Water Chemistry Manitou Springs Group Project

- hands on applied hydrogeochemistry project lab -

"MANITOU SPRINGS HYDROGEOCHEMISTRY" COURSE GROUP FIELD PROJECT

Maximal 4 group members - Everyone in the group will receive the SAME grade:

Group Member 1 Name:	Contact Info:
	Job Summary:
Group Member 2 Name:	Contact Info:
	Job Summary:
Group Member 3 Name:	Contact Info:
	Job Summary:
Group Member 4 Name:	Contact Info:
	Job Summary:
Overall Grade for Each Group Member	**FINAL GRADE /150**

/30 COMPOSITION & LAYOUT

The REPORT is neat, orderly, and professional. Title page mentions Name, Assignment Name, Course, and Date. Page with group member names and their project contributions is inserted after the title page. Pages are consecutively numbered and carry short title header on each page. The REPORT is typed, and graphics and data are electronically prepared and analyzed. Graphics and data are placed in a coherent form. At least 5 proper formatted citations are included.

30 pts - Everything present and of professional quality 25 pts - One report aspect poor or missing 20 pts - Two report aspects poor or missing
15 pts - Three report aspect poor or missing, generally subpar quality 10 pts - Four report aspect poor or missing, generally subpar quality
5 pts - Five or more report aspect poor or missing, generally subpar quality 0 pts - Missing

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/40 WRITING & GRAMMAR - one or multiple point deduction per infraction

Spelling and grammar are correct. Word repetition and use of first person language is avoided. Appropriate and complete language becoming to a professional report is used. Subscripts and superscripts are appropriately used.

/40 EXECUTION, DATA COLLECTION, INTERPRETATION

Appropriate procedural execution of the REPORT is evident from the writing and data. Procedural overview is given. Statements / graphics / charts / tables are factually correct. Units and significant digits are correct. Controls are used whenever possible - data integrity is verified through error calculations. Any inconsistencies are mentioned and adequately explained. Equations used or developed are adequately explicated. Conclusions / discussions follow the evidence and the data matches the conclusions in all aspects.

/40 GRAPHICS, ILLUSTRATIONS, TABLES

Graphical representations and analytical results are appropriate and complete according to the project description. All figures / data tables are captioned. Caption adequately explains graphic / table. All illustrations are electronically prepared. Pictures are clear, of high quality, and with neutral background. Graphs should have a title with appropriate axis and unit labels. Graphic fonts and labels are easily readable. Citation of any source used be included in the caption. Graphics are of adequate size for viewing.

Grading Scale for EXECUTION, DATA COLLECTION, INTERPRETATION & GRAPHICS, ILLUSTRATION, TABLES
40 pts - Everything present and of professional quality 35 pts - One aspect poor or missing 30 pts - Two aspects poor or missing
25 pts - Three aspects poor or missing 20 pts - Four aspects poor or missing, overall subpar quality
15 pts - Five aspects poor or missing, overall subpar quality 10 pts - Six aspects poor or missing, overall subpar quality
5 pts - Much poor or missing, very subpar quality 0 pts - Missing

PROJECT REPORT OVERVIEW:

1. Title Page: Project Name, Author(s), Course
2. Group Member and Project contribution page.
3. Table of Contents
4. Local Geology w/ location of Springs - 1 Paragraph
    a. Location Map
    b. Geologic Map
5. Project and procedural overview - 1 to 2 paragraphs.
6. Hydrochemical field data for each spring (direct measurement)
    a. Water Temperature
    b. Flow Rate (Q)
    c. Electric Conductivity / TDS
    d. pH
    e. Organoleptic Assessment (Taste description)
7. Laboratory Water Analysis
    a. Cation concentration measurements from Water Samples (ICP)
        i. The BIG four: Na^+, K^+, Ca^{++}, Mg^{++}
        ii. Other “noteworthy” cations
    b. Anion concentration measurements from Water Samples (Liquid Chromatograph + Titration)
        i. The BIG four Cl^-, SO_4^{--}, HCO_3^-, CO_3^{--}
        ii. Other “noteworthy” anions
8. Cation - Anion Balance
    a. Data Integrity
9. Analytical Results Presentation for ALL Springs (make comparing possible)
    a. Analytical Data Table (The important, don’t fret the small stuff), report concentrations in mg/L, mmol/L, meq./L
    b. Graphical Representations (make sure these have figure captions)
        i. Ion Balance Diagrams
        ii. Piper Diagram
        iii. Stiff Diagram
        iv. Schoeller Diagram
        v. Durov Diagram
10. Geochemical Water Classification for each Spring
11. Conclusion - summarizing and interpreting results
12. Citations - Should be compiled using Zotero (https://www.zotero.org/) Use the United States Geologics Survey (USGS) citation style in your document. You should have a minimum of 5 credible citations.

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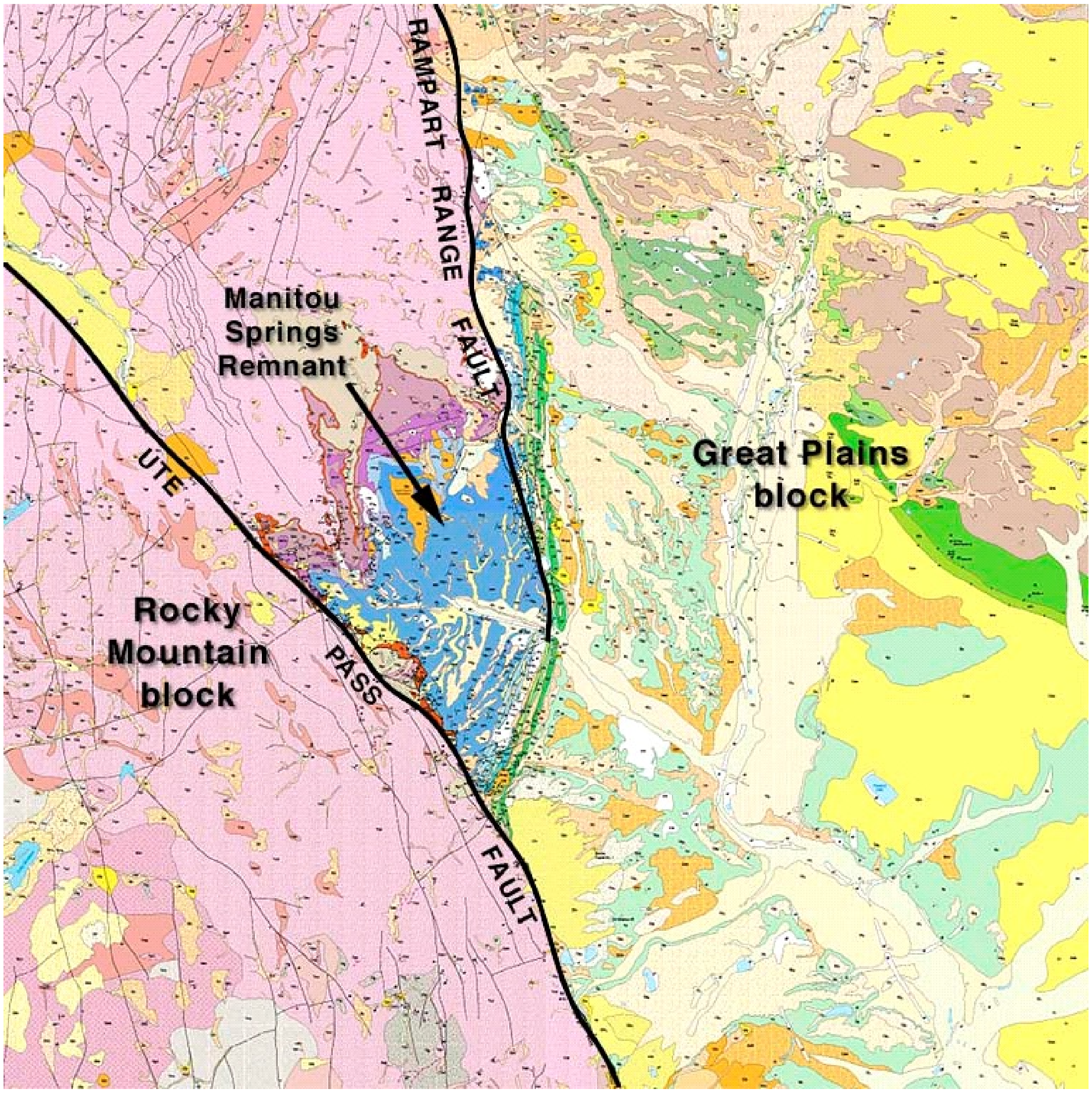
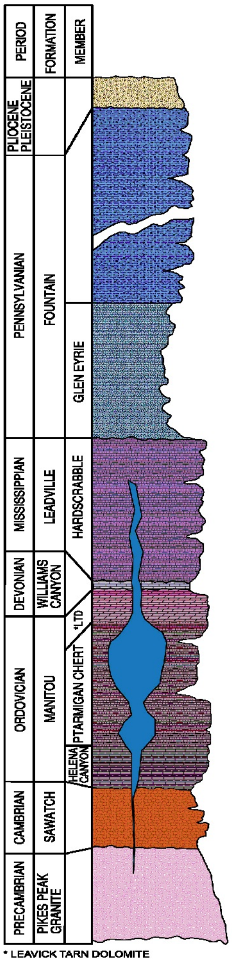
Introduction

Manitou Springs, located in Colorado, is renowned for its natural mineral springs that have attracted visitors for centuries. These unique springs, considered sacred by Native American tribes, were believed to possess healing properties. Today, visitors can experience the benefits of the various mineral springs through public fountains and well-marked drinking stations throughout the town. Each spring has its distinct flavor and mineral composition, ranging from iron and soda to lithium and natural arsenic (Don't worry, extremely low levels! It's safe to drink!). These mineral springs are naturally carbonated, which is not to everyone's liking.

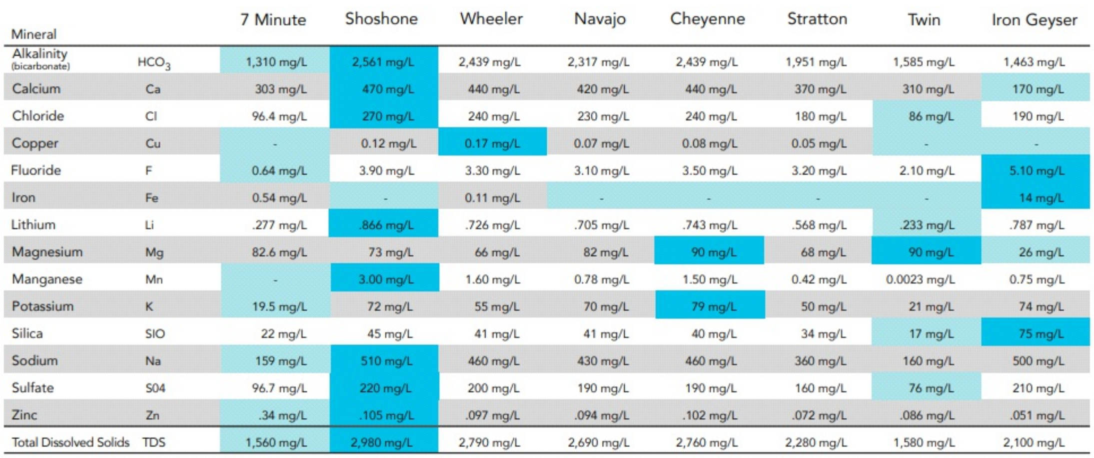


Geologic Overview Map (from Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)

Even though all springs are within walking distance from each other, they sometimes show significant compositional differences, which is a puzzling science question. Geologically speaking, these springs occur only in a small segment which is bound by the Ute Pass and the Rampart Range thrusts as indicated in the figure. Ongoing hydrochemical research at Metropolitan State University of Denver indicates a possible smaller fault block controlled system explaining the compositional differences.

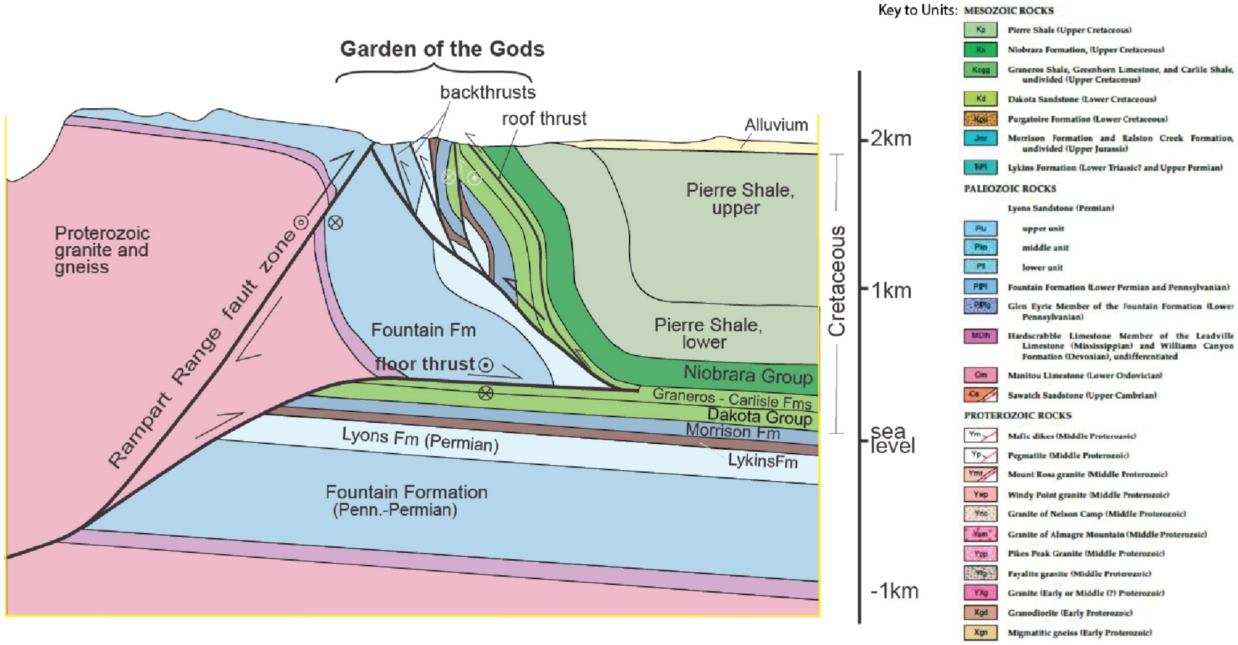


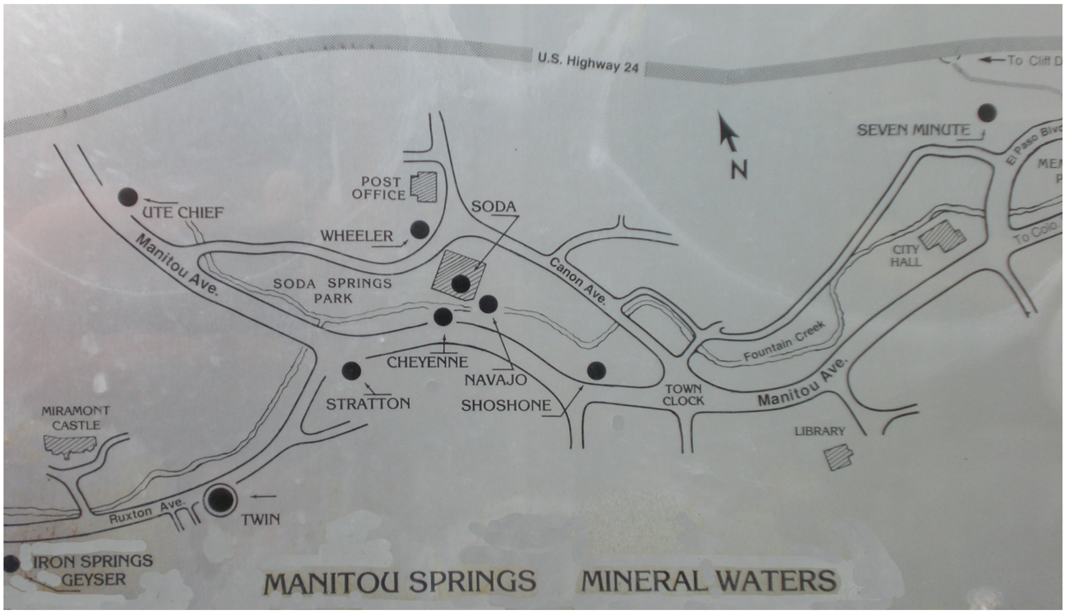
The Manitou Springs aquifer system appears to be concentrated within the Paleozoic formations shown in the stratigraphic column with the bulk of the aquifer system sitting within the Ordovician Manitou limestone sequence. The effervescent characteristic of these natural occurring mineral waters has been attributed to the liberation of carbon dioxide in the calcareous rock formations comprising the aquifer. However, as in Europe, where natural CO_2 waters are very common, helium isotope studies suggest an upper mantel derived carbon dioxide source, where the gas migrates upward into the aquifer through the Ute Pass and Rampart Range faults. (Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)



Mineral		7 Minute	Shoshone	Wheeler	Navajo	Cheyenne	Stratton	Twin	Iron Geyser
Alkalinity (bicarbonate)	HCO_3	1,310 mg/L	2,561 mg/L	2,439 mg/L	2,317 mg/L	2,439 mg/L	1,951 mg/L	1,585 mg/L	1,463 mg/L
Calcium	Ca	303 mg/L	470 mg/L	440 mg/L	420 mg/L	440 mg/L	370 mg/L	310 mg/L	170 mg/L
Chloride	Cl	96.4 mg/L	270 mg/L	240 mg/L	230 mg/L	240 mg/L	180 mg/L	86 mg/L	190 mg/L
Copper	Cu	-	0.12 mg/L	0.17 mg/L	0.07 mg/L	0.08 mg/L	0.05 mg/L	-	-
Fluoride	F	0.64 mg/L	3.90 mg/L	3.30 mg/L	3.10 mg/L	3.50 mg/L	3.20 mg/L	2.10 mg/L	5.10 mg/L
Iron	Fe	0.54 mg/L	-	0.11 mg/L	-	-	-	-	14 mg/L
Lithium	Li	.277 mg/L	.866 mg/L	.726 mg/L	.705 mg/L	.743 mg/L	.568 mg/L	.233 mg/L	.787 mg/L
Magnesium	Mg	82.6 mg/L	73 mg/L	66 mg/L	82 mg/L	90 mg/L	68 mg/L	90 mg/L	26 mg/L
Manganese	Mn	-	3.00 mg/L	1.60 mg/L	0.78 mg/L	1.50 mg/L	0.42 mg/L	0.0023 mg/L	0.75 mg/L
Potassium	K	19.5 mg/L	72 mg/L	55 mg/L	70 mg/L	79 mg/L	50 mg/L	21 mg/L	74 mg/L
Silica	SIO	22 mg/L	45 mg/L	41 mg/L	41 mg/L	40 mg/L	34 mg/L	17 mg/L	75 mg/L
Sodium	Na	159 mg/L	510 mg/L	460 mg/L	430 mg/L	460 mg/L	360 mg/L	160 mg/L	500 mg/L
Sulfate	S04	96.7 mg/L	220 mg/L	200 mg/L	190 mg/L	190 mg/L	160 mg/L	76 mg/L	210 mg/L
Zinc	Zn	.34 mg/L	.105 mg/L	.097 mg/L	.094 mg/L	.102 mg/L	.072 mg/L	.086 mg/L	.051 mg/L
Total Dissolved Solids	TDS	1,560 mg/L	2,980 mg/L	2,790 mg/L	2,690 mg/L	2,760 mg/L	2,280 mg/L	1,580 mg/L	2,100 mg/L

Hydrochemical composition of the mineral springs analyzed in 2015 (Mineral Springs Foundation, Manitou Springs, Colorado | Geology, 2015)





For this project you will travel in a group to the town of Manitou Springs to sample, analyze, study & interpret the unique natural mineral waters of the area.

You will be assigned one of the 8 working mineral springs as a group. Please make sure your contact information is correct in case group members need to contact you!:

Spring	Group Members & Contact Information
Twin Spring	
Seven Minute Spring	
Stratton Spring	
~~Ute Chief Spring~~	Not operational as of my last visit.
Cheyenne Spring	
Shoshone Spring	
Navajo Spring	
Wheeler Spring	
Iron Spring	
~~Soda Spring~~	Not running and no indicators that it will be restored at all.

Field Data Collection

Measurement & Data Collection for assigned Mineral Spring
Field Measurements Template:

Spring Name:	Location:	Geology:	Date:
Temperature: °C	Conductivity:	pH:	eh:
Organoleptic Assessment:			
Flow Rate Measurement:			
Sampling Technician w/ contact information:			

Organoleptic Testing: Odor & Taste test. Have a bottle of distilled water ready for taste comparison. Make sure you have not eaten any highly flavored or sweet foods right before the test. Take a swig of distilled water and observe taste carefully. Then follow with a sample of Mineral Spring water. Describe any odor or taste as accurately as possible. Salty taste may stem from high concentrations of Na and/or Cl, while a bitter taste may be the result of elevated $MgSO_4$. Sweet tasting water is often the product of bicarbonate ions with very little else. Tangy flavor is due to acidity such as produced by carbonic acid (natural carbonation). High concentrations of Iron have a distinct iron (almost blood like) taste, yuk!

Water Samples Field Sampling Bottles
The outlline is given below. Basically, TWO bottles are filled with mineral water from your spring. One bottle will be acidified to use for our cation ICP analysis, the other unadulterated sample will be analyzed by you for anions and other parameter within 24 hours after sampling. The non-acidified bottel is to be rinsed three to four times with the sampling water before being filled to the brim and tightly closed.

ALL bottles are to be transported in a cooler with ice or ice-packs away from light as described on the next page and stored in a refrigerator until analysis. The maximum storage time before testing is summarized below:

Compound	Preservation	Maximum Holding Time
Alkalinity	cool, 4°C	14 days
Boron, Hardness, Metals	HNO_3 pH<2	6 months
Bromide, Chloride, Fluoride	None	28 days
pH	None	Immediately
Nitrate	cool, 4°C	48 hrs
Sulfate, Phosphorous, Conductivity	cool, 4°C	28 days

AFTER FIELD SAMPLING YOU MUST DO ALL THE LISTED IN-HOUSE LABORATORY TESTS WITHIN 24 HOURS. PLAN YOUR SAMPLING TRIPS AND ANALYTICAL TIMES ACCORDINGLY!

MATERIALS:
Small ice cooler WITH ice, two(2) 500mL sample bottles (precleaned).
***Note:* Refrigerate ALL liquids used for 1 hr before proceeding.**

PRE-CLEANING:
All sampling vessels must be ABSOLUTELY CLEAN. Simple rinsing with DI water will NOT be sufficient. You will have to clean ALL sampling bottles carefully with soap and bottle brush. Rinse very, very thoroughly. Remember, the ICP-MS analysis will pick up any level of trace contamination.

PROCEDURE:
If the water is taken from a household faucet or a stagnate well, turn water on and let run for a few minutes to flush out any old water in the system.

Make sure sample bottle are appropriately labeled.

Take a sample bottle and fill 1/4 under steady stream of water. Replace lid and shake bottle vigorously. Then dump rinse water. Repeat this rinse procedure 3 times.

To take sample, fill bottle to overflowing, which means that NO air should remain. Replace lid very tightly and put sample bottle on ice inside the cooler. Do not expose to direct sunlight.

When back in lab, place sample bottle immediately into refrigerator. Then do any analysis and further sample preparation ASAP.

NOTES:
Proceed with any analytical work within 48 hours unless sample is acidified. Some compounds are more sensitive to timely analysis than others. Please consult chart..

CLEAN-UP:
Any unused sample should be discarded after 5 weeks of storage. Samples should not be used for analysis after this point. Wipe down work area with paper towels. Put equipment away. Bottles can be cleaned and recycled for further sampling.

Water Analysis

LABORATORY TESTING

CATION TESTING

USE THE ACIDIFIED SAMPLE!

Ca, K, Na, Mg-test: To test for calcium, potassium, sodium, and magnesium cations you will use our ICP-MS (Inductively Coupled Plasma Mass Spectrometer). Please contact the Lab Coordinator for time and place. Since the ICP is sensitive, our samples may have to be diluted. The Lab coordinator will advise you about the correct dilution factor. Raw data results are usually reported in ppb (parts per billion) which is equivalent to µg/L.

Additional Cations: Other selected cations will also be captured by the ICP-MS. Watch for those with significantly high concentrations.

ANION TESTING

USE THE NON-ACIDIFIED (UNADULTARATED) SAMPLE!

Major anions can be directly analyzed with our ion-chromatograph. While this should work for all anions of interest, especially bicarbonate needs to be verified by an alternate method.

HCO_3-test: To test for bicarbonate use the exact titration procedure learned in a previous lab exercise and as indicated below.

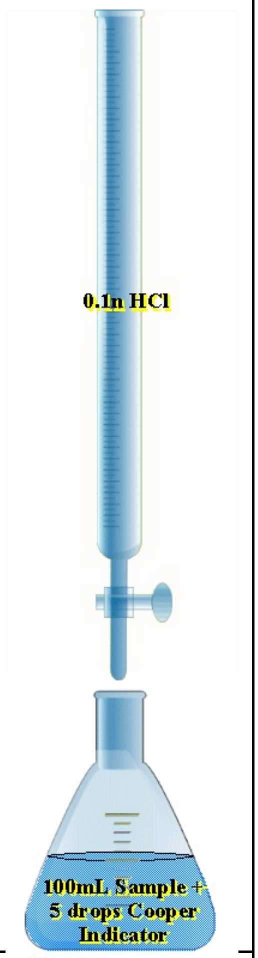
(optional, just in case) **SO_4-test:** To test for sulfate can use our professional laboratory spectrometer equipment. Follow instructions explicitly and keep equipment clean. Calculate S from SO_4 measurements.

(optional, just in case) **NO_3-test:** To test for nitrates, use an UV/VIS spectrometer. Measurement of UV absorption at 220 nm enables rapid determination of nitrate. In order to combat interference by dissolved organic matter, which also absorbs at 220 nm but does not absorb at 275 nm, use a second measurement made at 275 nm for correction.

(optional, just in case) **Cl-test:** To test for chloride either use a calibrated probe or spectrometer measurements as per instruction.

ALL ANALYTICAL RESULTS NEED TO BE SHARED WITH EVERYBODY IN THE COURSE IN A TIMELY MANNER! PLEASE DISTRIBUTE ELECTRONICALLY IMMEDIATELY AFTER ANALYSIS!

BICARBONATE IN WATER



MATERIALS:
Titration burette, 200mL beaker / Erlenmeyer flask, Cooper-Indicator, 50mL 0.1n HCl, Vessel with $CaCO_3$ chips for waste disposal

PROCEDURE:
Place 100.00mL water sample into flask. Add 5 drops Cooper indicator. Your water sample should turn blue.

Fill titration burette with 0.1n HCl. Carefully drop HCl from burette into flask. Shake flask continuously. When color changes from blue to clear or onion-skin color is achieved, immediately stop adding HCl.

NOTES:
Depending on the amount of HCO_3^- present, you may go faster at first, but at the end it is one drop at a time. Your point of color change MUST BE EXACT.

RESULTS:
Carefully record mL of HCl used. Then use the equation below to calculate HCO_3^- in mg/L:

$$\_\_\_\_\_\_ \frac{mg}{L}_{HCO_3} = \left(\frac{\_\_\_\_ mL_{0.1nHCl} \times 0.1n_{HCl} \times 1000\frac{mmol}{mol}}{100.00mL_{H_2O}} - 0.005\frac{mmol}{L} \right) \times 61\frac{mg}{mmol}_{HCO_3}$$

Note:
n = m = mol/L; 0.005mmol/L = acid correction factor due to H_2CO_3

CLEAN-UP:
Dump flask contents into vessel with $CaCO_3$ chips. Rinse flask with tap water and discard rinse into $CaCO_3$ chipped vessel. Use dish soap & bottle brush to clean flask. Rinse thoroughly with tap water, discard rinse into sink. Do a final rinse with DI water, discard rinse into sink. Dry outside with paper towels, put away to dry.

Empty left over burette contents into vessel with $CaCO_3$ chips. Rinse thoroughly with DI water and discard into same vessel. Dry outside with paper towels, put away to dry.

Put stands, clamps and other materials away. Wipe down work area with paper towels.

Making a 0.1nHCl solution from concentrated 37% HCl!
8.33cm^3 of 37% HCl in 991.67cm^3 DI water. (37% HCl = 12M HCl = 12N HCl; $8.33cm^3_{37\%HCl}=0.1N_{HCl}*1000cm^3/12N_{HCl}$)
Making Bicarbonate Titration Indicator after Cooper
Dissolve 0.02g methyl red and 0.10gbromocresol green in 100mL 95% alcohol.

DILUTION & ACIDIFICATION PROCEDURE FOR ICP-MS

MATERIALS:
Water samples, DI water, 20mL 1:1HNO$_3$, 2× 100mL mixing vessels, Scale, 100mL Graduate cylinder, 2× Shipping Vessels, Labeling Stickers, cleaning solution & bottle brushes. Vessel with CaCO$_3$ chips for waste disposal.
***Note:* Refrigerate ALL liquids used for 1 hr before proceeding.**

PRE-CLEANING:
All sampling and measuring vessels must be ABSOLUTELY CLEAN. Simple rinsing with DI water will NOT be sufficient. You will have to clean ALL your vessels used, including the sampling bottles carefully with soap and bottle brush. Remember, our analysis using an ICP-MS will pick up any level of trace contamination.

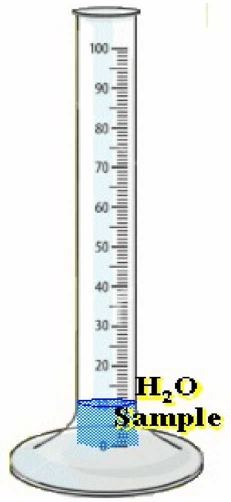
PROCEDURE:
Take two 100mL mixing bottles. Label one of the bottles with your Group & Sample Label we will call "SAMPLE". The other bottle should be labeled with your group and an acronym for blank we will call "BLANK".

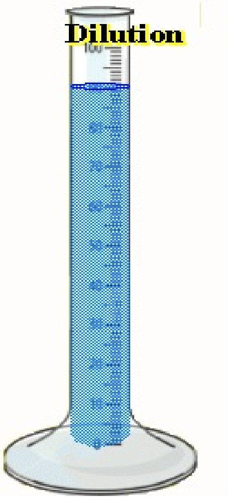
For the bottle labeled BLANK, fill with exactly 90.00mL of distilled or DI water. Then add exactly 10.00mL of 1:1 HNO3. Because all measurements need to be exact, you may want to use a scale instead of a graduate cylinder. Since all liquids are refrigerated (~4 °C), they are at the perfect density for using a scale without adjusting for temperature volume expansion.

Next, fill the SAMPLE mixing bottle with exactly 10.00mL of your water sample. Add exactly 80.00mL of distilled or DI water. Then add exactly 10.00mL of 1:1 HNO$_3$. Again, because all measurements need to be exact, you may want to use a scale instead of a graduate cylinder.

***Note:** If you do the BLANK first, you can use the measuring vessels again for the SAMPLE without re-cleaning your vessels.*

NOTES:
For GROUP use initials of Members
Example for Labels: YEAR-GROUP-SPRING (e.g.; 2011-JDSGBB-TWIN)
Example for "Blank" Label: YEAR-GROUP-BL (e.g.; 2011-JDSGBB-BL)
Remember, because we diluted the sample by a factor of 10, we have to multiply test results from returned analysis by 10 to convert values back to original concentration. A spreadsheet is very helpful for this calculation.





CLEAN-UP:
Acidified leftovers should be dumped into vessel with CaCO$_3$ chips. Rinse all glassware with tap water and discard rinse into CaCO$_3$ chipped vessel as well. Use dish soap & bottle brush to clean mixing vessels. Rinse thoroughly with tap water, discard rinse into sink. Do a final rinse with DI water, discard rinse into sink. Dry outside with paper towels, put away to dry.

Wipe down work area with paper towels. Put equipment away.

NITRATE IN WATER *(optional, if not measured via chromatograph)*

MATERIALS:
Spectrophotometer with cuvette that transmits UV light.
Nitrate-free water (Di-Water); stock nitrate solution; intermediate nitrate solution;
hydrochloric acid solution, HCl, 1 N.

PROCEDURE:
Sample Pretreatment: To 50 mL clear sample add 1 mL HCl (1N) solution and mix thoroughly.

Preparation of standard curve: Prepare calibration standards in the range of 0 to 7 mg NO_3^--N/L by diluting to 50 mL the following volumes of intermediate nitrate solution: 0, 1.00, 2.00, 4.00, 7.00, 35.0 mL. Treat standards in same manner as samples.

Spectrophotometric measurement: Read absorbance using distilled deionized water as the reference. Use a wavelength of 220 nm to obtain reading and a wavelength of 275 nm to determine interference due to dissolved organic matter.

NOTES:
Use this technique only for screening samples that have low organic matter contents, i.e., uncontaminated natural waters and potable water supplies. The calibration curve follows Beer's law up to 11 mg /L.
Presence of dissolved organic matter, surfactants, NO_2^- and Cr^{6+} interfere.

RESULTS:
For samples and standards, subtract two times the absorbance reading at 275 nm from the reading at 220 nm to obtain absorbance due to NO_3^- . Construct a standard curve by plotting absorbance due to NO_3^- against NO_3^- -N concentration of standard. Using corrected sample absorbances, obtain sample concentrations directly from standard curve.

Note:
If correction value is more than 10% of the reading at 220 nm, do not use this method.

CLEAN-UP:
Turn off and store instrument or replace dust cover.

Dilute samples with tap water and pour down the drain. Clean all cuvetes and vessels thoroughly with soap and water. Do a final rinse with DI water, discard rinse into sink. Dry outside with paper towels, put away to dry.

Put materials away. Wipe down work area with paper towels.

Stock nitrate solution: Dry potassium nitrate (KNO_3) in an oven at 105°C for 24 h. Dissolve 0.7218 g in water and dilute to 1000 mL; 1.00 mL = 100µg NO_3^--N.
Intermediate nitrate solution: Dilute 100 mL stock nitrate solution to 1000 mL with water, 1.00 mL = 10.0µg NO_3^--N.

You will need to report your findings as graphical representations. While there are EXCEL and other software solutions available, they often hide behind a paywall that can be pricey. I have indicated a few FREE solutions below as I have come across them. However, many, if not most of these diagrams can be compiled using EXCEL. (Note: there might be a learning curve)

One of the most inexpensive software solutions comes out of the EU from a company called HydroOffice https://hydrooffice.org/ They have a few FREE demo versions for various hydrochemistry plotting. I haven't tried them but they may give you just enough trials to complete the assignments. They offer some FREEWARE, and their perpetual licenses for certain applications are as low as 99€, which is fairly inexpensive in the world of professional hydrogeology software solutions.

Creating Analysis Computational Spreadsheet:

Anion-Cation Balance

Create your own spreadsheet to calculate the Cation-Anion balance. A "how-to" video primer can be found here: https://youtu.be/-GvAseOv_3Q?si=gi-KU17X_nLXk_6S Next to an EXCEL solution, this video also addresses the use of a FREE software solution called Visual MINTEQ https://vminteq.lwr.kth.se/
Do the Cation-Anion Balance to check your data integrity. If there is a large deviation (> 5%), check for other ions in your analysis that may play a significant role in your water balance and include them as well to possible improve the balance.
Spreadsheet solutions and technical notes for Cation-Anion Balances can be found:
https://www.danbp.org/p/en/node/100
https://projects.nilu.no/ccc/nasaames/ionbal_calc.xls
https://web.pdx.edu/~sytsmam/limno/ion%20balance%20answers.xls
https://www.hill-labs.co.nz/media/hbzngknw/13213v7_technical-note-anion-cation-balances.pdf

Graphical Hydrochemical Representations

For more information on some of these diagrams please read "Kresic, 2024. Hydrogeology 101: Section 11.10 Visualization of Groundwater Analyses"; and your optional text "Hölting & Coldewey, 2019, Hydrogeology: 13.2.4 Evaluation and Presentation of Analytical Results"

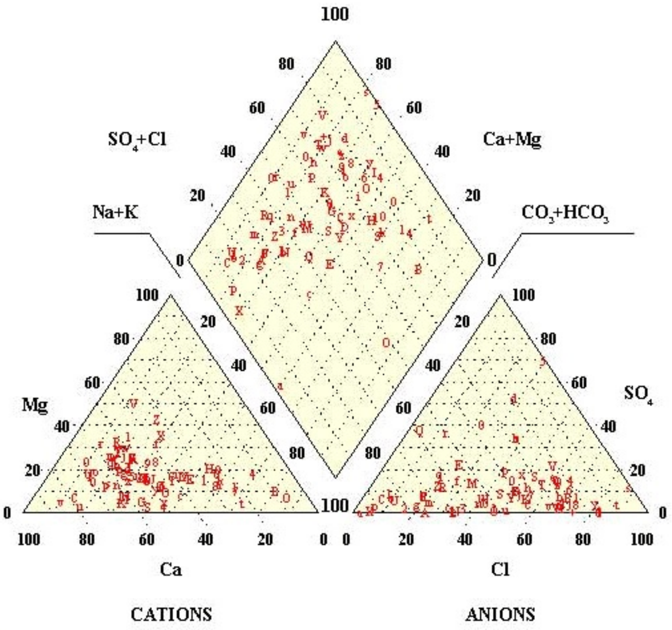
Additionally, a PowerPoint Tutorial on how to compile these graphs and their uses is given in "Griffy Field Teams and Water Sample Ids": https://www.slideserve.com/charles-crawford/griffy-field-teams-and-water-sample-ids

Most graphical manipulation can be accomplished by becoming familiar with and using the graphing functions in MS Excel or equivalent spreadsheet software.

Note: Having a working knowledge of Excel is a prerequisite for this class. So please do NOT ask me how to do this. There are plenty of tutoring websites available and I have neither time nor desire to help you learn such basic essential skills.

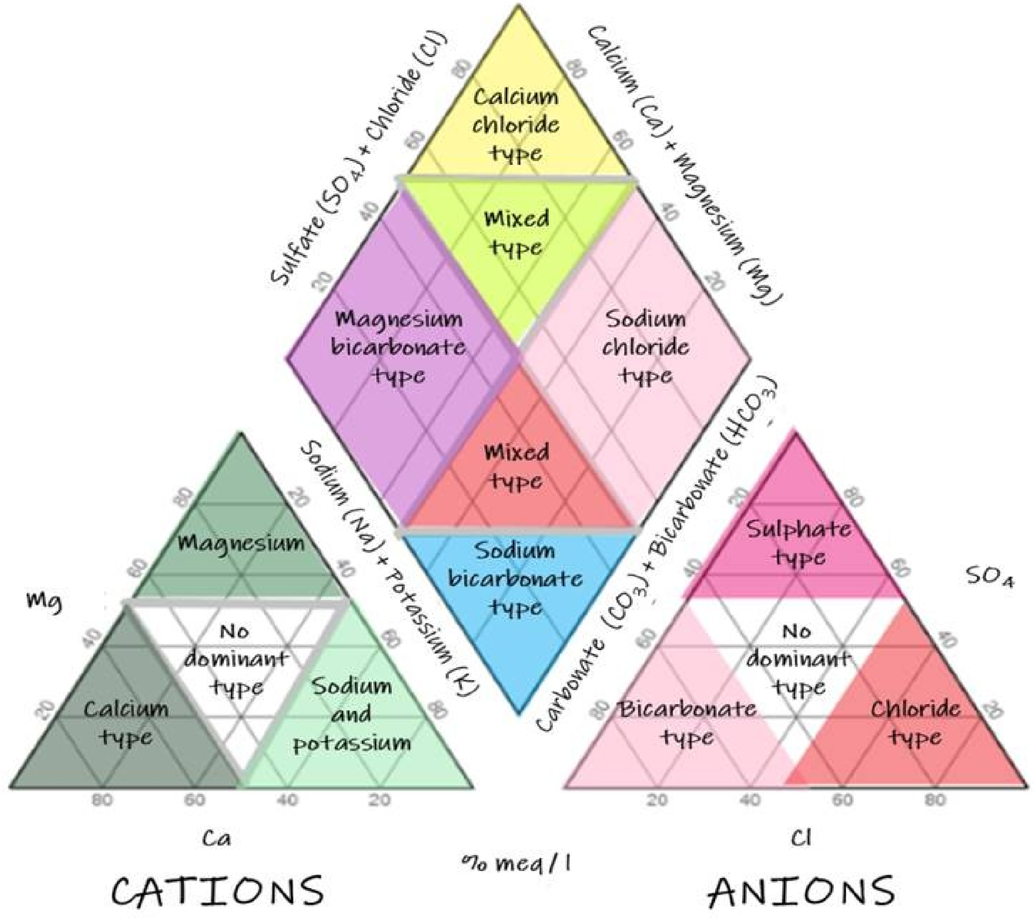
Piper Diagram:

Create a piper diagram for ALL SAMPLES. Obtain needed data from other Mineral Spring Groups. A blank piper diagram is attached. You may also play around with the free Software / Excel Solutions:
https://zenodo.org/records/5994293
https://halfordhydrology.com/piper-and-stiff/



This one is more complex, but does piper diagrams (among many other things): https://www.usgs.gov/software/gwchart-program-creating-specialized-graphs-used-groundwater-studies

Use the Piper diagram to classify the waters of the springs analyzed.



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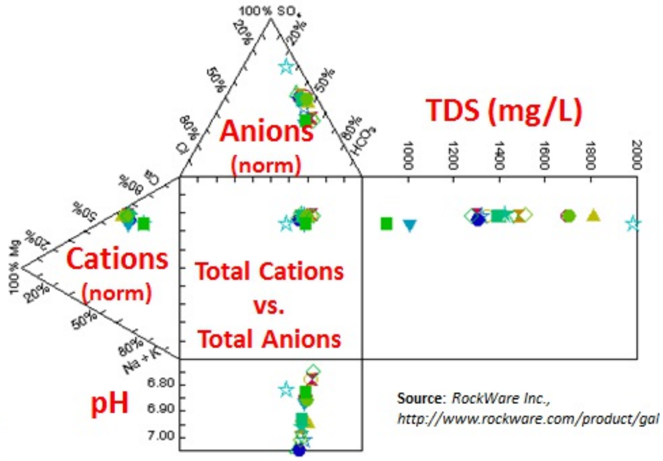
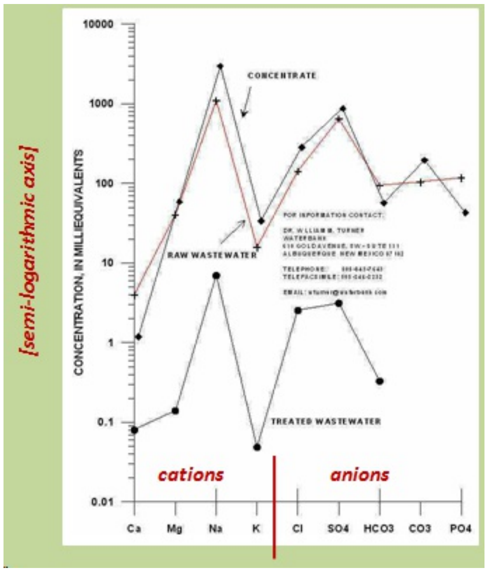
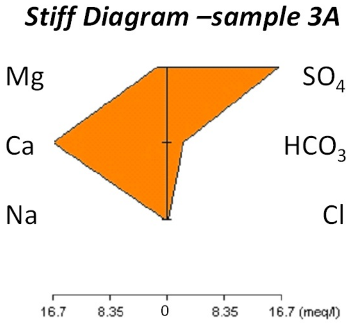


Source: *RockWare Inc., http://www.rockware.com/product/gal*

Durov Diagram:
The intersection of lines extended from the two sample points on the triangle to the central rectangle gives a point that represents the major-ion compositions on a percentage basis. From this point, lines extending to the adjacent scaled rectangles provide for representations of the analyses in terms of two parameters selected from various possibilities, such as total major-ion concentrations, total dissolved solids, ionic strength, specific conductance, hardness, total dissolved inorganic carbon, or pH.

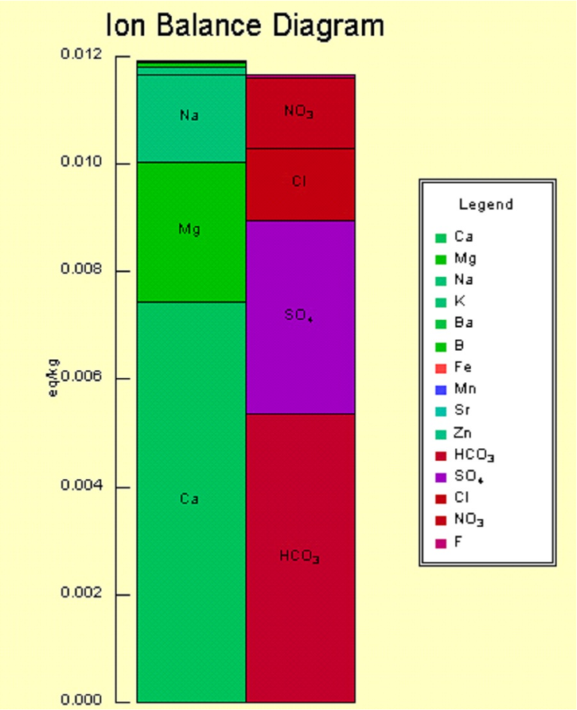
Schoeller Diagram:
A Schoeller Diagram is a semi-logarithmic diagram of the concentrations of the main ionic constituents in water (SO_4, HCO_3, Cl, Mg, Ca, Na/K) in milliequivalents per L of solution (meq/L). Concentrations of each ion in each sample are represented by points on six equally spaced lines and points are connected by a line. The diagram gives absolute concentration, but the line also gives the ratio between two ions in the same sample.
If a line joining two points representing ionic concentrations in a single sample is parallel to another line joining a second set of concentrations from another sample, the ratio of those ions in those samples are equal.
Hence equal slope = equal ratios!





Stiff Diagram:
A polygonal shape is created from three or four parallel horizontal axes extending on either side of a vertical zero axis. Cations are plotted in milliequivalents per liter on the left side of the zero axis, one to each horizontal axis, and anions are plotted on the right side. Stiff patterns are useful in making a rapid visual comparison between water from different sources.
Depending on the scope of the investigation, additional plot pairs may be added or exchanged, such as: Fe - NO_3, K - NO_3, Fe - CO_3
Free Excel Solution: https://halfordhydrology.com/piper-and-stiff/

Ion Balance Diagram:
Ion Balance diagrams are stacked bar graphs with the left stack representing the Cations, the right parallel stack are Anions. Plot concentration is millieqivalents per liter (meq/L). If both stacks have about the same height or are equal, the cations and anions are more or less balanced.



Water Chemistry Manitou Springs Group Project

- hands on applied hydrogeochemistry project lab -