 4 and vinegar has a pH around 2.8). Also, the concentration of aluminum in both springs exceeds the lower secondary guideline (50 µg/L) for aluminum. Aluminum concentrations above the secondary standard cause discoloration of the water. Elevated aluminum concentrations in these springs are consistent with the geochemistry of the aluminous rocks in the aquifer for these springs.

It is important to realize that these data represent a single sampling during the late summer. Variations in rainfall can cause significant variations in water chemistry, particulary for spring with shallow recharge zones.

ACKNOWLEDGMENTS

The cooperation of the National Park Service, especially Carroll Schell and Keith Langdon, was essential in completing this work.

Table 1. Comparison of spring waters to National Primary Drinking Water Regulations

SPRING	**Icewater**	**Mount Le Conte**	**Primary Drinking Water Standard**
Sample	IWSP-1-3	LCLD-1-3	MCL
Collection Date	9/13/1998 Filtered	9/13/1998 Filtered	
Be µg/L	< 0.05	< 0.05	4
Cr µg/L	< 1	< 1	100
Cu µg/L	< 0.5	3	1300
As µg/L	< 0.2	< 0.2	50
Se µg/L	< 0.2	< 0.2	50
Cd µg/L	< 0.02	< 0.02	5
Sb µg/L	0.04	0.02	6
Ba µg/L	16	7.8	2000
Tl µg/L	< 0.05	< 0.05	2
Pb µg/L	< 0.05	< 0.05	15

Table 2. Comparison of spring waters to National Secondary Drinking Water Regulations

SPRING	**Icewater**	**Mount Le Conte**	**Secondary Drinking Water Standard**
Sample	IWSP-1-3	LCLD-1-3	
Collection Date	9/13/1998 Filtered	9/13/1998 Filtered	
pH	5.3	5.7	6.5 - 8.5
Total Dissolved Solids mg/L	8.8	10.1	500
SO_4 mg/L	1.7	1	250
Cl mg/L	0.3	0.5	250
Al µg/L	130	70	50 - 200
Mn µg/L	17	20	50
Fe µg/L	15	< 10	300
Zn µg/L	3	28	5000
Ag µg/L	< 0.01	< 0.01	100

REFERENCES

Parkhurt, D.L., 1995, User's guide to PHREEQC - a computer program for speciation, reaction-path, advective-transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 95-4277, 142 p.

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APPENDIX 1: FIELD AND ANALYTICAL METHODS

Water samples were collected in one-liter high-density polyethylene bottles that were doubly-rinsed with sample water prior to collection. Samples were divided into four splits for chemical analysis: two for cation analysis, one for anion analysis, and one for alkalinity determination. The cations splits included filtered (dissolved) and unfiltered (total acid soluble) aliquots. Samples were filtered through 0.45 μm nitrocellulose filters. Cation splits were stored at ambient temperature in acid-washed (10 % HCl) high-density polyethylene bottles and preserved with 1 drop of ultra-pure nitric acid per each 10 ml of sample. Anion and alkalinity splits were stored high-density polyethylene bottles that were not acid-washed and were refrigerated until the time that they were analyzed.

On-site measurements at the time of collection included air temperature, water temperature, pH, specific conductance, and dissolved oxygen. The pH was measured using an Orion 230A pH meter with a 91-07probe, calibrated with pH = 4.00 and 7.00 buffer solutions. Specific conductance was measured with an Orion 135 specific conductance meter. Dissolved oxygen concentrations were determined with Chemetrix high-range ampoules. Alkalinity samples were analyzed by Gran titration with 0.18 N H_2SO_4:

Cations were analyzed at U.S. Geological Survey (Central Mineral Resources Team) laboratories in Denver, CO by inductively-coupled plasma mass spectrometry (ICP-MS). Anions were analyzed at U.S. Geological Survey (Water Resources Division) laboratories in Ocala, FL by ion chromatography.

APPENDIX 2: WATER-QUALITY DATA

Sample	**IWSP-1-3 Unfiltered**	**IWSP-1-3 Filtered**	**LCLD-1-3 Unfiltered**	**LCLD-1-3 Filtered**
Collection Date	9/13/1998	9/13/1998	9/13/1998	9/13/1998
T °C	10.6	10.6	12.9	12.9
Dissolved Oxygen mg/L	7.0	7.0	7.0	7.0
pH	5.3	5.3	5.7	5.7
Conductivity µS/cm	13.6	13.6	15.5	15.5
Total Dissolved Solids mg/L	8.8	8.8	10.1	10.1
Hardness $CaCO_3$ mg/L		3.3		4.3
Alkalinity $CaCO_3$ mg/L		0		0
SO_4 mg/L		1.7		1
Cl mg/L		0.3		0.5
Li µg/L	0.7	0.7	0.8	0.8
Be µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Na mg/L	0.53	0.51	0.21	0.23
Mg mg/L	0.27	0.26	0.32	0.32
Al µg/L	140	130	110	70
SiO_2 mg/L	3	3	1	1
K µg/L	100	98	64	61
Ca mg/L	0.87	0.84	1.2	1.2
Sc µg/L	0.2	0.2	0.2	< 0.1
Ti µg/L	< 0.1	< 0.1	< 0.1	< 0.1
V µg/L	< 0.1	< 0.1	< 0.1	< 0.1
Cr µg/L	< 1	< 1	< 1	< 1
Mn µg/L	16	17	22	20
Fe µg/L	12	15	17	< 10
Co µg/L	0.2	0.2	0.3	0.3
Ni µg/L	0.2	0.3	0.6	0.6
Cu µg/L	< 0.5	< 0.5	3	3
Zn µg/L	2	3	31	28
Ga µg/L	< 0.02	< 0.02	< 0.02	< 0.02
Ge µg/L	< 0.02	< 0.02	< 0.02	< 0.02
As µg/L	< 0.2	< 0.2	< 0.2	< 0.2
Se µg/L	< 0.2	< 0.2	< 0.2	< 0.2
Rb µg/L	0.76	0.77	0.3	0.3
Sr µg/L	7.3	7.4	3.2	3.2
Y µg/L	0.3	0.3	0.1	0.1
Zr µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Nb µg/L	< 0.02	< 0.02	< 0.02	< 0.02
Mo µg/L	0.08	0.07	0.03	0.03
Ag µg/L	< 0.01	< 0.01	< 0.01	< 0.01
Cd µg/L	< 0.02	< 0.02	< 0.02	< 0.02
In µg/L	< 0.01	< 0.01	< 0.01	< 0.01

Sample	IWSP-1-3 Unfiltered	IWSP-1-3 Filtered	LCLD-1-3 Unfiltered	LCLD-1-3 Filtered
Sn µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Sb µg/L	< 0.02	0.04	< 0.02	0.02
Te µg/L	< 2	< 2	< 2	< 2
Cs µg/L	< 0.01	< 0.01	< 0.01	< 0.01
Ba µg/L	15	16	6.4	7.8
La µg/L	0.51	0.51	0.2	0.2
Ce µg/L	0.4	0.4	0.65	0.4
Pr µg/L	0.2	0.2	0.07	0.07
Nd µg/L	0.69	0.64	0.29	0.28
Sm µg/L	0.1	0.1	0.05	0.06
Eu µg/L	0.03	0.03	0.009	0.006
Tb µg/L	0.01	0.01	0.007	0.005
Gd µg/L	0.11	0.096	0.053	0.051
Dy µg/L	0.067	0.080	0.04	0.03
Ho µg/L	0.01	0.008	0.005	0.008
Er µg/L	0.03	0.02	0.02	0.01
Tm µg/L	< 0.005	< 0.005	< 0.005	< 0.005
Yb µg/L	0.03	0.02	0.01	0.01
Hf µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Ta µg/L	< 0.02	< 0.02	< 0.02	< 0.02
W µg/L	< 0.02	0.02	< 0.02	< 0.02
Re µg/L	< 0.02	< 0.02	< 0.02	< 0.02
Au µg/L	< 0.01	< 0.01	< 0.01	< 0.01
Tl µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Pb µg/L	< 0.05	< 0.05	< 0.05	< 0.05
Bi µg/L	< 0.01	< 0.01	< 0.01	< 0.01
Th µg/L	< 0.005	< 0.005	< 0.005	< 0.005
U µg/L	< 0.005	< 0.005	< 0.005	< 0.005