Developing geochemical proxies for a high resolution hydroclimate record in Mono Lake basin.

by

Rahul Sahajpal

Submitted to the Graduate Faculty in the School of Earth & Environmental Sciences in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Graduate Center, The City University of New York

2013

This manuscript has been read and accepted for the Graduate Faculty in School of Earth & Environmental Sciences in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy

Dr. N. Gary Hemming
(Chair of the examining committee)

Date

Signature

Dr. Cindi Katz
(Executive Officer)

Date

Signature

Supervisory Committee

Dr. Sidney R. Hemming

Dr. Ashaki R. Rouff

Dr. Jacob L. Mey

Abstract

Developing geochemical proxies for a high resolution hydroclimate record in Mono Lake basin.

by

Rahul Sahajpal

Advisor: N. Gary Hemming

Hydrological fluctuations of Mono Lake, a terminal closed-basin lake in the western Great Basin, are related to the regional climate fluctuations. These hydrological changes lead to variations in paleosalinity which may be recorded at a high resolution by using geochemical proxies in the lacustrine Wilson Creek Formation sediments of the Mono Lake basin. Authigenic minerals such as calcite and Mg-smectite in the lacustrine sediments record the fluctuations in the lake level through the last glacial period.

During the course of this research project, I have developed leachable Li (hosted by the Mg-smectite) and other leachable ions as geochemical proxies for paleosalinity (and thus paleohydrology) in the Wilson Creek sediments. I applied a multi-pronged approach, including measurements of leachable ions. As a test of my hypothesis for their behavior I followed constructed empirical evaporation and mixing models using Geochemist Workbench and PHREEQC. I used this strategy to demonstrate that the freshening of Mono Lake during the last glacial period could explain the variations. These investigations in the Mono Lake basin have shown that leachable Li along with leachable ions like Ca, Mg and Sr closely follow the documented lake level based on stratigraphic and geomorphic evidence. The empirical models used to predict the geochemical evolution of Mono Lake with hydrological variations allow the accurate prediction of the behavior of authigenic mineral phases like Mg- smectite and the calcite proxy record for the paleolake level changes.

Acknowledgements

I always knew during the course of my PhD that I would be at a lack of words to express my gratitude to Gary Hemming and Sidney Hemming for their patience and guidance. I am eternally grateful to them for introducing me to the unique “Mono Lake basin” which I truly believe is the only basin where all aspects of geology can be studied. My work has been an attempt to continue on the groundbreaking work of Susan Zimmerman and her continuing support has been very critical for the quality of the work that I produced and some of the future work that I envision doing in the Mono Lake basin.

I am sure that that every student who decides to do a PhD shares a unique bond with his or her mentors, but in few words below I will try to explain why I will try my utmost to practice science the Hemmings…way!

I have known Gary Hemming for almost a third of my life so it is hard for me to summarize qualities I have come to appreciate in him. I have always been amazed by the fact that he always remains very calm, collected while working on some of the most complex geochemical problems, juggling between three campuses and multiple places he calls home and that too by just eating an apple for lunch. He is responsible for my hatred towards high fructose corn syrup and my love for good beers. His knack for working with analytical instruments and collecting good data will remain a gold standard for my future work in science. So in short I will say that I started my graduate work with Gary Hemming as my advisor and finished with Gary Hemming as my life coach.

The greatest joy of getting my PhD was to have Sidney Hemming as a mentor. I can never claim to be her best student but I strive to be the biggest fan she will ever have in geology. When I reflect on what I have learned from Sidney Hemming I am reminded of a Sanskrit verse

“vidyaa dadaati vinayam vinayaadyaati paatrataam paatratvaaddhanamaapnoti dhanaaddharmam tatah sukham”

Meaning: **"Knowledge generates humility, by humility one becomes worthy, being worthy one earns wealth, with wealth one gains religiosity, and by religiosity one becomes happy"**

I feel that this verse does a good job of describing Sidney as a person and why she is one of the best geoscientists the world will ever know, but it does not describe as to how she has been a star and source of inspiration to me and all the people she has and will work with in future.

I am thankful to my committee members Ashaki Rouff and Jacob Mey for their useful and critical comments. Ashaki has been extremely helpful in refining the evaporation and mixing model (E&M). My good friend and colleague Kale Clauson was of great help during the course of my data collection on the ICP-OES.

I am highly indebted to the faculty, staff and friends at Queens College for being extremely helpful in providing me with the opportunity to learn, teach and work there and for making it all a memorable experience.

I am thankful to my sister, brother in law and nephew for their support and love. I have been blessed with a great family who cared and inspired supported and nurtured me during the course of my PhD. It will be hard to name and thank everyone here but I hope that they feel my heartfelt appreciation for all the things they have done for me.

Dedication

This thesis is dedicated to

my parents

(Late) **Amrit lal Sahajpal and Suman Sahajpal**

without their support and blessings this work would never be possible

and to

Gary Hemming and Sidney Hemming

In them I found the best mentors that a student can ask for!

Table of Contents

Introduction

Chapter 1: Assessing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA)

Chapter 2: Precise determination of element concentrations in authigenic sediments of Mono Basin, California, using ICP-OES

Chapter 3: Developing evaporation and mixing models for mineral stability and validating geochemical proxy record for paleolake level and paleosalinity in Mono Lake basin, CA

Chapter 4: A python based program for automating simple mixing and evaporation based calculations using PHREEQC (version 2)

Appendix

List of Figures

Introduction

Chapter 1: Assessing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA)

Chapter 2: Precise determination of element concentrations in authigenic sediments of Mono Basin, California, using ICP-OES

Chapter 3:Developing evaporation and mixing models for mineral stability and validating geochemical proxy record for paleolake level and paleosalinity in Mono Lake basin, CA

Chapter 4: A python based program for automating simple mixing and evaporation based calculations using PHREEQC (version 2)

List of tables

Chapter 1: Assessing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA)

Chapter2: Precise determination of element concentrations in authigenic sediments of Mono Basin, California, using ICP-OES

Chapter 3: Developing evaporation and mixing models for mineral stability and validating geochemical proxy record for paleolake level and paleosalinity in Mono Lake basin, CA

Introduction: Mono Lake basin, California

1. Motivation

This research project was undertaken to develop and test geochemical proxies for understanding the paleohydrology of Mono Lake basin (Fig.1) with the goal of better understanding of past regional climate changes in the Great Basin. The Mono Basin has witnessed extreme changes in its hydrology due to natural climate change, and it has also been greatly modified by anthropogenic activity (Stine 1991). The scientific contribution in the following chapters includes the development of geochemical tools to allow a highly resolved hydroclimate record for Mono Basin, and modeling exercises that allow us to test what aspects of the hydrology have the most influence on Mono Lake chemistry. The geochemical modeling approach presented here is applied to the paleo-record, but the potential exists for future work to probe the anthropogenic modifications as well.

2. Geologic setting

Mono Basin lies on the western edge of the Great Basin region of the western United States. It has been a site of extensive volcanic and tectonic activity during the late Quaternary period (Gilbert et al., 1968; Bailey, 1976; Bursik and Sieh 1989; Reheis et al., 2002). The basin is bound by the Bodie Hills, Long Valley caldera, Cowtrack Mountains and Sierra Nevada on its north, south, east and western margins, respectively (Fig.1). The geomorphology of Mono Lake basin results from the Sierran glaciers and creeks (Russell 1889; Lajoie 1968), together with the volcanic activity in the region. The resulting Mono Lake sediment stratigraphy is a result of these activities, with inter-fingering glacial, lacustrine and volcanic deposits named as the Wilson Creek Formation by Lajoie (1968) (Fig. 2).

3. Hydrology

Mono Lake lies in the rain shadow of the Sierra Nevada (Fig.1) creating evaporative conditions with very low direct precipitation. Almost all of the water to the lake is supplied by Sierran creeks, groundwater springs and thermal springs. The current lake is hyper-saline with a high pH and alkalinity which has led to a high concentration of ions like lanthanides (Johannesson and Lyons, 1994; Johannesson et al., 1994), and actinides (Anderson et al., 1982; Simpson et al., 1980, 1984). The lake now is Na^+-CO_3^{2-}-SO_4^{2-}-Cl^- brine (Hardie and Eugster, 1970; Bischoff et al., 1993) and is saturated with authigenic minerals like calcite and Mg-silicate. Instantaneous precipitation of calcite in the lake has formed tufa towers (Fig.3) which also indicate the location of groundwater springs in and around the lake.

4. Previous work

The quaternary history of Mono Lake basin was first described in detail by Israel Russell (1889). His description of the glacial, lacustrine and volcanic history of the basin remains one of the best references available for geoscientists studying the basin. In his account of the basin, he points to the presence of shorelines and terraces formed by a much bigger lake (Lake Russell) that occupied the Mono Lake basin during glacial times along with the glacial and volcanic features. Many of these features have since been studied confirming Russell's findings (Benson et al., 1990; Chen et al., 1996; Zimmerman et al., 2006).

During the course of his graduate work in the Mono Lake basin, K.R. Lajoie (1968) identified the main rock stratigraphic unit in the basin, which he named the Wilson Creek Formation (Fig.2). This type section of the Wilson Creek Formation (WCF) is ~7 m high, comprising lacustrine sediments inter-layered by 18 rhyolitic and 1 basaltic ash layers overlying fluvial gravels (~2m) thick. These ash layers were numbered and grouped into five marker sequences from A (ashes 1-4, youngest) to E (ashes 18-19, oldest) by Lajoie (1968). These marker sequences allow confident correlation between exposures of Wilson Creek-age sediments throughout the Mono Lake basin. The lacustrine sediments are deposited in finely laminated strata, and contain ostracodes, inorganic carbonate pisoliths and clasts of plutonic and metamorphic rocks of Sierran origin, which have been shown to be ice-rafted dropstones (Benson et al., 1998; Lajoie, 1968; Russell, 1889; Zimmerman et al., 2011a).

Proxy development work carried out by Zimmerman et al (2006, 2011b) in the Mono Lake basin demonstrated that high calcite concentration in the lacustrine sediments is positively correlated to Lajoie's (1968) lake level curve (Fig.4), where high carbonate concentrations correspond to high lake levels and vice versa . This is in contrast to the adjoining Owens Lake basin where high carbonate concentrations in lacustrine sediments correspond to low lake levels (Bischoff et al., 1997). The reason for this contrasting behavior is the extreme differences in the basin geometries which prevented Mono Lake from overflowing and flushing out its ions, whereas in case of Owens Lake it was routinely flushed to the low lying Searles and China Lake basins during glacial periods (Zimmerman, 2006). These investigations showed that differences in aspects of hydrology can lead to major differences in the geochemistry of adjoining lake basins lying in the same regional watershed. These studies, though very insightful, underscored the need to develop more robust geochemical proxies that can lead to a comprehensive understanding of the hydrology of closed basin systems.

5. Proxies for paleohydrology

In order to develop a comprehensive understanding of the paleohydrology of Mono Lake basin and the factors influencing it, we used the leachable Li proxy (and other ions like Ca, Mg and Sr) developed by Bischoff et al (1997) in the lacustrine samples from the Wilson Creek Formation (WCF) as proxies for tracking the salinity of the lake through the late Pleistocene period (Sahajpal et al., 2011). The results are consistent with those of Zimmerman et al. (2006, 2011b) on the correlation of carbonate to lake level changes. These empirical results ground-truth the application of these proxies, and allow potentially highly resolved records of paleohydrologic change in the basin, but particularly because they are counter to simple intuition, we explored the use of thermodynamic models to probe the system. Our initial intuition that the more highly concentrated the lake the more highly concentrated the authigenic precipitates in the sediment was not borne out in the data, and we found a simple explanation for this in the landmark Garrels and Mackenzie model (1967), but were driven to further test our explanation beyond the constraints of that model.

6. Geochemical modeling of Mono Basin water chemistry

To further predict the chemical evolution of Mono Lake waters through the last glacial period, we applied thermodynamic modeling programs. These models are constrained by the geochemical data gathered by Tomascak et al. (2003) and Neumann and Dreiss (1995) on major (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-} and SO_4^{2-}) and trace ion species (Li^{+}, Sr^{2+} and B) in the lake and freshwater sources (creeks and groundwater springs). These models simulate the evaporation and mixing of saline and fresh waters based on proportions that approximate the changes in lake levels through the last glacial period. These models were developed using

PHREEQC, version 2 (Parkhurst and Appelo, 1999) and Geochemist Workbench, Standard 7.0 (Bethke and Yeakel, 2008), two commonly used geochemical programs. It is our hope that by developing high resolution proxies and supporting our findings using simple geochemical models that we have made robust proxies for Mono Lake basin with the potential for their use in other basins throughout the world.

Predicting evolution of natural brines in closed basins based on thermodynamic calculations used in geochemical models is an established tool. Garrels and Mackenzie (1967), in their pioneering model of evaporation of Sierran spring waters, found that the calculated evolution of natural brines in arid regions provides a good approximation of the lake water chemistry (Fig.5). Specifically, they demonstrate that simple thermodynamic calculations can be used to predict the behavior of chemical species like Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, CO_3^{2-}, SO_4^{2-} and SiO_2 along with the mineral phases such as calcite and Mg-silicate as water is progressively evaporated. This approach was further investigated in detail by Hardie and Eugster (1970), where they analyzed sixty seven subsurface and closed basin inflow waters using their model and interpreted that chemistry of waters undergoing evaporation changes in a succession of chemical divides. They predicted that the type of mineral phase precipitated depends on the initial composition of the water and the concentration of ions in the solution, and the solid phase changes accordingly. The first mineral to precipitate as a result of evaporation in almost all natural waters is calcite, which results in the first chemical divide. The next chemical divides occurs depending on whether the concentration of the Ca^{2+} ion is greater than or less than alkalinity, with gypsum or sepiolite forming (note that in our case we found that the Mg-silicate mineral is Mg-smectite while our theoretical models predict “talc”). As the residual dissolved salts get concentrated, the non-conservative elements like Ca and Mg are removed by precipitation, and the resulting solution is dominated by conservative ions like Na^+, Cl^-, SO_4^{2-} and CO_3^{2-}. The models of Garrels and Mackenzie (1967) and Hardie and Eugster (1970) are simplified in that they do not include the formation of double salts like high-magnesium calcite and dolomite and suggest the formation of sepiolite instead of Mg-smectite, which is believed to be the phase found in nature (Gac et al., 1977; Jones and Weir, 1983; Singer, 1984; Banfield et al., 1991; Sahajpal et al., 2011). Revisions by Eugster and Hardie (1978) have discussed the changes that can be made to their model to include these salts.

The scope of application of these models was broadened by studying the effect of evaporation on seawater (Harvie et al., 1980). Besides evaporation, Eugster and Jones (1979) studied the role of effects like selective dissolution of efflorescent crusts and sediment coatings, sorption on active surfaces, and degassing and redox reactions during chemical fractionation of major solutes in brine evolution. Since most natural brines and seawater are dominated by $Na\text{-}K\text{-}Mg\text{-}Ca\text{-}Cl\text{-}SO_4\text{-}CO_3\text{-}H_2O$, several follow up models were developed to predict the behavior of these species, resulting mineral phases, mineral equilibria and mineral solubilities at various concentrations, ionic strengths and saturation states of these waters (Eugster and Maglione, 1979; Harvie and Weare, 1980; Harvie et al., 1982; Harvie et al., 1984; Eugster et al., 1980). More recently Connell and Dreiss (1995) constructed evaporation and mixing models to understand the evolution of shallow groundwater on the northeast shore of Mono Lake. These investigations have led to a better understanding of the mechanisms controlling the evolution of closed basin lakes like Mono and Owens Lake, which subsequently led to the development of geochemical proxies that have made a direct connection between regional climate and the evolution of these lakes. (Bischoff et al., 1997; Zimmerman et al., 2011b; Sahajpal et al., 2011).

Most of the existing geochemical models are evaporation-based and have ignored the fact that most arid basin brines are fed by a nearly continuous flux of fresh water. For this project we have developed simple models of the predicted lake chemistry changes based on evaporation and mixing of saline and fresh waters in proportions that approximate the changes in lake level through the last glacial cycle. We have used the PHREEQC model to calculate the stability of mineral phases precipitating out of Mono Lake waters, thus providing insight about the chemical evolution of Mono Lake through the last glacial cycle. Since the proportion of fresh water flux to Mono Lake is expected to be different from what is currently observed in the basin, we also ran simulations of evaporation based models using Geochemist Workbench of creek and spring water end members along with a proportional mix of these waters. The details of these geochemical software packages and models developed for Mono Lake basin are included in the appendices of this dissertation.

7. Thesis chapters

This thesis has four chapters that detail the work done toward the goal of developing and interpreting the record of lake chemistry change of Mono Lake during the last glacial cycle. The first chapter provides a high resolution data set on leachable ions in the Wilson Creek Formation and compares them with the lake level history from physical stratigraphic constraints. The second chapter reports the details of the analytical technique that was developed to estimate the concentration of leachable ions in the lacustrine sediments reported in the first chapter, and is the basis for the supplementary document for Chapter 1 published in Geochemica et. Cosmochimica Acta (Sahajpal et al., 2011, and supplementary document). The third chapter explores thermodynamic models to predict the behavior of chemical species in Mono Lake water during high stands of the last glacial cycle.

The first chapter of this thesis was published in Geochimica et. Cosmochimica Acta, 2011. This chapter focused on developing leachable Li and other leachable ions like Mg, Ca and Sr as proxies for paleosalinity in the lacustrine sediments of the Wilson Creek Formation in the Mono Lake basin. These proxies were developed using the same sediment samples as Zimmerman et al. (2006, 2011b) used to develop calcite as a proxy for paleo-lake level in Mono Lake basin. This study is based on the leachable Li proxy of Bischoff et al. (1997), which they used to predict paleosalinity changes in the Owens Lake basin. Our findings are in excellent agreement with those of Zimmerman et al. (2006; 2011b), where high concentration of Li, Mg, Ca, Sr and $CaCO_3$ correspond to high lake levels, and low concentrations correspond to low lake levels. The results of our findings have created a very high resolution paleosalinity record for Mono Lake basin which is dated based on the high resolution paleomagnetism based age model of Zimmerman et al. (2006). In addition to the specific record we have produced for the Mono Basin, this work provides a portable tool for understanding hydrological changes in similar closed basin lakes.

Chapter 2 describes in detail the methodology that was used to analyze the leachable ions from the lacustrine sediments. The development of this technique was the first step towards the goals of creating the data set that is the basis of chapter 1, and is the motivation for the theoretical calculations of chapter 3. The approach follows the strategy developed by Bischoff et al. (1997), and the preliminary leachable Li dataset that Susan Zimmerman reported in her Columbia University Ph.D. thesis (Zimmerman, 2006). The development of this chapter was a major challenge of the thesis because of the very large number of samples, and because some work was already done by a different method (Zimmerman, 2006), requiring a cross-calibration. This was a major development as the Queens College ICP-OES at the School of Earth and Environmental Sciences (SEES) had not previously been used. The samples were originally collected for the thesis work of Susan Zimmerman (Zimmerman, 2006) as well as SEES student Crystal Pearl's master's thesis (Pearl, 2006). The leaching of the sediment samples was partly performed by Perry Girard-Little and Dee Pederson under Susan Zimmerman's supervision at Lamont Doherty Earth Observatory, and partly by SEES undergraduate student Luis Devarez under my supervision at Queens College. The processed samples were analyzed by Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) at Queens College. Once the equipment was working properly and a protocol was devised, extreme care was taken during the analyses to generate a highly reproducible dataset. A mixed standard approximating the concentration of ions that are expected in the Mono Lake sediments was analyzed every five samples, no more than thirty samples were run during each batch, and five replicate samples from another day's runs were repeated in a second batch.

The third chapter of this thesis explains in detail a simple evaporation and mixing based geochemical model that we have developed for Mono Lake basin, and is being prepared for publication in a journal such as Chemical Geology. This chapter uses the water budget estimates of Tomascak et al. (2003) and the sources and sinks of various ions and their concentration based on Tomascak et al. (2003) and Neumann and Dreiss (1995). The chapter has two components to it;. In the first part we have simulated evaporation of fresh waters that feed Mono Lake using Geochemist Workbench (Standard 7.0). These include the evaporation of creek and spring water end members and a proportional mix of the two waters to a concentration factor of ~3000 which is the current expected concentration factor of Mono Lake water relative to the fresh water sources that feed the lake based on Tomascak et al. (2003). The results of this exercise help predict the behavior of various ions as different fresh source waters are evaporated. These results are as expected and in agreement with Garrels and Mackenzie's (1967) evaporation based model.

For the second part of this chapter we used PHREEQC (version 2) to simulate evaporation and mixing of fresh waters and saline waters in proportions that approximate lake level changes extending into the last glacial period. This was accomplished with the help of a Python programming language based code developed by Ritvik Sahajpal which allowed us to simulate the filling up of Mono Lake with a constant flux of fresh water and a constant evaporation rate. We used this model to approximate the changes in the chemistry of the lake water since the last glacial period when it was ~ 200 meters higher than its current level (1946 m). Another important outcome of this model was that it confirmed that the increased concentration of calcite in the sediments during high lake levels was a result of a constant flux of Ca^{2+} to the lake by the fresh water sources to the lake.

The fourth chapter gives the details of the python computer language program that was written to automate the simulations described and discussed in chapter 3.

8. Future directions

Our research in the Mono Lake basin enabled us to create a high resolution hydroclimate record for the basin. This has given us several leads to further improve and develop our understanding of these changes in the broader Great Basin region of the western United States. The first step in this direction is to integrate the geochemical model with the hydrological models so we can have a better understanding of hydrologic budgets throughout the lake's history and eventually incorporate this information into climate models. Since little work has been done on the mineralogy of Mono Lake sediments, the geochemical dataset produced as a result of our current research can contribute to future studies of sediment mineralogy, and a proposal is in the works to study struvite in the Mono Lake basin in collaboration with Dr. Ashaki Rouff.

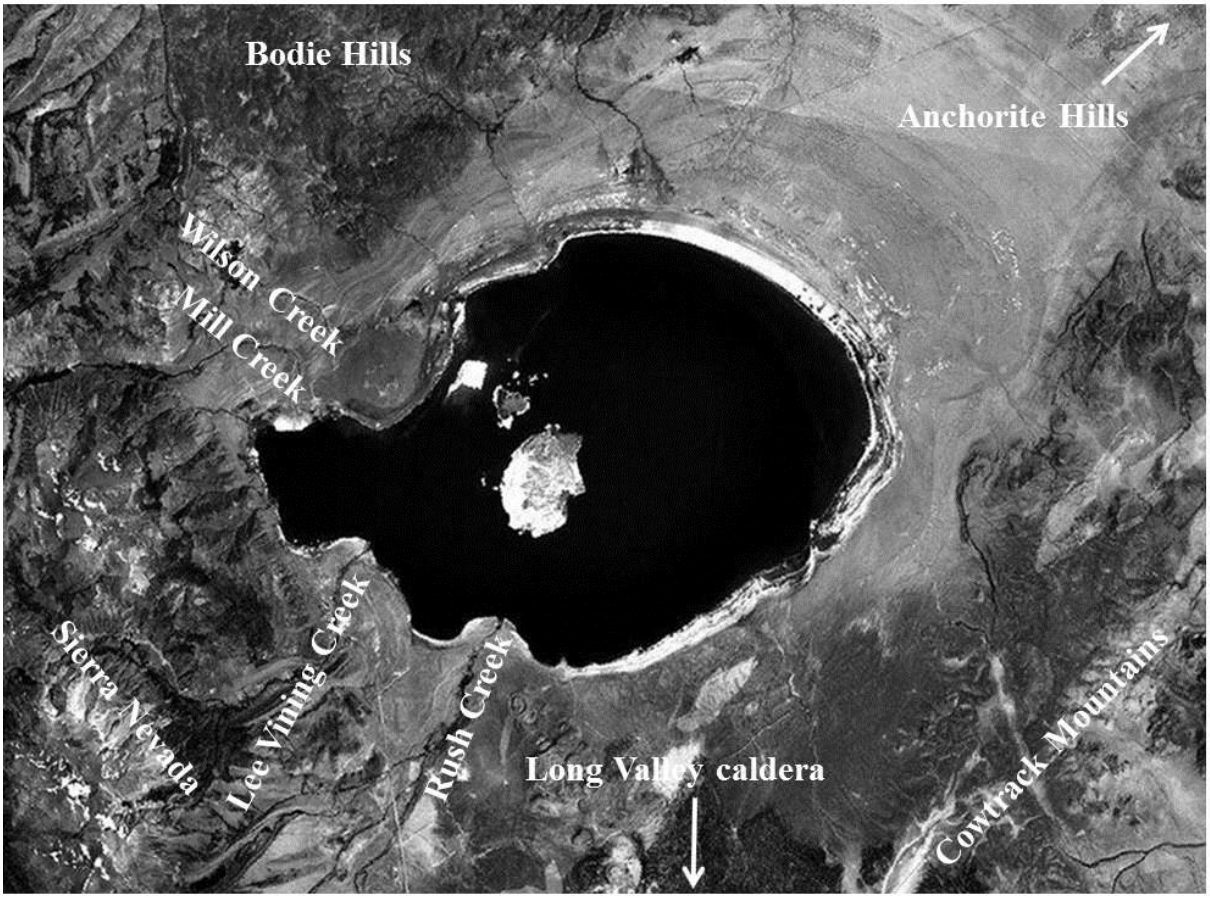

Figure I-1 A Landsat image of the Mono Basin depicting the location of surrounding features and major creeks that feed the lake.

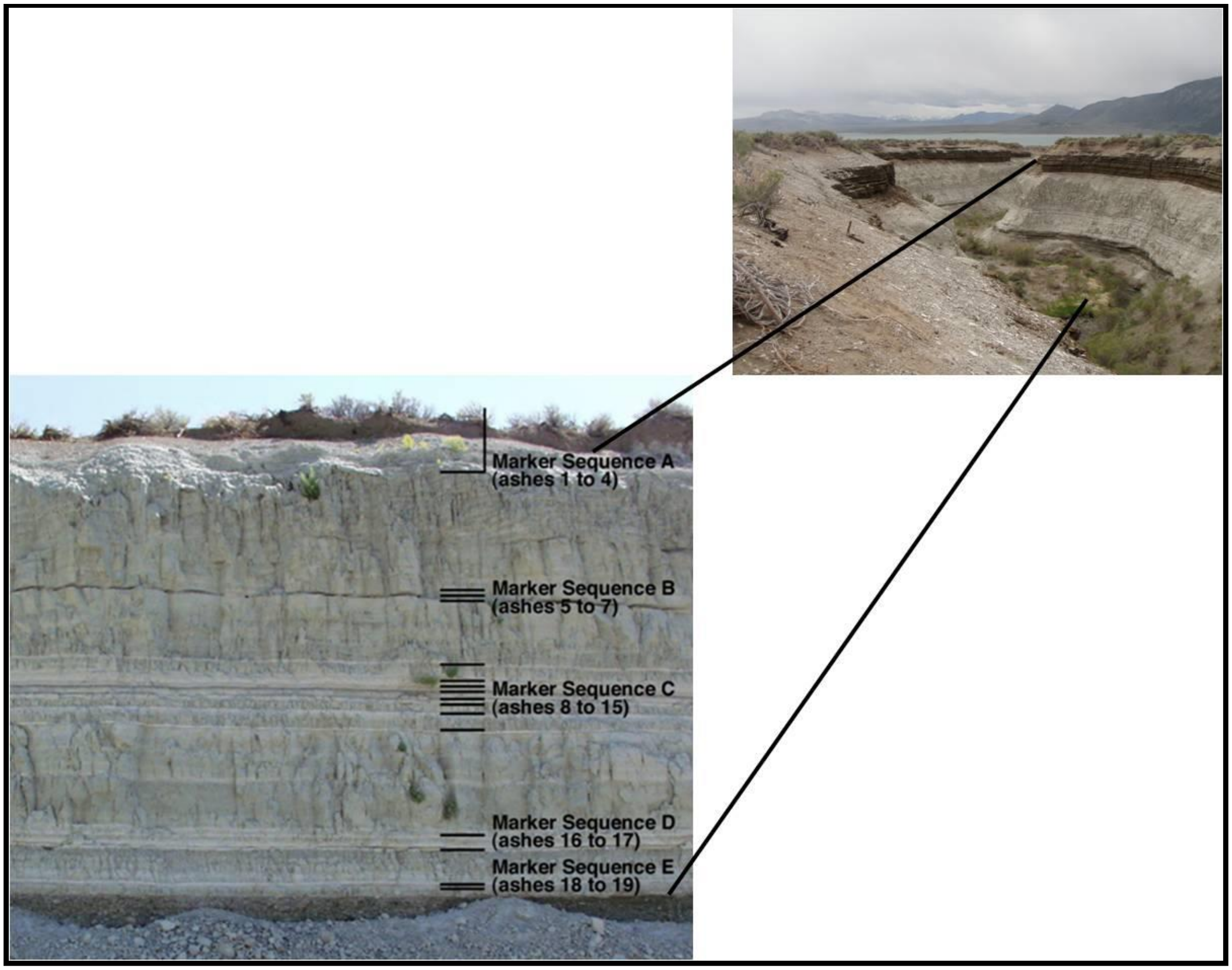

Figure I-2 The type section of the Wilson Creek formation. Lacustrine silts inter-finger eighteen rhyoltic and one basaltic ash layer grouped into five marker sequences (Lajoie 1968).

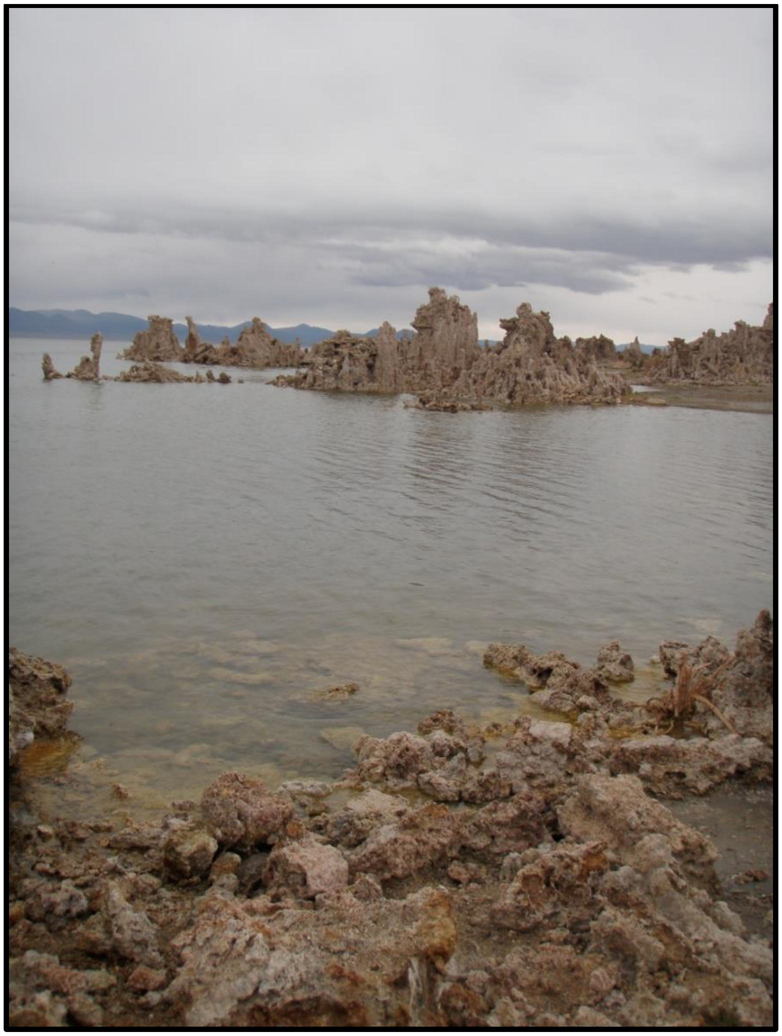

Figure I-3 Tufa towers form near springs and where freshwater enter the lake. These $CaCO_3$ towers form as a result of mixing of Ca^{2+} rich freshwater with HCO_3^-/CO_3^{2-} lake water. These towers start forming below the lake and grow upwards.

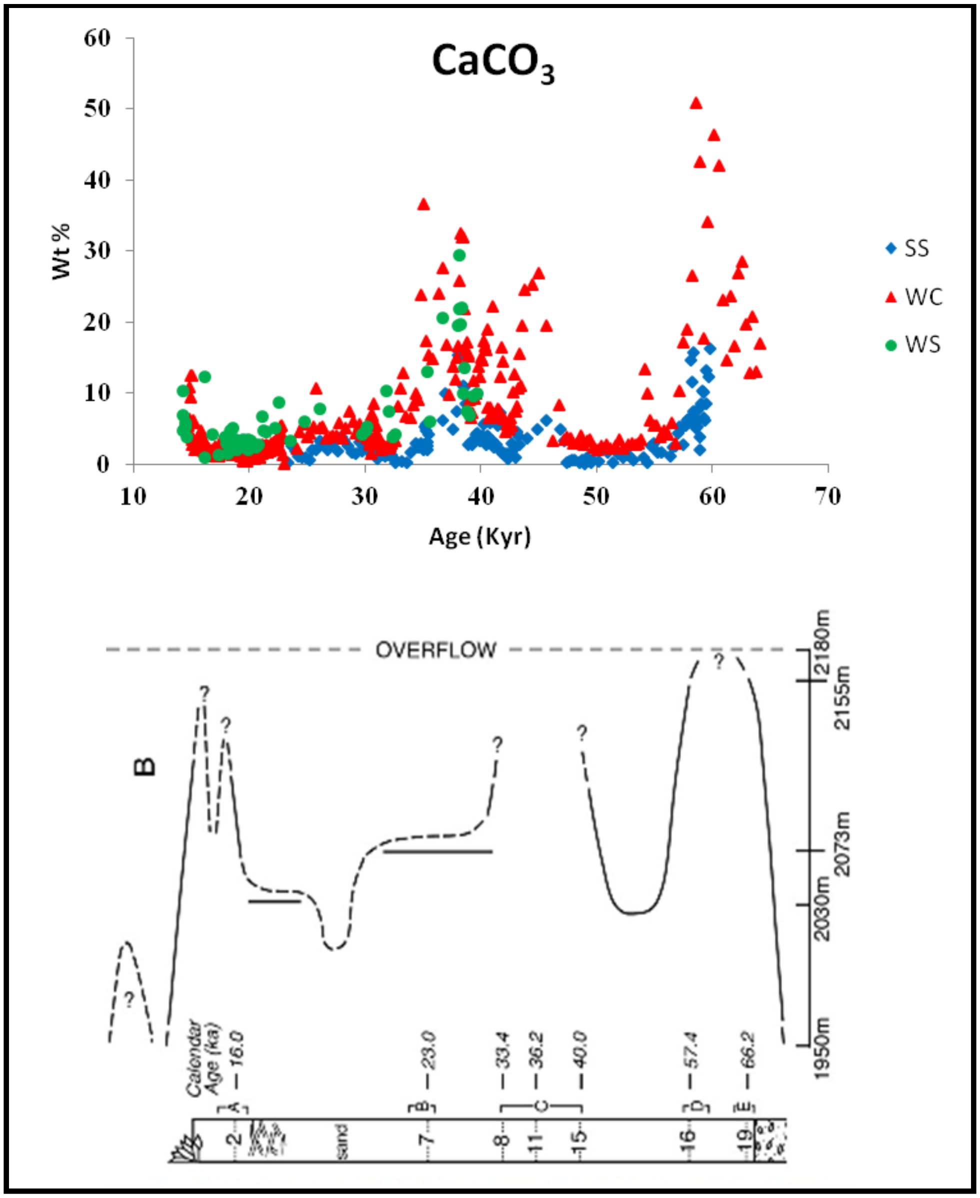

Figure I-4 Calcite concentration in lacustrine sediments of Mono Basin plotted against relative paleo-intensity based age estimates. The lower panel shows the stratigraphic column of the Wilson Creek formation developed by Lajoie (1968) and his interpretation of the lake level.

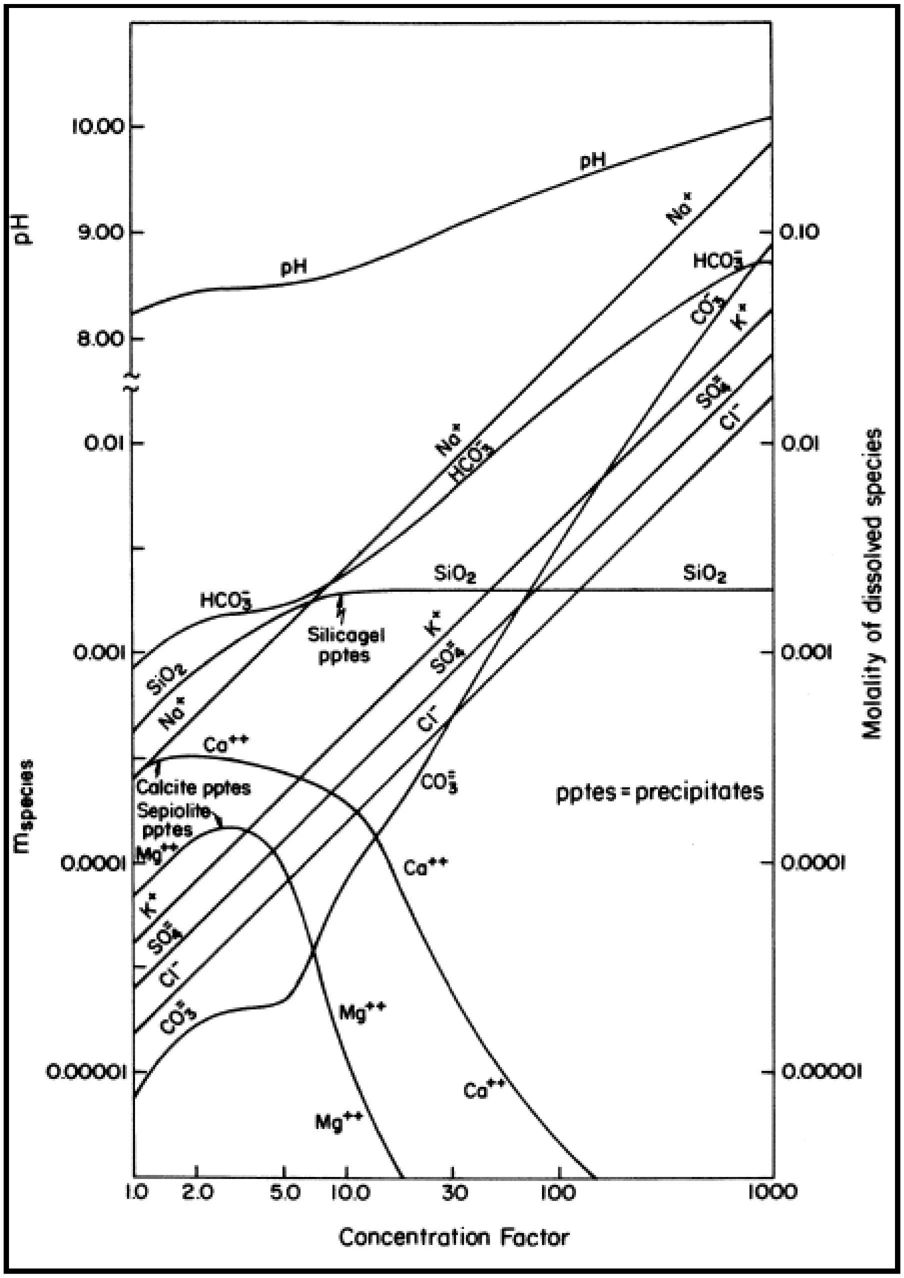

Figure I-5 Results of Garrels and Mackenzie's (1967) theoretical model depicting the behavior of various chemical species during the evaporation of typical Sierran spring water.

Chapter 1: Assessing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA)

Rahul Sahajpal[a], Susan R.H. Zimmerman[b], Saugata Datta[c], N. Gary Hemming[a,d], Sidney R. Hemming[d]

a. School of Earth and Environmental Sciences, Queens College, Flushing, NY 11367, United States

b. Center for Acceleratory Mass Spectrometry, Lawrence Livermore National Laboratory, Liv.ermore, CA 94551, United States

c. Department of Geology, Kansas State University, Manhattan, KS 66506-3201, United States

d. Lamont-Doherty Earth Observatory of Columbia University, Rt. 9W, Palisades, NY 10964, United States

Corresponding author: N. Gary Hemming

Published in: Geochimica et Cosmochimica Acta

Received 22 November 2010; accepted in revised form 25 August 2011; available online 8 October 2011

Abstract

Regional climate-driven hydrological changes are accompanied by salinity changes in closed basin lakes. We have investigated acid leachable Li, along with other leachable ions including Mg, Ca and Sr, as geochemical proxies of salinity in lake sediments in the Mono Basin, California. All the elements in the acid leachable suite show a strong correlation with paleo-lake level estimates based on physical and stratigraphic evidence. The $CaCO_3$ content of lake sediments, which has been shown to be a reliable proxy for lake level changes in the Mono basin and the adjoining Owens Lake basin, corresponds well with our acid-leachable proxy data.

1. Introduction

Understanding the strong tele-connections between global climate and hydrological changes in closed basin lakes of arid regions requires the development of geochemical proxies for paleo-hydrology (Broecker et al., 1988; Lin et al., 1996). Mono Lake is one of many Great Basin lakes that experienced significant lake level fluctuations over glacial-interglacial timescales. Paleoclimate studies of the Owens and paleo-Lake Lahontan systems (Davis, 1983; Benson and Thompson, 1987; Hostetler and Benson, 1990; Benson et al., 1996; Lin et al., 1996; Bischoff et al., 1997; Smith and Bischoff, 1997; Bischoff and Cummins, 2001; Li et al., 2004; Bacon et al., 2006) provide evidence of significantly wetter conditions in the region during glacial times. Mono Lake also experienced wet/dry cycles, but unlike the Owens and Lahontan systems it did not spill out of its basin in at least the last glacial cycle. As in other closed basin lakes, changes in hydrology strongly affect the water chemistry of Mono Lake. Mono Lake water has highly unusual chemistry (Blevins et al., 1984; Simpson et al., 1980, 1982; Anderson et al., 1982; Johannesson and Lyons, 1994; Johannesson et al., 1994), including extremely high pH (9.8), alkalinity (~400 mM) and salinity (~8.1%). In this study we investigate acid leachable Li, Mg, Ca and Sr in bulk lake sediments to test their applicability as salinity proxies for Mono Lake. We present data from the late Pleistocene Wilson Creek Formation (Lajoie, 1968) from three locations around the Mono Basin: South Shore (SS), Warm Springs (WS) and Wilson Creek (WC), the type section (Fig. 1), with the goal to test the acid leachable Li proxy for salinity developed by Bischoff et al., (1997b) for Owens Lake, and to compare the results with other acid leachable ions (Ca, Mg and Sr).

Lake level proxies like leachable Li and calcium carbonate concentration in lacustrine sediments have successfully been tested as proxies for paleo-salinity and paleo-lake levels in the

Owens Lake basin, where both these proxies have lower values during glacial stages and higher values during interglacial stages (Bischoff et al. 1997b). In this study we investigate acid leachable Li, Mg, Ca and Sr in bulk lake sediments, composed of glacial flour and authigenic minerals including calcite and Mg-silicate, to test their applicability as salinity proxies (and therefore lake level proxies) for Mono Lake. We present data from the late Pleistocene Wilson Creek Formation (Lajoie, 1968) from three locations around the Mono Basin: South Shore (SS), Warm Springs (WS) and Wilson Creek (WC), the type section (Fig. 1). The goal of our work is to test the acid leachable Li proxy for salinity developed by Bischoff et al. (1997b) for Owens Lake, and to compare the results with other acid leachable ions (Ca, Mg and Sr) and the correlation of these geochemical proxies to Lajoie's (1968) lake level curve based on physical stratigraphic evidence.

1.1. Geologic setting

Mono Lake basin is a structural depression of the Basin and Range province, bounded on the west by the steep eastern bounding fault of the Sierra Nevada (Bursik and Sieh, 1989). Volcanics to the north (Bodie Hills), to the east (Anchorite Hills and Cowtrack Mountains), and to the south (Long Valley Caldera) form the other basin boundaries (Fig. 1). Mono basin itself contains young volcanic centers, including the Mono-Inyo Craters, and Paoha and Negit Islands (Fig. 1). The volcanic activity in the Mono Lake basin has been attributed to the Long Valley caldera (Bailey et al. al., 1976; Hildreth and Mahood, 1986). This caldera was created by an eruption that occurred at 767.1±0.9 ka (Crowley et al., 2007). In addition to the volcanic and tectonic activity in the region, glacial processes as well as lake level changes have played a major role in the geomorphology of the Mono basin (Stine, 1990; Bursik and Gillepsie, 1993).

1.2 Hydrology

Mono Lake is thought to have existed for ~ 3 Ma and has been hydrologically closed for ~ 1 Ma (Phillips et al., 1995). It lies in the rain-shadow east of the Sierra Nevada in eastern California. The lake was greatly expanded during Pleistocene glacial periods (Stine, 1990), and the last glacial high stand left visible evidence in the form of lake terraces (Fig. 1) and exposed lake sediments (Russel, 1889; Lajoie, 1968).

Modern Mono Lake receives most of its water from runoff from melting snow in the Sierra Nevada. Based on Li isotope mass balance, Tomascak et al. (2003) estimated that 85% of the water to the lake is contributed by Sierran streams, the remainder being supplied by groundwater and thermal springs (Blevins et al., 1984), and a negligible amount being supplied by direct precipitation. The compositions of stream and spring waters have been reported by Neumann and Dreiss (1995) and Conell and Dreiss (1995). The chemistry of the streams and springs results from weathering processes, and these inputs to Mono Lake, along with evaporation processes and mineral formation within the lake, are responsible for the lake chemistry (Tomascak, 2003).

The lake is at an advanced stage of brine evolution, dominated by Na-CO_3-Cl-SO_4 ions (Bischoff et al., 1993). It is famous for its tufa towers which are fossil spring deposits that form by spontaneous precipitation when fresh water carrying Ca^{2+} ions enters the highly alkaline lake (Li et al., 1997). The high alkalinity of the lake is responsible for anomalously high concentrations of certain elements like the lanthanides and actinides due to complexing of these ions with the carbonate ion (Simpson et al., 1980, 1982; Anderson et al., 1982; Johannesson and Lyons, 1994; and Johannesson et al., 1994).

1.3 Stratigraphy

The late Pleistocene lake sediments of the Mono Basin form the Wilson Creek Formation, named and described by Lajoie (1968). At the type section in Wilson Creek Canyon, an erosional feature formed by the diversion of Mill Creek, the Wilson Creek Formation is composed of ~7 m of lake sediment overlying fluvial sand and gravel (Fig. 2a). The top of the formation is approximately 12 ka (Benson et al., 1990, 1998) and the bottom is approximately 67 ka (Zimmerman et al., 2006) (Fig. 2b). Sediments in the Wilson Creek Formation are generally fine grained lacustrine silts, indicative of deep lake environments, and they contain moderate to high concentrations of inorganic and organic carbonate (Benson et al., 1998). Outsized clasts of igneous and metamorphic rocks are interspersed within the lake sediments (Zimmerman et al., 2006, 2011 a).

The lacustrine sediments of the Wilson Creek Formation contain 19 volcanic ash layers, eighteen of which are rhyolitic. Ash 2, near the top of the section, is a basaltic layer originating from the eruption of the Black Point volcanic center (Fig. 1). Lajoie (1968) used these tephra layers for stratigraphic correlation in the basin. He grouped them into 5 marker sequences with marker sequence A (ashes 1-4) near the top and marker sequence E (ashes 18 and 19) near the bottom (Fig. 2a). These marker sequences are clearly visible in exposures of Wilson Creek Formation.

2. Materials and Methods

Bulk sediment samples were collected every 2 cm at the South Shore, Warm Springs and Wilson Creek sections (locations shown in Fig. 1), and stratigraphic positions were documented with reference to vertical distance from the ashes. Sampling was conducted during two field seasons in June 2001 and June 2005. The samples were prepared for analysis using the following method developed by Bischoff et al. (1997b). Approximately 0.5 g samples were weighed into 15 ml centrifuge tubes. Ten ml of de-ionized water was added to the samples and the tubes were agitated on a shaker table overnight to dissolve any interstitial salts. Samples were then centrifuged, and the water removed and stored. The samples were leached with 10ml 1N HCl for 24 hours on a shaker table, followed by centrifuging for 20 minutes and removal of the supernatant to a new tube for dilution and analysis. Samples were prepared for ICP-OES measurement by pipetting 0.5 ml of the supernatant into a 200 ml nalgene bottle, and 99.5 ml of 2% HNO_3 was added to make 100 ml solutions for Li measurements (200:1 dilution). Samples were further diluted to 2000:1 for Ca, Mg, and Sr measurements. The solutions were analyzed using an Inductively Coupled Plasma- Optical Emission Spectrometer (ICP-OES; Perkin-Elmer Inc. 5300 DV). Two samples, one from Wilson Creek (WC-16-31) and the other from South Shore (SS-08-29) were used to monitor instrument drift. For these monitor standards, the concentrations of Li, Ca, Mg and Sr was determined by standard addition. Monitor standards (2000:1 dilution only), as well as a mixed standard solution, are analyzed repeatedly, bracketing every five samples. The mixed standard solution was prepared using Fisher Scientific 1000 ppm standard solutions of Li, Ca, Mg, and Sr mixed and diluted such that the concentration of each element approximates the expected concentration of the samples. Samples were run in batches of 30. For this project, the samples were analyzed over a 15 day period. Four replicate samples from previous batches were run during each analytical session. Uncertainties for the Li, Ca, Mg, and Sr measurements are 3%, 2.7%, 3.6% and 2.4% relative standard deviation, respectively. Based on standard addition tests, we estimate the data are accurate at the level of the precision. Further details of sampling, data collection and drift correction are provided in the supplementary material. Data are reported as weight of analyte per weight of sediment sample, in ppm.

The clay-sized fraction of the bulk lake sediments was studied to identify the Mg silicate mineral phase, using three different strategies. The first approach involves making geochemical measurements on decarbonated <2 µm fraction to determine the bulk composition. In order to do so, the <63 µm fraction of ~10.0 g of bulk sample was separated by wet sieving, and then the >2 µm fraction settled out according to Stokes' Law. The <2µm fraction was then decanted and collected by centrifuging for 4-6 hours (with $CsCl_2$ or $KHCO_3$ added to aid flocculation), and the supernate drawn off with a syringe and discarded. Samples were treated with a solution of excess 0.1 N HCl + 5% H_2O_2 to remove carbonate and organic matter, followed by analysis of ~100 mg of sample by XRF for major and trace elements at XRAL Laboratories (Ontario, Canada). Stated detection limit for major elements is 0.01 ppm. Four samples were analyzed twice, with replicates generally within 5% for Na_2O and CaO and 1% for MgO.

The second approach involves measuring four of the <2 µm fraction samples prepared for X-ray diffraction (XRD) to identify the clay minerals using the technique developed by Moore and Reynolds (1989). The <2 µm size fractions was separated by standard sedimentation and centrifugation techniques. Non-clay contamination in this size fraction consists of minor quartz and feldspar. Mineralogy and sample purity were then determined by powder X-ray diffraction of both oriented and randomly oriented mineral- aggregate samples. The <2 µm fraction was dried at 0 and 54% relative humidity and solvated with ethylene glycol at 60-70°C for 4 hrs, and subsequently heated at 400°C (~1/2 hour) and 550°C (~1/2 hour). Samples were then scanned at 1° (2θ) per minute on a Philips X'Pert-MPD Multi-Purpose Diffractometer, which has a theta-theta goniometer, and is equipped with computer-controlled, theta-compensating optics, and a Cu

X-ray tube and a Peltier-cooled, high-sensitivity Kevex energy dispersive detector. Clay polytypes were identified following the approach of Moore and Reynolds (1989). Lastly, these phases were confirmed by Scanning Electron Microscope study with Energy Dispersive Spectroscopy analyses. The surface micromorphology of the clays and the textural relationships of the Mg-smectite phases were determined by a Cambridge 250 SEM and the association of Mg was confirmed by a Kevex 8000 EDX attached to the SEM.

3. Results

Leachable Li concentrations range from 12 to 282 ppm, with high concentrations generally corresponding to periods of high lake level (Fig. 3). Leachable Mg, Ca and Sr concentrations, as well as carbonate concentrations (calculated as calcium carbonate) co-vary positively with Li concentrations (Fig. 3). Results of SEM, XRD and major element composition (Fig. 4) suggest that the Mg-silicate phase in Mono Basin sediments is Mg-smectite rather than sepiolite as previously reported for Owens Lake (Bischoff et al., 1997b). . This is consistent with the findings of Banfield et al (1991), who found Mg-smectite in alkaline Abert Lake, Oregon. Our data show a strong co-variance in leachable Li and Mg concentrations (Fig. 5), similar to that found in the Bischoff et al. (1997b) Owens Lake study.

Further, the variation of the leachable elements with Mono Lake levels is opposite that found in Owens Lake (Bischoff et al., 1997a, b), consistent with the observations made by Zimmerman et al. (2006, in press b) for calcium carbonate. These results document important differences between these two lakes, discussed below.

4. Discussion

Bischoff et al. (1997b) showed that 20-30% of the fine fraction of lacustrine sediments in Owens Lake basin is composed of a pure Mg-silicate phase, and the concentration of this phase is greater during times of higher paleo-salinity. They showed that on a weight basis 57 % of the total bulk Mg is acid soluble authigenic silicate, 34% is in non-leachable clastic component and the rest is associated with the carbonate phase. In Owens Lake basin the concentration of the Mg-silicate phase is greater during times of higher paleo-salinity. Because Mono Lake shares a similar setting as Owens Lake, similar authigenic sediments are deposited in both basins. Exceptions are minerals representing playa conditions (gaylussite and gypsum), which are found in Mono Basin with no known traces in Owens Lake basin (Bischoff et al., 1997a). Our estimates based on scanning electron microscopy, X-ray diffraction and major element composition (Fig. 4) suggest that the Mg-silicate phase in Mono Basin sediments is Mg-smectite**.** Evaporation experiments conducted using Chari river water, which feeds Lake Chad a closed basin, hyper-saline and highly evaporative body of water show that lake waters are depleted in Ca and Mg as these elements precipitate out as calcite and Mg-silicate mineral respectively. Subsequent work done by Jones and Weir (1983) and Banfield et al. (1981) in Lake Abert showed that this Mg-silicate mineral was in fact Mg-smectite. Singer (1984) went on to show that while clay mineral kaolinite was indicative of humid climates, smectites indicate pronounced dry periods conforming to the conditions in Mono Basin. These studies support our findings that the Mg-silicate mineral found in Mono Lake basin is indeed Mg-smectite. Leachable Li was demonstrated to be a sensitive proxy for salinity in the Owens Lake basin (Bischoff, 1997b). Lithium tends to replace Mg in Mg-smectite due to their similar ionic size, and we expect that almost all of the Li found in the sediments is hosted by the Mg-smectite. Both the Bischoff et al. (1997b) study and our data show a strong co-variance in leachable Li and Mg concentrations (Fig. 5). The Bischoff et al. (1997b) study suggested that leachable Li should be a more reliable proxy for salinity, as Mg may be found in other mineral phases.

4.1 Expected behavior of elements in Mono Lake water

A possible explanation for the contrasting records between Owens Lake and Mono Lake comes from considering the residence time of water in the basins. Throughout the last glacial cycle, Mono Lake never spilled (Phillips et al., 1995), while Owens Lake frequently spilled into Searles Lake (Bischoff et al., 1997b). The flushing of ions out of Owens Lake during wet times results in a short residence time for the ions in the lake and therefore generally fresher water. In contrast, the only removal mechanism for salt in Mono Lake is mineral precipitation and adsorption. The classic model of evaporative concentration of Sierran spring water by Garrels and Mackenzie (1967) provides a first order explanation for the high Li, Mg, Ca and Sr concentrations in Wilson Creek sediments, and for the increased concentrations during high lake levels. The model tracks the concentration of major ions in Sierra Nevada spring water as it is evaporates and minerals precipitate. Ions such as Na^+, K^+, Cl^- and SO_4^{2-} (and Li^+, Tomascak et al., 2003) behave conservatively, and show increasing concentration proportional to the evaporative concentration factor (CF) achieved. The CF is the ratio of the initial volume of water to the volume remaining after evaporation (Drever, 1997), so describes a universal affect upon which individual ions in solution can be modeled. In contrast, ions that form minerals that are saturated at relatively low CF, such as Ca^{2+} (compared to HCO_3^-) and Mg^{2+} (compared to H_4SiO_4), are effectively titrated out of the water as their mineral host gets saturated. This leads to a situation where most of the time Mono Lake water is supersaturated with calcite and Mg-smectite, but has very low concentrations of Ca and Mg due to greater molar ratios of HCO_3^-/ Ca^{2+} and H_4SiO_4/ Mg^{2+}. Thus, as fresh water increasingly flows into the lake (high lake), more

Ca and Mg are available and thus higher concentrations of calcite and Mg-smectite are found in the sediments. This is initially counter-intuitive, but is understandable when considering that precipitation of these phases is essentially a Ca and Mg supply-limited process, so during highstands the total flux increases.

The extremely conservative nature of Li leads to a long residence time (~ 28 ka) and correspondingly high Li concentration in Mono Lake water (Tomascak et al., 2003). Lithium flux estimates made by Tomascak et al. (2003) for Mono Lake show that groundwater springs supply most of the Li (6.00×10^5 g/a), almost three times as much as streams (2.10×10^5 g/a) feeding the lake. Less than 3% of the spring flow is contributed by thermal springs, but along with groundwater springs, supplies > 50% of the total Li to the lake.

In contrast to Li, concentrations of Ca, Mg, and Sr ions are depleted in Mono Lake water relative to the fresh water sources (Tomascak et al., 2003). Estimates of Ca, Mg, and Sr concentration factors are shown in Table 1. Flux estimates made by Tomascak et al. (2003) show that most of the Ca and Mg to the lake is supplied by the creeks, followed by groundwater and thermal springs. Almost all the Ca^{2+} supplied to the lake is precipitated as calcite when it reacts with the abundant HCO_3^- ion in the lake water. The precipitation of calcite forms the first chemical divide as the concentration factor increases. Calcite concentrations in Wilson Creek Formation sediments faithfully follow the changes in lake level based on physical stratigraphic evidence (Zimmerman et al., 2006, in press b).

Factors that might govern the concentration of leachable Li include the following:

1) The flux of Mg-smectite to the sediments is an important consideration. As the host for Li in the sediments, greater concentrations of Mg-smectite would yield greater concentrations of leachable Li. While generally an excellent foundation for

discussing the evolution of Mono Lake water chemistry, the model of Garrels and MacKenzie needs some modification. For one thing, Sierran springs are not the only source of water and ions (Tomascak et al., 2003). Additionally, the modern concentration of Mg in Mono Lake indicates a greater residence time for Mg than for Ca (Tomascak et al., 2003). In contrast, the Garrels and Mackenzie model has Mg titrated to zero at a lower CF than the Ca. In their model, a concentration factor of ~20 corresponds to near zero Mg, which is removed by sepiolite precipitation, while a concentration factor of ~100 has Ca depleted by calcite precipitation. Although this is not completely accurate for the Mono system, as the observed Mg-mineral is smectite and not sepiolite (Fig. 4), this modeling approach still explains the main geochemical observations of Mono Lake water.

2) The Li/Mg of the lake water certainly increases with increasing salinity of the lake, and in turn for the minerals precipitating from the water. To emphasize this we note that the Li/Mg of Mono Lake water is 0.244 while the Li/Mg of the inputs is 0.0016. During the time of Wilson Creek Formation deposition, the lake was always considerably higher than today, and it is likely that the range of concentration factors was less than 10 (Fig. 6). In this case, it might be expected that the Li/Mg of lake water during Wilson Creek Formation deposition was lower than in the modern lake.

3) There could be variations in the distribution coefficient ($K_{d,}$ defined as the ratio of the concentration of a chemical species in two different phases) of Li in Mg-smectite. We would expect this would be a very minor effect compared to the very large effect expected due to changes in the Li/Mg of the water. As mentioned above, Li ion tends to replace Mg due to their similar size, but due to their different chemical behavior in

the lake water, it is possible that the K_d for Li into Mg-smectite might vary with higher concentration factors as Mg is titrated out.

4.2 Acid leachable Li and lake level

Lajoie (1968) established a lake level curve for Mono Lake using physical stratigraphic evidence from the Wilson Creek formation, and based on paleo-lake terraces and sedimentary facies. Lajoie used ash layers to correlate the sedimentary sequences throughout the basin and into the terraces. This curve provides an important test for any proxy developed for tracking salinity changes of the lake. If leachable Li in the lacustrine sediments is a proxy for salinity, we should expect a correlation to the lake level curve. The leachable Li proxy generally follows the lake level curve between 20 to 67 ka (Fig. 3). Leachable Li concentrations also show an excellent agreement with $CaCO_3$ concentrations throughout the Wilson Creek Formation, which has been previously demonstrated to follow lake level (Zimmerman et al., 2006, in press b). It also appears to document millennial timescale changes which are not explicitly documented in the much lower resolution lake level curve, but are seen in the $CaCO_3$ record (Benson et al., 1998; Zimmerman et al., 2006). However, the Li concentrations corresponding to the interval from Ash 8 to the top of the Wilson Creek Formation fail to reflect the extremely high lake at approximately 14 ka. The interval above Ash 8 is known to be the timing of Tioga glaciation (e.g., Benson et al., 1998). Thus, a likely reason for this mismatch is the very high glacial flour flux during Tioga glaciation (Benson et al., 1998) that would have diluted the Mg-smectite component. The flux of Mg-smectite to the lake sediment could be determined if a highly resolved time scale were available. The samples representing the younger part of the record belong to only the Warm Springs section, so for a more detailed investigation, samples of the same age need to be collected from the Wilson Creek type section and the South Shore localities.

5. Summary

Leachable Li was successfully tested as a paleo-salinity proxy in the adjoining Owens Lake basin by Bischoff et al. (1997b). The current study supports those results, and establishes Li and other leachable ions as robust proxies for salinity. Our study further concludes that the inverse relationship between calcite and Li between the two basins is an artifact of the geologic setting of the two basins that leads to an important difference in their aqueous chemistry. The acid leachable Li, Mg, Ca and Sr from Wilson Creek Formation sediments at Mono Lake accurately trace the lake level throughout the last glacial cycle. We can make the following general conclusions:

1) A tight correlation between Li and Mg is consistent with the interpretation that the Li found in the lacustrine sediments resides in the Mg-silicate phase.
2) Leachable Li concentrations are also strongly correlated with calcite concentrations, consistent with both Mg-smectite and calcite precipitation being controlled by fresh water fluxes to the lake.
3) The opposite relationship seen for calcite and lake levels between Mono and Owens Lake basins is also found in the leachable Li concentrations. This relationship is explained by Mono Lake being entirely closed while Owens Lake overflowed during wet intervals.
4) Leachable Li has proved to be a portable proxy to record salinity changes at a very high resolution in in Mono and Owens Lake basins and promising for similar arid basin lakes throughout the world.

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gca.2011.10.001 and at the end in appendices 1a-c.

Table 1-1 Concentrations of cations in Mono Lake water and the source waters.

Element	Source waters (creeks + thermal springs + groundwater springs) mg/l	Mono Lake mg/l[*]	Concentration factor[**]
Li	0.0037	10	2660
Mg	10	41	18
Ca	2.27	4	0.398
Sr	0.01	0.025	0.385

[*] Source: Tomascak et al. (2003)

[**]Concentration factor is the ratio of the initial volume of water to the volume remaining after evaporation (Source: Drever, 1997)

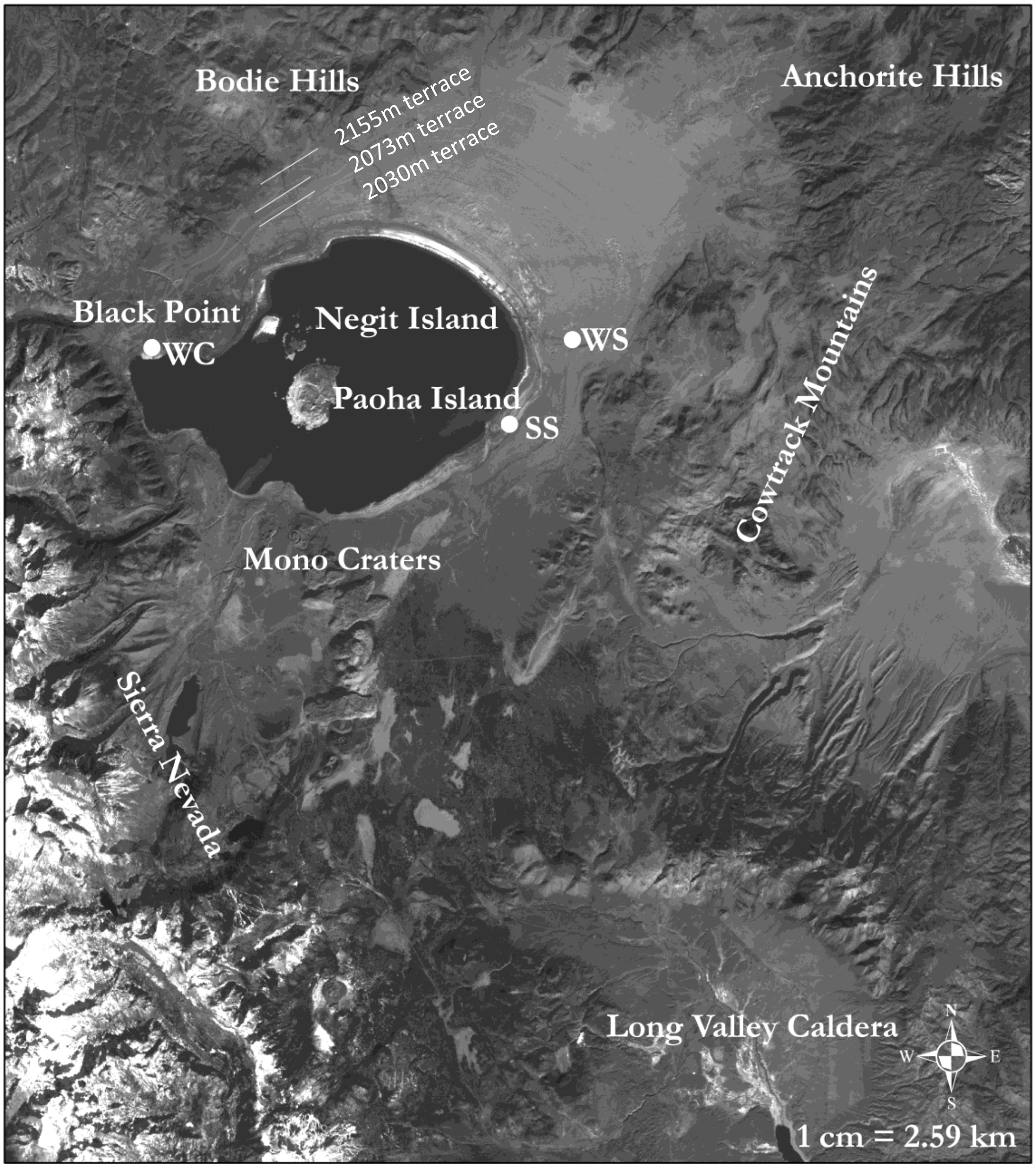

Figure 1-1 Satellite image of the Mono Basin and surrounding features. Outcrops (SS, WC and WS) examined for this study are marked by dots. Major lake terraces are highlighted on the NW side of the lake (Battaglia et al., 2003).

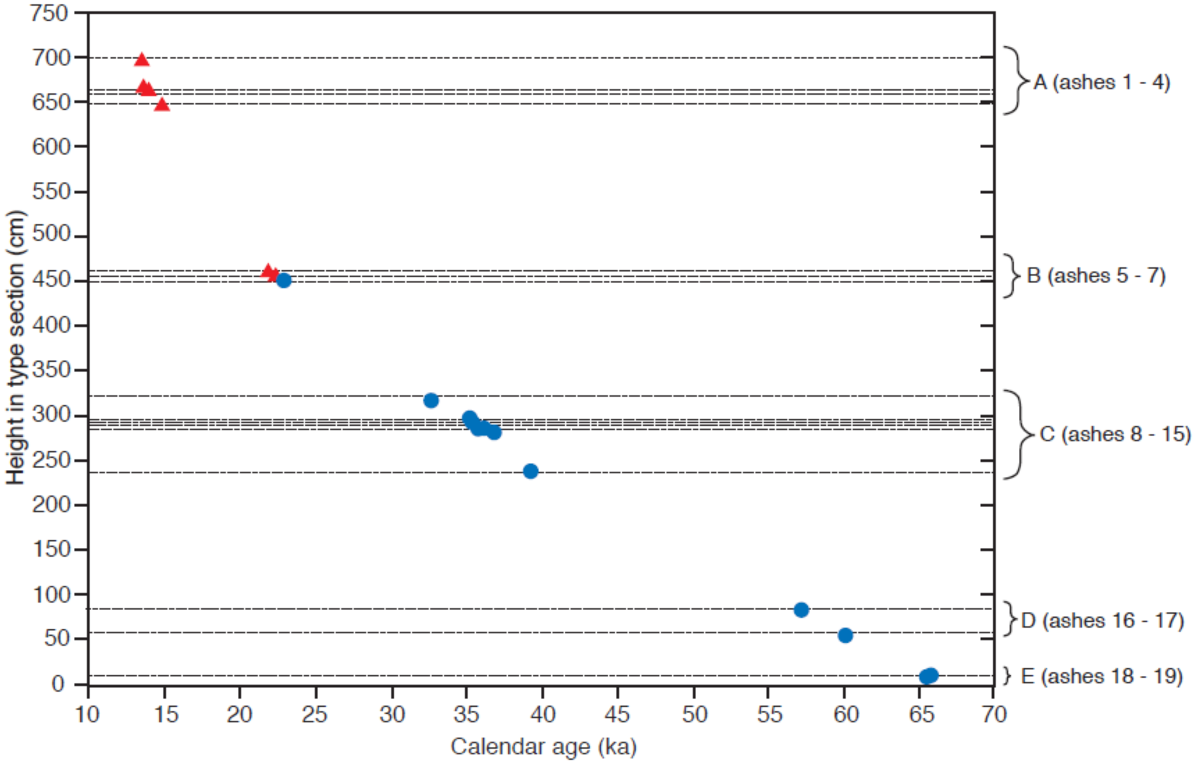

Figure 1- 2 a. Photograph of the Wilson Creek type section described by Lajoie (1968) from exposures in the Wilson Creek canyon. Eighteen rhyolitic ashes from the Mono Craters and one basaltic ash from Black Point are grouped into five marker sequences. **b**. Published age estimates for the Wilson Creek Formation based on the relative paleo-intensity of Mono Lake basin sediments (Zimmerman et al., 2006). The age estimates using relative paleo-intensity are for the lower part of the Wilson Creek Formation (ashes 7-19, circles). Age estimates for the upper part of Wilson Creek Formation are from Benson et al., 1990 (triangles). The dashed lines indicate the locations of the ash beds in the Wilson Creek Formation grouped as marker sequences following Lajoie (1968).

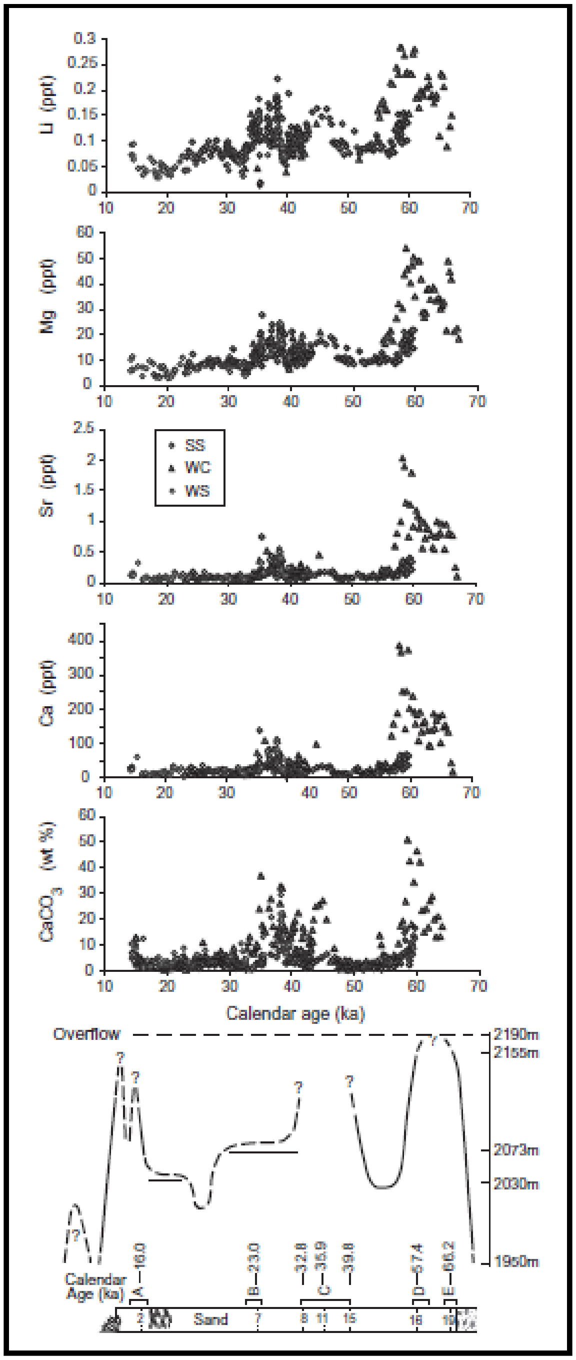

Figure 1-3 The concentrations of leachable Li, Mg, Sr and Ca and $CaCO_3$. The lower panel shows the lake level interpretation modified from Lajoie (1968).

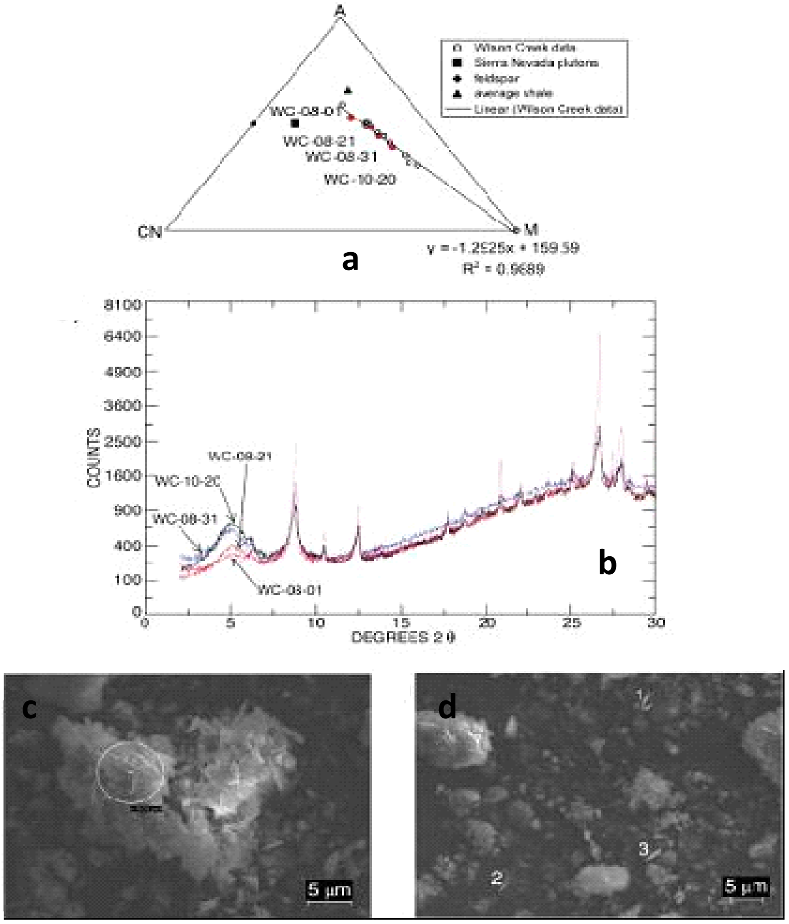

Figure 1-4 a. CaO + Na_2O - Al_2O_3 - MgO (CN-A-M) ternary plot. **b**. XRD scans. **c**. Scanning Electron Microscope (SEM) images. **c**. The circle highlights the presence of smectite-like platy minerals and needle-shaped crystallites. **d**. Chemical composition of Needle 1 (MgO 13.3, SiO_2 67.7, Al_2O_3 18.9), Needle 2 (MgO 12.1, SiO_2 87.4), Needle 3 (MgO18.2, SiO_2 81.7).

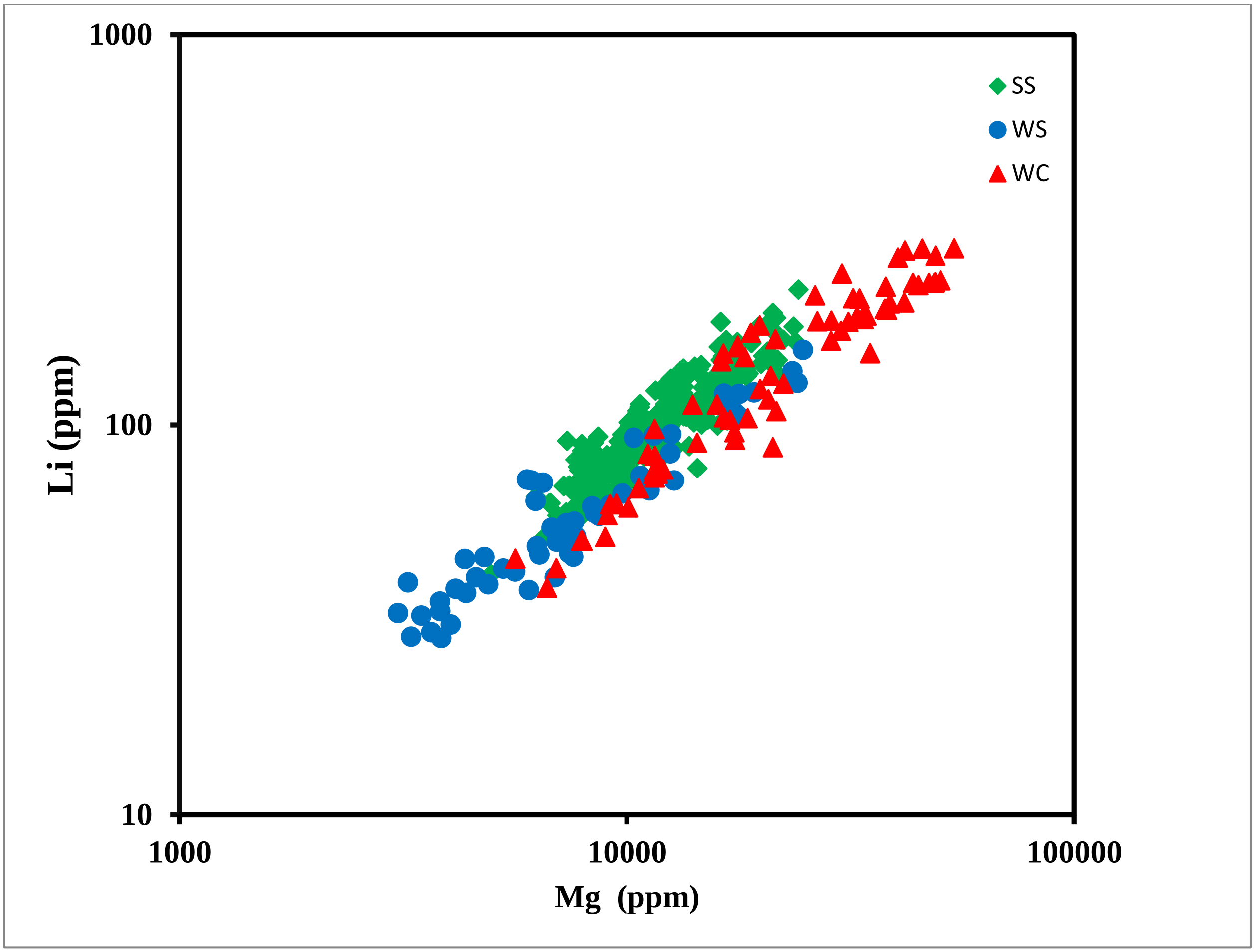

Figure 1-5 Acid leachable lithium versus magnesium for the Wilson Creek Formation.

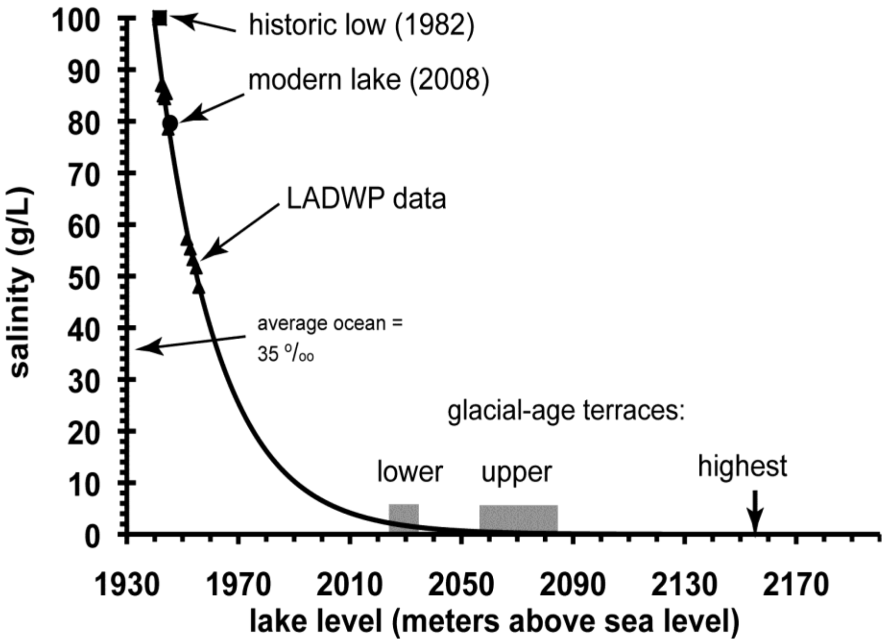

Figure 1-6 Relationship between lake level and salinity in Mono Lake. The curve below the modern day symbols is schematic. The elevation of modern day terraces is shown along the x axis. Figure modified from Zimmerman (2006).

Chapter 2: Precise determination of element concentrations in authigenic sediments of Mono Basin, California, using ICP-OES

Abstract

Lacustrine sediments in closed arid environments can record the chemical signatures for hydrological changes. Proxy development work in such basins has mainly focused on the saline waters of these lakes. Here we present a technique for rapid analysis of leachable ions Li, Mg, Ca and Sr in the lacustrine sediments from the Wilson Creek Formation collected from three localities in the Mono Lake basin. Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) provides us with a rapid technique to investigate the geochemistry of the lake sediments with a high resolution data set. The results obtained in this technique have been published in the companion study (Sahajpal et al. 2011).

1. Introduction

Most of the geochemical work done in the arid closed basins until recently had focused on the saline lake waters that generally occupy these basins (Garrels and Mckenzie, 1967; Hardie and Eugster 1970; Eugster and Jones, 1979; Eugster and Maglione 1979). The geochemistry of the sediments occupying in these basins was mostly ignored in these investigations. A significant component of these sediments is the authigenic mineral phases that deposit from saline lakes (Bischoff et al. 1997a, 1997b; Menking 1997), so in order to develop comprehensive geochemical proxies for arid closed basins it is imperative to study both the geochemistry of the sediments and lake waters in these basins.

Until recently, most geochemical studies of closed basin lakes focused on the saline lake waters, while little work was done on the chemistry of the lake sediments (Garrels and Mackenzie, 1967; Hardie and Eugster 1970; Eugster and Jones, 1979; Eugster and Maglione 1979). A significant component of these sediments are authigenic mineral phases (Bischoff et al. 1997a, 1997b; Menking 1997), so in order to develop comprehensive geochemical proxies for arid closed basin lakes, it is imperative to study both the geochemistry of the sediments and lake waters in these basins.

The Great Basin in the western United States is an internally drained arid basin with numerous sub-basins like Owens and Mono Lake basin. These two basins are the most studied basins in the Great Basin region. These are adjoining basins that abut the Sierra Nevada. These basins due to their proximity have experienced same climate regimes and depend on the precipitation falling on Sierra Nevada for their annual water supply. The difference in the geology of these basins has led them to have contrasting paleo-hydrology (Bischoff et al., 1997a; Zimmerman et al. 2006, 2011a, 2011b). Investigations conducted in the lacustrine sediments of the Owens Lake (Bischoff et al. 1997a, 1997b) and Mono Lake (Zimmerman et al. 2006, 2011a, 2011b; Sahajpal et al. 2011) basins have shown that proxies like calcite and leachable Li can be developed in these sediments as proxies for paleolake level and paleosalinity.

This chapter discusses the sampling and detailed analytical technique we developed for rapidly analyzing leachable ions in lacustrine sediments from South Shore Warms Springs and Wilson Creek type section of the Wilson Creek Formation (WCF) (Fig.1) for Sahajpal et al. (2011). Using this technique we measured leachable Li and other leachable ions like Ca, Mg and Sr in lacustrine sediments at a very high resolution using Inductively Coupled Plasma-Optical Emission Spectrometer. The advantage of using this instrument is its ability to measure multiple ions simultaneously at parts per billion concentrations simultaneously which makes it a cheaper and a highly effective tool in conducting similar analysis.

2. Instrumentation

All the samples analyzed for this study were analyzed on a Perkin Elmer Inc. ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometer) model 5300*DV* with an AS-93 plus auto-sampler. It is a dual view instrument that allows samples to be viewed in both axial and radial positions and has the capability of switching between the two modes during analysis. This instrument directs argon gas through a torch which consists of three concentric rings made out of quartz. The top end of the torch is surrounded by a copper coil which is connected to an RF generator. When current is passed through the coil the current oscillates producing magnetic and electric fields and when argon gas passes through this torch it gets ionized. The process of adding energy to the electrons in this manner is called inductive coupling. These ions of Ar continue to ionize more atoms like a chain reaction producing plasma at (~6000-10,000°C). The liquid sample is nebulized into the plasma as an aerosol where the plasma desolvates, vaporizes and then atomizes the sample. Once the sample has been atomized the sample gets excited to higher energy level. The spectra emitted by different elements during the excitation and ionization process is detected by the optics in the instrument and recorded.

The choice of ICP-OES for the current analysis was made because of its high throughput of samples, ability to measure element ratios with a very high precision (Schrag 1999). This instrument is capable of analyzing up to 70 elements at parts per billion (ppb) concentrations. The upper limit of detection for most elements is usually $10^4 – 10^6$ times its detection limit. This enables the instrument to have a long Linear Dynamic Range (LDR) of the emission line. It is the range between the detection limit and the upper limit of concentration for any element measured by the instrument. Because of its long LDR it is preferred over instruments like Atomic Absorption Spectrometer (AAS) which have LDRs that extend over one or two orders of magnitude. High LDR of ICP-OES enables calibration using a blank and a single high concentration standard. Due to its high resolution spectrometers coupled with advanced background correction techniques and numerous emission lines reduces the possibility of interference. The settings on the instrument used for this analysis is listed in (Table 2-1).

2.1 Sampling

Three major outcrops of the Wilson Creek formation were sampled during the summers of 2001 and 2005 in the Mono Basin, namely South Shore (SS), Warm Springs (WS) and Wilson Creek (WC) Formation type section. Samples at each site were collected every 2 cm, since it is difficult to obtain a complete set of samples from one location sampling was done in sections where there was a clear demarcation between the lacustrine sediments and the volcanic ash layers. The samples analyzed in this study are the same samples that Zimmerman et al.

(2006, 2011b) used for developing the relative paleointensity based age scale for Wilson Creek Formation and calcite as a proxy for paleolake level. Sampling locations, sections and the dates on which the sampling was done are shown in (Table.2-2).

2.2 Acid Leaching

The preparation of samples follows the procedure of Bischoff et al. (1997b). Approximately 0.5 g of sample is weighed in 15 ml centrifuge tubes. The samples are washed with 10 ml of de-ionized water and left overnight on a shaker table to remove any interstitial salts. Following centrifuging and removal of the excess water, the samples are then leached with 10 ml of 1N HCl (trace metal grade) for 24 hours, and centrifuged for 20 minutes, after which the acid was removed to a separate tube. The leaches were then sealed and stored for future analysis.

2.3 Solutions and Standards

In order to prepare samples for analysis on the ICP-OES, 0.5 ml of leach acid is completely dried and dissolved in 100 ml of 2% HNO3 (trace metal grade). Two samples, one from the Wilson Creek (WC-16-31) and the other from South Shore (SS-08-29) sites, was taken to prepare two monitor standards by drying down 5 ml of the leach acid and re-dissolving it in 1000 ml 2% HNO3. For these monitor standards, the concentrations of Li, Ca, Mg and Sr was determined by standard addition. These monitor standards were diluted 10 times and run repeatedly as a matrix-matched monitor of instrumental drift. As an additional monitor of instrumental drift, a mixed standard solution was prepared using Li, Ca, Mg, Sr standard.

3. Data Collection

The data were collected in two steps. The Li concentrations were measured in the original (200X dilution) solution, and then these solutions were diluted 10X more for measuring Ca, Mg and Sr. The concentration for Li, Mg, Ca and Sr in the solutions and the monitor standards was calculated using the following formula

$$X\ (\text{unknown}) = X\ (\text{standard}) * X\ \text{signal}\ (\text{unknown}) / X\ \text{signal}\ (\text{standard})$$

$$X = \text{Li, Mg, Ca or Sr}$$

Because of the large number of analyses, they were carried out over a course of several days. In order to determine the reliability with which the estimated concentrations can be reported and to make sure that the instrumental drift is taken into account, an external monitor referred to as the "mixed standard solution" was run after every 5 samples during a single day, and typically about 30 samples were run each day. In order to ensure analytical uniformity, a single stock solution of the mixed standard was prepared and lasted the entire course of the analyses. About 10% of the samples analyzed each day were rerun the following day to ensure replicable results on a day to day basis. The use of the mixed standard as a monitor for daily and day to day instrumental drift ensured consistency in the data set. A graphical representation of our analysis plan is presented in Fig.2.

3.1 Drift Correction

In order to have a reliable data set it is extremely important to monitor instrumental drift, especially for an analysis which spans over several days. In this study an external monitor referred to as the "mixed standard" was used for this purpose. The mixed standards were run every five samples during each day of analysis, which meant that we obtained about eight signal intensity values for the mixed standards for each element during each day. This was used as a monitor for the instrumental drift by taking the mean of the first and last signal intensities for each element for the mixed standard and using that as a correction factor (Fig.3).

3.2 Data Reproducibility

The first test of reproducibility was to rerun 10% of the samples from the previous day. The average absolute difference between these replicate analyses is less than 4% (Table 1). The WC and SS monitor solutions, which were run at the start and end of each analytical session, were reproducible to 4 to 9.5%. However, the ratio between the monitors (WC/SS) is consistent over the same period. The monitors may have somewhat poorer reproducibility as compared to the mixed standards (less than 2%) because there are fewer runs for the monitors as compared to the duplicates. Duplicate aliquots of bulk samples used by Zimmerman et al. (2006) were also prepared (total sample replicates). The average absolute difference between the duplicates was within 10% (Appendix 3) which is slightly higher than for the monitor standard replicates. This work involved the participation of many people, especially for sample processing, and it was spread over a long period of time, so it is an indication of procedural consistency solutions with the concentration of each element approximating the concentration in our monitor solutions.

4. Results and Discussion

The lake chemistry and the chemistry of the sediments are closely tied in the Mono Basin. Much of the work that has been done in the basin has focused on the lake water and how its chemistry has evolved over time. The immense potential of lacustrine sediments in developing proxies was highlighted by Zimmerman et al. (2006; 2011a; 2011b). For her graduate work Zimmerman (2006) used the relative paleointensity of lacustrine sediments to develop a highly resolved age scale for the Wilson Creek formation. Subsequently Zimmerman et al (2006, 2011b) utilized the same sediments to develop calcite as a proxy for paleolevel in Mono Basin. This analysis extends the work initiated by Zimmerman et al. (2006; 2011b) and helps to develop a comprehensive understanding of the authigenic mineral chemistry in the lake sediments.

This study is unique because it provides a high resolution estimate of concentrations of ions forming major authigenic minerals in the Mono Basin (Appendix 1). The two main authigenic minerals found in the lacustrine sediments of Mono Basin are calcite and Mg-smectite other minerals like gaylussite and gypsum are reported but they are not found to be as widespread in the basin as calcite and Mg-smectite. Gaylussite is primarily found at the lake bottom (Bischoff et al. 1993) and gypsum is restricted to a very small part of the basin. Based on this knowledge we primarily focused our attention on cations associated with calcite and Mg-smectite (i.e. Ca, Mg, Li and Sr)

Lithium ion tends to replace Mg ion due its ionic size, so one of the goals of this investigation was to calibrate the Mg concentration in the lake sediments and to prove without a doubt that Mg-smectite is the host of Li in the Mono Basin. The strong correlation between Li and Mg concentrations for three localities in Mono Baisn shows that the leachable Li in the basin hosted in the Mg smectite phase (Fig.4). A similar strong correlation exists between the Calcium and calcite proving that most of the Ca in the sediments comes from calcite (Fig.5).

Some investigative measurements were made for leachable Li on a few lacustrine sediments samples from WC and SS outcrops by Zimmerman et al. (2006) when plotted against the measurements on the samples Li was intuitive for this investigation as leachable Li concentrations were estimated for WC and SS using ICP-MS were conducted for the same set of samples. The samples were run for Li again on the ICP-OES to validate the estimates made by Zimmerman and to test the reproducibility of Li estimates between the two machines. A strong almost one to one relationship between the samples runs on the ICP-MS and the ICP-OES for the South Shore and Wilson Creek formations confirms that our estimates of Li for this study and those of Zimmerman are comparable, some scatter that is observed maybe due to different instruments used during the two analyses (Fig. 6, Fig.7).

5. Conclusion

The goal in carrying out this investigation was to develop a cost effective high resolution estimate for ions forming major authigenic minerals in the mono Basin. We were able to develop one of the most comprehensive data set to date for Li, Mg, Ca and Sr ion estimate from multiple locations in the basin. We have calibrated these elements for the basin and proved without doubt that Li is hosted by Mg-smectite and almost all the Ca is present as calcite in the lacustrine sediments. This methodology forms the basis for our companion study, Sahajpal et al. (2011) and provides an excellent reference for studying the geochemistry of the Mono Basin sediments.

Table 2-1 Instrumental Settings for Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES)

RF power	**1500 Watts**
Viewing position	**Axial**
Plasma gas flow rate	**15 (L/min)**
Auxiliary gas flow rate	**0.1 (L/min)**
Nebulizer gas flow rate	**0.7 (L/min)**

Table 2-2 List of the sample collection sites in the Mono Lake basin

Sample location	Section sampled	Sampling date
Wilson Creek Formation type section (N38.03 W119.12)	Ash 8-Ash15	06/08/01
	Ash 15- base of WCF	06/10/01
South Shore (N38.00 W118.90)	Ash 8- Ash 10	06/14/01
	Ash 10-Ash 13	06/15/01
	Ash 13- Ash 15	06/17/01
	Ash 7- Ash 8	06/19/01
	Ash 15- Ash 16	06/20/01
	Ash 16- Below ash 17	06/21/01
Warm Springs (N38.03 W118.89)	Ash 1- Ash 4	06/23/05
	Ash 5- Ash 15	06/24/05

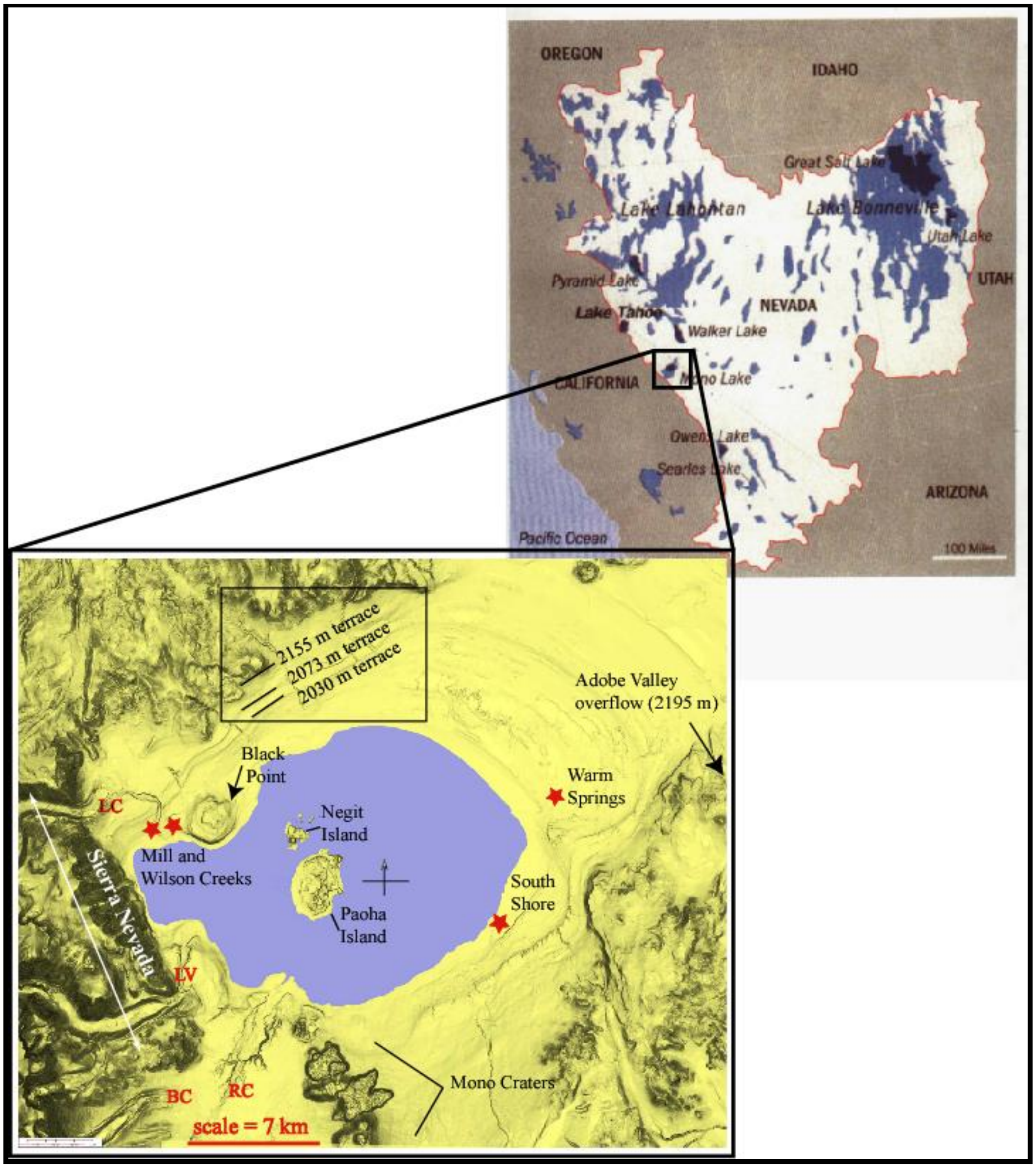

Figure 2-1 The Digital Elevation Model (DEM) map of the Mono Lake Basin. The red stars indicate the sampling locations for this study. The black lines indicate the lake level terraces along the northern margin of the lake. Black point is the source of the basaltic ash layer 2. Mono craters are believed to be the source of the rhyolitic ash layes in the basin.

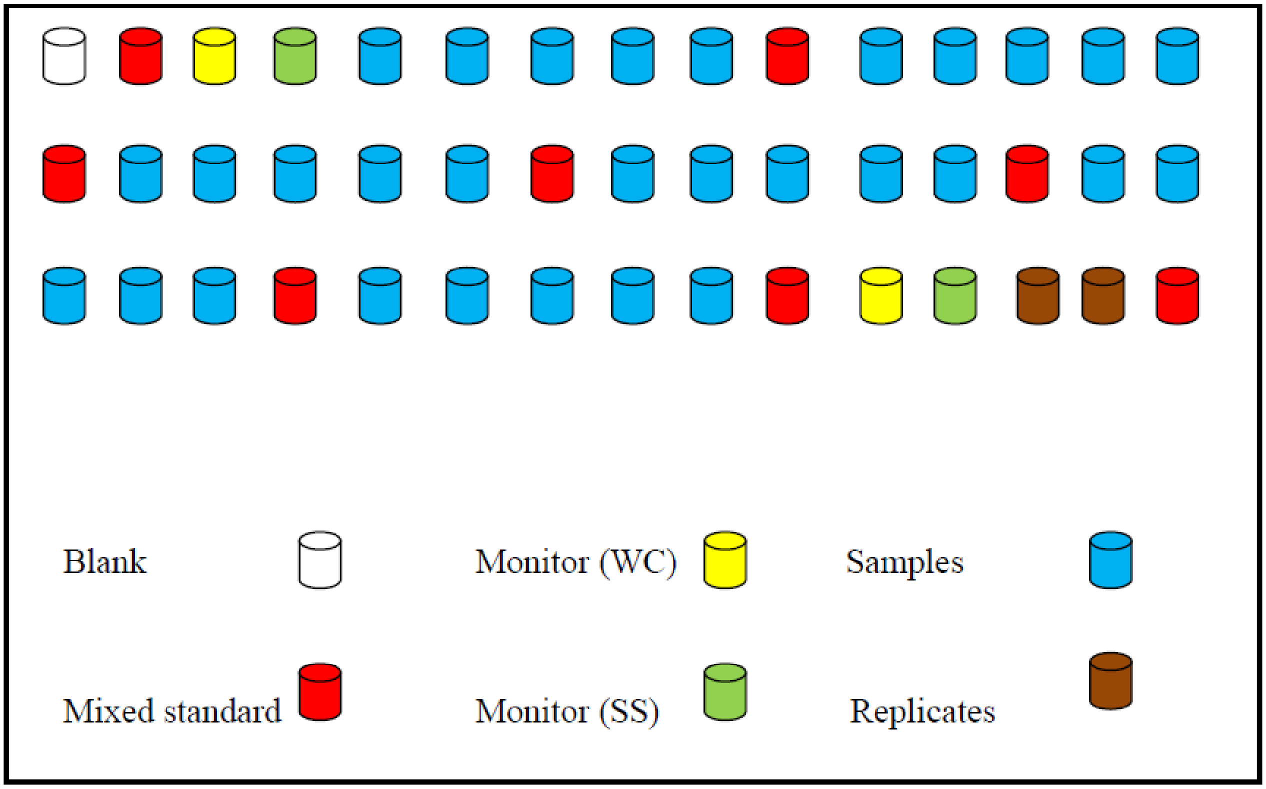

Figure 2-2 A graphical representation of the sample sequence for each day.

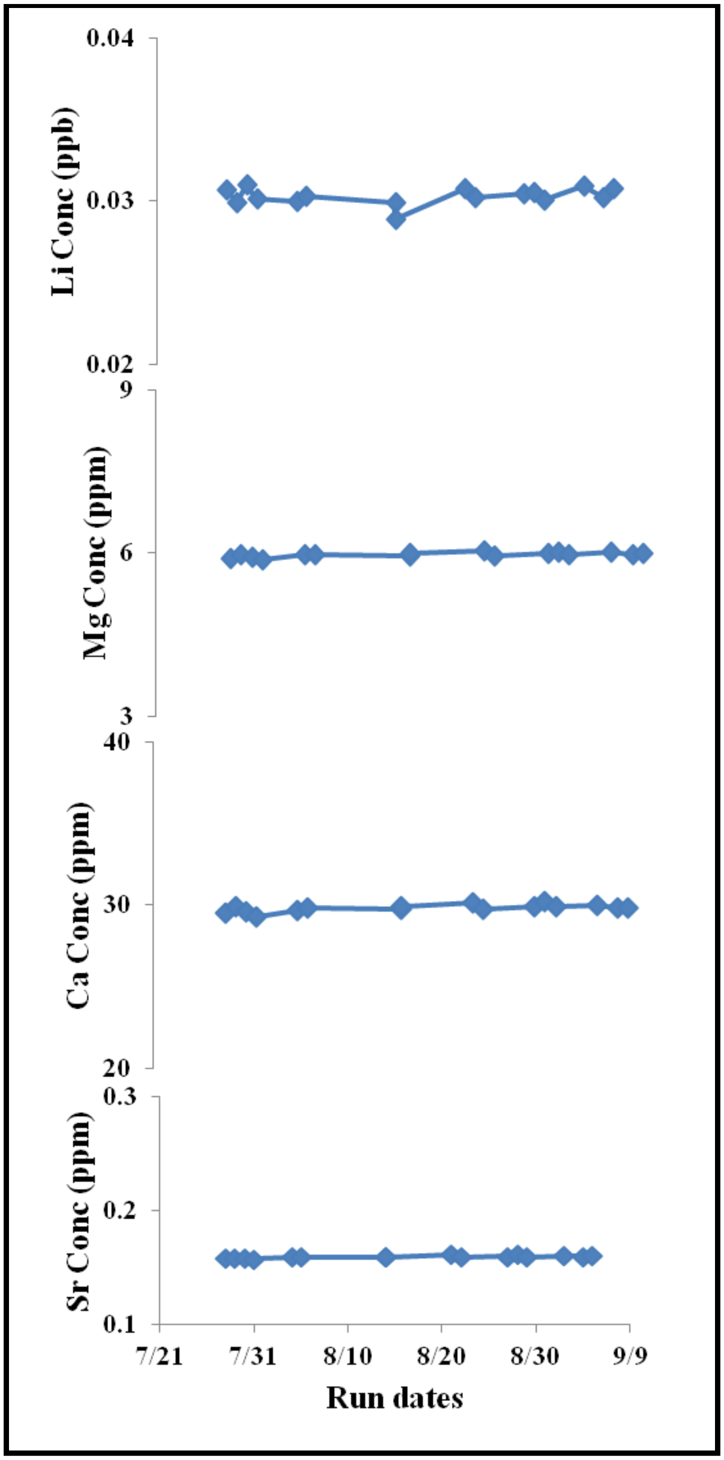

Figure 2-3 A plot of the drift correction performed for this study for which the data collection spanned over 15 days.

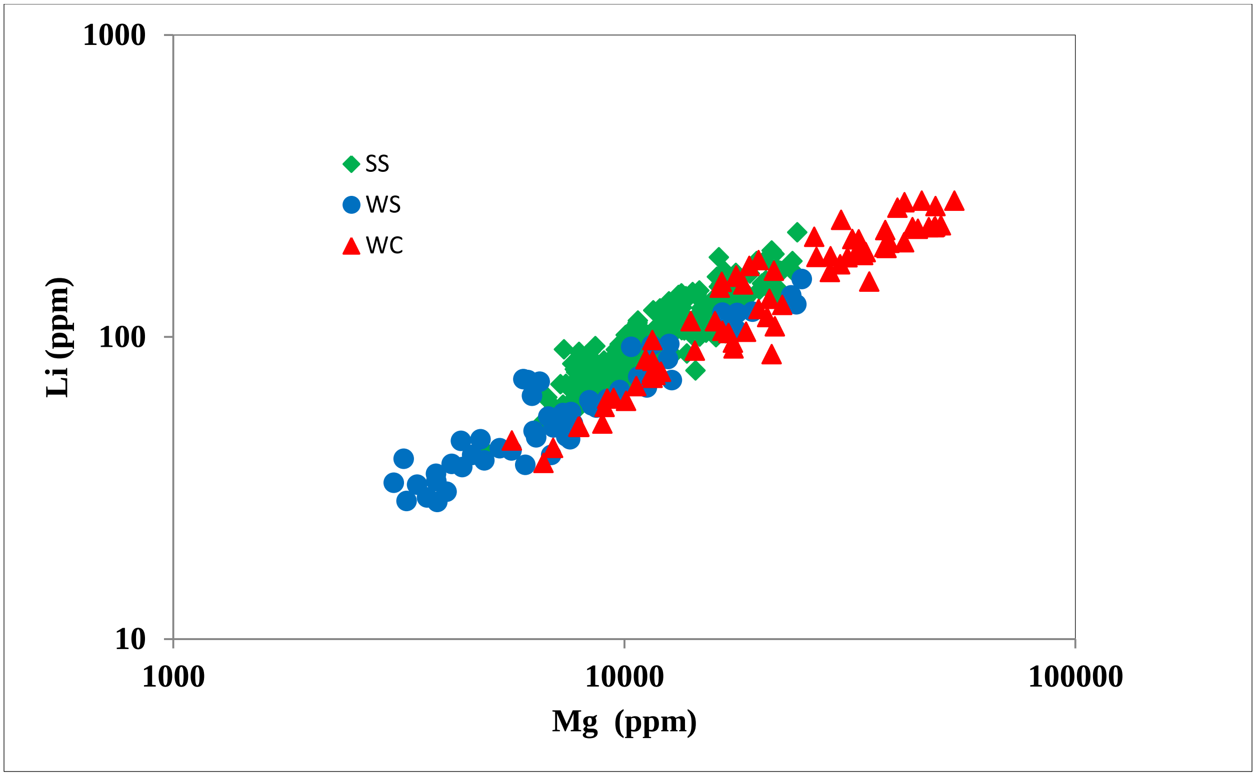

Figure 2-4 Acid leachable lithium versus magnesium for the Wilson Creek Formation.

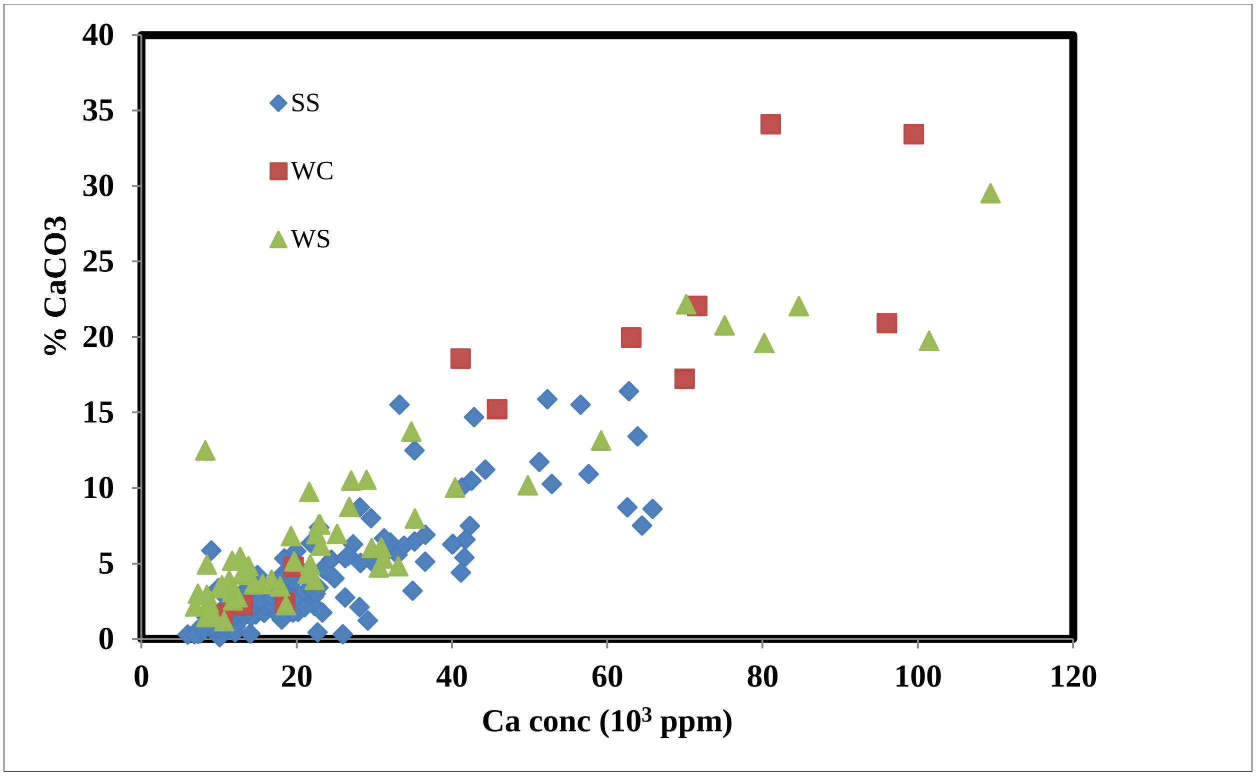

Figure 2-5 The acid leachable calcium concentration is positively correlated to the percent carbonate estimates in the lake sediments indicating that almost all of the calcium in the lake sediments resides in the calcite phase.

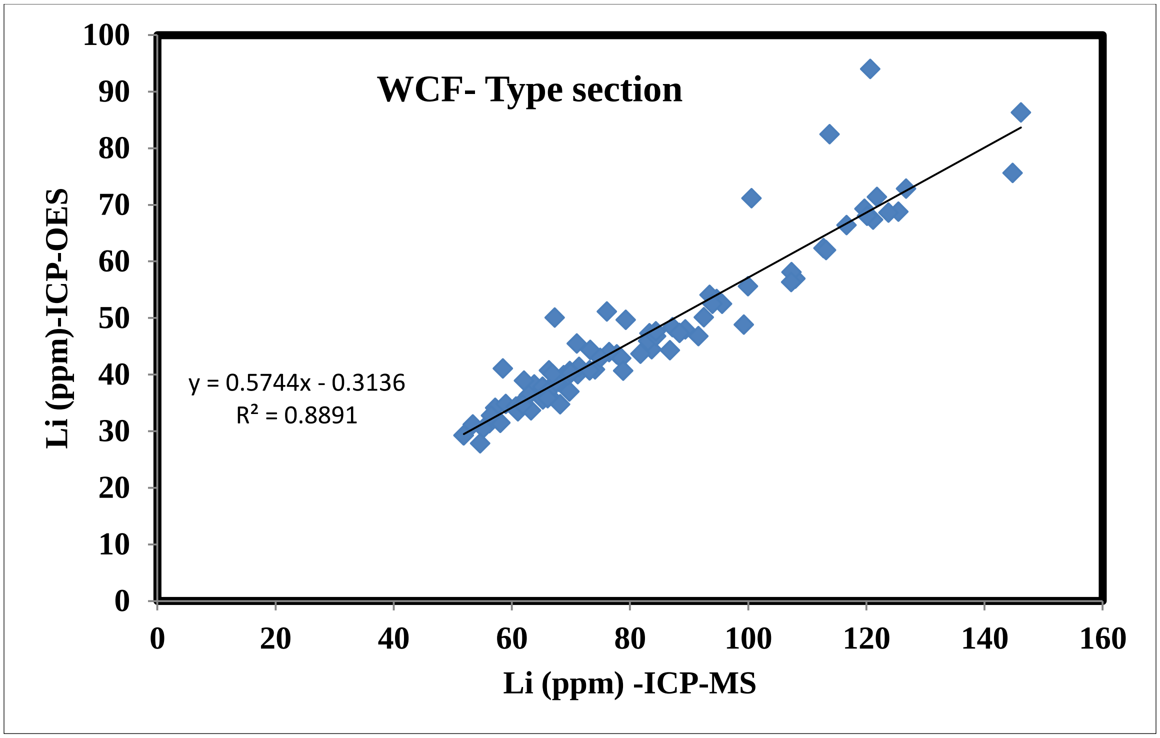

Figure 2-6 A cross-plot between Lithium estimates conducted by Zimmerman (2006) and Sahajpal et al. (2011) for the Wilson Creek formation type section.

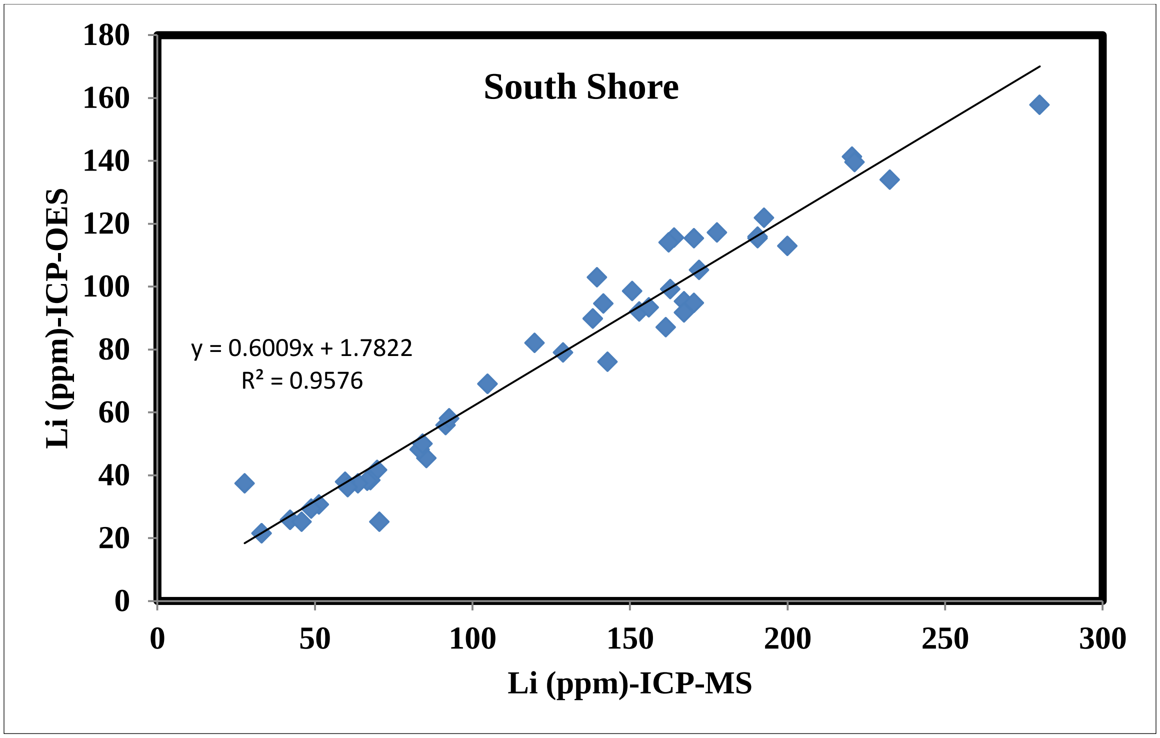

Figure 2-7 A cross-plot between Lithium estimates conducted by Zimmerman (2006) and Sahajpal et al. (2011) for the South Shore formation type section.

Chapter 3: Developing evaporation and mixing models for mineral stability and validating geochemical proxy records for paleolake level and paleosalinity in Mono Lake basin, CA.

Abstract

Closed basin lakes in arid environments are highly sensitive to hydro-climate change, making the Mono Basin of eastern California an important locality for evaluating the geologic record of this change in the western Great Basin. During the last glacial period the lake was much higher, and the physical stratigraphic evidence for lake level fluctuations has been linked to the carbonate flux record in the late Pleistocene Wilson Creek Formation. Additionally, the lake sediments show large variation in leachable Li, Mg, Sr and Ca which precipitate in the authigenic mineral phases that correspond to the variations in carbonate. In order to better understand the controls on precipitation of these authigenic phases, with the goal of developing a highly resolved record of paleo-hydroclimate for the Mono Basin, we are making simple models of the predicted lake chemistry changes based on evaporation and mixing of saline and fresh waters in proportions that approximate the changes in lake level through the last glacial cycle. We have used the Geochemist Workbench and PHREEQC geochemical programs to calculate the stability of mineral phases precipitating out of Mono Lake waters, thus providing insight about the chemical evolution of Mono Lake through the last glacial cycle. The results support our observational evidence, initially counterintuitive, that glacial-age Mono Lake sediments have high carbonate and leachable Li concentrations when lake level is high.

1. Introduction

It is important to understand the past changes in regional hydrology and their relation with climate changes in order to make predictions of the effects of future climate change in a warming world. High shorelines around lakes in the Great Basin region of the western US such as Mono Lake (e.g., Russell, 1889; Lajoie, 1968), provide dramatic evidence of significant changes in the balance between precipitation and evaporation (Stine., 1990, 1994; Broecker., 1996).

Shoreline deposits are robust measures of lake level, but they provide only spot measurements in time. Lake sediments on the other hand potentially provide a continuous record, but proxy indicators in the sediments require assumptions based on thorough understanding of the depositional history and geochemistry of the sediments to infer the hydrological change. We have previously interpreted the variation in geochemistry of the sediments at Mono Lake as indicating past lake level variations (Zimmerman et al., 2011b; Sahajpal et al., 2011). Authigenic carbonate and leachable Li (a proxy for Mg-silicate) are found in high concentrations in sediments when the geomorphic and physical stratigraphic evidence shows that Mono Lake was at high levels (Zimmerman et al., 2006, 2011b; Sahajpal et al., 2011). We therefore reasoned that during dry times, the precipitation of authigenic calcite and Mg-silicate would cause a drawdown of Ca^{2+} and Mg^{2+} in the water, while the addition of freshwater during wet times brings these ions into the lake where they are quickly incorporated into authigenic minerals.

Here we explore the simple application of thermodynamic approaches to evaporation and mixing of waters in the Mono Basin, and calculate the mineral equilibria in mixtures of fresh stream and spring water into the highly evaporated Mono Lake water, as well as evaporation of mixtures. A primary goal of this modeling is to test whether our previous interpretations of salinity (lake level) changes from proxy records is reasonable based on the assumptions inherent in such interpretations. Mono Lake is unusual in that it has remained hydrologically closed at least through the last glacial cycle. While every lake basin has a unique chemical setting, the approach we have taken for Mono Lake can be applied broadly to understand changes in hydrology of lakes and former lakes in arid lands.

2. The Mono Lake basin

2.1 Hydrology and geochemistry

Most of the freshwater feeding the lake today is supplied by creeks (~85%) and springs (~15%), with negligible input from direct precipitation (Neumann and Dreiss 1995; Tomascak et al. 2003). The streams are fed by snowmelt from the eastern Sierra Nevada (Fig.1) and their chemistry is set by weathering of the granodioritic and metasedimentary/metavolcanic bedrock. Faults and the sedimentary architecture of the now-exposed glacial-age sediments also produce numerous groundwater and thermal springs around the lake. The chemistry of these is controlled by interaction with Tertiary volcanic bedrock and the young volcanics and volatile exhalation of the Mono/Inyo Craters, as well as previous sedimentary deposits in the Mono Basin. The spring waters are dominated by Na^+ and HCO_3^- (Fig. 2) and are significant despite being a small fraction of the total water input, because they have a considerably higher concentration of ions than the creek waters and supply a majority of the ions to the lake (Table.3-1).

Present day Mono Lake is a Na^+-CO_3^{2-}-SO_4^{2-}-Cl^- brine (Bischoff et al., 1993; terminology of Hardie and Eugster 1970) with a very high alkalinity (~400mM), and pH (9.8). The dissolved ions in the lake are the combined product of stream and spring contributions, and modifications due to evaporative loss in the lake and precipitation of authigenic minerals. On an average the evaporation rate over the present day lake is ~1.14 m/yr and the freshwater entering the lake is ~

2 m^3/s in extremely dry years and in extremely wet years 4 m^3/s (Vorster 1985;; Mono Lake Committee). Mono Lake has ~50% of its natural volume due to diversions of its streams into the Los Angeles water supply (Blevins et al. 1984). Mono Lake is currently about 1945 m above sea level, while the natural level under recent climate conditions would likely be approximately 12-15 m higher (Stine, 1990). During the last glacial period the lake level reached as high as 2155 m (Fig.1) above sea level; there is no indication that the lake overtopped its sill (at ~2195 m) at any time in the last 70,000 years. The rise and fall in lake level has left a geomorphic and physical stratigraphic record that has been used to infer past changes in the lake level (Russell 1889; Lajoie, 1968; Benson et al., 1990, Stine 1990; Stine 1991). .

2.2 Paleohydrology proxies

The fluvial and lacustrine deposits of the last glacial period at Mono Lake were named the Wilson Creek Formation (WCF) after their type section in Wilson Creek canyon (Lajoie, 1968). The Wilson Creek Formation crops out around the lake basin to elevations as high as 2070 m above sea level, and variations in the sedimentary facies imply relative changes in lake level. This physical evidence for the lake level variations has been tied to geochemical proxy evidence by using the tephrostratigraphy to correlate between exposures around the basin (Zimmerman et al., 2006, 2011b; Sahajpal et al., 2011), providing a first order test of the geochemical proxy interpretation.

Authigenic calcite, inorganic pisoliths and ostracodes form a significant portion of the Wilson Creek Formation lacustrine sediments in the Mono Basin. These carbonates have been used as a material for geochronology of WCF and as a proxy for paleo-lake levels. Zimmerman et al. (2006, 2011b) developed authigenic carbonate as a proxy for lake level in Mono Basin demonstrating that times of high lake level are times of high carbonate concentrations in Wilson

Creek Formation sediments (Fig. 3). Leachable Li and other leachable ions like Ca, Mg and Sr were tested as a proxy for paleosalinity in the Mono Lake basin (Sahajpal et al. 2011) based on the method developed by Bischoff et al. (1997) in Owens Lake. Bischoff et al. (1997) observed that high abundance of authigenic Mg-silicate and high concentration of acid-leachable Li corresponded to high calcium carbonate abundance during interglacials, and reasoned that the Li is hosted in authigenic Mg-silicate due to its similar ionic size to Mg.

In the Mono basin, the leachable Li, Ca, Mg, and Sr follow the carbonate pattern of high concentration/high lake and low concentration/low lake (Fig. 3.), opposite to what was observed in the Owens Lake basin. This contrast was interpreted to be due to the fact that Owens Lake spilled frequently and thus flushed out the ions while Mono Lake did not overflow during the last glacial period (Zimmerman et al., 2006, 2011a; Sahajpal et al., 2011). The interpretation of these observations was that precipitation of authigenic minerals is limited by the supply of Ca^{2+} and other ions from the freshwater sources. The calcium ions fed to the lake is titrated out as calcite due to high HCO_3^-/Ca^{2+} molar ratios, so during times of high lake levels, which we expect to be periods of high freshwater input, more Ca^{2+} ion is supplied to the lake as compared to times of lower freshwater input. The purpose of this study is to provide a theoretical basis for this proxy interpretation.

3. Evaporation based models

Traditionally, evaporation based models have been used to explain the geochemistry of arid basin lakes and the mineral phases that precipitate from these waters (Garrels and Mackenzie, 1967; Hardie and Eugster, 1970; Bischoff, 2006 pers comm.). Since evaporation is the dominant factor in arid basins, these models predict the behavior of various chemical species with a reasonable accuracy. However, they fail to account for the effect of continuous flux of fresh water and ions to a lake and how these factors affect the geochemical evolution of the lake's chemistry.

We therefore simulate the evaporation of three freshwaters from the Mono Lake basin, creek and spring end-members and a creek/spring mix (in proportions based on estimates by Tomascak et al., 2003), similar to existing evaporation models (Garrels and Mackenzie, 1967; Hardie and Eugster, 1970; Bischoff, 2006 per comm.). In our simulations we have made evaporation models more comprehensive by including species like Sr^{2+}, Li^{+} and B ($B(OH)_4^{-}$ + $B(OH)_3$) species, and extending the modeled range of concentration factors to 3000x to include the current conditions of basins like the Mono Lake basin, which are beyond the concentration factor range of the existing models. To understand the proxy records of the Wilson Creek Formation, we also simulate the mixing of each of these freshwaters into the saline Mono Lake water, because geomorphic and sedimentary evidence indicates that the pre-Wilson Creek (last interglacial) Mono Lake level was similar to the modern lake (Zimmerman et al., 2011a).

4. Methods

We have used the React subprogram of Geochemist Workbench (Bethke and Yeakel., 2008; LLNL database) to simulate the behavior of various chemical species as three compositions of fresh water (Table 3-1) are progressively evaporated at T = 25˚C and $CO_2(g)$ = 350 ppm. The React subprogram is capable of tracing reaction paths of fluids, minerals, and gases, in addition to calculating the distribution of species in aqueous solution, mineral saturations and gas fugacities. The modeled fresh waters for our study are evaporated through a concentration factor (CF) range of 1x to 3000x, where a CF of 1x is the initial fresh water (average spring, creek or mixed water) and a CF of 3000x is approximately the current concentration factor of Mono Lake water based on the estimate of Tomascak et al. (2003). In addition to major ions (Ca^{2+}, Mg^{2+}, K^+, Na^+, HCO_3^-, CO_3^{2-}, SiO_2, Cl^- and SO_4^{2-}), the model includes species like Li^+, B($B(OH)_3$, and $B(OH)_4^-$), and Sr^{2+}.

In order to simulate evaporation and the mixing of waters (E&M) together, we used the PHREEQC version 2 (LLNL database) (Pankhurst and Appelo., 1999) geochemical modeling program developed by the USGS, to construct a simple box model, where we simulate the mixing of saline (Mono Lake water) and fresh waters at T = 25˚C and CO_2 (g) = 350 ppm, in proportions that allow us to approximate the lake volume range of the last glacial cycle. This program is written in C programming language and is designed to perform low temperature geochemical calculations. For our study we have used the speciation and saturation-index calculations, mixing of solutions and inverse modeling that estimates transfer of mineral and gas that account for differences in composition between waters, within specified compositional uncertainty limits.

In order to simulate the high lake level conditions of glacial Mono Lake, we have increased the volume of our lake by mixing in a constant flux of fresh water, ~7% of the current lake volume, into the Mono Lake water which is approximately equal to the runoff from the creeks and springs to the present day lake, and by keeping the evaporation factor constant. This empirical approach allows us to increase the lake volume to the highest levels achieved during the last glacial period and to model the resulting geochemical evolution of the lake water from its current concentrated state to the more dilute state. In its current form, PHREEQC version 2 limits the number of mixing and evaporation scenarios that can be performed, so in order to increase the ability of PHREEQC to run a desired number of mixing scenarios, a Python programming language-based computer program (see Chapter four) was developed to carry out multiple mixing and evaporation scenarios until the desired lake volume was attained.

5. Results

5.1 Chemical evolution during evaporation of fresh waters

Model results of our three evaporation scenarios using Geochemist workbench, (creek water; spring water; creek/spring mix) are presented in Fig. 4, Fig. 5 and Fig. 6. We have plotted all the modeled chemical species against Cl^- concentration, which in our model increases 3000x relative to the initial concentration in the source water. This was done to include the present day concentration factor of Mono Lake relative to its source waters based on the estimates of Tomascak et al. (2003).

Modeled Na^+, K^+ and Li^+ behave vary conservatively as the water is concentrated to a concentration factor of 3000x in all three scenarios (Fig.3, Fig.4 and Fig.5). The SO_4^{2-} ion titrates out after 1000x is attained (Fig.5) in the spring water end member, and thereafter behaves conservatively in a proportional mix of creek and spring waters (Fig.6). For the creek end member, SO_4^{2-} concentration increases conservatively up to a 100x concentration, between 100x-1000x it increases less conservatively and it shows signs of titrating out beyond 3000x (Fig. 4).

Modeled Ca^{2+} and Sr^{2+} ion concentrations behave conservatively in creek water, showing only a slight drop in concentration at a concentration factor of ~ 10x, when calcite begins to precipitate (Fig.3). In case of the spring water end member and the creek/spring mix, Ca^{2+} and Sr^{2+} behave non-conservatively, with all the Sr^{2+} titrating out between 10x-100x, and negligible amounts of Ca^{2+} remaining in the water beyond a 1000x concentration factor (Fig.5, Fig. 6). The concentrations of HCO_3^- and CO_3^{2-} are non-conservative during the evaporation of creek water beyond a concentration factor of 10x (Fig.4), but in the case of the spring and the creek/spring mix they behave conservatively after all of the Ca^{2+} and Sr^{2+} have been titrated out (Fig. 5, Fig. 6). Magnesium ion exhibits non-conservative behavior in all three scenarios, starting to titrate out at a concentration factor of ~10x and titrating out completely at a concentration factor of ~1000x in the spring water and the creek/spring mix (Fig.5, Fig.6). In the creek end member some Mg^{2+} still remains at 3000x.

5.2 Evaporation and mixing of lake and fresh waters

The results of our E&M model developed using PHREEQC show that Na^{+}, K^{+}, Li^{+}, SO_4^{2}, HCO_3^{-} and CO_3^{2-} behave conservatively whereas ions like Ca^{2+}, Sr^{2+}, Mg^{2+} and SiO_2 (aq) that precipitate in the authigenic mineral phases (calcite and Mg-silicate) behave non-conservatively (Fig.7). The saturation indices of the authigenic mineral phases produced by the E&M model, when plotted against the volume factor of the lake, demonstrate that these phases remain saturated in the lake water and are almost independent of the composition of the freshwater mixed into the lake simulated to raise its level to its glacial period high (Fig. 8 and Fig. 9).

6. Discussion

6.1 Evaporation-based models

The conventional approach to explain the evolution of arid-basin lakes has been to start with a volume of freshwater and then dry it down to concentrated brine, following the pioneering evaporation-based model of Garrels and Mackenzie (1967). This model is a theoretical prediction of the different mineral phases that precipitate upon progressive evaporation of Sierran spring water at a fixed temperature and partial pressure of CO_2 (g), with the assumption that there is no reaction between water and the precipitated phase or suspended sediments.

According to this model, as the water gets concentrated, conservative ions like, Na^+, K^+, Cl^- and SO_4^{2-} remain in water and non-conservative ions like Ca^{2+} and Mg^{2+} react with carbonate (HCO_3^-) and silica (SiO_2) and precipitate out as calcite and sepiolite, respectively. The final composition of the resulting brine depends on the chemical composition of the starting freshwaters (Hardie and Eugster 1970). Since its conception, this model has undergone several revisions in order to make it more inclusive of the phenomenon that are generally witnessed in waters of arid basins (Hardie and Eugster 1970; Eugster and Hardie 1978; Eugster and Jones 1979; Harvie and Weare 1980; Harvie et al., 1984; Eugster and Hardie.,1978; Eugster and Maglione., 1979).

In almost all natural waters, calcite is the first mineral to precipitate (Garrels and Mackenzie 1967). However, in high-alkalinity waters such as Mono Lake, after all the Ca^{2+} has been removed as calcium carbonate the alkalinity is still higher than Mg^{2+} concentration, and the subsequent step is formation of Mg-silicate. In waters like Mono Lake, this leads to a situation where the lake water is almost always saturated with respect calcite and Mg-silicate, but contains low concentrations of Ca^{2+} and Mg^{2+} (e.g., in modern Mono Lake Ca^{2+} = 4 ppm). These evaporation models have formed the basis of developing calcite (Zimmerman et al., 2006, 2011b) and leachable Li (Sahajpal et al., 2011) as proxies for lake level and paleosalinity in the Mono Lake basin.

6.2 Evolution of Mono Lake based on Evaporation and Mixing model (E&M model).

Since Mono Lake is a closed basin lake, any change in the lake chemistry is a result of the flux of freshwater input and rate of evaporation, as well as mineral precipitation, so geochemical models need to include both evaporation and mixing processes, unlike existing models that only take evaporation into account. The model that we have developed for this study is a first step in this direction, including both evaporation and mixing processes to explain the evolution of Mono Lake.

To understand the geochemical evolution of the lake water since the last glacial period, in our E&M model we have raised the lake from the present-day level (~1945 m,) up to its last-glacial highstand level of 2155 m (Fig.1) by keeping the evaporation rate constant and adding a constant flux of freshwater. We have chosen the present day lake as a starting point for our model because the current water budget and mass balance of different chemical species in the Mono Lake basin is well constrained (Neumann and Dreiss 1995; Tomascak et al. 2003) and because we assume that previous interglacials may have experienced similar evaporation effects.

In order to understand how change in the flux of freshwaters from different sources may affect the resulting lake chemistry and precipitation of authigenic mineral phases, we examined two scenarios. The first scenario uses the fresh water mix estimated by Tomascak et al. (2003), and assumes that just like today the creeks and springs were both feeding the lake with the streams supplying the majority of the water but with an increased flux from both creeks and springs due to much wetter conditions than today. The results of this scenario show that calcite and Mg-silicate remain saturated in the lake through its glacial period high level (Fig. 9). The second scenario predicts the behavior of chemical species if the present day Mono Lake was to be filled up to the highest level it attained during the last glacial period (2155 m) using only the average creek water end member (Fig.7 and Fig. 8). The latter in our estimate should more closely reflect the conditions during glacial times where we expect the flux of creeks might have been much higher than the spring end members, and the concentration of ions in the fresh water may have been much lower. The outcome of our second scenario demonstrates that even when waters as dilute as the creek water end members are fed to the lake, authigenic minerals like calcite and Mg-silicate continue to remain oversaturated in the water column.

This model supports our initial hypothesis that the greater the fresh water flux, regardless of its chemical composition, the greater the amount of these elements in the sediments. The model results also show that authigenic minerals like calcite and Mg-silicate remained saturated in the lake water even when the lake is filled up to its spill level (Fig.7, Fig. 8 and Fig. 9).

6.3 Comparison of evaporation and mixing model with evaporation based models.

The approach we have used in developing our model is opposite to that of evaporation based models. The E&M model starts with concentrated brine like Mono Lake water and dilutes the lake with enough freshwaters proportionally (average creek end member and creek and spring mixed water) to raise the lake to its glacial period high level. Besides explaining the evolution of Mono Lake the E&M model also predicts the oversaturation and therefore potential for precipitation of authigenic mineral phases like calcite and Mg-silicate (Fig. 8 and Fig. 9). The following section briefly discusses the end member evaporation scenarios followed by a discussion and comparison of the E&M model to the evaporation models.

It is impossible to attain concentrated brine with composition like Mono Lake through evaporation of the creek water end member alone (Fig. 4), as this model shows the build-up of ions like Ca^{2+}, Sr^{2+} SiO_2 (aq) in the brine and a drawdown in the concentration of ions like HCO_3^- and CO_3^{2-}. The opposite is true in the actual lake waters (low Ca^{2+}, Sr^{2+} and SiO_2 (aq), high alkalinity).

In contrast, the evaporation of the average spring water end member (Fig. 5) closely matches the actual behavior of different chemical species during the evolution of Mono Lake and these results are in broad agreement to the theoretical Garrels and Mackenzie (1967) model.

Despite a close match to the Garrels and Mackenzie (1967) model the results of this scenario do not represent the actual conditions witnessed in Mono Lake. However, springs today only supply a small portion of the freshwater to the lake, ~ 15% based on Tomascak et al. (2003), and it is likely that the proportion may have been even less during wet times. Sr-isotopes indicate a larger proportion of inflow from the hills to the north, east, and south of the basin during wet periods (Zimmerman et al. 2011a), and the chemical composition of modern springs in those hills suggests that streams from the hills might have been significant contributors of dissolved ions to the lake.

The scenario of evaporating mixed creek and spring waters best describes the actual conditions in Mono Lake basin (Fig. 6) because the current geochemical evolution is a result of both mixing and evaporation of creek and spring waters. The results in this case closely match the spring water end member scenario thus highlighting the control of springs in regulating the Mono Lake water chemistry. The evaporation based models go only as far as explaining the drawdown of ions like Ca and Mg due to the precipitation of authigenic mineral phases, thus predicting a low concentration of these ions in the sediments during high lake level and vice versa.

Published results of Zimmerman et al (2006; 2011b) and Sahajpal et al. (2011) for Mono Lake basin have shown that high lake levels correspond to high concentrations of leachable ions like Ca, Mg, Sr and Li. This can only be explained by taking continuous mixing of ions by fresh water sources along with the evaporation in to the closed basin lake as shown in the E&M model, so during wet conditions when there is a higher flux of water and ions from fresh water sources the concentration of these ions builds up compared to the drier conditions as these ions persist in the basin due to its structural geometry. The E&M model is unique in that it explains the geochemical evolution of Mono Lake water since that last glacial period and reaffirms the proxy record of Zimmerman et al. (2006; 2011b) and Sahajpal et al. (2011).

Based on the above discussion it is reasonable to conclude that the evaporating average creek or average spring end members into concentrated brine fails to match the present day Mono Lake water and hence does not offer a plausible explanation for the geochemical evolution of Mono Lake water. Whereas starting with a proportional mix of creek and spring water and evaporating it into concentrated brine offers the closest match to the conditions that are witnessed in the present day Mono Lake (Fig. 6).

After evaluating all possible evaporation based scenarios for explaining the present composition of Mono Lake water, we propose that our empirical evaporation and mixing model provides the best explanation for the current chemistry of Mono Lake, and it further offers support for the geochemical proxy record for Mono Lake basin. Our model predicts that just like in evaporation based models Na^+, K^+ and Li^+ and SO_4^{2-} are conservative in the water however it appears that SO_4^{2-} may start to precipitate out beyond a concentration factor of 3000x. The HCO_3^- and CO_3^{2-} are so enriched in the lake water that their concentration always remains high even after these ions titrate out with Ca^{2+} and Sr^{2+} in the carbonate phase. The concentration of Mg^{2+} starts to increase in the water after most of the SiO_2 (aq) gets precipitated out as Mg-silicate. This observation is in agreement with findings of Tomascak et al. (2003) that Mg^{2+} has a higher residence time than Ca^{2+} in the water.

7. Validation of the geochemical proxy record using E&M model

The results of the E&M model strongly support our interpretation of the calcite and leachable Li proxy records from the Wilson Creek Formation. According to our model the precipitation of both calcite and Mg-silicate in the Mono Lake basin is directly related to the flux of water to the lake where the ions added by the freshwater are transferred into the calcite and Mg-silicate mineral phases. Importantly, as outlined above, although the precipitation of authigenic mineral phases is strongly correlated to the flux of water to the lake it is largely independent of the composition of the freshwater that is fed to the lake. Since Mono Lake never spilled over during the last glacial cycle, the periods of greater freshwater flux are periods of greater flux of authigenic phases to the lake floor (Fig. 3).

8. Future improvements to the evaporation and mixing model

Our evaporation and mixing based model aims to include both evaporation and mixing of fresh water to convey a more accurate depiction of the conditions that lead to the brine evolution in the Mono Lake basin. This model is purely a thermodynamic model and does not take into account the kinetics but a carefully constructed thermodynamic model can give us valuable insight into the geochemical evolution of Mono Lake. The main shortcomings of this model are the fact that it assumes a constant evaporation rate and a constant flux of water to the lake in order to increase the lake level, which is not what is expected in a natural situation. Since our assumptions are based on observations made in the present day Mono Lake, these assumptions do serve as a reasonable starting point for developing more accurate geochemical models. The obvious next step in order to better understand brine evolution in Mono basin and improve this model will be to integrate it with a hydrologic model to better account for water budgets throughout the history of the lake. Improvement in existing geochemical models and their integration with climate models will ultimately lead to developing more comprehensive geochemical proxies and enable us to correlate them on an inter-basin scale.

9. Conclusions

In carrying out this study we have made an attempt to develop a theoretical model that more accurately depicts the hydrological processes, namely the continuous mixing of fresh water into the saline Mono Lake, along with the significant evaporation in this arid basin. This approach significantly improves our ability to explain the modern composition as well as geochemical evolution during freshening of Mono Lake during glacial periods, and supports the proxy record in the Mono Lake basin. Based on this study we can make the following general conclusions.

1. A combined evaporation and mixing based model gives a more accurate depiction of the modern composition of Mono Lake and provide an explanation for the proxy records of calcite for lake level and Mg-silicate (leachable Li) for paleosalinity, specifically their positive correlation with physical evidence for lake levels in the last glacial period.
2. The precipitation of authigenic calcite and Mg-silicate is controlled by the flux of ions supplied by the freshwater, and they should have remained saturated in the lake water throughout the last glacial period when the lake volume was up to ~ 30x higher, independent of the composition of the freshwater mixed into the lake.
3. Our evaporation and mixing model is a first step toward explaining the geochemical evolution this arid lake basin, and should be portable to other closed basin lakes. However, a significant future improvement will be to integrate the evaporation and mixing model with hydrological models in order to make more realistic estimates of water budgets.

Supplementary data associated with this article can be found at the end in appendices 2a-e.

Table 3-1 Initial composition of fresh waters and Mono lake water based on estimates of Neumann and Dreiss (1995) and Tomascak et al. (2003)

	Spring water (average) mmolal	Creek water (average) mmolal	Mixed water (Spring+Creek) mmolal	Mono Lake water ppm mmolal
Ca	0.25	0.25	0.25	0.11
Mg	0.17	0.075	0.1	1.54
Na	8.94	0.12	1.91	1478.2
K	0.47	0.02	0.36	44.1
Li	0.002	0.0002	0.001	1.43
Sr	0.006	0.004	0.0003	0.0001
HCO_3	9.44	0.41	7.81	414.7
Cl	0.25	0.20	0.21	576.2
SO_4	0.31	0.1	0.26	139.0
Si	1.1	0.14	0.84	0.22
B	0.04	0.002	0.01	0.001

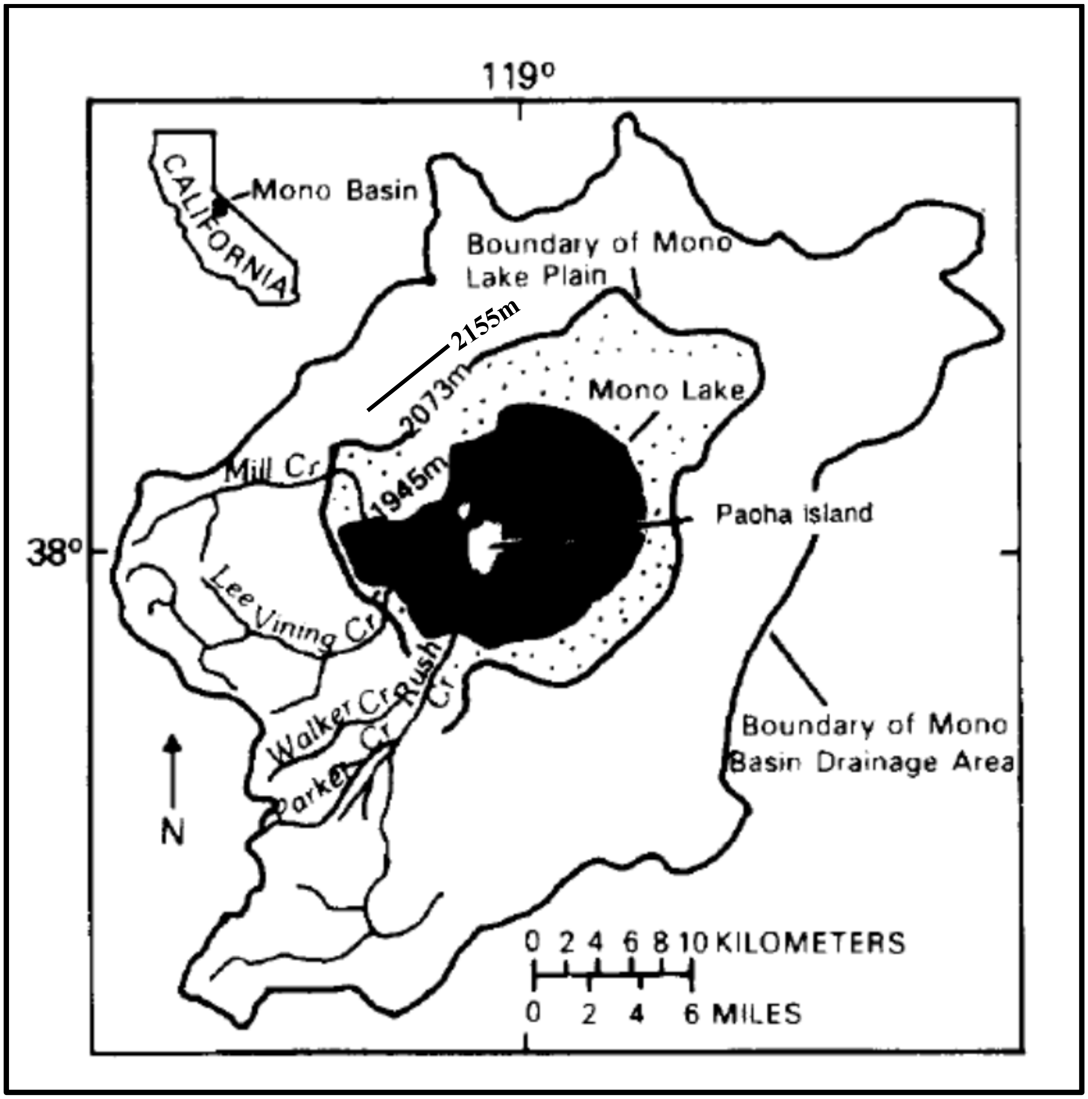

Figure 3-1 Map of the drainage basin of Mono Lake basin adapted from (Benson et al. 1990 originally from Vorster 1985). Also indicated in the map are the boundaries of Mono Lake (1945m) and the boundaries of 2073m and 2155m terrace.

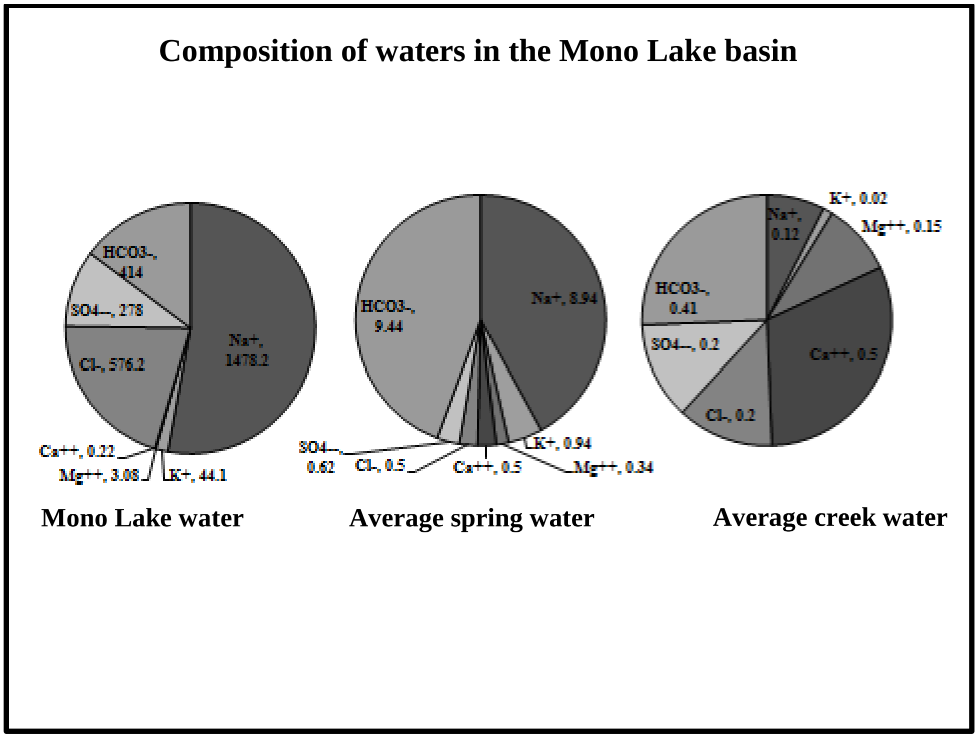

Figure 3-2 The shape of the pie pieces is based on the relative concentration of the cations and anions in miliequivalents per liter.

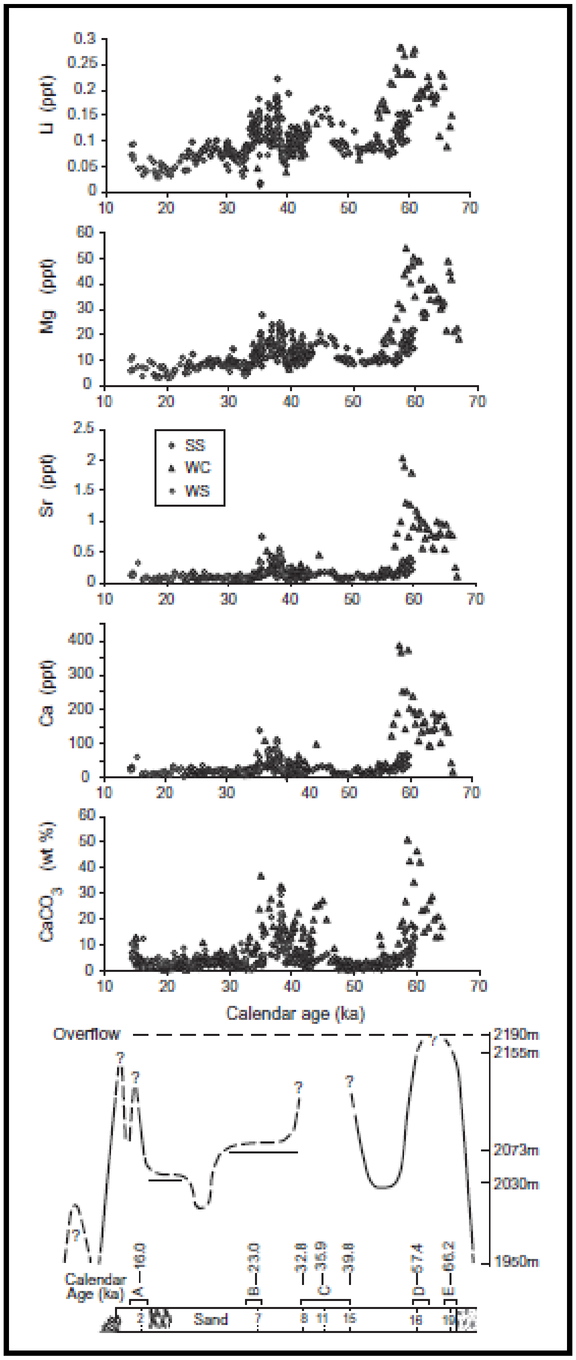

Figure 3-3 High concentrations of leachable Li, Mg, Sr, Ca and $CaCO_3$ correspond to high lake levels and low concentrations correspond to low lake levels of Mono Lake (Sahajpal et al., 2011).

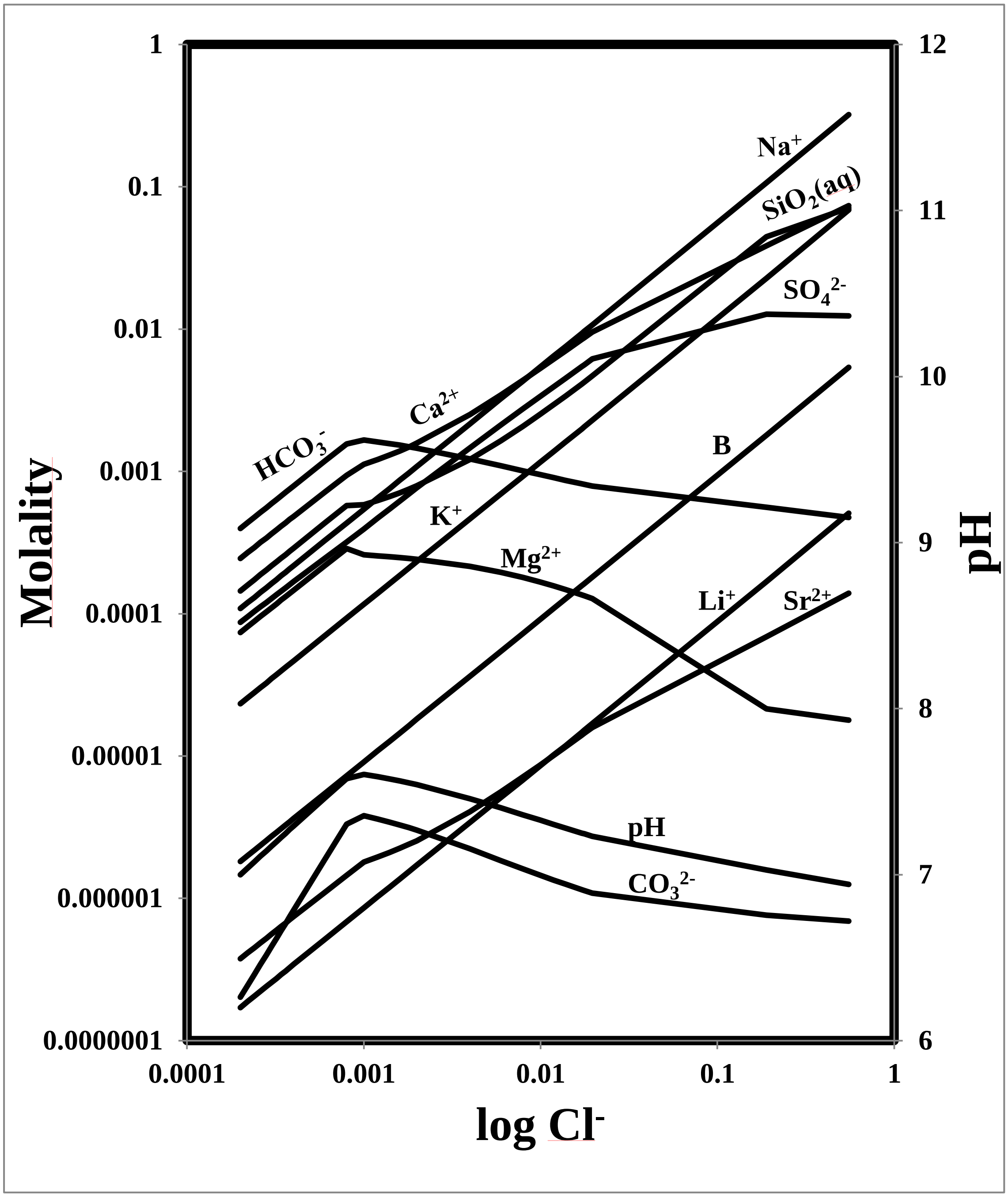

Figure 3-4 Calculated results of evaporating average creek water feeding the Mono Lake at 25° C and $P_{CO2} = 10^{-3.5}$ atm. The non-conservative behavior of ions like HCO_3^- , CO_3^{2-} and increased abundance of ions like Ca^{2+}, Sr^{2+} in the water does not match Mono Lake. The predicted pH using this model is not in agreement with Mono Lake.

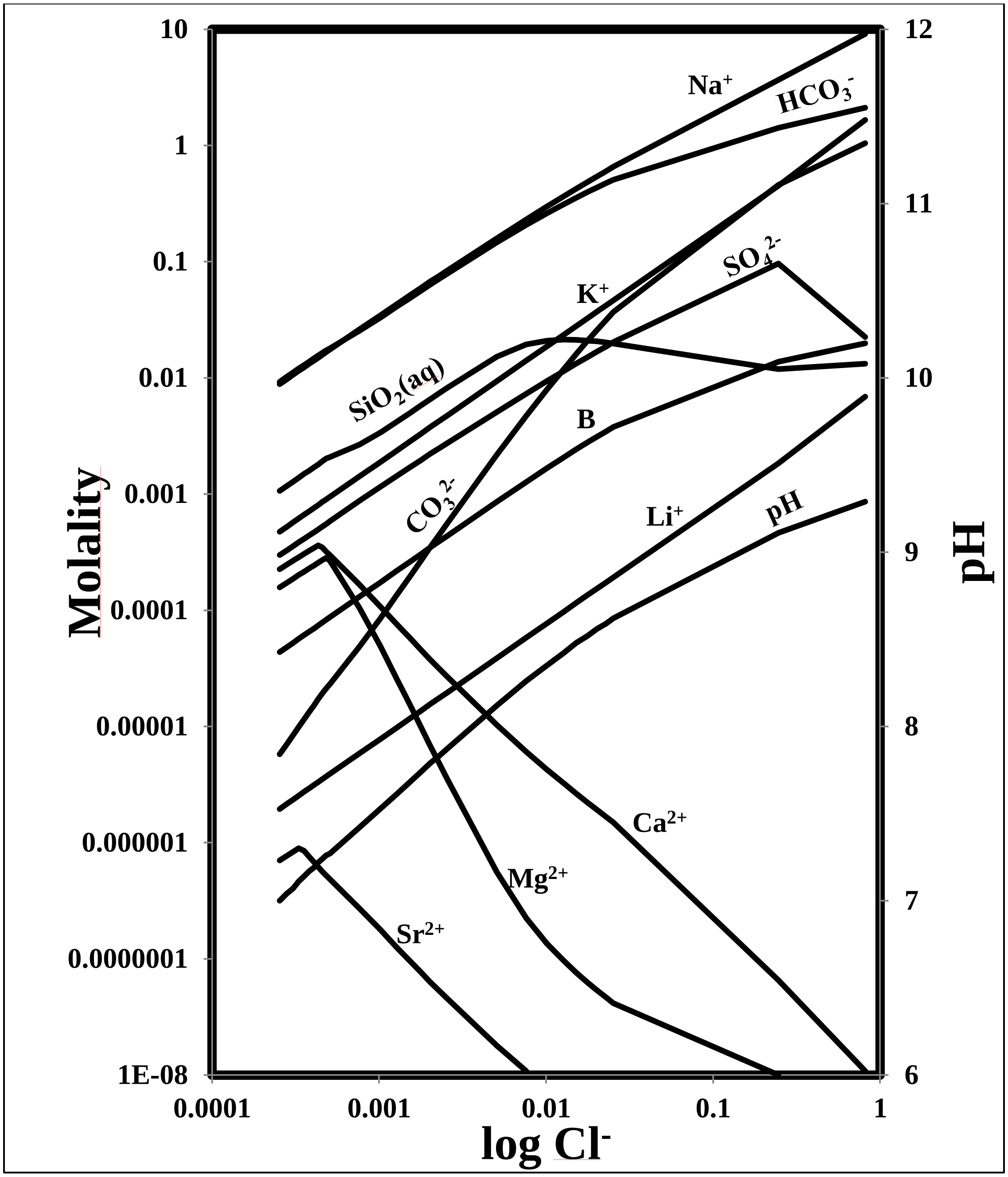

Figure 3-5 Calculated results of evaporating average spring waters feeding the Mono Lake at 25° C and $P_{CO2} = 10^{-3.5}$ atm. The results are in general agreement with Garrels and Mackenzie model (1967). The dramatic titration of SO_4^{2-} ion after a concentration factor of ~3000x does not match Mono Lake water. The predicted pH is similar to Mono Lake water.

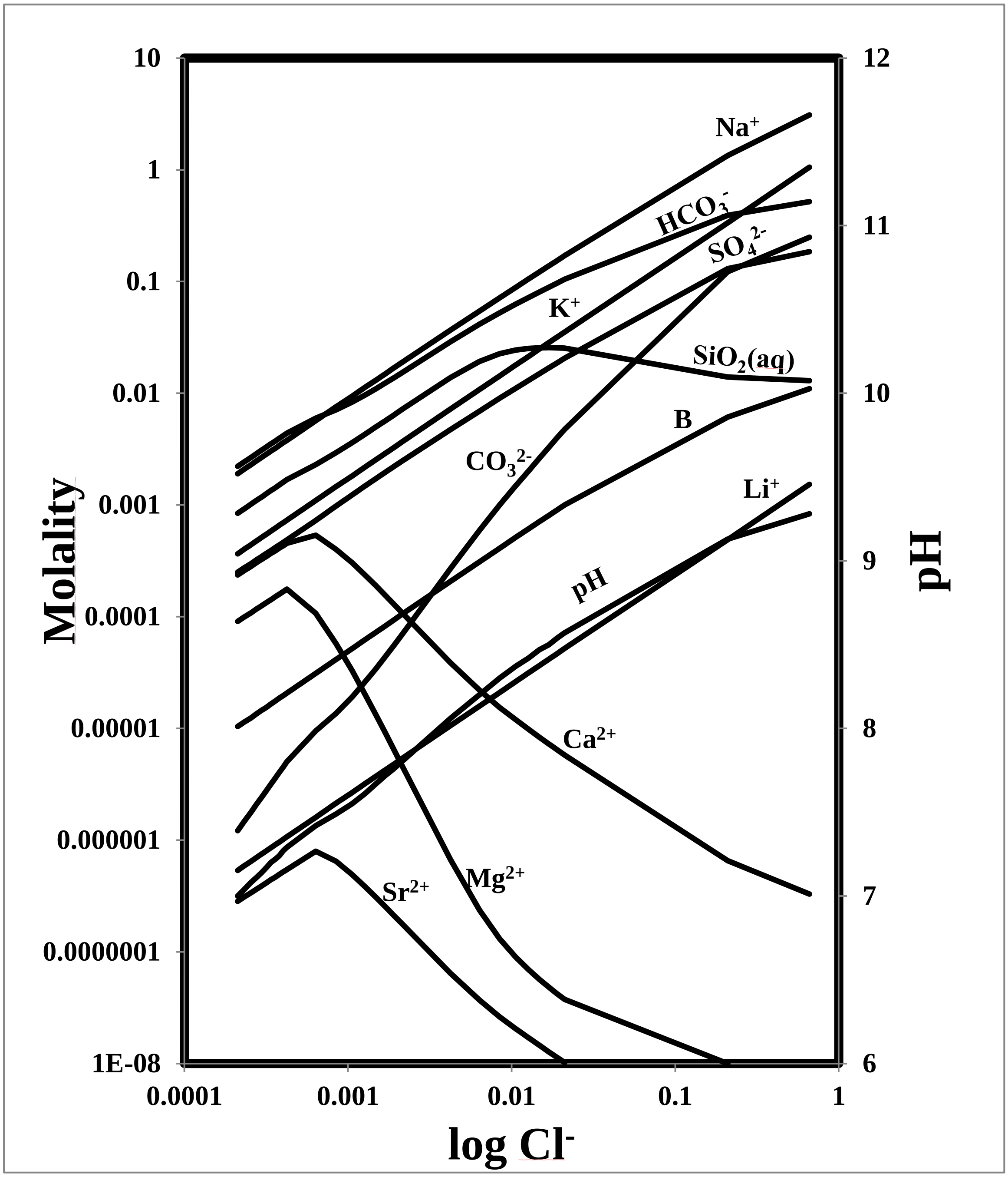

Figure 3-6 Calculated results of evaporating a mix of average creek and spring waters feeding Mono Lake based on Tomascak et al.' s (2003) estimates at 25° C and $P_{CO2} = 10^{-3.5}$ atm. The results are in general agreement with Garrels and Mackenzie (1968) model however the starting composition of the water in this model is a more accurate depiction of the water feeding Mono Lake. The predicted pH closely matches Mono Lake water.

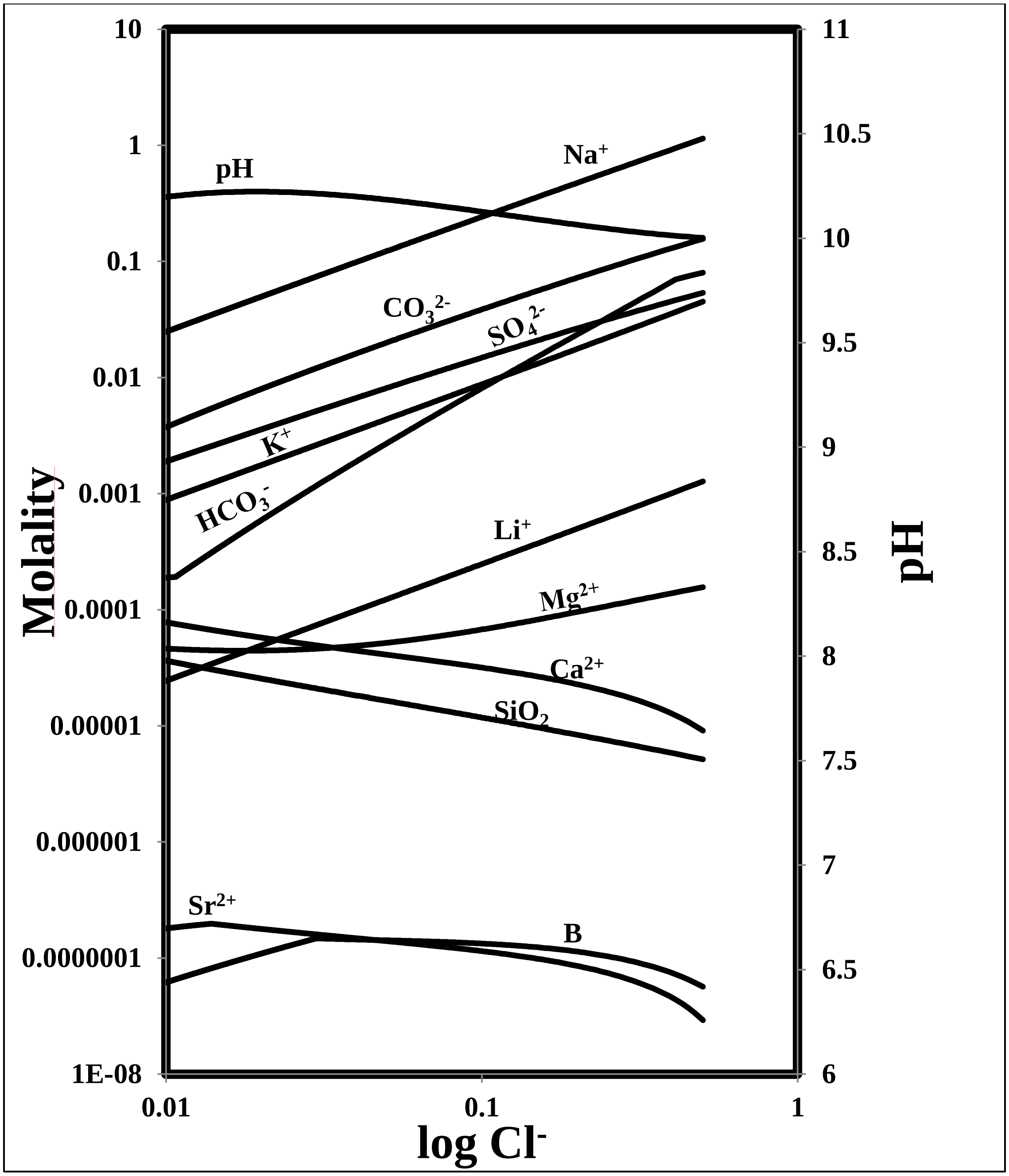

Figure 3-7 Calculated results of evaporation and mixing based model predicting the evolution of Mono Lake from the present day lake to its spill level at 25° C and PCO2= 10-3.5 atm. There is a broad agreement with Garrels and Mackenzie's (1968) model. The higher residence of Mg^{2+} as compared to Ca^{2+} matches Mono Lake water.

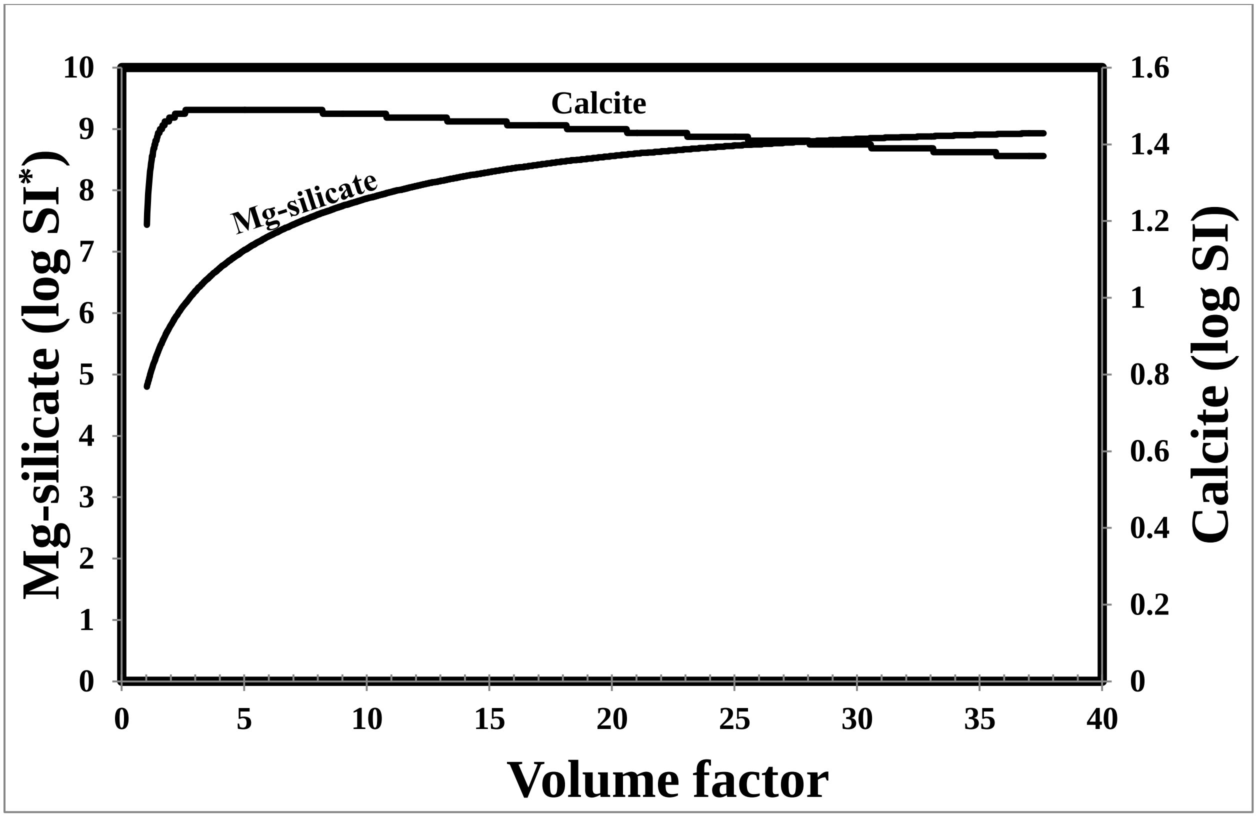

Figure 3-8 Modeling results of the evaporation and mixing model using a constant flux of water with average creek composition. Calcite and Mg-silicate remain saturated in the Mono Lake water. The volume factors at significant lake levels at Mono are: 2030 (lower Pleistocene terrace)=7; 2073 (upper Pleistocene terrace)= 12; 2155 (Highest lake level attained during last glacial)==24 and 2195 (Mono Lake basin spill level)= 31.

SI^*- Saturation index is defined as the log Ion activity product (IAP)/Solubility product (K_{sp})

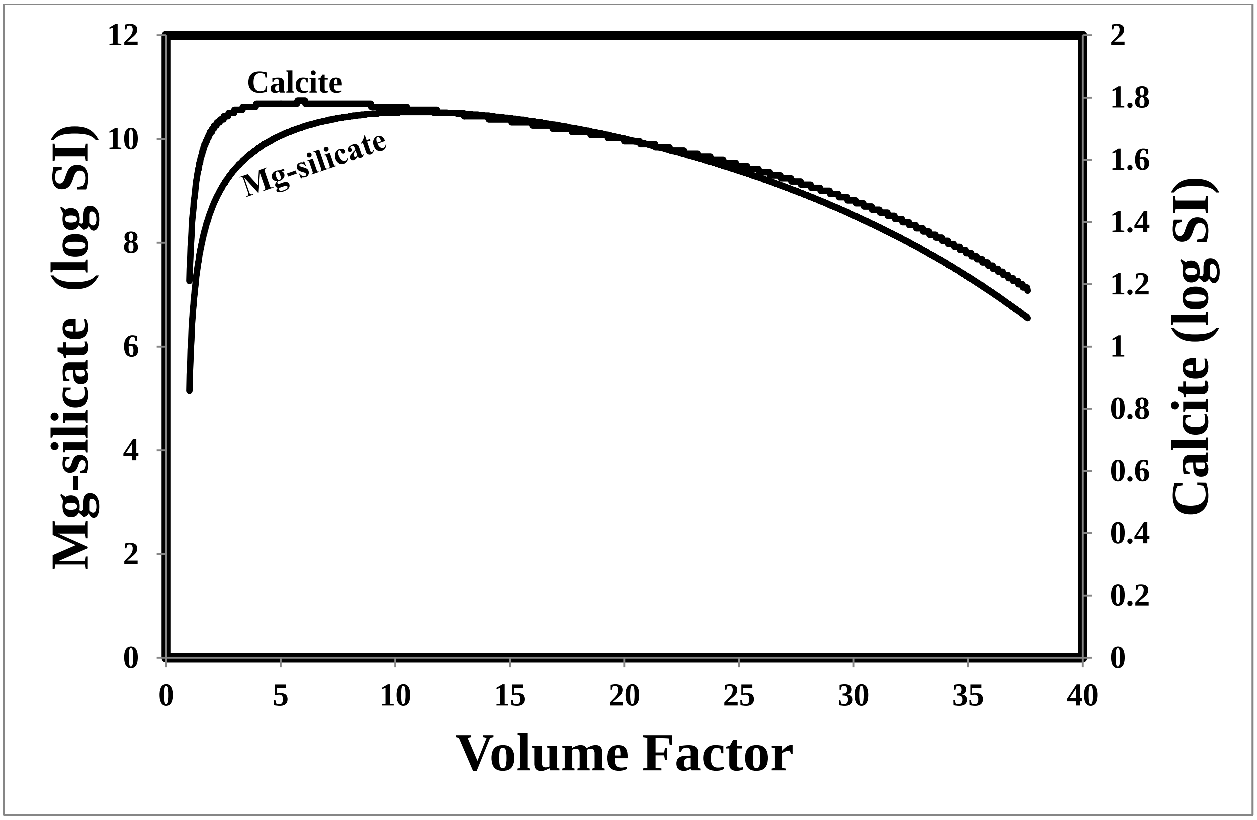

Figure 3-9 Modeling results of the evaporation and mixing model using a constant flux of water with proportional mix of average creek and spring composition based on Tomascak et al.'s (2003) estimate. Calcite and Mg-silicate remain saturated in the Mono Lake water. The volume factors at significant lake levels at Mono are: 2030 (lower Pleistocene terrace)=7; 2073 (upper Pleistocene terrace)= 12; 2155 (Highest lake level attained during last glacial)==24 and 2195 (Mono Lake basin spill level)= 31.

Chapter 4: A python based program for automating simple mixing and evaporation based calculations using PHREEQC (version 2).

Abstract

Constructing geochemical models using commercially available software such as PHREEQC, Geochemist Workbench, and Minteq has been used for solving complex geochemical problems. Increased computing power has enabled the construction of more comprehensive models performing specific tasks. Here we present a simple python computing language based code that enabled us to simulate the geochemical evolution of Mono Lake since its last glacial period high level. This code allowed us to simulate the filling up of Mono Lake starting from the present day lake. The details of the results and the metadata produced can be found in the companion study (Chapter 3).

1. Introduction

The importance of geochemical models in conducting comprehensive geochemical investigations in arid lake basins was realized in the early part of the twentieth century (Garrels and Mackenzie 1967, Hardie and Eugster 1970, Harvie et al., 1980, 1984). These models use the principles of chemical thermodynamics and chemical kinetics to predict reactions occurring in a given geologic system. The geochemical models initially developed were computed by hand (i.e. Garrels and Mackenzie, 1967), but increasing computing power enabled development of more sophisticated models like **PHREEQC**, **PHREEQE**, **MINTEQ**, **WATEQ4F** and, more recently, **Geochemist Workbench**. The current versions of these programs are capable of dealing with complex geochemical problems. Despite the complexity and comprehensiveness of these models, they sometimes lack the flexibility necessary for non-routine applications. They can be improved with more intuitive interfaces and with automation of iterative calculations.

Our motivation for the work presented here stems from difficulty in applying the available models to real-world hydrologic regimes we have been studying using multiple geochemical tools. The goal of our study was to simulate the filling up of Mono Lake, an internally drained, highly saline lake in eastern California. The current level is 1946m AMSL, but in the last glacial period it stood at 2155m AMSL. In order to predict the geochemistry of the lake at its high level, we used PHREEQC (version 2) software to simulate a sequential addition of a constant flux of water and assuming a constant evaporation rate, as perennial flux of water from creeks and springs and evaporation are the only mechanisms responsible for changing the water budget of Mono Lake since there is no outflow.

The PHREEQC (version 2) software from the USGS allows the user to perform mixing and evaporation of solutions by manually inputting the data into the software. However, if it is necessary to perform multiple iterations for a few hundred or thousands of simulations, then this method is error prone and time consuming. We present a simple code to allow multiple automated sequential simulations of evaporation and mixing until the desired lake level is attained.

2. Motivation

Lake levels of closed basin lakes in arid basins are excellent indicators of regional climate, where dry periods correspond to low lake levels and vice versa. Mono Lake in the western Great Basin region is one such lake which attained its historic low level in 1982. Based on physical and stratigraphic evidence it has been predicted that the lake level at the last glacial maximum was ~ 200m higher than its current level, and the volume was ~ 30x that of today. The geochemical signatures of this large lake level variation are recorded in the authigenic mineral phases of the lake sediments that precipitate from the lake water. High concentrations of leachable ions such as Li, Ca, Mg and Sr in the authigenic phases correspond to high lake levels (Sahajpal et al. 2011).

The motivation of this study is to present a computer code that enabled us to model and predict the geochemistry of Mono Lake water up to its glacial level high. The detailed model, which is presented in the companion study of this paper, also allowed us to test the findings of Sahajpal et al. (2011). Chapter 3 contains the detailed modeling of Mono Lake water.

3. Objective

The goal of developing this code is to simplify the modeling of sequential evaporation and mixing of waters in Mono Lake with the eventual goal of simulating lake chemistry changes from the present day lake to its glacial period high level. A flowchart (Fig.1) is presented below that shows the framework that was used to construct the model. Here we only present the computer code that aided in our simulation of the geochemical evolution of Mono Lake water.

3.1 PHREEQC (version 2)

PHREEQC is a geochemical program developed by the USGS that performs low temperature aqueous geochemical calculations (Parkhurst and Appelo., 1999). The model is more flexible as compared to Geochemist Workbench, allowing users to modify the code depending on what is required by their research question. The program is based on equilibrium chemistry of aqueous solutions interacting with minerals, gases, solid solutions, and sorption surfaces. It is capable of modeling kinetic reactions with rate equations that can be specified by the user. The inverse modeling capability allows identification of reactions that account for observed water compositions along a flowline or in the time course of an experiment. The model contains an extensive geochemical database (llnl, pitzer, minteq, waterq4f) that allows application of the reaction, transport, and inverse-modeling capabilities to all natural waters.

4. Results and Discussion

The code was written in Python programming language in order to automate the iterative steps required for evaporation and mixing processes in saline lakes (Fig.2). The result required from the code is to be able to incrementally add water to the saline mix and constantly evaporate water at a fixed rate. We chose the Python programming language because it is a powerful and yet simple tool which can produce a text based script that can easily be added to PHREEQC (version 2) code.

The present study, along with its companion study, is unique because this is the first known application that takes into account the mixing of a constant fresh water flux as well as evaporation to model the geochemical evolution of arid basin lakes, unlike the existing geochemical models that only use evaporation as the dominant process.

We recommend the use of this code as a template for developing similar text based scripts for automating other functions performed by PHREEQC (version 2).

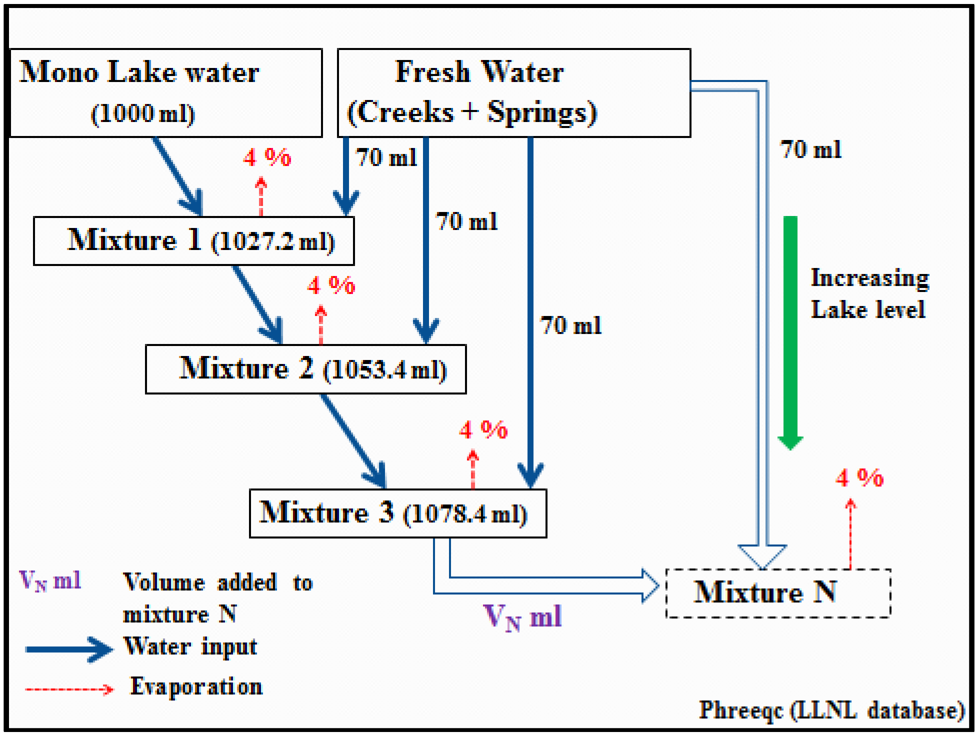

Figure 4-1 A flowchart depicting the assumptions made to simulate the filling up of Mono Lake up to its glacial period high level.

.

```
import os
count = 5000
conc1 = 1
conc2 = 0.07
h2oconc = 0.8325
counter = 1
fp =
open('C:\\Users\\rahul\\Desktop\\Pytech\\'+str(count)+'_'+
str(h2oconc)+'.txt','w')
for i in range(1, count):
    fp.write('MIX ' + str(i)+'\n')
    if (i == 1):
        fp.write('\t '+str(i)+' \t '+str(conc1)+'\n')
    else:
        fp.write('\t '+str(i+counter)+' \t '+str(conc1)+'\n')
    fp.write('\t 2'+' \t '+str(conc2)+'\n')
    fp.write('\n')
    fp.write('Save solution '+str(i+1+counter)+'\n')
    fp.write('\n')
    fp.write('Reaction '+str(i))
    fp.write('\n\n')
    fp.write('H2O         -1.0\n\n')
    fp.write(str(h2oconc)+' moles\n\n')
    fp.write('Save solution '+str(i+2+counter)+'\n\n')
    fp.write('END\n')
    fp.write('\n')
    counter = counter + 1

    print('DONE\n') run simulation
```

Figure 4-2 A python based computer code used for automating the simulation used to predict the geochemical evolution of Mono Lake waters since the last glacial period.

Appendix- 1a

Sample Id	Age (Kyr)	Li (µg/g)	Mg (µg/g)	Ca (µg/g)	Sr (µg/g)	% CaCO3
SS-07-01	23.08	41.37	4971.17	2525.28	25.82	
SS-07-02	23.35	68.18	7505.97	5970.90	46.77	0.28
SS-07-03	23.65	79.61	9273.43	18302.36	103.23	2.72
SS-07-04	23.96	76.41	7825.45	15466.12	88.95	2.06
SS-07-05	24.26	96.74	12342.59	29193.62	171.76	1.22
SS-07-06	24.57	63.01	6752.93	11532.86	62.40	1.10
SS-07-07	24.88	69.61	7222.06	10182.79	61.37	1.07
SS-07-08	25.19	62.81	6711.58	10797.78	57.24	0.79
SS-07-09	25.49	72.26	7950.03	12692.90	67.79	2.24
SS-07-10	25.80	77.37	8505.32	16238.25	74.07	2.17
SS-07-11	26.11	83.13	8513.98	13664.24	69.31	3.35
SS-07-12	26.42	80.35	8274.16	14444.76	71.21	2.91
SS-07-13	26.72	88.89	10017.65	14286.48	72.80	2.08
SS-07-14	27.03	98.46	10545.42	22282.26	100.62	2.80
SS-07-15	27.34	69.81	7425.44	19356.53	74.64	3.24
SS-07-16	27.64	80.13	8780.28	15054.16	73.84	1.97
SS-07-17	27.95	87.10	9789.43	14600.26	72.34	3.89
SS-07-18	28.26	100.04	10157.21	18414.44	89.24	3.40
SS-07-19	28.57	82.15	8494.34	16782.80	79.59	2.69
SS-07-20	28.87	72.74	7868.74	20199.83	65.39	1.78
SS-07-21	29.18	65.97	7843.19	10730.63	55.93	1.55
SS-07-22	29.49	71.11	7844.23	21754.48	82.24	3.25
SS-07-23	29.80	77.61	8856.40	18126.38	82.67	2.00
SS-07-24	29.88	81.45	7674.23	12609.63	69.34	2.45
SS-07-25	29.96	88.73	9767.40	19430.38	102.55	4.43
SS-07-26	30.03	94.51	9764.93	18474.24	97.22	3.57
SS-07-27	30.11	91.88	9920.97	15983.49	84.63	3.41
SS-07-28	30.19	97.57	11231.84	16739.72	89.60	3.33
SS-07-29	30.26	85.49	9657.48	11375.44	65.34	2.38
SS-07-30	30.34	73.98	9004.95	11624.22	65.27	1.95
SS-07-31	30.42	82.71	9224.52	12453.29	73.20	2.52
SS-07-32	30.49	76.87	8618.77	12781.67	69.89	2.56
SS-07-33	30.57	79.77	8473.95	8365.84	50.93	1.69
SS-07-34	30.65	77.88	8571.01	10145.68	60.22	1.77
SS-07-35	30.72	69.40	8636.04	11570.92	65.10	2.17
SS-07-36	30.80	77.36	14383.81	11621.03	64.10	1.74
SS-07-37	30.88	68.12	8885.95	10609.77	59.96	1.82
SS-07-38	30.95	81.18	8287.55	12925.81	75.84	2.68

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (μg/g)**	**Mg (μg/g)**	**Ca (μg/g)**	**Sr (μg/g)**	**% CaCO3**
SS-07-39	31.03	74.80	9725.82	10166.02	63.59	1.58
SS-07-40	31.11	79.73	9324.38	9140.20	62.01	0.87
SS-07-41	31.18	68.61	8163.18	8427.63	59.90	1.43
SS-07-42	31.26	66.93	8317.09	10232.51	66.28	1.75
SS-07-43	31.34	67.28	8092.74	9930.55	71.42	1.69
SS-07-44	31.41	75.11	9245.83	10898.18	78.54	1.67
SS-07-45	31.49	60.92	7779.68	10813.94	84.18	2.06
SS-07-46	31.60	69.37	8819.59	13197.63	77.17	1.46
SS-07-47	31.75	62.92	7774.16	9456.11	52.69	1.19
SS-07-48	31.90	64.59	8284.02	14034.72	94.95	1.63
SS-07-49	32.05	55.66	7210.62	9287.21	57.84	1.35
SS-07-50	32.20	62.37	8056.06	22352.09	65.44	2.16
SS-07-51	32.35	58.52	6984.23	12225.23	58.24	1.40
SS-07-52	32.50	75.66	9174.82	12182.85	62.76	0.81
SS-07-53	32.65	59.61	7312.85	7612.71	38.66	0.36
SS-08-01	32.99	85.76	8413.30	5604.81	63.13	
SS-08-02	33.09	65.37	6261.72	21574.17	71.80	
SS-08-03	33.19	90.96	7350.59	7226.23	59.99	0.54
SS-08-04	33.29	78.08	7775.59	15495.79	81.07	
SS-08-05	33.39	89.22	7934.55	7165.82	71.57	
SS-08-06	33.49	87.11	8258.52	17298.72	68.10	
SS-08-07	33.60	85.78	7943.02	22727.98	58.03	0.43
SS-08-08	33.70	89.89	8430.30	7223.72	57.79	
SS-08-09	33.80	122.27	11606.61	10313.83	81.40	
SS-08-10	33.90	124.15	12000.51	11446.30	88.15	
SS-08-11	34.00	111.16	10697.66	15851.12	85.21	1.72
SS-08-12	34.10	85.34	8209.81	8209.95	69.94	
SS-08-13	34.20	108.63	10580.54	21761.35	143.77	
SS-08-14	34.26	136.37	13697.86	12845.75	111.24	
SS-08-15	34.31	131.08	12561.50	17184.16	106.50	
SS-08-16	34.36	93.19	8632.95	21268.49	102.30	
SS-08-17	34.42	124.62	12425.56	22456.14	137.51	2.98
SS-08-18	34.47	134.52	13802.23	24734.81	143.92	
SS-08-19	34.52	103.11	10409.09	26143.81	111.36	
SS-08-20	34.58	113.06	12208.74	23543.90	104.73	
SS-08-21	34.61	137.52	13206.26	20595.07	106.02	2.56

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (µg/g)**	**Mg (µg/g)**	**Ca (µg/g)**	**Sr (µg/g)**	**% CaCO3**
SS-08-22	34.67	113.07	10719.62	27983.05	91.70	
SS-08-23	34.73	121.23	12064.50	20590.80	96.41	
SS-08-24	34.79	121.21	12900.96	19895.23	94.10	
SS-08-25	34.85	137.18	14022.40	17559.21	90.78	3.08
SS-08-26	34.91	138.65	14481.11	20683.26	96.61	
SS-08-27	34.97	139.34	13392.29	17445.06	117.34	
SS-08-28	35.03	133.43	13464.31	25810.82	91.23	
SS-08-29	35.10	134.65	13773.04	21081.88	147.99	2.11
SS-08-30		101.44	10080.66	25986.41	109.09	
SS-08-31	35.19	154.47	16495.46	17478.32	126.27	
SS-08-32	35.22	153.14	17493.87	41627.85	213.72	5.39
SS-08-33	35.25	182.52	20732.40	30095.92	180.62	4.92
SS-08-34	35.27	158.25	16061.13	31737.12	171.85	5.82
SS-08-35	35.30	149.87	16399.66	16006.97	114.62	
SS-08-36	35.32	114.17	12808.51	21117.10	127.73	3.13
SS-08-37	35.35	101.24	11283.10	19049.78	107.76	2.16
SS-08-38	35.38	120.38	13379.71	26280.99	145.37	2.73
SS-08-39	35.40	70.64	7775.75	16662.87	105.29	
SS-08-40	35.43	99.50	10619.62	34940.32	132.50	3.17
SS-08-41	35.45	12.43	27644.37	137211.07	740.35	
SS-08-42		17.61	17842.90	29279.98	213.99	
SS-08-43	35.51	140.75	14189.82	41170.43	167.39	4.39
SS-08-44		105.86	10710.05	29809.02	123.75	
SS-13-01	36.59	103.20	15195.52	32264.34	189.81	
SS-13-02	36.65	123.97	15658.43	35068.94	189.74	
SS-13-03	36.70	145.68	18152.10	27292.56	158.14	6.25
SS-13-04	36.75	97.80	11800.32	35847.21	195.31	
SS-13-05	36.81	114.86	14652.20	37549.74	195.77	
SS-13-06	36.86	138.51	16545.51	35522.68	216.58	
SS-13-07	36.92	172.53	21418.93	41303.42	241.93	10.02
SS-13-08	36.97	133.01	18525.81	61289.47	329.05	
SS-13-09	37.03	163.09	23856.63	80753.23	425.94	
SS-13-10		123.05	16576.45	48892.41	241.07	
SS-14-01	37.18	88.50	11901.26	33431.56	191.05	
SS-14-02	37.37	99.04	12488.56	28115.56	153.54	
SS-14-03	37.56	102.30	12336.36	36548.12	210.00	5.12

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (µg/g)**	**Mg (µg/g)**	**Ca (µg/g)**	**Sr (µg/g)**	**% CaCO3**
SS-14-04	37.78	110.94	12143.36	26033.08	156.36	
SS-14-05	37.84	90.61	9584.62	13302.82	77.72	
SS-14-06	37.90	116.93	12389.25	32318.42	178.32	
SS-14-07	37.97	142.33	14685.16	42347.23	246.66	7.49
SS-14-08	38.03	183.55	16222.46	25549.19	153.33	
SS-14-09	38.09	164.87	16686.23	33273.55	199.23	15.50
SS-14-10	38.16	178.08	19658.08	52415.06	294.82	
SS-14-11	38.22	187.93	21551.11	56577.73	316.57	15.50
SS-14-12	38.28	221.77	24202.06	55614.25	318.57	
SS-14-13	38.34	165.14	22381.49	46177.68	270.35	
SS-14-14	38.41	178.31	23598.53	51233.22	288.60	
SS-14-15	38.47	165.40	22137.24	44333.73	252.92	11.21
SS-14-16	38.53	150.07	20201.26	49371.23	288.00	
SS-14-17	38.59	142.68	21359.59	57639.49	335.01	10.91
SS-14-18	38.66	116.27	17057.67	29132.47	183.68	
SS-14-19	38.72	102.56	16757.09	28161.73	177.61	8.71
SS-14-20	38.78	99.63	15962.70	26600.31	181.96	
SS-14-21	38.85	88.02	13775.45	22684.59	145.70	
SS-14-22	38.91	87.29	12823.96	18339.40	125.51	
SS-14-23	38.97	80.21	11679.13	19395.40	115.88	2.84
SS-14-24	39.03	72.75	10506.66	14633.66	88.15	
SS-14-25	39.10	65.52	9067.40	15083.65	88.36	3.15
SS-14-26	39.16	143.20	19955.29	26968.86	163.59	
SS-14-27	39.22	58.35	7927.51	19833.04	82.03	2.92
SS-14-28	39.28	62.23	8824.41	18273.66	80.33	
SS-14-29	39.35	64.15	8545.19	12011.79	65.73	
SS-14-30	39.41	66.46	8641.73	16530.93	83.20	
SS-14-31	39.47	73.82	9925.87	14322.18	78.63	3.45
SS-14-32	39.54	69.22	9529.51	18082.02	109.22	
SS-14-33	39.60	71.59	10150.81	21019.73	109.84	4.33
SS-14-34	39.66	73.39	9555.80	21572.19	105.18	
SS-14-35	39.72	75.51	10113.16	21558.58	114.26	4.51
SS-14-36		51.37	6524.07	4751.64	38.33	
SS-15-01	39.73	65.10	7948.25	5410.64	46.55	
SS-15-02	39.78	79.56	10112.64	4841.45	51.45	
SS-15-03	39.83	82.99	10940.84	9228.83	77.76	

Appendix- 1a

Sample Id	Age (Kyr)	Li (µg/g)	Mg (µg/g)	Ca (µg/g)	Sr (µg/g)	% CaCO3
SS-15-04	39.88	79.25	9948.99	12395.77	97.14	
SS-15-05	39.93	87.39	10738.76	14136.32	108.27	3.36
SS-15-06	39.98	69.48	8805.19	12582.03	87.75	
SS-15-07	40.03	89.95	10938.18	17177.17	118.40	
SS-15-08	40.08	112.15	13891.05	28810.20	177.44	
SS-15-09	40.12	80.38	9558.49	14954.80	91.24	4.22
SS-15-10	40.17	111.48	12938.80	16872.71	120.69	
SS-15-11	40.22	193.30	21218.33	23827.50	191.60	
SS-15-12	40.27	109.15	14287.51	19976.66	122.85	5.82
SS-15-13	40.32	77.15	9439.61	10284.72	75.70	
SS-15-14	40.37	97.83	11547.33	11187.68	88.78	
SS-15-15	40.42	82.37	9857.71	10818.85	75.49	2.79
SS-15-17	40.52	111.94	13484.93	24473.13	135.64	
SS-15-18	40.57	103.78	12944.23	18538.68	121.74	
SS-15-19	40.62	87.33	10872.59	18078.31	101.00	4.19
SS-15-20	40.67	126.18	15835.05	22466.72	142.74	
SS-15-21	40.71	105.14	13413.94	21238.32	131.69	
SS-15-22	40.77	83.14	10013.74	10729.30	89.43	
SS-15-23	40.82	93.56	10932.19	9041.01	72.01	5.85
SS-15-24	40.87	70.46	8399.41	8387.28	69.83	
SS-15-25	40.92	91.33	10517.95	9199.50	78.23	
SS-15-26	40.97	80.16	9093.53	9940.56	68.38	3.35
SS-15-27	41.02	70.88	7890.68	8507.64	62.95	
SS-15-28	41.07	91.79	10639.10	11299.98	82.02	
SS-15-29	41.13	95.27	10824.43	12981.84	85.40	2.60
SS-15-30	41.18	82.82	12013.62	8456.30	64.63	
SS-15-33	41.33	106.63	11703.59	13727.26	92.27	2.81
SS-15-34	41.38	104.12	12070.20	15321.56	107.71	
SS-15-35	41.43	122.05	15063.52	22881.12	132.23	
SS-15-36	41.48	123.99	15354.62	26702.49	165.54	5.50
SS-15-38	41.58	124.63	14809.84	26518.79	150.67	
SS-15-39	41.63	113.85	14542.87	36624.88	161.24	6.89
SS-15-40	41.69	118.72	14981.98	34435.04	171.07	
SS-15-41	41.74	114.51	14282.39	22941.54	136.36	7.36
SS-15-42	41.79	116.11	14613.53	25240.51	148.67	
SS-15-43	41.84	100.37	12175.76	17291.62	97.08	1.78

Appendix- 1a

Sample Id	Age (Kyr)	Li (μg/g)	Mg (μg/g)	Ca (μg/g)	Sr (μg/g)	% CaCO3
SS-15-44	41.89	94.74	11059.87	9982.67	66.68	1.66
SS-15-45	41.94	104.95	14933.60	12612.72	112.69	1.87
SS-15-48	42.09	77.89	8345.70	26465.84	84.90	
SS-15-49	42.14	98.35	11505.03	10960.83	93.58	
SS-15-51	42.24	81.74	9156.25	8434.24	69.05	1.56
SS-15-53	42.35	89.26	10651.54	8649.06	59.87	0.93
SS-15-55	42.45	107.47	12275.08	10000.70	80.64	1.20
SS-15-57	42.69	105.79	12307.33	13814.91	98.33	2.97
SS-15-59	42.83	112.04	13095.15	16970.74	109.52	2.22
SS-15-61	42.97	102.41	11173.91	11365.15	94.71	1.16
SS-15-63	43.11	132.75	15865.60	23428.25	151.58	4.63
SS-15-65	43.26	125.26	13430.44	18415.97	130.75	4.10
SS-15-67	43.40	117.07	12578.34	20266.50	118.92	2.86
SS-15-71	44.06	155.53	16618.67	19614.14	118.26	3.83
SS-15-73	44.85	162.96	17675.56	28245.02	160.23	5.02
SS-15-75	45.64	146.59	16222.65	32059.94	168.76	6.38
SS-15-77.2	46.44	161.90	19007.83	26925.53	156.42	
SS-15-79.2	46.93	143.47	17906.83	30687.43	183.09	5.06
SS-15-81.2	47.20	132.37	15688.54	22860.19	136.20	3.39
SS-15-83.2	47.43	95.83	10793.87	12075.13	78.84	0.43
SS-15-85.2	47.65	96.74	10927.40	7967.14	64.97	0.55
SS-15-87.2	47.88	92.19	10688.33	10509.16	72.21	0.77
SS-15-89.2	48.11	95.55	10626.62	8946.44	65.66	0.68
SS-15-91.2	48.34	90.87	10565.64	10440.67	63.63	
SS-15-93.2	48.57	83.12	9737.26	7321.21	54.31	0.33
SS-15-95.2	48.80	99.26	11188.47	7648.94	72.12	0.69
SS-15-97.2	49.03	132.91	14716.52	10089.78	85.44	0.11
SS-15-99.2	49.25	71.23	8756.69	10174.66	75.21	1.11
SS-15-101.2	49.48	93.59	10350.88	6867.94	62.53	0.30
SS-15-103.2	49.68	87.88	10030.22	9700.18	73.27	0.66
SS-15-105.2	50.15	75.41	8473.05	7988.48	69.37	0.58
SS-15-109.2	51.02	118.46	13474.66	19525.01	142.96	1.73
SS-15-111.2	51.45	85.85	9468.97	25983.68	101.47	0.31
SS-15-113.2	51.89	73.78	8635.65	14781.28	95.76	1.61
SS-15-115.2	52.32	82.76	9444.25	10220.54	67.41	1.04
SS-15-117.2	52.76	83.13	9377.98	14151.26	91.80	1.46

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (µg/g)**	**Mg (µg/g)**	**Ca (µg/g)**	**Sr (µg/g)**	**% CaCO3**
SS-15-119.2	53.19	88.57	9822.91	9206.81	87.27	0.78
SS-15-123.2	53.79	93.49	11031.36	15697.63	97.70	3.03
SS-15-125.2	54.09	80.22	9086.30	9766.80	66.88	0.99
SS-15-127.2	54.39	83.50	9019.09	14060.89	79.91	0.34
SS-15-129.2	54.68	109.83	12833.30	18462.00	115.82	2.64
SS-15-131.2	54.98	98.24	11094.03	13440.94	93.94	3.12
SS-15-133.2	55.28	83.28	9703.99	13812.98	87.14	1.87
SS-15-135.2	55.62	89.15	10568.31	23342.25	124.26	1.75
SS-15-139.2	56.39	77.75	9728.06	18106.49	114.83	1.28
SS-15-141.2	56.66	71.17	8543.21	15184.18	85.72	2.58
SS-15-143.2	56.83	78.29	9038.77	19565.43	113.33	2.63
SS-15-145.2	57.00	97.51	12215.42	23797.33	142.27	4.51
SS-15-147.2	57.17	80.88	10308.50	18424.02	110.29	5.32
SS-15-149.2	57.34	90.83	11880.33	29885.82	156.82	5.30
SS-16-03		76.75	9927.58	16885.48	102.55	2.79
SS-16-05	57.70	119.93	15974.74	33018.47	196.14	5.57
SS-16-07	57.80	117.35	15632.06	40144.02	197.68	6.28
SS-16-09	57.91	123.52	16462.51	35210.85	224.91	6.44
SS-16-11	58.01	105.67	13738.94	41775.35	221.52	6.56
SS-16-13	58.12	131.03	17384.03	42878.77	291.12	14.69
SS-16-15	58.22	151.18	21012.28	51298.54	345.56	11.72
SS-16-17	58.33	135.27	18716.01	52296.95	344.36	15.87
SS-16-19	58.42	130.74	17636.39	64523.65	345.15	7.51
SS-16-21	58.50	116.73	15642.53	33862.66	203.50	6.16
SS-16-23	58.58	95.94	12553.00	24477.58	141.43	5.24
SS-16-25	58.66	104.93	13582.56	26269.92	150.42	5.34
SS-16-27	58.74	112.64	15498.66	21849.82	129.91	6.33
SS-16-29	58.82	101.40	14123.86	29593.85	163.34	7.99
SS-16-31	58.90	94.68	12479.08	28131.87	130.08	2.10
SS-16-33	58.98	126.01	16655.37	24887.56	153.11	4.00
SS-16-35	59.06	132.81	16769.63	62631.30	267.66	8.72
SS-16-37	59.14	153.82	20619.72	42543.49	274.60	10.48
SS-16-39	59.22	140.68	17846.05	31286.61	206.45	6.66
SS-16-41	59.30	146.42	20647.80	52891.44	355.66	10.25
SS-16-43	59.38	138.57	18441.54	40073.55	215.91	6.26
SS-16-45	59.46	136.07	18656.96	65866.00	396.46	8.61

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (μg/g)**	**Mg (μg/g)**	**Ca (μg/g)**	**Sr (μg/g)**	**% CaCO3**
SS-16-47	59.54	146.65	21734.08	63931.77	356.66	13.41
SS-16-51	59.70	100.21	14690.54	35219.62	206.74	12.49
SS-16-53	59.78	134.56	21749.55	62828.64	333.64	16.40
SS-17-01		99.79	16964.20	77420.70	436.76	
SS-17-03		89.86	13266.62	47775.89	277.24	
SS-17-05		79.98	14334.16	61372.80	337.66	
SS-17-07		94.19	16416.48	47598.93	267.99	
SS-17-09		109.64	19437.15	65179.03	367.82	
SS-17-11		83.43	15061.20	104847.61	547.47	
SS-17-13		87.61	15294.38	48617.84	276.07	
SS-17-15		82.72	14092.43	59650.44	324.01	
SS-17-17		73.66	12710.37	44002.53	238.02	
SS-17-19		66.28	11652.36	43205.07	238.30	
SS-17-21		76.17	12581.55	43822.26	247.97	
SS-17-23		65.71	10470.74	26966.33	149.53	
SS-17-25		82.37	14296.57	34251.65	198.47	
SS-17-27		83.70	14885.57	44703.68	254.33	
SS-17-29		73.59	12654.98	33185.33	188.92	
SS-17-31		66.53	11532.92	36832.07	204.87	
SS-17-33		59.72	10434.16	31771.21	169.72	
SS-17-35		69.41	12225.72	37404.40	206.47	
SS-17-37		71.06	12316.10	27528.30	160.94	
SS-17-39		63.01	11095.10	28026.71	153.71	
SS-17-41		55.06	8637.68	19320.82	106.66	
SS-17-43		103.03	15182.03	30777.51	173.81	
SS-17-45		57.56	8725.37	17273.54	96.49	
SS-17-47		63.41	10400.83	18824.67	103.18	
SS-17-49		85.03	15508.93	36025.47	188.02	
SS-17-51		36.78	6358.05	10070.08	52.11	
SS-17-53		10.99	1804.89	3287.10	18.86	

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (µg/g)**	**Mg (µg/g)**	**Ca (µg/g)**	**Sr (µg/g)**	**% CaCO3**
WC-07-05		42.89	6952.45	45059.41	174.18	
WC-07-10		61.32	10088.28	38649.33	164.07	
WC-07-15		50.40	7956.15	20731.24	103.68	
WC-07-20		62.51	9172.16	31030.63	143.64	
WC-07-25		51.59	8951.37	34000.89	157.36	
WC-07-30		58.60	9041.99	21421.96	108.42	
WC-07-35		83.25	11562.96	26345.76	136.05	
WC-07-40		76.69	12069.90	21852.02	113.49	
WC-07-45		76.31	11522.03	15503.46	86.66	
WC-07-55		50.32	7947.05	15180.07	79.46	
WC-07-60		50.39	7908.67	13094.02	71.38	
WC-08-01	32.96	45.33	5633.60	13047.27	77.25	2.23
WC-08-06	33.99	152.15	16451.26	26661.99	152.01	
WC-08-11	35.06	45.33	20324.75	71609.59	357.16	22.05
WC-08-16	36.30	102.99	17023.84	106870.79	512.28	
WC-08-21	37.79	112.75	15908.43	81066.31	398.17	34.08
WC-08-26	38.29	116.14	20732.83	110189.61	529.28	
WC-08-31	38.78	91.54	17473.23	70005.73	382.21	17.22
WC-08-36	39.27	74.76	11500.36	26765.64	130.21	
WC-08-41	39.76	38.24	6626.60	10483.52	59.02	1.65
WC-15-06	40.35	104.05	18634.39	47369.19	251.34	
WC-15-10	40.75	74.85	11723.32	41141.26	203.80	18.56
WC-15-11	40.85	73.17	11560.70	33838.54	173.91	
WC-15-15	41.26	90.00	14352.97	36206.81	176.85	
WC-15-16	41.36	104.64	16498.30	33679.30	178.77	
WC-15-20	41.77	95.77	17422.21	63091.99	292.65	19.95
WC-15-21	41.87	123.50	19854.34	51370.19	243.35	
WC-15-25	42.28	68.70	10644.43	24382.47	121.81	
WC-15-30	42.79	75.15	11605.19	45820.41	215.26	15.21
WC-15-35	43.30	112.58	14041.20	29253.46	149.82	
WC-15-40	44.74	133.49	20971.41	96022.47	444.11	20.91
WC-15-60	51.77	62.74	9475.25	18517.71	98.38	2.38
WC-15-65	53.45	84.26	11157.58	22542.46	129.52	
WC-15-70	54.67	97.55	11548.10	19624.88	112.24	4.76
WC-15-71	54.91	158.06	17722.62	38944.32	213.21	
WC-15-72	55.16	145.42	16287.15	30772.76	175.00	
WC-15-73	55.40	171.90	18944.06	34498.64	197.51	
WC-15-74	55.72	179.59	19839.25	32630.78	187.02	

Appendix- 1a

Sample Id	Age (Kyr)	Li (µg/g)	Mg (µg/g)	Ca (µg/g)	Sr (µg/g)	% CaCO3
WC-15-75	56.03	165.72	21481.70	39561.98	218.81	
WC-15-76	56.35	159.47	17710.39	29990.16	165.16	
WC-15-78	56.98	214.45	26357.20	120863.14	591.79	
WC-15-79	57.29	210.86	32030.70	155621.75	797.17	
WC-16-02	57.93	243.76	30252.76	186538.99	986.71	
WC-16-03	58.24	230.98	43564.62	386287.25	2031.28	
WC-16-04	58.52	282.74	53965.80	367046.48	1894.78	
WC-16-05	58.76	282.65	45701.44	250037.28	1293.88	
WC-16-07	59.24	267.83	40349.59	141020.77	741.24	
WC-16-08	59.48	230.69	47316.61	250993.90	1265.51	
WC-16-09	59.73	234.33	50340.58	373757.63	1788.63	
WC-16-10	59.97	152.54	34956.23	200743.88	905.07	
WC-16-12	60.45	230.65	48697.70	237125.22	1170.85	
WC-16-13	60.69	270.98	48982.01	191405.75	1078.51	
WC-16-14	60.93	279.14	41839.69	155053.97	880.90	
WC-16-15	61.18	184.65	28681.03	181240.57	1011.33	
WC-16-16	61.42	184.05	26680.10	105770.68	554.21	
WC-16-17	61.66	164.14	28596.52	190862.55	974.50	
WC-16-18	61.90	198.31	37699.95	132038.74	714.97	
WC-16-19	62.14	196.97	38138.81	157615.70	876.94	
WC-16-20	62.38	189.23	33718.35	163330.31	861.36	
WC-16-22	62.87	204.77	38702.84	136285.50	764.55	
WC-16-23	63.11	225.84	37903.24	92670.32	567.55	
WC-16-24	63.35	210.54	33121.39	90027.68	533.97	
WC-16-25	63.59	186.62	33847.15	135866.23	743.23	
WC-16-26	63.83	190.64	34332.45	185937.43	986.87	
WC-16-27	64.07	174.00	30131.37	142176.94	770.72	
WC-16-28	64.32	183.40	31265.78	166114.80	805.09	
WC-16-29	64.56	189.52	32695.67	176598.61	950.47	
WC-16-31	65.04	108.36	21587.64	99506.27	539.61	33.42
WC-16-32	65.28	231.60	48906.00	181668.28	944.36	
WC-16-33	65.52	227.94	44812.22	145776.52	771.53	
WC-16-34	65.77	205.78	41726.55	152616.52	806.84	
WC-16-37	66.25	87.58	21218.81	132635.75	765.59	
WC-16-39	66.73	127.45	22408.64	42116.80	240.04	
WC-16-40	66.97	149.04	18344.77	15823.53	96.85	

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (μg/g)**	**Mg (μg/g)**	**Ca (μg/g)**	**Sr (μg/g)**	**% CaCO3**
WS-01-04	14.23	72.41	5976.24	27060.88	127.24	10.48
WS-01-06	14.28	92.75	10367.69	21754.65	112.06	4.92
WC-01-07	14.31	71.94	6115.31	25249.71	136.12	6.95
WS-01-13	14.47	71.00	6492.94	31199.82	157.74	5.31
WS-01-16	14.55	93.86	11494.38	29685.27	152.23	6.02
WS-01-17	14.58	63.86	6244.28	22344.65	110.75	3.91
WS-04-01		45.84	7588.37	59662.90	322.77	
WS-04-04	16.14	33.32	3830.36	8243.31	41.99	12.47
WS-04-05	16.19	46.81	7432.96	10683.00	63.07	1.16
WS-04-15	16.77	40.66	6892.08	13828.56	94.33	4.24
WS-04-25	17.34	66.65	9774.85	8385.99	51.76	1.44
WS-04-35	17.91	58.37	8666.71	11329.35	65.23	3.87
WS05-04-37	18.03	40.68	4604.33	11702.33	61.06	3.10
WS05-04-40	18.20	35.21	3822.93	9315.56	49.30	1.54
WS05-04-43	18.37	28.63	3294.02	8473.80	45.01	4.91
WS05-04-47	18.60	29.40	3653.86	11729.87	64.96	5.16
WS05-04-50	18.77	28.42	3849.74	10406.18	100.05	3.54
WS05-04-53	18.94	39.44	3244.20	6930.95	37.83	2.13
WS-04-54	19.00	56.42	7622.17	8686.43	50.80	2.40
WS-ML-01	19.06	50.09	6962.26	12415.59	68.13	2.76
WS-ML-08	19.46	51.64	7695.88	15612.65	85.14	3.62
WS-ML-15	19.86	37.73	6036.17	18634.97	102.49	2.23
WS05-TL-01	19.92	37.98	4144.43	14510.46	84.79	3.60
WS05-TL-04	20.09	45.27	4345.51	10083.08	62.02	3.36
WS05-TL-07	20.26	32.89	3082.99	7285.18	39.70	2.99
WS05-TL-13	20.61	37.06	4373.24	11818.19	71.98	2.54
WS05-TL-16	20.78	32.40	3474.51	8444.56	42.41	2.91
WS05-TL-22	21.12	45.76	4800.57	19292.89	96.58	6.81
WS05-TL-25	21.29	46.48	6378.03	33108.91	167.34	4.82
WS05-TL-28	21.47	48.79	6294.12	30612.55	158.55	4.72
WS-TL-41	22.21	59.35	8474.06	19729.20	99.78	5.13
WS-TL-48	22.61	70.03	11154.21	26778.24	139.88	8.73
WS-07-02	23.54	42.75	5293.93	17880.04	88.47	3.47
WS-07-05	24.82	54.47	6787.70	23142.87	111.75	6.16
WS-07-08	26.10	61.74	8361.49	35259.93	178.70	7.97
WS-07-20	29.79	52.29	7236.00	21432.09	105.20	4.32
WS05-07-26	30.08	52.89	7314.31	13817.18	66.63	4.81
WS05-07-29	30.22	42.09	5624.01	12749.90	61.53	5.42

Appendix- 1a

Sample Id	**Age (Kyr)**	**Li (μg/g)**	**Mg (μg/g)**	**Ca (μg/g)**	**Sr (μg/g)**	**% CaCO3**
WS05-07-44	31.84	62.28	9159.59	29003.33	138.79	10.52
WS05-07-47	32.11	55.90	7313.36	23050.01	112.74	7.56
WS05-07-50	32.38	38.99	4895.42	16791.62	79.55	3.92
WS05-07-53	32.65	30.74	4039.51	12952.22	60.32	4.28
WS-09-02	35.38	105.84	17710.87	59238.34	322.92	13.14
WS-09-04	35.63	107.96	17377.42	30927.64	166.74	6.05
WS05-13-01	36.68	71.97	12759.30	75139.21	380.33	20.76
WS-14-02	38.09	121.25	19260.36	80269.75	397.02	19.59
WS05-14-03	38.14	108.72	16795.72	84691.52	416.48	22.04
WS-14-04	38.19	155.57	24747.90	109383.14	550.52	29.51
WS-14-06	38.29	137.21	23442.60	101493.71	503.09	19.75
WS-14-08	38.38	128.10	24090.04	70184.95	413.97	22.16
WS-14-10	38.48	119.97	17802.93	40432.38	236.72	10.01
WS-14-12	38.58	120.24	16495.41	34806.32	197.34	13.74
WS-14-14	38.83	94.70	12578.86	22874.51	125.74	7.58
WS-14-16	39.09	84.57	12503.50	22563.46	117.94	6.93
WS-14-18	39.34	73.91	10732.76	21651.44	108.23	9.72
WS-14-20	39.66	67.95	11233.62	49773.86	248.58	10.17

Appendix-1b

Li daily duplicates

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % difference
7/28/2008	SS-07-49	55.66	7/29/2008	SS-07-49	57.62	3.46
7/28/2008	SS-07-50	62.37	7/29/2008	SS-07-50	63.03	1.05
7/29/2008	SS-07-51	58.52	7/30/2008	SS-07-51	56.80	2.99
7/29/2008	SS-07-52	75.66	7/30/2008	SS-07-52	77.83	2.83
7/29/2008	WC-16-01D	128.37	7/30/2008	WC-16-01D	122.03	5.07
7/29/2008	WC-16-02	243.76	7/30/2008	WC-16-02	234.09	4.04
7/30/2008	SS-08-26	138.65	7/31/2008	SS-08-26	144.36	4.03
7/30/2008	SS-08-27	139.34	7/31/2008	SS-08-27	130.72	6.39
7/30/2008	WC-16-03	230.98	7/31/2008	WC-16-03	240.16	3.90
7/30/2008	WC-16-04	282.74	7/31/2008	WC-16-04	290.38	2.66
7/31/2008	SS-08-28	130.34	8/4/2008	SS-08-28	126.09	3.31
7/31/2008	SS-08-29	131.54	8/4/2008	SS-08-29	133.14	1.21
7/31/2008	WC-16-28	183.40	8/4/2008	WC-16-28	182.11	0.70
7/31/2008	WC-16-29	189.52	8/4/2008	WC-16-29	190.71	0.63
8/4/2008	SS-07-14	102.04	8/5/2008	SS-07-14	96.10	6.00
8/4/2008	SS-07-15	71.30	8/5/2008	SS-07-15	68.78	3.60
8/4/2008	WC-07-05	41.66	8/5/2008	WC-07-05	39.59	5.08
8/4/2008	WC-07-10	60.89	8/5/2008	WC-07-10	58.54	3.94
8/5/2008	SS-07-16	80.13	8/14/2008	SS-07-16	83.23	3.80
8/5/2008	WC-15-10D	73.93	8/14/2008	WC-15-10D	69.18	6.64
8/14/2008	SS-07-35	69.40	8/14/2008	SS-07-35	66.52	4.24
8/14/2008	WC-15-15	90.00	8/14/2008	WC-15-15	88.35	1.86
8/14/2008	SS-14-03	81.16	8/21/2008	SS-14-03	85.52	5.23
8/14/2008	SS-14-04	88.02	8/21/2008	SS-14-04	88.77	0.85
8/14/2008	WC-16-31D	108.36	8/21/2008	WC-16-31D	101.88	6.16
8/14/2008	WC-16-32	231.60	8/21/2008	WC-16-32	210.58	9.51
8/21/2008	SS-09-31	154.47	8/22/2008	SS-09-31	152.79	1.09
8/21/2008	SS-09-32	153.14	8/22/2008	SS-09-32	155.37	1.45
8/21/2008	WS-14-04	155.57	8/22/2008	WS-14-04	157.43	1.19
8/21/2008	WS-14-06	137.21	8/22/2008	WS-14-06	138.16	0.69
8/22/2008	SS-14-26	143.20	8/27/2008	SS-14-26	142.21	0.70
8/22/2008	SS-14-27	58.35	8/27/2008	SS-14-27	57.55	1.39
8/22/2008	WS-14-08	118.62	8/27/2008	WS-14-08	127.03	6.85
8/22/2008	WS-14-10	119.57	8/27/2008	WS-14-10	121.57	1.66
8/27/2008	SS-14-28	62.23	8/28/2008	SS-14-28	61.22	1.63

Appendix-1b

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % difference
8/27/2008	SS-14-29	64.15	8/28/2008	SS-14-29	63.76	0.61
8/27/2008	WS-15-21	105.14	8/28/2008	WS-15-21	107.74	2.45
8/27/2008	WS-15-22	83.14	8/28/2008	WS-15-22	82.92	0.26
8/28/2008	SS-15-23	93.56	8/29/2008	SS-15-23	96.21	2.79
8/28/2008	SS-15-24	70.46	8/29/2008	SS-15-24	72.81	3.29
8/28/2008	SS-15-63	132.75	8/29/2008	SS-15-63	139.36	4.86
8/29/2008	SS-15-65B	128.38	9/2/2008	SS-15-65B	118.64	7.89
8/29/2008	SS-15-67A	107.89	9/2/2008	SS-15-67A	103.55	4.10
8/29/2008	SS-15-95.2	99.26	9/2/2008	SS-15-95.2	93.94	5.51
8/29/2008	SS-15-97.2	132.91	9/2/2008	SS-15-97.2	128.12	3.67
9/2/2008	SS-15-99.2	71.23	9/4/2008	SS-15-99.2	74.80	4.88
9/2/2008	SS-15-101.2	93.59	9/4/2008	SS-15-101.2	96.88	3.46
9/2/2008	SS-15-143.2	81.48	9/4/2008	SS-15-143.2	80.99	0.60
9/2/2008	SS-15-145.2	108.07	9/4/2008	SS-15-145.2	112.08	3.64
9/4/2008	SS-15-145-2	86.78	9/5/2008	SS-15-145-2	86.10	0.79
9/4/2008	SS-15-147-2	71.92	9/5/2008	SS-15-147-2	71.23	0.96
9/4/2008	SS-16-51	100.03	9/5/2008	SS-16-51	99.82	0.21
9/4/2008	SS-16-53	134.32	9/5/2008	SS-16-53	134.22	0.07
					Average Absolute% Difference	3.13

Appendix-1b

Daily Mg duplicates

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % Difference
7/28/2008	SS-07-49	7187.23	7/29/2008	SS-07-49	6674.07	7.40
7/28/2008	SS-07-50	8029.93	7/29/2008	SS-07-50	7793.09	2.99
7/28/2008	WC-15-21D	19854.34	7/29/2008	WC-15-21D	19396.70	2.33
7/28/2008	WC-15-25	10644.43	7/29/2008	WC-15-25	10600.11	0.42
7/29/2008	SS-07-51	6984.23	7/30/2008	SS-07-51	7309.80	4.56
7/29/2008	SS-07-52	9174.81	7/30/2008	SS-07-52	9077.50	1.07
7/29/2008	WC-16-01D	13882.52	7/30/2008	WC-16-01D	14253.30	2.64
7/29/2008	WC-16-02	30252.76	7/30/2008	WC-16-02	30151.06	0.34
7/30/2008	SS-08-26	14481.11	7/31/2008	SS-08-26	13751.58	5.17
7/30/2008	SS-08-27	13392.30	7/31/2008	SS-08-27	13160.51	1.75
7/30/2008	WC-16-03	43564.63	7/31/2008	WC-16-03	45469.22	4.28
7/30/2008	WC-16-04	53965.80	7/31/2008	WC-16-04	53840.60	0.23
7/31/2008	SS-08-28	13456.24	8/4/2008	SS-08-28	13370.90	0.64
7/31/2008	SS-08-29	13764.78	8/4/2008	SS-08-29	13589.39	1.28
7/31/2008	WC-16-28	31247.04	8/4/2008	WC-16-28	30516.24	2.37
7/31/2008	WC-16-29	32676.07	8/4/2008	WC-16-29	32583.37	0.28
8/4/2008	SS-07-14	10863.52	8/5/2008	SS-07-14	9807.17	10.22
8/4/2008	SS-07-15	7649.43	8/5/2008	SS-07-15	6839.22	11.18
8/4/2008	WC-07-05	7477.24	8/5/2008	WC-07-05	6638.61	11.88
8/4/2008	WC-07-10	10849.78	8/5/2008	WC-07-10	9723.11	10.95
8/5/2008	SS-07-16	8780.28	8/14/2008	SS-07-16	8814.73	0.39
8/5/2008	WC-15-10D	11513.03	8/14/2008	WC-15-10D	11563.10	0.43
8/14/2008	SS-07-35	8633.06	8/14/2008	SS-07-35	8759.96	1.46
8/14/2008	WC-15-15	14348.03	8/14/2008	WC-15-15	14624.86	1.91
8/14/2008	SS-14-03	12336.36	8/21/2008	SS-14-03	11663.17	5.61
8/14/2008	SS-14-04	12143.35	8/21/2008	SS-14-04	11464.97	5.75
8/14/2008	WC-16-31D	21587.63	8/21/2008	WC-16-31D	20523.29	5.05
8/14/2008	WC-16-32	48906.00	8/21/2008	WC-16-32	46281.92	5.51
8/21/2008	SS-09-31	16495.46	8/22/2008	SS-09-31	16465.64	0.18
8/21/2008	SS-09-32	17493.86	8/22/2008	SS-09-32	17484.59	0.05
8/21/2008	WS-14-04	24658.63	8/22/2008	WS-14-04	25313.84	2.62
8/21/2008	WS-14-06	23358.04	8/22/2008	WS-14-06	23594.23	1.01
8/22/2008	SS-14-26	19955.28	8/27/2008	SS-14-26	19385.00	2.90
8/22/2008	SS-14-27	7927.51	8/27/2008	SS-14-27	7941.69	0.18
8/22/2008	WS-14-08	24090.04	8/27/2008	WS-14-08	24354.72	1.09
8/22/2008	WS-14-10	17802.93	8/27/2008	WS-14-10	17825.46	0.13
8/27/2008	SS-14-28	8824.42	8/28/2008	SS-14-28	8727.85	1.10

Appendix-1b

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % Difference
8/27/2008	SS-14-29	8545.20	8/28/2008	SS-14-29	8566.04	0.24
8/27/2008	WS-15-21	13413.94	8/28/2008	WS-15-21	13242.55	1.29
8/27/2008	WS-15-22	10013.75	8/28/2008	WS-15-22	9813.34	2.02
8/28/2008	SS-15-23	10932.20	8/29/2008	SS-15-23	11181.38	2.25
8/28/2008	SS-15-24	8399.41	8/29/2008	SS-15-24	8501.73	1.21
8/28/2008	SS-15-63	15865.61	8/29/2008	SS-15-63	16061.21	1.23
8/29/2008	SS-15-65B	13589.56	9/2/2008	SS-15-65B	13413.99	1.30
8/29/2008	SS-15-67A	11428.20	9/2/2008	SS-15-67A	11446.21	0.16
8/29/2008	SS-15-95.2	11188.48	9/2/2008	SS-15-95.2	10973.11	1.94
8/29/2008	SS-15-97.2	14716.53	9/2/2008	SS-15-97.2	14567.83	1.02
9/2/2008	SS-15-99.2	8756.68	9/4/2008	SS-15-99.2	8861.67	1.19
9/2/2008	SS-15-101.2	10350.87	9/4/2008	SS-15-101.2	10380.74	0.29
9/2/2008	SS-15-143.2	9179.25	9/4/2008	SS-15-143.2	9613.27	4.62
9/2/2008	SS-15-145.2	13537.60	9/4/2008	SS-15-145.2	13739.84	1.48
9/4/2008	SS-15-145-2	10893.22	9/5/2008	SS-15-145-2	10825.36	0.62
9/4/2008	SS-15-147-2	9826.94	9/5/2008	SS-15-147-2	9019.17	8.57
9/4/2008	SS-16-51	14690.53	9/5/2008	SS-16-51	14368.79	2.21
9/4/2008	SS-16-53	21749.55	9/5/2008	SS-16-53	21524.00	1.04
					Average Absolute% Difference	2.73

Appendix-1b

Daily Ca duplicates

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute %difference
7/28/2008	SS-07-49	9287.21	7/29/2008	SS-07-49	8798.53	5.40
7/28/2008	SS-07-50	22352.08	7/29/2008	SS-07-50	21958.72	1.78
7/28/2008	WC-15-21D	51370.17	7/29/2008	WC-15-21D	49864.20	2.98
7/28/2008	WC-15-25	24382.46	7/29/2008	WC-15-25	24372.45	0.04
7/29/2008	SS-07-51	12225.23	7/30/2008	SS-07-51	12622.57	3.20
7/29/2008	SS-07-52	12182.85	7/30/2008	SS-07-52	11862.61	2.66
7/29/2008	WC-16-01D	70594.62	7/30/2008	WC-16-01D	72763.14	3.03
7/29/2008	WC-16-02	186538.94	7/30/2008	WC-16-02	185062.65	0.79
7/30/2008	SS-08-26	20683.27	7/31/2008	SS-08-26	19657.89	5.08
7/30/2008	SS-08-27	17445.07	7/31/2008	SS-08-27	16857.46	3.43
7/30/2008	WC-16-03	386287.40	7/31/2008	WC-16-03	390635.33	1.12
7/30/2008	WC-16-04	367046.65	7/31/2008	WC-16-04	353166.78	3.85
7/31/2008	SS-08-28	25810.59	8/4/2008	SS-08-28	24657.14	4.57
7/31/2008	SS-08-29	21081.68	8/4/2008	SS-08-29	20678.58	1.93
7/31/2008	WC-16-28	166114.76	8/4/2008	WC-16-28	161684.87	2.70
7/31/2008	WC-16-29	176598.57	8/4/2008	WC-16-29	174491.90	1.20
8/4/2008	SS-07-14	23321.04	8/5/2008	SS-07-14	20503.96	12.86
8/4/2008	SS-07-15	20258.92	8/5/2008	SS-07-15	17685.78	13.56
8/4/2008	WC-07-05	49183.44	8/5/2008	WC-07-05	41920.68	15.94
8/4/2008	WC-07-10	42186.69	8/5/2008	WC-07-10	36609.44	14.16
8/5/2008	SS-07-16	15054.15	8/14/2008	SS-07-16	14421.05	4.30
8/5/2008	WC-15-10D	40473.54	8/14/2008	WC-15-10D	40951.69	1.17
8/14/2008	SS-07-35	11570.91	8/14/2008	SS-07-35	10849.12	6.44
8/14/2008	WC-15-15	36206.81	8/14/2008	WC-15-15	33839.88	6.76
8/14/2008	SS-14-03	36548.11	8/21/2008	SS-14-03	34124.70	6.86
8/14/2008	SS-14-04	26033.07	8/21/2008	SS-14-04	24652.40	5.45
8/14/2008	WC-16-31D	99506.24	8/21/2008	WC-16-31D	95289.90	4.33
8/14/2008	WC-16-32	181668.21	8/21/2008	WC-16-32	173637.96	4.52
8/21/2008	SS-09-31	17478.31	8/22/2008	SS-09-31	16756.62	4.22
8/21/2008	SS-09-32	41627.84	8/22/2008	SS-09-32	40246.39	3.37
8/21/2008	WS-14-04	108054.29	8/22/2008	WS-14-04	110399.63	2.15
8/21/2008	WS-14-06	100260.70	8/22/2008	WS-14-06	101338.29	1.07
8/22/2008	SS-14-26	26968.87	8/27/2008	SS-14-26	25970.17	3.77
8/22/2008	SS-14-27	19833.03	8/27/2008	SS-14-27	19600.12	1.18
8/22/2008	WS-14-08	70184.96	8/27/2008	WS-14-08	70791.45	0.86
8/22/2008	WS-14-10	40432.38	8/27/2008	WS-14-10	40310.60	0.30
8/27/2008	SS-14-28	18273.66	8/28/2008	SS-14-28	17500.60	4.32

Appendix-1b

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % Difference
8/27/2008	SS-14-29	12011.79	8/28/2008	SS-14-29	11656.30	3.00
8/27/2008	WS-15-21	21238.32	8/28/2008	WS-15-21	20804.81	2.06
8/27/2008	WS-15-22	10729.30	8/28/2008	WS-15-22	10586.50	1.34
8/28/2008	SS-15-23	9041.01	8/29/2008	SS-15-23	9315.61	2.99
8/28/2008	SS-15-24	8387.28	8/29/2008	SS-15-24	8835.08	5.20
8/28/2008	SS-15-63	23428.25	8/29/2008	SS-15-63	23992.87	2.38
8/29/2008	SS-15-65B	18584.76	9/2/2008	SS-15-65B	17610.83	5.38
8/29/2008	SS-15-67A	19474.61	9/2/2008	SS-15-67A	19561.47	0.45
8/29/2008	SS-15-95.2	7648.94	9/2/2008	SS-15-95.2	7593.81	0.72
8/29/2008	SS-15-97.2	10089.77	9/2/2008	SS-15-97.2	10030.92	0.58
9/2/2008	SS-15-99.2	10174.66	9/4/2008	SS-15-99.2	10039.65	1.34
9/2/2008	SS-15-101.2	6867.94	9/4/2008	SS-15-101.2	6700.98	2.46
9/2/2008	SS-15-143.2	19935.74	9/4/2008	SS-15-143.2	20379.34	2.20
9/2/2008	SS-15-145.2	26333.69	9/4/2008	SS-15-145.2	26849.89	1.94
9/4/2008	SS-15-145-2	21260.99	9/5/2008	SS-15-145-2	20978.18	1.34
9/4/2008	SS-15-147-2	16163.37	9/5/2008	SS-15-147-2	16670.85	3.09
9/4/2008	SS-16-51	35219.63	9/5/2008	SS-16-51	34299.79	2.65
9/4/2008	SS-16-53	62828.67	9/5/2008	SS-16-53	61737.06	1.75
					Average Absolute% Difference	3.68

Appendix-1b

Daily Sr duplicates

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % Difference
7/28/2008	SS-07-49	57.84	7/29/2008	SS-07-49	55.22	4.62
7/28/2008	SS-07-50	65.44	7/29/2008	SS-07-50	67.34	2.86
7/28/2008	WC-15-21D	243.35	7/29/2008	WC-15-21D	240.02	1.38
7/28/2008	WC-15-25	121.81	7/29/2008	WC-15-25	123.15	1.09
7/29/2008	SS-07-51	58.22	7/30/2008	SS-07-51	57.48	1.29
7/29/2008	SS-07-52	62.74	7/30/2008	SS-07-52	58.40	7.16
7/29/2008	WC-16-01D	366.81	7/30/2008	WC-16-01D	381.33	3.88
7/29/2008	WC-16-02	986.41	7/30/2008	WC-16-02	981.99	0.45
7/30/2008	SS-08-26	96.61	7/31/2008	SS-08-26	90.83	6.17
7/30/2008	SS-08-27	117.34	7/31/2008	SS-08-27	110.87	5.67
7/30/2008	WC-16-03	2031.28	7/31/2008	WC-16-03	2003.74	1.37
7/30/2008	WC-16-04	1894.78	7/31/2008	WC-16-04	1795.13	5.40
7/31/2008	SS-08-28	91.23	8/4/2008	SS-08-28	91.37	0.16
7/31/2008	SS-08-29	147.99	8/4/2008	SS-08-29	151.46	2.31
7/31/2008	WC-16-28	805.09	8/4/2008	WC-16-28	805.03	0.01
7/31/2008	WC-16-29	950.47	8/4/2008	WC-16-29	938.36	1.28
8/4/2008	SS-07-14	93.33	8/5/2008	SS-07-14	92.03	1.41
8/4/2008	SS-07-15	69.23	8/5/2008	SS-07-15	74.07	6.75
8/4/2008	WC-07-05	164.54	8/5/2008	WC-07-05	161.32	1.97
8/4/2008	WC-07-10	154.98	8/5/2008	WC-07-10	156.68	1.09
8/5/2008	SS-07-16	73.84	8/14/2008	SS-07-16	71.29	3.52
8/5/2008	WC-15-10D	200.15	8/14/2008	WC-15-10D	202.44	1.14
8/14/2008	SS-07-35	65.10	8/14/2008	SS-07-35	65.28	0.27
8/14/2008	WC-15-15	176.85	8/14/2008	WC-15-15	190.39	7.38
8/14/2008	SS-14-03	210.00	8/21/2008	SS-14-03	195.74	7.03
8/14/2008	SS-14-04	156.36	8/21/2008	SS-14-04	148.33	5.27
8/14/2008	WC-16-31D	539.61	8/21/2008	WC-16-31D	516.58	4.36
8/14/2008	WC-16-32	944.36	8/21/2008	WC-16-32	906.86	4.05
8/21/2008	SS-09-31	126.27	8/22/2008	SS-09-31	123.25	2.42
8/21/2008	SS-09-32	213.72	8/22/2008	SS-09-32	212.66	0.50
8/21/2008	WS-14-04	554.27	8/22/2008	WS-14-04	570.57	2.90
8/21/2008	WS-14-06	506.52	8/22/2008	WS-14-06	512.99	1.27
8/22/2008	SS-14-26	155.79	8/27/2008	SS-14-26	150.77	3.28
8/22/2008	SS-14-27	78.12	8/27/2008	SS-14-27	78.34	0.28
8/22/2008	WS-14-08	394.23	8/27/2008	WS-14-08	400.31	1.53
8/22/2008	WS-14-10	225.44	8/27/2008	WS-14-10	227.57	0.94
8/27/2008	SS-14-28	80.33	8/28/2008	SS-14-28	76.80	4.49

Appendix-1b

Days of Run	Sample Id	Conc (ppm)	Days of Run	Sample Id	Conc (ppm)	Absolute % Difference
8/27/2008	SS-14-29	65.73	8/28/2008	SS-14-29	63.86	2.87
8/27/2008	WS-15-21	131.69	8/28/2008	WS-15-21	128.64	2.34
8/27/2008	WS-15-22	89.43	8/28/2008	WS-15-22	87.36	2.33
8/28/2008	SS-15-23	72.01	8/29/2008	SS-15-23	73.74	2.37
8/28/2008	SS-15-24	69.83	8/29/2008	SS-15-24	70.78	1.36
8/28/2008	SS-15-63	151.58	8/29/2008	SS-15-63	153.58	1.31
8/29/2008	SS-15-65B	134.51	9/2/2008	SS-15-65B	131.64	2.15
8/29/2008	SS-15-67A	113.68	9/2/2008	SS-15-67A	114.90	1.07
8/29/2008	SS-15-95.2	72.12	9/2/2008	SS-15-95.2	69.39	3.86
8/29/2008	SS-15-97.2	85.44	9/2/2008	SS-15-97.2	84.97	0.54
9/2/2008	SS-15-99.2	75.21	9/4/2008	SS-15-99.2	74.35	1.15
9/2/2008	SS-15-101.2	62.53	9/4/2008	SS-15-101.2	62.37	0.26
9/2/2008	SS-15-143.2	116.21	9/4/2008	SS-15-143.2	117.28	0.91
9/2/2008	SS-15-145.2	158.11	9/4/2008	SS-15-145.2	158.58	0.30
9/4/2008	SS-15-145-2	126.52	9/5/2008	SS-15-145-2	125.66	0.68
9/4/2008	SS-15-147-2	96.70	9/5/2008	SS-15-147-2	97.84	1.18
9/4/2008	SS-16-51	206.74	9/5/2008	SS-16-51	207.97	0.59
9/4/2008	SS-16-53	333.64	9/5/2008	SS-16-53	336.76	0.93
					Average Absolute% Difference	2.42

Appendix-1c

Duplicates using different aliquots of bulk sediment samples

Sample Id	Li (ppm)	Mg (ppm)	Ca (ppm)	Sr (ppm)	Sample Id	Li (ppm)	Mg (ppm)	Ca (ppm)	Sr (ppm)	Li	Mg	Ca	Sr
										Absolute % difference			
SS-15-65A	**122.14**	**13271.38**	**18247.19**	**126.99**	**SS-15-65B**	**128.38**	**13589.51**	**18584.76**	**134.51**	**4.98**	**2.37**	**1.83**	**5.75**
SS-15-67A	**107.89**	**11428.16**	**19474.62**	**113.68**	**SS-15-67B**	**126.26**	**13728.52**	**21058.39**	**124.15**	**15.69**	**18.29**	**7.81**	**8.80**
SS-15-71A	**159**	**17027.97**	**21204.27**	**128.3**	**SS-15-71B**	**152.05**	**16209.37**	**18024**	**108.23**	**4.47**	**4.93**	**16.21**	**16.96**
SS-15-73A	**161.52**	**17558.09**	**30600.13**	**163.19**	**SS-15-73B**	**164.41**	**17793.02**	**25889.92**	**157.27**	**1.77**	**1.33**	**16.68**	**3.69**
SS-15-75A	**140.82**	**15563.87**	**31499.43**	**166.47**	**SS-15-75B**	**152.35**	**16881.44**	**32620.44**	**171.05**	**7.87**	**8.12**	**3.50**	**2.71**
SS-15-77.2A	**162.05**	**19007.83**	**26925.53**	**156.42**	**SS-15-77.2B**	**161.75**	**18936.63**	**27821.58**	**165.03**	**0.19**	**0.38**	**3.27**	**5.35**
SS-15-79.2A	**139.89**	**17415.2**	**29296.73**	**175.77**	**SS-15-79.2B**	**147.04**	**18398.46**	**32078.13**	**190.41**	**4.98**	**5.49**	**9.06**	**8.00**
SS-15-81.2A	**128.75**	**15281.23**	**22671.53**	**133.64**	**SS-15-81.2B**	**135.99**	**16095.85**	**23048.84**	**138.76**	**5.47**	**5.19**	**1.65**	**3.76**
SS-15-83.2A	**95.11**	**10488.5**	**11755.44**	**72.74**	**SS-15-83.2B**	**96.54**	**11099.24**	**12394.83**	**84.94**	**1.50**	**5.66**	**5.30**	**15.48**
SS-15-85.2A	**93.64**	**10556.36**	**7766.22**	**64.3**	**SS-15-85.2B**	**99.83**	**11298.45**	**8168.06**	**65.65**	**6.40**	**6.79**	**5.04**	**2.06**
SS-15-87.2A	**89.49**	**10317.3**	**11250.57**	**75.2**	**SS-15-87.2B**	**94.9**	**11059.35**	**9767.76**	**69.22**	**5.87**	**6.94**	**14.11**	**8.29**
SS-15-89.2A	**88.96**	**9774.61**	**8211.33**	**62.09**	**SS-15-89.2B**	**102.15**	**11478.62**	**9681.55**	**69.24**	**13.80**	**16.04**	**16.43**	**10.90**
SS-15-91.2A	**88.04**	**10565.64**	**10440.67**	**63.63**	**SS-15-91.2B**	**93.71**	**11223.74**	**8628.94**	**71.05**	**6.25**	**6.04**	**19.00**	**11.02**
									Average	**6.10**	**6.74**	**9.22**	**7.91**

Appendix-1c

Duplicates using different aliquots of bulk sediment samples

Sample Id	Li (ppm)	Mg (ppm)	Ca (ppm)	Sr (ppm)	Sample Id	Li (ppm)	Mg (ppm)	Ca (ppm)	Sr (ppm)	Li	Mg	Ca	Sr
										Absolute % difference			
SS-15-125-2	73.93	8522.74	9510.19	64.12	SS-15-125.2	86.5	9649.85	10023.41	69.64	15.67	12.40	5.25	8.25
SS-15-127-2	86.01	9209.18	14374.69	81.43	SS-15-127.2	80.99	8828.99	13747.08	78.38	6.02	4.22	4.46	3.81
SS-15-129-2	108.3	12603.58	18070.39	113.26	SS-15-129.2	111.37	13063.01	18853.61	118.38	2.80	3.58	4.24	4.42
SS-15-131-2	91.24	10346.64	12482.6	87.05	SS-15-131.2	105.23	11841.42	14399.28	100.84	14.25	13.47	14.26	14.68
SS-15-133-2	75.03	8813.21	12414.79	78.45	SS-15-133.2	91.53	10594.77	15211.18	95.82	19.81	18.36	20.24	19.92
SS-15-135-2	87.92	10408.33	22855.91	121.53	SS-15-135.2	90.39	10728.28	23828.59	126.99	2.77	3.03	4.17	4.40
SS-15-139-2	74.13	9357.23	17434.45	110.16	SS-15-139.2	81.36	10098.88	18778.54	119.5	9.30	7.62	7.42	8.14
SS-15-141-2	69.8	8360.91	14918.93	83.67	SS-15-141.2	72.55	8725.5	15449.42	87.76	3.87	4.27	3.49	4.77
SS-15-143-2	75.1	8898.3	19195.12	110.5	SS-15-143.2	81.48	9179.25	19935.74	116.16	8.14	3.11	3.79	4.99
SS-15-145-2	86.94	10893.23	21260.99	126.52	SS-15-145.2	108.07	13537.61	26333.68	158.03	21.68	21.65	21.32	22.15
SS-15-147-2	72.05	9088.48	16163.37	96.7	SS-15-147.2	89.71	11528.52	20684.68	123.88	21.83	23.67	24.54	24.65
SS-15-149-2	90.01	11745	29725.29	156.25	SS-15-149.2	91.64	12015.67	30046.36	157.39	1.80	2.28	1.07	0.73
WC-08-01	46.3	5850.69	14317.48	83.95	WC-08-01D	44.36	5416.5	11777.06	70.56	4.28	7.71	19.47	17.34
WC-08-11	116.37	17736.16	70764.18	350.91	WC-08-11D	151.64	22913.33	72454.99	363.42	26.31	25.47	2.36	3.50
WC-21	111.82	15952.67	78843.91	389.2	WC-21E	113.68	15864.19	83288.71	407.15	1.65	0.56	5.48	4.51
WC-08-31	90.8	17204.3	69905.4	382.49	WC-08-31D	92.28	17742.16	70106.07	381.94	1.62	3.08	0.29	0.14
WC-08-41	39.17	7324.58	11255.29	62.31	WC-08-41D	37.31	5928.63	9711.76	55.72	4.85	21.07	14.72	11.16
WC-15-10	75.76	11933.61	41808.98	207.45	WC-15-10D	73.93	11513.03	40473.54	200.15	2.45	3.59	3.25	3.58
WC-15-20	96.4	17704.28	67160.22	310.5	WC-15-20D	95.14	17140.15	59023.76	274.8	1.32	3.24	12.90	12.20
WC-15-30	72.21	11517.29	41030.38	198.46	WC-15-30D	78.1	11693.09	50610.44	232.07	7.84	1.51	20.91	15.61
WC-15-40	138.08	21322.93	101506.88	468.69	WC-15-40D	128.9	20619.89	90538.06	419.53	6.88	3.35	11.42	11.07
WC-15-60D	62	8918.04	17326.66	92.19	WC-15-60E	63.48	10032.47	19708.76	104.57	2.36	11.76	12.86	12.58
WC-15-70A	100	11762.04	18711.58	107.81	WC-15-70D	95.1	11334.16	20538.18	116.68	5.02	3.71	9.31	7.90
									Average	8.37	8.81	9.88	9.59

Appendix 2a- Results of simulation of evaporation of average creek waters using Geochemist workbench

Cl-	**Ca++**	**Mg++**	**Na+**	**K+**	**HCO3-**	**CO3--**	**SO4--**	**SiO2**	**Li+**	**Sr++**	**B**	**pH**
0.000201	0.000245	7.39E-05	0.0001087	2.33E-05	0.0003978	2.02E-07	8.69E-05	0.0001448	1.71E-07	3.77E-07	1.82E-06	7
0.000221	0.000269	8.12E-05	0.0001196	2.57E-05	0.0004373	2.45E-07	9.52E-05	0.0001592	1.89E-07	4.14E-07	2.00E-06	7.04
0.000241	0.000293	8.85E-05	0.0001304	2.80E-05	0.0004767	2.92E-07	1.04E-04	0.0001737	2.06E-07	4.51E-07	2.18E-06	7.08
0.000261	0.000317	9.57E-05	0.0001413	3.03E-05	0.0005161	3.44E-07	1.12E-04	0.0001881	2.23E-07	4.87E-07	2.36E-06	7.11
0.000281	0.000341	1.03E-04	0.0001522	3.26E-05	0.0005554	3.99E-07	1.20E-04	0.0002025	2.40E-07	5.24E-07	2.55E-06	7.14
0.000301	0.000365	1.10E-04	0.000163	3.50E-05	0.0005947	4.59E-07	1.28E-04	0.000217	2.57E-07	5.61E-07	2.73E-06	7.17
0.000321	0.000388	1.17E-04	0.0001739	3.73E-05	0.0006339	5.23E-07	1.36E-04	0.0002314	2.74E-07	5.97E-07	2.91E-06	7.20
0.000341	0.000412	1.25E-04	0.0001847	3.96E-05	0.0006731	5.92E-07	1.44E-04	0.0002458	2.91E-07	6.34E-07	3.09E-06	7.22
0.000361	0.000436	1.32E-04	0.0001956	4.20E-05	0.0007123	6.64E-07	1.52E-04	0.0002602	3.08E-07	6.70E-07	3.27E-06	7.25
0.000381	0.000459	1.39E-04	0.0002064	4.43E-05	0.0007514	7.41E-07	1.60E-04	0.0002747	3.26E-07	7.07E-07	3.45E-06	7.27
0.000401	0.000483	0.000146	0.0002173	4.66E-05	0.0007904	8.22E-07	0.0001679	0.0002891	3.43E-07	7.43E-07	3.64E-06	7.29
0.000601	0.000714	0.000217	0.0003257	6.99E-05	0.001178	1.87E-06	0.000245	0.0004329	5.14E-07	1.10E-06	5.45E-06	7.46
0.0008	0.00094	0.000287	0.0004339	9.32E-05	0.001561	3.33E-06	0.000319	0.0005762	6.85E-07	1.45E-06	7.26E-06	7.58
0.001	0.001124	0.000259	0.0005422	0.0001164	0.00166	3.80E-06	0.0003939	0.0005845	8.56E-07	1.80E-06	9.08E-06	7.60
0.001199	0.001213	0.000255	0.0006506	0.0001397	0.001612	3.61E-06	0.0004701	0.0006257	1.03E-06	1.95E-06	1.09E-05	7.59
0.001399	0.001303	0.000251	0.0007588	0.0001629	0.001568	3.43E-06	0.0005454	0.000667	1.20E-06	2.10E-06	1.27E-05	7.58
0.001598	0.001394	0.000248	0.0008671	0.0001861	0.001528	3.28E-06	0.0006199	0.0007086	1.37E-06	2.25E-06	1.45E-05	7.56
0.001797	0.001486	0.000245	0.0009753	0.0002093	0.001491	3.14E-06	0.0006937	0.0007503	1.54E-06	2.40E-06	1.63E-05	7.55
0.001996	0.001578	0.000241	0.001083	0.0002324	0.001457	3.01E-06	0.0007668	0.0007921	1.71E-06	2.54E-06	1.82E-05	7.54
0.003982	0.002513	0.000215	0.002163	0.0004635	0.001226	2.23E-06	0.001465	0.001214	3.41E-06	4.07E-06	3.63E-05	7.46
0.00596	0.003444	0.000196	0.00324	0.0006937	0.001097	1.84E-06	0.00212	0.001642	5.10E-06	5.60E-06	5.44E-05	7.40
0.007929	0.00436	0.00018	0.004314	0.000923	0.001012	1.61E-06	0.002745	0.002072	6.79E-06	7.12E-06	7.25E-05	7.36
0.009891	0.00526	0.000168	0.005386	0.001152	0.0009504	1.46E-06	0.003348	0.002505	8.48E-06	8.62E-06	9.06E-05	7.33
0.01185	0.006144	0.000157	0.006456	0.00138	0.0009036	1.35E-06	0.003934	0.00294	1.02E-05	1.01E-05	1.09E-04	7.30
0.0138	0.007015	0.000148	0.007523	0.001607	0.0008663	1.26E-06	0.004507	0.003377	1.18E-05	1.16E-05	1.27E-04	7.28
0.01709	0.008465	0.000136	0.009331	0.001992	0.0008172	1.15E-06	0.005455	0.004121	1.47E-05	1.40E-05	1.58E-04	7.25
0.01768	0.008723	0.000134	0.009656	0.002061	0.0008097	1.14E-06	0.005622	0.004256	1.52E-05	1.45E-05	1.63E-04	7.25
0.01962	0.009559	0.000128	0.01072	0.002287	0.0007875	1.09E-06	0.006166	0.004696	1.69E-05	1.59E-05	1.81E-04	7.23
0.1896	0.03857	2.15E-05	0.1067	0.02279	0.0005597	7.62E-07	0.01274	0.0445	0.000168	6.89E-05	1.80E-03	7.03
0.5538	0.07367	1.79E-05	0.3211	0.06872	0.0004755	6.92E-07	0.01238	0.07114	0.000508	0.000139	5.39E-03	6.94

Appendix 2b- Results of simulation of evaporation of average spring water using Geochemist workbench

Cl-	**Ca++**	**Mg++**	**Na+**	**K+**	**HCO3-**	**CO3--**	**SO4--**	**SiO2**	**Li+**	**Sr++**	**B**	**pH**
2.54E-04	2.26E-04	1.57E-04	8.84E-03	4.74E-04	9.25E-03	5.75E-06	2.99E-04	1.06E-03	1.95E-06	7.04E-07	4.36E-05	7
2.80E-04	2.47E-04	1.72E-04	9.72E-03	5.21E-04	1.02E-02	7.00E-06	3.27E-04	1.17E-03	2.15E-06	7.68E-07	4.79E-05	7.04
3.05E-04	2.67E-04	1.86E-04	1.06E-02	5.69E-04	1.11E-02	8.38E-06	3.56E-04	1.28E-03	2.34E-06	8.31E-07	5.23E-05	7.07
3.30E-04	2.86E-04	2.01E-04	1.15E-02	6.16E-04	1.20E-02	9.89E-06	3.84E-04	1.38E-03	2.54E-06	8.93E-07	5.67E-05	7.11
3.56E-04	3.06E-04	2.15E-04	1.23E-02	6.63E-04	1.29E-02	1.15E-05	4.12E-04	1.49E-03	2.74E-06	8.50E-07	6.10E-05	7.14
3.81E-04	3.25E-04	2.29E-04	1.32E-02	7.11E-04	1.38E-02	1.33E-05	4.40E-04	1.59E-03	2.93E-06	7.58E-07	6.54E-05	7.17
4.07E-04	3.44E-04	2.42E-04	1.41E-02	7.58E-04	1.47E-02	1.52E-05	4.68E-04	1.70E-03	3.13E-06	6.81E-07	6.97E-05	7.19
4.32E-04	3.62E-04	2.56E-04	1.49E-02	8.05E-04	1.56E-02	1.72E-05	4.95E-04	1.80E-03	3.32E-06	6.16E-07	7.41E-05	7.22
4.57E-04	3.47E-04	2.70E-04	1.58E-02	8.53E-04	1.64E-02	1.92E-05	5.24E-04	1.91E-03	3.52E-06	5.65E-07	7.84E-05	7.24
4.83E-04	3.20E-04	2.83E-04	1.67E-02	9.00E-04	1.72E-02	2.12E-05	5.53E-04	2.02E-03	3.71E-06	5.21E-07	8.28E-05	7.26
5.08E-04	2.98E-04	2.67E-04	1.75E-02	9.47E-04	1.79E-02	2.32E-05	5.83E-04	2.08E-03	3.91E-06	4.86E-07	8.72E-05	7.27
7.63E-04	1.66E-04	1.05E-04	2.61E-02	1.42E-03	2.54E-02	4.86E-05	8.75E-04	2.66E-03	5.85E-06	2.72E-07	1.31E-04	7.42
1.02E-03	1.07E-04	4.85E-05	3.46E-02	1.89E-03	3.32E-02	8.58E-05	1.16E-03	3.40E-03	7.80E-06	1.77E-07	1.74E-04	7.53
1.27E-03	7.60E-05	2.59E-05	4.29E-02	2.36E-03	4.09E-02	1.35E-04	1.43E-03	4.18E-03	9.74E-06	1.26E-07	2.18E-04	7.61
1.53E-03	5.77E-05	1.54E-05	5.12E-02	2.83E-03	4.86E-02	1.95E-04	1.70E-03	4.98E-03	1.17E-05	9.62E-08	2.61E-04	7.68
1.78E-03	4.57E-05	9.90E-06	5.94E-02	3.30E-03	5.62E-02	2.67E-04	1.96E-03	5.78E-03	1.36E-05	7.66E-08	3.04E-04	7.74
2.03E-03	3.75E-05	6.77E-06	6.75E-02	3.77E-03	6.37E-02	3.51E-04	2.22E-03	6.57E-03	1.56E-05	6.31E-08	3.48E-04	7.79
2.29E-03	3.15E-05	4.85E-06	7.54E-02	4.24E-03	7.11E-02	4.45E-04	2.48E-03	7.36E-03	1.75E-05	5.33E-08	3.91E-04	7.83
2.54E-03	2.70E-05	3.60E-06	8.34E-02	4.71E-03	7.85E-02	5.52E-04	2.73E-03	8.15E-03	1.94E-05	4.59E-08	4.34E-04	7.87
5.08E-03	1.03E-05	5.54E-07	1.59E-01	9.40E-03	1.47E-01	2.19E-03	5.10E-03	1.52E-02	3.88E-05	1.79E-08	8.59E-04	8.12
7.61E-03	6.06E-06	2.24E-07	2.30E-01	1.41E-02	2.07E-01	4.71E-03	7.30E-03	1.94E-02	5.80E-05	1.08E-08	1.27E-03	8.26
1.01E-02	4.26E-06	1.35E-07	2.98E-01	1.87E-02	2.61E-01	7.94E-03	9.38E-03	2.09E-02	7.72E-05	1.08E-08	1.67E-03	8.35
1.27E-02	3.26E-06	9.69E-08	3.63E-01	2.34E-02	3.10E-01	1.18E-02	1.14E-02	2.13E-02	9.64E-05	1.08E-08	2.06E-03	8.42
1.52E-02	2.64E-06	7.59E-08	4.25E-01	2.80E-02	3.55E-01	1.61E-02	1.33E-02	2.12E-02	1.16E-04	1.08E-08	2.43E-03	8.48
1.77E-02	2.21E-06	6.26E-08	4.85E-01	3.26E-02	3.97E-01	2.08E-02	1.51E-02	2.09E-02	1.35E-04	1.08E-08	2.78E-03	8.52
2.02E-02	1.91E-06	5.34E-08	5.43E-01	3.73E-02	4.36E-01	2.59E-02	1.69E-02	2.06E-02	1.54E-04	1.08E-08	3.12E-03	8.56
2.28E-02	1.67E-06	4.67E-08	6.00E-01	4.19E-02	4.73E-01	3.13E-02	1.86E-02	2.02E-02	1.73E-04	1.08E-08	3.45E-03	8.59
2.53E-02	1.49E-06	4.15E-08	6.55E-01	4.65E-02	5.07E-01	3.69E-02	2.03E-02	1.97E-02	1.92E-04	1.08E-08	3.77E-03	8.62
2.46E-01	6.56E-08	1.00E-08	3.66E+00	4.49E-01	1.42E+00	4.58E-01	9.66E-02	1.19E-02	1.84E-03	1.08E-08	1.38E-02	9.11
8.15E-01	1.08E-08	0.00E+00	9.14E+00	1.66E+00	2.12E+00	1.05E+00	2.24E-02	1.32E-02	6.89E-03	1.08E-08	1.98E-02	9.29

Appendix 2c- Results of simulation of evaporation of mix of average creek and average spring water using Geochemist workbench

Cl-	**Ca++**	**Mg++**	**Na+**	**K+**	**HCO3-**	**CO3--**	**SO4--**	**SiO2**	**Li+**	**Sr++**	**B**	**pH**
0.00021	0.0002367	9.07E-05	0.0019	0.00037	0.002216	1.22E-06	0.00025	0.00084	5.35E-07	2.83E-07	1.04E-05	7
0.00023	0.0002591	9.94E-05	0.00209	0.0004	0.002436	1.48E-06	0.00027	0.00093	5.89E-07	3.10E-07	1.14E-05	7.04
0.00025	0.0002813	1.08E-04	0.00228	0.00044	0.002655	1.77E-06	0.0003	0.00101	6.42E-07	3.36E-07	1.24E-05	7.08
0.00028	0.0003034	1.17E-04	0.00247	0.00048	0.002874	2.08E-06	0.00032	0.0011	6.96E-07	3.63E-07	1.35E-05	7.11
0.0003	0.0003253	1.25E-04	0.00266	0.00051	0.003093	2.42E-06	0.00035	0.00118	7.49E-07	3.89E-07	1.45E-05	7.14
0.00032	0.000347	1.34E-04	0.00285	0.00055	0.003311	2.79E-06	0.00037	0.00126	8.03E-07	4.15E-07	1.55E-05	7.17
0.00034	0.0003686	1.42E-04	0.00304	0.00059	0.003529	3.18E-06	0.00039	0.00135	8.56E-07	4.42E-07	1.66E-05	7.2
0.00036	0.00039	1.51E-04	0.00323	0.00062	0.003747	3.60E-06	0.00042	0.00143	9.10E-07	4.67E-07	1.76E-05	7.22
0.00038	0.0004113	1.59E-04	0.00342	0.00066	0.003965	4.05E-06	0.00044	0.00151	9.63E-07	4.93E-07	1.87E-05	7.24
0.0004	0.0004324	1.68E-04	0.00361	0.00069	0.004182	4.52E-06	0.00046	0.0016	1.02E-06	5.19E-07	1.97E-05	7.27
0.00042	0.0004533	1.76E-04	0.00379	0.00073	0.004399	5.02E-06	0.00049	0.00168	1.07E-06	5.44E-07	2.07E-05	7.29
0.00063	0.0005372	1.07E-04	0.00568	0.0011	0.005976	9.51E-06	0.00073	0.0023	1.60E-06	7.93E-07	3.11E-05	7.42
0.00085	0.0003999	5.73E-05	0.00756	0.00146	0.007091	1.36E-05	0.00098	0.00294	2.14E-06	6.47E-07	4.14E-05	7.49
0.00106	0.0003034	3.29E-05	0.00943	0.00182	0.008329	1.91E-05	0.00123	0.00361	2.67E-06	4.92E-07	5.18E-05	7.55
0.00127	0.0002364	2.02E-05	0.01129	0.00218	0.009642	2.60E-05	0.00148	0.0043	3.20E-06	3.84E-07	6.22E-05	7.61
0.00148	0.0001892	1.32E-05	0.01315	0.00255	0.011	3.43E-05	0.00172	0.005	3.73E-06	3.08E-07	7.25E-05	7.67
0.00169	0.000155	9.06E-06	0.015	0.00291	0.01238	4.41E-05	0.00197	0.00569	4.26E-06	2.53E-07	8.28E-05	7.72
0.00191	0.0001297	6.48E-06	0.01684	0.00327	0.01377	5.53E-05	0.00221	0.00639	4.79E-06	2.12E-07	9.32E-05	7.76
0.00212	0.0001104	4.79E-06	0.01868	0.00363	0.01517	6.79E-05	0.00245	0.00709	5.32E-06	1.81E-07	1.04E-04	7.8
0.00423	3.87E-05	6.69E-07	0.03672	0.00722	0.02888	2.70E-04	0.00474	0.01378	1.06E-05	6.43E-08	2.07E-04	8.06
0.00635	2.20E-05	2.38E-07	0.05428	0.01078	0.04144	5.93E-04	0.00691	0.01922	1.58E-05	3.70E-08	3.09E-04	8.2
0.00846	1.54E-05	1.31E-07	0.0715	0.01433	0.05255	1.00E-03	0.00901	0.02258	2.10E-05	2.62E-08	4.10E-04	8.3
0.01057	1.20E-05	9.01E-08	0.08848	0.01786	0.06255	1.48E-03	0.01105	0.02432	2.62E-05	2.05E-08	5.11E-04	8.37
0.01269	9.83E-06	6.93E-08	0.1053	0.02139	0.07181	2.02E-03	0.01304	0.02515	3.14E-05	1.70E-08	6.11E-04	8.42
0.0148	8.35E-06	5.68E-08	0.1218	0.0249	0.08056	2.62E-03	0.01498	0.02549	3.66E-05	1.46E-08	7.10E-04	8.47
0.01691	7.26E-06	4.83E-08	0.1382	0.02841	0.08891	3.28E-03	0.01688	0.02557	4.17E-05	1.27E-08	8.07E-04	8.5
0.01903	6.42E-06	4.21E-08	0.1545	0.03191	0.09694	4.00E-03	0.01875	0.02549	4.68E-05	1.13E-08	9.04E-04	8.54
0.02114	5.76E-06	3.75E-08	0.1706	0.03539	0.1047	4.77E-03	0.02058	0.02533	5.20E-05	1.02E-08	1.00E-03	8.57
0.21	6.56E-07	1.00E-08	1.341	0.3364	0.3916	1.23E-01	0.1307	0.01397	0.00049	1.02E-08	6.11E-03	9.13
0.662	3.29E-07	1.00E-08	3.101	1.055	0.5193	2.50E-01	0.1852	0.01296	0.001534	1.02E-08	1.10E-02	9.28

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
1.02	1.21	5.15	1.52	1.61	7.91	2.02	1.70	8.69
1.04	1.25	5.46	1.54	1.61	7.96	2.04	1.70	8.71
1.06	1.29	5.72	1.56	1.62	8.00	2.06	1.70	8.73
1.08	1.32	5.94	1.58	1.62	8.04	2.08	1.70	8.76
1.10	1.35	6.13	1.60	1.63	8.08	2.10	1.71	8.78
1.12	1.37	6.30	1.62	1.63	8.12	2.12	1.71	8.80
1.14	1.40	6.45	1.64	1.64	8.16	2.14	1.71	8.82
1.16	1.42	6.59	1.66	1.64	8.19	2.16	1.71	8.84
1.18	1.43	6.71	1.68	1.65	8.23	2.18	1.71	8.85
1.20	1.45	6.82	1.70	1.65	8.26	2.20	1.71	8.87
1.22	1.47	6.93	1.72	1.65	8.29	2.22	1.72	8.89
1.24	1.48	7.02	1.74	1.66	8.32	2.24	1.72	8.91
1.26	1.49	7.11	1.76	1.66	8.36	2.26	1.72	8.93
1.28	1.51	7.20	1.78	1.66	8.39	2.28	1.72	8.94
1.30	1.52	7.27	1.80	1.67	8.41	2.30	1.72	8.96
1.32	1.53	7.35	1.82	1.67	8.44	2.32	1.72	8.98
1.34	1.54	7.42	1.84	1.67	8.47	2.34	1.72	8.99
1.36	1.55	7.48	1.86	1.68	8.50	2.36	1.73	9.01
1.38	1.56	7.55	1.88	1.68	8.52	2.38	1.73	9.03
1.40	1.57	7.61	1.90	1.68	8.55	2.40	1.73	9.04
1.42	1.57	7.66	1.92	1.69	8.57	2.42	1.73	9.06
1.44	1.58	7.72	1.94	1.69	8.60	2.44	1.73	9.07
1.46	1.59	7.77	1.96	1.69	8.62	2.46	1.73	9.09
1.48	1.59	7.82	1.98	1.69	8.65	2.48	1.73	9.10
1.50	1.60	7.87	2.00	1.69	8.67	2.50	1.73	9.12

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
2.52	1.74	9.13	3.02	1.76	9.43	3.52	1.77	9.65
2.54	1.74	9.14	3.04	1.76	9.44	3.54	1.77	9.66
2.56	1.74	9.16	3.06	1.76	9.45	3.56	1.77	9.67
2.58	1.74	9.17	3.08	1.76	9.46	3.58	1.77	9.67
2.60	1.74	9.19	3.10	1.76	9.47	3.60	1.77	9.68
2.62	1.74	9.20	3.12	1.76	9.48	3.62	1.77	9.69
2.64	1.74	9.21	3.14	1.76	9.49	3.64	1.77	9.70
2.66	1.74	9.22	3.16	1.76	9.50	3.66	1.77	9.70
2.68	1.74	9.24	3.18	1.76	9.51	3.68	1.77	9.71
2.70	1.74	9.25	3.20	1.76	9.52	3.70	1.77	9.72
2.72	1.75	9.26	3.22	1.76	9.52	3.72	1.77	9.72
2.74	1.75	9.27	3.24	1.76	9.53	3.74	1.77	9.73
2.76	1.75	9.29	3.26	1.76	9.54	3.76	1.77	9.74
2.78	1.75	9.30	3.28	1.76	9.55	3.78	1.77	9.74
2.80	1.75	9.31	3.30	1.76	9.56	3.80	1.77	9.75
2.82	1.75	9.32	3.32	1.76	9.57	3.82	1.77	9.76
2.84	1.75	9.33	3.34	1.77	9.58	3.84	1.77	9.76
2.86	1.75	9.34	3.36	1.77	9.59	3.86	1.77	9.77
2.88	1.75	9.36	3.38	1.77	9.59	3.88	1.77	9.78
2.90	1.75	9.37	3.40	1.77	9.60	3.90	1.77	9.78
2.92	1.75	9.38	3.42	1.77	9.61	3.92	1.78	9.79
2.94	1.75	9.39	3.44	1.77	9.62	3.94	1.78	9.80
2.96	1.75	9.40	3.46	1.77	9.63	3.96	1.78	9.80
2.98	1.76	9.41	3.48	1.77	9.63	3.98	1.78	9.81
3.00	1.76	9.42	3.50	1.77	9.64	4.00	1.78	9.82

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
4.02	1.78	9.82	4.52	1.78	9.96	5.02	1.78	10.07
4.04	1.78	9.83	4.54	1.78	9.96	5.04	1.78	10.08
4.06	1.78	9.83	4.56	1.78	9.97	5.06	1.78	10.08
4.08	1.78	9.84	4.58	1.78	9.97	5.08	1.78	10.08
4.10	1.78	9.85	4.60	1.78	9.98	5.10	1.78	10.09
4.12	1.78	9.85	4.62	1.78	9.98	5.12	1.78	10.09
4.14	1.78	9.86	4.64	1.78	9.99	5.14	1.78	10.10
4.16	1.78	9.86	4.66	1.78	9.99	5.16	1.78	10.10
4.18	1.78	9.87	4.68	1.78	10.00	5.18	1.78	10.10
4.20	1.78	9.88	4.70	1.78	10.00	5.20	1.78	10.11
4.22	1.78	9.88	4.72	1.78	10.01	5.22	1.78	10.11
4.24	1.78	9.89	4.74	1.78	10.01	5.24	1.78	10.12
4.26	1.78	9.89	4.76	1.78	10.02	5.26	1.78	10.12
4.28	1.78	9.90	4.78	1.78	10.02	5.28	1.78	10.12
4.30	1.78	9.90	4.80	1.78	10.03	5.30	1.78	10.13
4.32	1.78	9.91	4.82	1.78	10.03	5.32	1.78	10.13
4.34	1.78	9.91	4.84	1.78	10.03	5.34	1.78	10.13
4.36	1.78	9.92	4.86	1.78	10.04	5.36	1.78	10.14
4.38	1.78	9.92	4.88	1.78	10.04	5.38	1.78	10.14
4.40	1.78	9.93	4.90	1.78	10.05	5.40	1.78	10.14
4.42	1.78	9.93	4.92	1.78	10.05	5.42	1.78	10.15
4.44	1.78	9.94	4.94	1.78	10.06	5.44	1.78	10.15
4.46	1.78	9.94	4.96	1.78	10.06	5.46	1.78	10.15
4.48	1.78	9.95	4.98	1.78	10.06	5.48	1.78	10.16
4.50	1.78	9.95	5.00	1.78	10.07	5.50	1.78	10.16

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
5.52	1.78	10.16	6.02	1.79	10.24	6.52	1.78	10.31
5.54	1.78	10.17	6.04	1.79	10.24	6.54	1.78	10.31
5.56	1.78	10.17	6.06	1.79	10.25	6.56	1.78	10.31
5.58	1.78	10.17	6.08	1.78	10.25	6.58	1.78	10.31
5.60	1.78	10.18	6.10	1.78	10.25	6.60	1.78	10.31
5.62	1.78	10.18	6.12	1.78	10.26	6.62	1.78	10.32
5.64	1.78	10.18	6.14	1.78	10.26	6.64	1.78	10.32
5.66	1.78	10.19	6.16	1.78	10.26	6.66	1.78	10.32
5.68	1.78	10.19	6.18	1.78	10.26	6.68	1.78	10.32
5.70	1.78	10.19	6.20	1.78	10.27	6.70	1.78	10.33
5.72	1.78	10.20	6.22	1.78	10.27	6.72	1.78	10.33
5.74	1.79	10.20	6.24	1.78	10.27	6.74	1.78	10.33
5.76	1.79	10.20	6.26	1.78	10.27	6.76	1.78	10.33
5.78	1.79	10.21	6.28	1.78	10.28	6.78	1.78	10.33
5.80	1.79	10.21	6.30	1.78	10.28	6.80	1.78	10.34
5.82	1.79	10.21	6.32	1.78	10.28	6.82	1.78	10.34
5.84	1.79	10.22	6.34	1.78	10.28	6.84	1.78	10.34
5.86	1.79	10.22	6.36	1.78	10.29	6.86	1.78	10.34
5.88	1.79	10.22	6.38	1.78	10.29	6.88	1.78	10.34
5.90	1.79	10.22	6.40	1.78	10.29	6.90	1.78	10.35
5.92	1.79	10.23	6.42	1.78	10.29	6.92	1.78	10.35
5.94	1.79	10.23	6.44	1.78	10.30	6.94	1.78	10.35
5.96	1.79	10.23	6.46	1.78	10.30	6.96	1.78	10.35
5.98	1.79	10.24	6.48	1.78	10.30	6.98	1.78	10.35
6.00	1.79	10.24	6.50	1.78	10.30	7.00	1.78	10.36

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
7.02	1.78	10.36	7.52	1.78	10.40	8.02	1.78	10.44
7.04	1.78	10.36	7.54	1.78	10.40	8.04	1.78	10.44
7.06	1.78	10.36	7.56	1.78	10.41	8.06	1.78	10.44
7.08	1.78	10.36	7.58	1.78	10.41	8.08	1.78	10.44
7.10	1.78	10.37	7.60	1.78	10.41	8.10	1.78	10.44
7.12	1.78	10.37	7.62	1.78	10.41	8.12	1.78	10.44
7.14	1.78	10.37	7.64	1.78	10.41	8.14	1.78	10.44
7.16	1.78	10.37	7.66	1.78	10.41	8.16	1.78	10.45
7.18	1.78	10.37	7.68	1.78	10.41	8.18	1.78	10.45
7.20	1.78	10.38	7.70	1.78	10.42	8.20	1.78	10.45
7.22	1.78	10.38	7.72	1.78	10.42	8.22	1.78	10.45
7.24	1.78	10.38	7.74	1.78	10.42	8.24	1.78	10.45
7.26	1.78	10.38	7.76	1.78	10.42	8.26	1.78	10.45
7.28	1.78	10.38	7.78	1.78	10.42	8.28	1.78	10.45
7.30	1.78	10.38	7.80	1.78	10.42	8.30	1.78	10.45
7.32	1.78	10.39	7.82	1.78	10.42	8.32	1.78	10.45
7.34	1.78	10.39	7.84	1.78	10.43	8.34	1.78	10.46
7.36	1.78	10.39	7.86	1.78	10.43	8.36	1.78	10.46
7.38	1.78	10.39	7.88	1.78	10.43	8.38	1.78	10.46
7.40	1.78	10.39	7.90	1.78	10.43	8.40	1.78	10.46
7.42	1.78	10.39	7.92	1.78	10.43	8.42	1.78	10.46
7.44	1.78	10.40	7.94	1.78	10.43	8.44	1.78	10.46
7.46	1.78	10.40	7.96	1.78	10.43	8.46	1.78	10.46
7.48	1.78	10.40	7.98	1.78	10.43	8.48	1.78	10.46
7.50	1.78	10.40	8.00	1.78	10.44	8.50	1.78	10.46

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
8.52	1.78	10.47	9.02	1.77	10.49	9.52	1.77	10.50
8.54	1.78	10.47	9.04	1.77	10.49	9.54	1.77	10.50
8.56	1.78	10.47	9.06	1.77	10.49	9.56	1.77	10.50
8.58	1.78	10.47	9.08	1.77	10.49	9.58	1.77	10.50
8.60	1.78	10.47	9.10	1.77	10.49	9.60	1.77	10.50
8.62	1.78	10.47	9.12	1.77	10.49	9.62	1.77	10.51
8.64	1.78	10.47	9.14	1.77	10.49	9.64	1.77	10.51
8.66	1.78	10.47	9.16	1.77	10.49	9.66	1.77	10.51
8.68	1.78	10.47	9.18	1.77	10.49	9.68	1.77	10.51
8.70	1.78	10.47	9.20	1.77	10.49	9.70	1.77	10.51
8.72	1.78	10.47	9.22	1.77	10.49	9.72	1.77	10.51
8.74	1.78	10.48	9.24	1.77	10.49	9.74	1.77	10.51
8.76	1.78	10.48	9.26	1.77	10.50	9.76	1.77	10.51
8.78	1.78	10.48	9.28	1.77	10.50	9.78	1.77	10.51
8.80	1.78	10.48	9.30	1.77	10.50	9.80	1.77	10.51
8.82	1.78	10.48	9.32	1.77	10.50	9.82	1.77	10.51
8.84	1.78	10.48	9.34	1.77	10.50	9.84	1.77	10.51
8.86	1.78	10.48	9.36	1.77	10.50	9.86	1.77	10.51
8.88	1.78	10.48	9.38	1.77	10.50	9.88	1.77	10.51
8.90	1.78	10.48	9.40	1.77	10.50	9.90	1.77	10.51
8.92	1.78	10.48	9.42	1.77	10.50	9.92	1.77	10.51
8.94	1.78	10.48	9.44	1.77	10.50	9.94	1.77	10.51
8.96	1.77	10.48	9.46	1.77	10.50	9.96	1.77	10.51
8.98	1.77	10.49	9.48	1.77	10.50	9.98	1.77	10.51
9.00	1.77	10.49	9.50	1.77	10.50	10.00	1.77	10.51

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
10.02	1.77	10.51	10.52	1.76	10.52	11.02	1.76	10.52
10.04	1.77	10.51	10.54	1.76	10.52	11.04	1.76	10.52
10.06	1.77	10.51	10.56	1.76	10.52	11.06	1.76	10.52
10.08	1.77	10.51	10.58	1.76	10.52	11.08	1.76	10.52
10.10	1.77	10.51	10.60	1.76	10.52	11.10	1.76	10.52
10.12	1.77	10.51	10.62	1.76	10.52	11.12	1.76	10.52
10.14	1.77	10.51	10.64	1.76	10.52	11.14	1.76	10.52
10.16	1.77	10.52	10.66	1.76	10.52	11.16	1.76	10.52
10.18	1.77	10.52	10.68	1.76	10.52	11.18	1.76	10.52
10.20	1.77	10.52	10.70	1.76	10.52	11.20	1.76	10.52
10.22	1.77	10.52	10.72	1.76	10.52	11.22	1.76	10.52
10.24	1.77	10.52	10.74	1.76	10.52	11.24	1.76	10.52
10.26	1.77	10.52	10.76	1.76	10.52	11.26	1.76	10.52
10.28	1.77	10.52	10.78	1.76	10.52	11.28	1.76	10.52
10.30	1.77	10.52	10.80	1.76	10.52	11.30	1.76	10.52
10.32	1.77	10.52	10.82	1.76	10.52	11.32	1.76	10.52
10.34	1.77	10.52	10.84	1.76	10.52	11.34	1.76	10.52
10.36	1.77	10.52	10.86	1.76	10.52	11.36	1.76	10.52
10.38	1.77	10.52	10.88	1.76	10.52	11.38	1.76	10.52
10.40	1.77	10.52	10.90	1.76	10.52	11.40	1.76	10.52
10.42	1.77	10.52	10.92	1.76	10.52	11.42	1.76	10.52
10.44	1.77	10.52	10.94	1.76	10.52	11.44	1.76	10.52
10.46	1.77	10.52	10.96	1.76	10.52	11.46	1.76	10.52
10.48	1.77	10.52	10.98	1.76	10.52	11.48	1.76	10.52
10.50	1.77	10.52	11.00	1.76	10.52	11.50	1.76	10.52

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
11.52	1.76	10.52	12.02	1.75	10.51	12.52	1.75	10.50
11.54	1.76	10.52	12.04	1.75	10.51	12.54	1.75	10.50
11.56	1.76	10.52	12.06	1.75	10.51	12.56	1.75	10.50
11.58	1.76	10.52	12.08	1.75	10.51	12.58	1.75	10.50
11.60	1.76	10.52	12.10	1.75	10.51	12.60	1.75	10.50
11.62	1.76	10.52	12.12	1.75	10.51	12.62	1.75	10.50
11.64	1.76	10.52	12.14	1.75	10.51	12.64	1.75	10.50
11.66	1.76	10.52	12.16	1.75	10.51	12.66	1.75	10.50
11.68	1.76	10.51	12.18	1.75	10.51	12.68	1.75	10.50
11.70	1.76	10.51	12.20	1.75	10.51	12.70	1.75	10.49
11.72	1.76	10.51	12.22	1.75	10.51	12.72	1.75	10.49
11.74	1.76	10.51	12.24	1.75	10.51	12.74	1.75	10.49
11.76	1.76	10.51	12.26	1.75	10.51	12.76	1.75	10.49
11.78	1.76	10.51	12.28	1.75	10.50	12.78	1.75	10.49
11.80	1.76	10.51	12.30	1.75	10.50	12.80	1.75	10.49
11.82	1.76	10.51	12.32	1.75	10.50	12.82	1.75	10.49
11.84	1.75	10.51	12.34	1.75	10.50	12.84	1.75	10.49
11.86	1.75	10.51	12.36	1.75	10.50	12.86	1.75	10.49
11.88	1.75	10.51	12.38	1.75	10.50	12.88	1.75	10.49
11.90	1.75	10.51	12.40	1.75	10.50	12.90	1.75	10.49
11.92	1.75	10.51	12.42	1.75	10.50	12.92	1.75	10.49
11.94	1.75	10.51	12.44	1.75	10.50	12.94	1.75	10.49
11.96	1.75	10.51	12.46	1.75	10.50	12.96	1.75	10.49
11.98	1.75	10.51	12.48	1.75	10.50	12.98	1.75	10.49
12.00	1.75	10.51	12.50	1.75	10.50	13.00	1.74	10.49

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
13.02	1.74	10.49	13.52	1.74	10.47	14.02	1.74	10.45
13.04	1.74	10.48	13.54	1.74	10.47	14.04	1.74	10.45
13.06	1.74	10.48	13.56	1.74	10.47	14.06	1.74	10.45
13.08	1.74	10.48	13.58	1.74	10.47	14.08	1.73	10.45
13.10	1.74	10.48	13.60	1.74	10.47	14.10	1.73	10.44
13.12	1.74	10.48	13.62	1.74	10.46	14.12	1.73	10.44
13.14	1.74	10.48	13.64	1.74	10.46	14.14	1.73	10.44
13.16	1.74	10.48	13.66	1.74	10.46	14.16	1.73	10.44
13.18	1.74	10.48	13.68	1.74	10.46	14.18	1.73	10.44
13.20	1.74	10.48	13.70	1.74	10.46	14.20	1.73	10.44
13.22	1.74	10.48	13.72	1.74	10.46	14.22	1.73	10.44
13.24	1.74	10.48	13.74	1.74	10.46	14.24	1.73	10.44
13.26	1.74	10.48	13.76	1.74	10.46	14.26	1.73	10.44
13.28	1.74	10.48	13.78	1.74	10.46	14.28	1.73	10.44
13.30	1.74	10.48	13.80	1.74	10.46	14.30	1.73	10.44
13.32	1.74	10.48	13.82	1.74	10.46	14.32	1.73	10.43
13.34	1.74	10.47	13.84	1.74	10.46	14.34	1.73	10.43
13.36	1.74	10.47	13.86	1.74	10.45	14.36	1.73	10.43
13.38	1.74	10.47	13.88	1.74	10.45	14.38	1.73	10.43
13.40	1.74	10.47	13.90	1.74	10.45	14.40	1.73	10.43
13.42	1.74	10.47	13.92	1.74	10.45	14.42	1.73	10.43
13.44	1.74	10.47	13.94	1.74	10.45	14.44	1.73	10.43
13.46	1.74	10.47	13.96	1.74	10.45	14.46	1.73	10.43
13.48	1.74	10.47	13.98	1.74	10.45	14.48	1.73	10.43
13.50	1.74	10.47	14.00	1.74	10.45	14.50	1.73	10.43

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
14.52	1.73	10.43	15.02	1.73	10.40	15.52	1.72	10.37
14.54	1.73	10.42	15.04	1.73	10.40	15.54	1.72	10.37
14.56	1.73	10.42	15.06	1.73	10.40	15.56	1.72	10.37
14.58	1.73	10.42	15.08	1.72	10.40	15.58	1.72	10.37
14.60	1.73	10.42	15.10	1.72	10.39	15.60	1.72	10.37
14.62	1.73	10.42	15.12	1.72	10.39	15.62	1.72	10.36
14.64	1.73	10.42	15.14	1.72	10.39	15.64	1.72	10.36
14.66	1.73	10.42	15.16	1.72	10.39	15.66	1.72	10.36
14.68	1.73	10.42	15.18	1.72	10.39	15.68	1.72	10.36
14.70	1.73	10.42	15.20	1.72	10.39	15.70	1.72	10.36
14.72	1.73	10.41	15.22	1.72	10.39	15.72	1.72	10.36
14.74	1.73	10.41	15.24	1.72	10.39	15.74	1.72	10.36
14.76	1.73	10.41	15.26	1.72	10.39	15.76	1.72	10.36
14.78	1.73	10.41	15.28	1.72	10.38	15.78	1.72	10.35
14.80	1.73	10.41	15.30	1.72	10.38	15.80	1.72	10.35
14.82	1.73	10.41	15.32	1.72	10.38	15.82	1.72	10.35
14.84	1.73	10.41	15.34	1.72	10.38	15.84	1.72	10.35
14.86	1.73	10.41	15.36	1.72	10.38	15.86	1.72	10.35
14.88	1.73	10.41	15.38	1.72	10.38	15.88	1.72	10.35
14.90	1.73	10.41	15.40	1.72	10.38	15.90	1.72	10.35
14.92	1.73	10.40	15.42	1.72	10.38	15.92	1.72	10.35
14.94	1.73	10.40	15.44	1.72	10.38	15.94	1.72	10.34
14.96	1.73	10.40	15.46	1.72	10.37	15.96	1.72	10.34
14.98	1.73	10.40	15.48	1.72	10.37	15.98	1.72	10.34
15.00	1.73	10.40	15.50	1.72	10.37	16.00	1.71	10.34

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
16.02	1.71	10.34	16.52	1.71	10.31	17.02	1.70	10.27
16.04	1.71	10.34	16.54	1.71	10.30	17.04	1.70	10.27
16.06	1.71	10.34	16.56	1.71	10.30	17.06	1.70	10.27
16.08	1.71	10.34	16.58	1.71	10.30	17.08	1.70	10.27
16.10	1.71	10.33	16.60	1.71	10.30	17.10	1.70	10.26
16.12	1.71	10.33	16.62	1.71	10.30	17.12	1.70	10.26
16.14	1.71	10.33	16.64	1.71	10.30	17.14	1.70	10.26
16.16	1.71	10.33	16.66	1.71	10.30	17.16	1.70	10.26
16.18	1.71	10.33	16.68	1.71	10.29	17.18	1.70	10.26
16.20	1.71	10.33	16.70	1.71	10.29	17.20	1.70	10.26
16.22	1.71	10.33	16.72	1.71	10.29	17.22	1.70	10.25
16.24	1.71	10.32	16.74	1.71	10.29	17.24	1.70	10.25
16.26	1.71	10.32	16.76	1.71	10.29	17.26	1.70	10.25
16.28	1.71	10.32	16.78	1.71	10.29	17.28	1.70	10.25
16.30	1.71	10.32	16.80	1.71	10.29	17.30	1.70	10.25
16.32	1.71	10.32	16.82	1.71	10.28	17.32	1.70	10.25
16.34	1.71	10.32	16.84	1.71	10.28	17.34	1.70	10.25
16.36	1.71	10.32	16.86	1.71	10.28	17.36	1.70	10.24
16.38	1.71	10.32	16.88	1.70	10.28	17.38	1.70	10.24
16.40	1.71	10.31	16.90	1.70	10.28	17.40	1.70	10.24
16.42	1.71	10.31	16.92	1.70	10.28	17.42	1.70	10.24
16.44	1.71	10.31	16.94	1.70	10.28	17.44	1.70	10.24
16.46	1.71	10.31	16.96	1.70	10.27	17.46	1.70	10.24
16.48	1.71	10.31	16.98	1.70	10.27	17.48	1.70	10.23
16.50	1.71	10.31	17.00	1.70	10.27	17.50	1.70	10.23

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
17.52	1.70	10.23	18.02	1.69	10.19	18.52	1.68	10.15
17.54	1.70	10.23	18.04	1.69	10.19	18.54	1.68	10.15
17.56	1.70	10.23	18.06	1.69	10.19	18.56	1.68	10.14
17.58	1.70	10.23	18.08	1.69	10.19	18.58	1.68	10.14
17.60	1.70	10.22	18.10	1.69	10.18	18.60	1.68	10.14
17.62	1.70	10.22	18.12	1.69	10.18	18.62	1.68	10.14
17.64	1.70	10.22	18.14	1.69	10.18	18.64	1.68	10.14
17.66	1.70	10.22	18.16	1.69	10.18	18.66	1.68	10.13
17.68	1.70	10.22	18.18	1.69	10.18	18.68	1.68	10.13
17.70	1.70	10.22	18.20	1.69	10.17	18.70	1.68	10.13
17.72	1.69	10.22	18.22	1.69	10.17	18.72	1.68	10.13
17.74	1.69	10.21	18.24	1.69	10.17	18.74	1.68	10.13
17.76	1.69	10.21	18.26	1.69	10.17	18.76	1.68	10.13
17.78	1.69	10.21	18.28	1.69	10.17	18.78	1.68	10.12
17.80	1.69	10.21	18.30	1.69	10.17	18.80	1.68	10.12
17.82	1.69	10.21	18.32	1.69	10.16	18.82	1.68	10.12
17.84	1.69	10.21	18.34	1.69	10.16	18.84	1.68	10.12
17.86	1.69	10.20	18.36	1.69	10.16	18.86	1.68	10.12
17.88	1.69	10.20	18.38	1.69	10.16	18.88	1.68	10.11
17.90	1.69	10.20	18.40	1.69	10.16	18.90	1.68	10.11
17.92	1.69	10.20	18.42	1.69	10.16	18.92	1.68	10.11
17.94	1.69	10.20	18.44	1.69	10.15	18.94	1.68	10.11
17.96	1.69	10.20	18.46	1.69	10.15	18.96	1.68	10.11
17.98	1.69	10.19	18.48	1.69	10.15	18.98	1.68	10.11
18.00	1.69	10.19	18.50	1.69	10.15	19.00	1.68	10.10

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
19.02	1.68	10.10	19.52	1.67	10.05	20.02	1.66	10.00
19.04	1.68	10.10	19.54	1.67	10.05	20.04	1.66	10.00
19.06	1.68	10.10	19.56	1.67	10.05	20.06	1.66	10.00
19.08	1.68	10.10	19.58	1.67	10.05	20.08	1.66	10.00
19.10	1.68	10.09	19.60	1.67	10.05	20.10	1.66	10.00
19.12	1.68	10.09	19.62	1.67	10.04	20.12	1.66	9.99
19.14	1.68	10.09	19.64	1.67	10.04	20.14	1.66	9.99
19.16	1.68	10.09	19.66	1.67	10.04	20.16	1.66	9.99
19.18	1.68	10.09	19.68	1.67	10.04	20.18	1.66	9.99
19.20	1.68	10.09	19.70	1.67	10.04	20.20	1.66	9.99
19.22	1.68	10.08	19.72	1.67	10.03	20.22	1.66	9.98
19.24	1.68	10.08	19.74	1.67	10.03	20.24	1.66	9.98
19.26	1.68	10.08	19.76	1.67	10.03	20.26	1.66	9.98
19.28	1.67	10.08	19.78	1.67	10.03	20.28	1.66	9.98
19.30	1.67	10.08	19.80	1.67	10.03	20.30	1.66	9.98
19.32	1.67	10.07	19.82	1.67	10.02	20.32	1.66	9.97
19.34	1.67	10.07	19.84	1.67	10.02	20.34	1.66	9.97
19.36	1.67	10.07	19.86	1.67	10.02	20.36	1.66	9.97
19.38	1.67	10.07	19.88	1.67	10.02	20.38	1.66	9.97
19.40	1.67	10.07	19.90	1.67	10.02	20.40	1.66	9.97
19.42	1.67	10.06	19.92	1.67	10.01	20.42	1.66	9.96
19.44	1.67	10.06	19.94	1.67	10.01	20.44	1.66	9.96
19.46	1.67	10.06	19.96	1.67	10.01	20.46	1.66	9.96
19.48	1.67	10.06	19.98	1.67	10.01	20.48	1.66	9.96
19.50	1.67	10.06	20.00	1.66	10.01	20.50	1.66	9.95

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
20.52	1.66	9.95	21.02	1.65	9.90	21.52	1.64	9.84
20.54	1.66	9.95	21.04	1.65	9.90	21.54	1.64	9.84
20.56	1.66	9.95	21.06	1.65	9.89	21.56	1.64	9.84
20.58	1.66	9.95	21.08	1.65	9.89	21.58	1.64	9.84
20.60	1.66	9.94	21.10	1.65	9.89	21.60	1.64	9.83
20.62	1.66	9.94	21.12	1.65	9.89	21.62	1.64	9.83
20.64	1.66	9.94	21.14	1.65	9.89	21.64	1.64	9.83
20.66	1.66	9.94	21.16	1.65	9.88	21.66	1.64	9.83
20.68	1.66	9.94	21.18	1.65	9.88	21.68	1.64	9.82
20.70	1.65	9.93	21.20	1.65	9.88	21.70	1.64	9.82
20.72	1.65	9.93	21.22	1.65	9.88	21.72	1.64	9.82
20.74	1.65	9.93	21.24	1.65	9.87	21.74	1.64	9.82
20.76	1.65	9.93	21.26	1.65	9.87	21.76	1.64	9.81
20.78	1.65	9.92	21.28	1.65	9.87	21.78	1.64	9.81
20.80	1.65	9.92	21.30	1.65	9.87	21.80	1.64	9.81
20.82	1.65	9.92	21.32	1.65	9.87	21.82	1.64	9.81
20.84	1.65	9.92	21.34	1.65	9.86	21.84	1.64	9.81
20.86	1.65	9.92	21.36	1.64	9.86	21.86	1.64	9.80
20.88	1.65	9.91	21.38	1.64	9.86	21.88	1.64	9.80
20.90	1.65	9.91	21.40	1.64	9.86	21.90	1.64	9.80
20.92	1.65	9.91	21.42	1.64	9.85	21.92	1.64	9.80
20.94	1.65	9.91	21.44	1.64	9.85	21.94	1.64	9.79
20.96	1.65	9.91	21.46	1.64	9.85	21.96	1.64	9.79
20.98	1.65	9.90	21.48	1.64	9.85	21.98	1.64	9.79
21.00	1.65	9.90	21.50	1.64	9.84	22.00	1.63	9.79

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
22.02	1.63	9.78	22.52	1.63	9.72	23.02	1.62	9.66
22.04	1.63	9.78	22.54	1.63	9.72	23.04	1.62	9.66
22.06	1.63	9.78	22.56	1.63	9.72	23.06	1.62	9.66
22.08	1.63	9.78	22.58	1.63	9.72	23.08	1.62	9.65
22.10	1.63	9.77	22.60	1.63	9.71	23.10	1.62	9.65
22.12	1.63	9.77	22.62	1.62	9.71	23.12	1.62	9.65
22.14	1.63	9.77	22.64	1.62	9.71	23.14	1.62	9.65
22.16	1.63	9.77	22.66	1.62	9.71	23.16	1.62	9.64
22.18	1.63	9.77	22.68	1.62	9.70	23.18	1.62	9.64
22.20	1.63	9.76	22.70	1.62	9.70	23.20	1.62	9.64
22.22	1.63	9.76	22.72	1.62	9.70	23.22	1.61	9.64
22.24	1.63	9.76	22.74	1.62	9.70	23.24	1.61	9.63
22.26	1.63	9.76	22.76	1.62	9.69	23.26	1.61	9.63
22.28	1.63	9.75	22.78	1.62	9.69	23.28	1.61	9.63
22.30	1.63	9.75	22.80	1.62	9.69	23.30	1.61	9.62
22.32	1.63	9.75	22.82	1.62	9.69	23.32	1.61	9.62
22.34	1.63	9.75	22.84	1.62	9.68	23.34	1.61	9.62
22.36	1.63	9.74	22.86	1.62	9.68	23.36	1.61	9.62
22.38	1.63	9.74	22.88	1.62	9.68	23.38	1.61	9.61
22.40	1.63	9.74	22.90	1.62	9.68	23.40	1.61	9.61
22.42	1.63	9.74	22.92	1.62	9.67	23.42	1.61	9.61
22.44	1.63	9.73	22.94	1.62	9.67	23.44	1.61	9.61
22.46	1.63	9.73	22.96	1.62	9.67	23.46	1.61	9.60
22.48	1.63	9.73	22.98	1.62	9.67	23.48	1.61	9.60
22.50	1.63	9.73	23.00	1.62	9.66	23.50	1.61	9.60

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
23.52	1.61	9.60	24.02	1.60	9.53	24.52	1.59	9.46
23.54	1.61	9.59	24.04	1.60	9.53	24.54	1.59	9.46
23.56	1.61	9.59	24.06	1.60	9.52	24.56	1.59	9.45
23.58	1.61	9.59	24.08	1.60	9.52	24.58	1.59	9.45
23.60	1.61	9.59	24.10	1.60	9.52	24.60	1.59	9.45
23.62	1.61	9.58	24.12	1.60	9.52	24.62	1.59	9.45
23.64	1.61	9.58	24.14	1.60	9.51	24.64	1.59	9.44
23.66	1.61	9.58	24.16	1.60	9.51	24.66	1.59	9.44
23.68	1.61	9.57	24.18	1.60	9.51	24.68	1.59	9.44
23.70	1.61	9.57	24.20	1.60	9.50	24.70	1.59	9.43
23.72	1.61	9.57	24.22	1.60	9.50	24.72	1.59	9.43
23.74	1.61	9.57	24.24	1.60	9.50	24.74	1.59	9.43
23.76	1.61	9.56	24.26	1.60	9.50	24.76	1.59	9.43
23.78	1.60	9.56	24.28	1.60	9.49	24.78	1.59	9.42
23.80	1.60	9.56	24.30	1.60	9.49	24.80	1.59	9.42
23.82	1.60	9.56	24.32	1.60	9.49	24.82	1.59	9.42
23.84	1.60	9.55	24.34	1.59	9.48	24.84	1.59	9.41
23.86	1.60	9.55	24.36	1.59	9.48	24.86	1.59	9.41
23.88	1.60	9.55	24.38	1.59	9.48	24.88	1.58	9.41
23.90	1.60	9.55	24.40	1.59	9.48	24.90	1.58	9.41
23.92	1.60	9.54	24.42	1.59	9.47	24.92	1.58	9.40
23.94	1.60	9.54	24.44	1.59	9.47	24.94	1.58	9.40
23.96	1.60	9.54	24.46	1.59	9.47	24.96	1.58	9.40
23.98	1.60	9.53	24.48	1.59	9.47	24.98	1.58	9.39
24.00	1.60	9.53	24.50	1.59	9.46	25.00	1.58	9.39

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
25.02	1.58	9.39	25.52	1.57	9.31	26.02	1.56	9.24
25.04	1.58	9.38	25.54	1.57	9.31	26.04	1.56	9.23
25.06	1.58	9.38	25.56	1.57	9.31	26.06	1.56	9.23
25.08	1.58	9.38	25.58	1.57	9.30	26.08	1.56	9.23
25.10	1.58	9.38	25.60	1.57	9.30	26.10	1.56	9.22
25.12	1.58	9.37	25.62	1.57	9.30	26.12	1.56	9.22
25.14	1.58	9.37	25.64	1.57	9.30	26.14	1.56	9.22
25.16	1.58	9.37	25.66	1.57	9.29	26.16	1.56	9.22
25.18	1.58	9.36	25.68	1.57	9.29	26.18	1.56	9.21
25.20	1.58	9.36	25.70	1.57	9.29	26.20	1.56	9.21
25.22	1.58	9.36	25.72	1.57	9.28	26.22	1.56	9.21
25.24	1.58	9.36	25.74	1.57	9.28	26.24	1.56	9.20
25.26	1.58	9.35	25.76	1.57	9.28	26.26	1.56	9.20
25.28	1.58	9.35	25.78	1.57	9.27	26.28	1.56	9.20
25.30	1.58	9.35	25.80	1.57	9.27	26.30	1.56	9.19
25.32	1.58	9.34	25.82	1.57	9.27	26.32	1.56	9.19
25.34	1.58	9.34	25.84	1.57	9.26	26.34	1.56	9.19
25.36	1.58	9.34	25.86	1.57	9.26	26.36	1.55	9.18
25.38	1.57	9.33	25.88	1.56	9.26	26.38	1.55	9.18
25.40	1.57	9.33	25.90	1.56	9.26	26.40	1.55	9.18
25.42	1.57	9.33	25.92	1.56	9.25	26.42	1.55	9.17
25.44	1.57	9.33	25.94	1.56	9.25	26.44	1.55	9.17
25.46	1.57	9.32	25.96	1.56	9.25	26.46	1.55	9.17
25.48	1.57	9.32	25.98	1.56	9.24	26.48	1.55	9.16
25.50	1.57	9.32	26.00	1.56	9.24	26.50	1.55	9.16

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
26.52	1.55	9.16	27.02	1.54	9.08	27.52	1.53	8.99
26.54	1.55	9.15	27.04	1.54	9.07	27.54	1.53	8.99
26.56	1.55	9.15	27.06	1.54	9.07	27.56	1.53	8.99
26.58	1.55	9.15	27.08	1.54	9.07	27.58	1.53	8.98
26.60	1.55	9.14	27.10	1.54	9.06	27.60	1.53	8.98
26.62	1.55	9.14	27.12	1.54	9.06	27.62	1.53	8.97
26.64	1.55	9.14	27.14	1.54	9.06	27.64	1.53	8.97
26.66	1.55	9.14	27.16	1.54	9.05	27.66	1.53	8.97
26.68	1.55	9.13	27.18	1.54	9.05	27.68	1.53	8.96
26.70	1.55	9.13	27.20	1.54	9.05	27.70	1.53	8.96
26.72	1.55	9.13	27.22	1.54	9.04	27.72	1.52	8.96
26.74	1.55	9.12	27.24	1.54	9.04	27.74	1.52	8.95
26.76	1.55	9.12	27.26	1.54	9.04	27.76	1.52	8.95
26.78	1.55	9.12	27.28	1.54	9.03	27.78	1.52	8.95
26.80	1.55	9.11	27.30	1.53	9.03	27.80	1.52	8.94
26.82	1.55	9.11	27.32	1.53	9.03	27.82	1.52	8.94
26.84	1.54	9.11	27.34	1.53	9.02	27.84	1.52	8.94
26.86	1.54	9.10	27.36	1.53	9.02	27.86	1.52	8.93
26.88	1.54	9.10	27.38	1.53	9.02	27.88	1.52	8.93
26.90	1.54	9.10	27.40	1.53	9.01	27.90	1.52	8.93
26.92	1.54	9.09	27.42	1.53	9.01	27.92	1.52	8.92
26.94	1.54	9.09	27.44	1.53	9.01	27.94	1.52	8.92
26.96	1.54	9.09	27.46	1.53	9.00	27.96	1.52	8.92
26.98	1.54	9.08	27.48	1.53	9.00	27.98	1.52	8.91
27.00	1.54	9.08	27.50	1.53	9.00	28.00	1.52	8.91

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
28.02	1.52	8.91	28.52	1.51	8.82	29.02	1.49	8.72
28.04	1.52	8.90	28.54	1.51	8.81	29.04	1.49	8.72
28.06	1.52	8.90	28.56	1.50	8.81	29.06	1.49	8.72
28.08	1.52	8.89	28.58	1.50	8.80	29.08	1.49	8.71
28.10	1.52	8.89	28.60	1.50	8.80	29.10	1.49	8.71
28.12	1.52	8.89	28.62	1.50	8.80	29.12	1.49	8.70
28.14	1.52	8.88	28.64	1.50	8.79	29.14	1.49	8.70
28.16	1.51	8.88	28.66	1.50	8.79	29.16	1.49	8.70
28.18	1.51	8.88	28.68	1.50	8.79	29.18	1.49	8.69
28.20	1.51	8.87	28.70	1.50	8.78	29.20	1.49	8.69
28.22	1.51	8.87	28.72	1.50	8.78	29.22	1.49	8.68
28.24	1.51	8.87	28.74	1.50	8.78	29.24	1.49	8.68
28.26	1.51	8.86	28.76	1.50	8.77	29.26	1.49	8.68
28.28	1.51	8.86	28.78	1.50	8.77	29.28	1.49	8.67
28.30	1.51	8.86	28.80	1.50	8.76	29.30	1.49	8.67
28.32	1.51	8.85	28.82	1.50	8.76	29.32	1.49	8.67
28.34	1.51	8.85	28.84	1.50	8.76	29.34	1.49	8.66
28.36	1.51	8.84	28.86	1.50	8.75	29.36	1.48	8.66
28.38	1.51	8.84	28.88	1.50	8.75	29.38	1.48	8.65
28.40	1.51	8.84	28.90	1.50	8.75	29.40	1.48	8.65
28.42	1.51	8.83	28.92	1.50	8.74	29.42	1.48	8.65
28.44	1.51	8.83	28.94	1.50	8.74	29.44	1.48	8.64
28.46	1.51	8.83	28.96	1.50	8.73	29.46	1.48	8.64
28.48	1.51	8.82	28.98	1.49	8.73	29.48	1.48	8.63
28.50	1.51	8.82	29.00	1.49	8.73	29.50	1.48	8.63

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
29.52	1.48	8.63	30.02	1.47	8.53	30.52	1.45	8.43
29.54	1.48	8.62	30.04	1.47	8.52	30.54	1.45	8.42
29.56	1.48	8.62	30.06	1.47	8.52	30.56	1.45	8.42
29.58	1.48	8.62	30.08	1.47	8.52	30.58	1.45	8.41
29.60	1.48	8.61	30.10	1.47	8.51	30.60	1.45	8.41
29.62	1.48	8.61	30.12	1.46	8.51	30.62	1.45	8.41
29.64	1.48	8.60	30.14	1.46	8.50	30.64	1.45	8.40
29.66	1.48	8.60	30.16	1.46	8.50	30.66	1.45	8.40
29.68	1.48	8.60	30.18	1.46	8.50	30.68	1.45	8.39
29.70	1.48	8.59	30.20	1.46	8.49	30.70	1.45	8.39
29.72	1.48	8.59	30.22	1.46	8.49	30.72	1.45	8.38
29.74	1.47	8.58	30.24	1.46	8.48	30.74	1.45	8.38
29.76	1.47	8.58	30.26	1.46	8.48	30.76	1.45	8.38
29.78	1.47	8.58	30.28	1.46	8.48	30.78	1.45	8.37
29.80	1.47	8.57	30.30	1.46	8.47	30.80	1.45	8.37
29.82	1.47	8.57	30.32	1.46	8.47	30.82	1.44	8.36
29.84	1.47	8.56	30.34	1.46	8.46	30.84	1.44	8.36
29.86	1.47	8.56	30.36	1.46	8.46	30.86	1.44	8.36
29.88	1.47	8.56	30.38	1.46	8.46	30.88	1.44	8.35
29.90	1.47	8.55	30.40	1.46	8.45	30.90	1.44	8.35
29.92	1.47	8.55	30.42	1.46	8.45	30.92	1.44	8.34
29.94	1.47	8.54	30.44	1.46	8.44	30.94	1.44	8.34
29.96	1.47	8.54	30.46	1.45	8.44	30.96	1.44	8.33
29.98	1.47	8.54	30.48	1.45	8.43	30.98	1.44	8.33
30.00	1.47	8.53	30.50	1.45	8.43	31.00	1.44	8.33

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
31.02	1.44	8.32	31.50	1.42	8.22	31.98	1.41	8.11
31.04	1.44	8.32	31.52	1.42	8.21	32.00	1.41	8.10
31.06	1.44	8.31	31.54	1.42	8.21	32.02	1.41	8.10
31.08	1.44	8.31	31.56	1.42	8.20	32.04	1.41	8.10
31.10	1.44	8.30	31.58	1.42	8.20	32.06	1.41	8.09
31.12	1.44	8.30	31.60	1.42	8.19	32.08	1.41	8.09
31.14	1.44	8.30	31.62	1.42	8.19	32.10	1.41	8.08
31.16	1.43	8.29	31.64	1.42	8.19	32.12	1.41	8.08
31.18	1.43	8.29	31.66	1.42	8.18	32.14	1.40	8.07
31.20	1.43	8.28	31.68	1.42	8.18	32.16	1.40	8.07
31.22	1.43	8.28	31.70	1.42	8.17	32.18	1.40	8.06
31.24	1.43	8.27	31.72	1.42	8.17	32.20	1.40	8.06
31.26	1.43	8.27	31.74	1.42	8.16	32.22	1.40	8.05
31.28	1.43	8.27	31.76	1.42	8.16	32.24	1.40	8.05
31.30	1.43	8.26	31.78	1.42	8.15	32.26	1.40	8.04
31.32	1.43	8.26	31.80	1.42	8.15	32.28	1.40	8.04
31.34	1.43	8.25	31.82	1.41	8.15	32.30	1.40	8.04
31.36	1.43	8.25	31.84	1.41	8.14	32.32	1.40	8.03
31.38	1.43	8.24	31.86	1.41	8.14	32.34	1.40	8.03
31.40	1.43	8.24	31.88	1.41	8.13	32.36	1.40	8.02
31.42	1.43	8.23	31.90	1.41	8.13	32.38	1.40	8.02
31.44	1.43	8.23	31.92	1.41	8.12	32.40	1.40	8.01
31.46	1.43	8.23	31.94	1.41	8.12	32.42	1.40	8.01
31.48	1.43	8.22	31.96	1.41	8.11	32.44	1.39	8.00

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
32.46	1.39	8.00	32.96	1.38	7.88	33.46	1.36	7.75
32.48	1.39	7.99	32.98	1.38	7.87	33.48	1.36	7.75
32.50	1.39	7.99	33.00	1.38	7.87	33.50	1.36	7.74
32.52	1.39	7.98	33.02	1.38	7.86	33.52	1.36	7.74
32.54	1.39	7.98	33.04	1.37	7.86	33.54	1.36	7.73
32.56	1.39	7.97	33.06	1.37	7.85	33.56	1.36	7.73
32.58	1.39	7.97	33.08	1.37	7.85	33.58	1.36	7.72
32.60	1.39	7.96	33.10	1.37	7.84	33.60	1.35	7.72
32.62	1.39	7.96	33.12	1.37	7.84	33.62	1.35	7.71
32.64	1.39	7.96	33.14	1.37	7.83	33.64	1.35	7.71
32.66	1.39	7.95	33.16	1.37	7.83	33.66	1.35	7.70
32.68	1.39	7.95	33.18	1.37	7.82	33.68	1.35	7.70
32.70	1.39	7.94	33.20	1.37	7.82	33.70	1.35	7.69
32.72	1.39	7.94	33.22	1.37	7.81	33.72	1.35	7.69
32.74	1.38	7.93	33.24	1.37	7.81	33.74	1.35	7.68
32.76	1.38	7.93	33.26	1.37	7.80	33.76	1.35	7.68
32.78	1.38	7.92	33.28	1.37	7.80	33.78	1.35	7.67
32.80	1.38	7.92	33.30	1.37	7.79	33.80	1.35	7.67
32.82	1.38	7.91	33.32	1.36	7.79	33.82	1.35	7.66
32.84	1.38	7.91	33.34	1.36	7.78	33.84	1.35	7.66
32.86	1.38	7.90	33.36	1.36	7.78	33.86	1.35	7.65
32.88	1.38	7.90	33.38	1.36	7.77	33.88	1.34	7.65
32.90	1.38	7.89	33.40	1.36	7.77	33.90	1.34	7.64
32.92	1.38	7.89	33.42	1.36	7.76	33.92	1.34	7.64
32.94	1.38	7.88	33.44	1.36	7.76	33.94	1.34	7.63

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
33.96	1.34	7.63	34.46	1.32	7.49	34.96	1.30	7.36
33.98	1.34	7.62	34.48	1.32	7.49	34.98	1.30	7.35
34.00	1.34	7.62	34.50	1.32	7.48	35.00	1.30	7.35
34.02	1.34	7.61	34.52	1.32	7.48	35.02	1.30	7.34
34.04	1.34	7.61	34.54	1.32	7.47	35.04	1.30	7.33
34.06	1.34	7.60	34.56	1.32	7.47	35.06	1.30	7.33
34.08	1.34	7.60	34.58	1.32	7.46	35.08	1.30	7.32
34.10	1.34	7.59	34.60	1.32	7.46	35.10	1.30	7.32
34.12	1.34	7.58	34.62	1.32	7.45	35.12	1.30	7.31
34.14	1.33	7.58	34.64	1.32	7.45	35.14	1.30	7.31
34.16	1.33	7.57	34.66	1.31	7.44	35.16	1.29	7.30
34.18	1.33	7.57	34.68	1.31	7.43	35.18	1.29	7.30
34.20	1.33	7.56	34.70	1.31	7.43	35.20	1.29	7.29
34.22	1.33	7.56	34.72	1.31	7.42	35.22	1.29	7.28
34.24	1.33	7.55	34.74	1.31	7.42	35.24	1.29	7.28
34.26	1.33	7.55	34.76	1.31	7.41	35.26	1.29	7.27
34.28	1.33	7.54	34.78	1.31	7.41	35.28	1.29	7.27
34.30	1.33	7.54	34.80	1.31	7.40	35.30	1.29	7.26
34.32	1.33	7.53	34.82	1.31	7.40	35.32	1.29	7.26
34.34	1.33	7.53	34.84	1.31	7.39	35.34	1.29	7.25
34.36	1.33	7.52	34.86	1.31	7.38	35.36	1.29	7.24
34.38	1.33	7.52	34.88	1.31	7.38	35.38	1.29	7.24
34.40	1.32	7.51	34.90	1.31	7.37	35.40	1.28	7.23
34.42	1.32	7.50	34.92	1.30	7.37	35.42	1.28	7.23
34.44	1.32	7.50	34.94	1.30	7.36	35.44	1.28	7.22

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
35.46	1.28	7.22	35.96	1.26	7.07	36.46	1.24	6.92
35.48	1.28	7.21	35.98	1.26	7.06	36.48	1.24	6.91
35.50	1.28	7.20	36.00	1.26	7.06	36.50	1.24	6.91
35.52	1.28	7.20	36.02	1.26	7.05	36.52	1.24	6.90
35.54	1.28	7.19	36.04	1.26	7.05	36.54	1.23	6.89
35.56	1.28	7.19	36.06	1.26	7.04	36.56	1.23	6.89
35.58	1.28	7.18	36.08	1.26	7.03	36.58	1.23	6.88
35.60	1.28	7.18	36.10	1.25	7.03	36.60	1.23	6.87
35.62	1.28	7.17	36.12	1.25	7.02	36.62	1.23	6.87
35.64	1.27	7.16	36.14	1.25	7.02	36.64	1.23	6.86
35.66	1.27	7.16	36.16	1.25	7.01	36.66	1.23	6.86
35.68	1.27	7.15	36.18	1.25	7.00	36.68	1.23	6.85
35.70	1.27	7.15	36.20	1.25	7.00	36.70	1.23	6.84
35.72	1.27	7.14	36.22	1.25	6.99	36.72	1.23	6.84
35.74	1.27	7.13	36.24	1.25	6.99	36.74	1.23	6.83
35.76	1.27	7.13	36.26	1.25	6.98	36.76	1.22	6.82
35.78	1.27	7.12	36.28	1.25	6.97	36.78	1.22	6.82
35.80	1.27	7.12	36.30	1.25	6.97	36.80	1.22	6.81
35.82	1.27	7.11	36.32	1.24	6.96	36.82	1.22	6.81
35.84	1.27	7.10	36.34	1.24	6.95	36.84	1.22	6.80
35.86	1.27	7.10	36.36	1.24	6.95	36.86	1.22	6.79
35.88	1.26	7.09	36.38	1.24	6.94	36.88	1.22	6.79
35.90	1.26	7.09	36.40	1.24	6.94	36.90	1.22	6.78
35.92	1.26	7.08	36.42	1.24	6.93	36.92	1.22	6.77
35.94	1.26	7.08	36.44	1.24	6.92	36.94	1.22	6.77

Appendix 2d- Results E&M model simulation for mix of average proportional mix of creek and spring waters in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI
36.96	1.22	6.76
36.98	1.21	6.76
37.00	1.21	6.75
37.02	1.21	6.74
37.04	1.21	6.74
37.06	1.21	6.73
37.08	1.21	6.72
37.10	1.21	6.72
37.12	1.21	6.71
37.14	1.21	6.70
37.16	1.21	6.70
37.18	1.21	6.69
37.20	1.20	6.69
37.22	1.20	6.68
37.24	1.20	6.67
37.26	1.20	6.67
37.28	1.20	6.66
37.30	1.20	6.65
37.32	1.20	6.65
37.34	1.20	6.64
37.36	1.20	6.63
37.38	1.20	6.63
37.40	1.19	6.62
37.42	1.19	6.61
37.44	1.19	6.61
37.46	1.19	6.60
37.48	1.19	6.59
37.50	1.19	6.59
37.52	1.19	6.58
37.54	1.19	6.57
37.56	1.19	6.57
37.58	1.19	6.56
37.60	1.18	6.55

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicate SI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
1.02	1.19	4.80	1.52	1.43	5.41	2.02	1.47	5.82
1.04	1.22	4.83	1.54	1.43	5.43	2.04	1.47	5.83
1.06	1.25	4.86	1.56	1.44	5.45	2.06	1.47	5.84
1.08	1.27	4.89	1.58	1.44	5.47	2.08	1.47	5.86
1.10	1.29	4.91	1.60	1.44	5.49	2.10	1.47	5.87
1.12	1.30	4.94	1.62	1.44	5.50	2.12	1.47	5.88
1.14	1.32	4.97	1.64	1.44	5.52	2.14	1.47	5.90
1.16	1.33	5.00	1.66	1.45	5.54	2.16	1.47	5.91
1.18	1.34	5.03	1.68	1.45	5.56	2.18	1.48	5.92
1.20	1.35	5.05	1.70	1.45	5.57	2.20	1.48	5.94
1.22	1.36	5.08	1.72	1.45	5.59	2.22	1.48	5.95
1.24	1.37	5.10	1.74	1.45	5.61	2.24	1.48	5.96
1.26	1.37	5.13	1.76	1.46	5.62	2.26	1.48	5.97
1.28	1.38	5.15	1.78	1.46	5.64	2.28	1.48	5.98
1.30	1.39	5.18	1.80	1.46	5.66	2.30	1.48	6.00
1.32	1.39	5.20	1.82	1.46	5.67	2.32	1.48	6.01
1.34	1.40	5.22	1.84	1.46	5.69	2.34	1.48	6.02
1.36	1.40	5.24	1.86	1.46	5.70	2.36	1.48	6.03
1.38	1.41	5.27	1.88	1.46	5.72	2.38	1.48	6.04
1.40	1.41	5.29	1.90	1.46	5.73	2.40	1.48	6.05
1.42	1.41	5.31	1.92	1.46	5.75	2.42	1.48	6.07
1.44	1.42	5.33	1.94	1.47	5.76	2.44	1.48	6.08
1.46	1.42	5.35	1.96	1.47	5.78	2.46	1.48	6.09
1.48	1.43	5.37	1.98	1.47	5.79	2.48	1.48	6.10
1.50	1.43	5.39	2.00	1.47	5.80	2.50	1.48	6.11

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
2.52	1.48	6.12	3.02	1.49	6.36	3.52	1.49	6.57
2.54	1.48	6.13	3.04	1.49	6.37	3.54	1.49	6.57
2.56	1.48	6.14	3.06	1.49	6.38	3.56	1.49	6.58
2.58	1.48	6.15	3.08	1.49	6.39	3.58	1.49	6.59
2.60	1.49	6.16	3.10	1.49	6.40	3.60	1.49	6.60
2.62	1.49	6.17	3.12	1.49	6.41	3.62	1.49	6.60
2.64	1.49	6.18	3.14	1.49	6.42	3.64	1.49	6.61
2.66	1.49	6.19	3.16	1.49	6.42	3.66	1.49	6.62
2.68	1.49	6.20	3.18	1.49	6.43	3.68	1.49	6.62
2.70	1.49	6.21	3.20	1.49	6.44	3.70	1.49	6.63
2.72	1.49	6.22	3.22	1.49	6.45	3.72	1.49	6.64
2.74	1.49	6.23	3.24	1.49	6.46	3.74	1.49	6.65
2.76	1.49	6.24	3.26	1.49	6.47	3.76	1.49	6.65
2.78	1.49	6.25	3.28	1.49	6.47	3.78	1.49	6.66
2.80	1.49	6.26	3.30	1.49	6.48	3.80	1.49	6.67
2.82	1.49	6.27	3.32	1.49	6.49	3.82	1.49	6.67
2.84	1.49	6.28	3.34	1.49	6.50	3.84	1.49	6.68
2.86	1.49	6.29	3.36	1.49	6.51	3.86	1.49	6.69
2.88	1.49	6.30	3.38	1.49	6.51	3.88	1.49	6.69
2.90	1.49	6.31	3.40	1.49	6.52	3.90	1.49	6.70
2.92	1.49	6.32	3.42	1.49	6.53	3.92	1.49	6.71
2.94	1.49	6.33	3.44	1.49	6.54	3.94	1.49	6.71
2.96	1.49	6.34	3.46	1.49	6.54	3.96	1.49	6.72
2.98	1.49	6.35	3.48	1.49	6.55	3.98	1.49	6.73
3.00	1.49	6.36	3.50	1.49	6.56	4.00	1.49	6.73

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
4.02	1.49	6.74	4.52	1.49	6.89	5.02	1.49	7.03
4.04	1.49	6.75	4.54	1.49	6.90	5.04	1.49	7.03
4.06	1.49	6.75	4.56	1.49	6.90	5.06	1.49	7.04
4.08	1.49	6.76	4.58	1.49	6.91	5.08	1.49	7.04
4.10	1.49	6.77	4.60	1.49	6.91	5.10	1.49	7.05
4.12	1.49	6.77	4.62	1.49	6.92	5.12	1.49	7.05
4.14	1.49	6.78	4.64	1.49	6.93	5.14	1.49	7.06
4.16	1.49	6.78	4.66	1.49	6.93	5.16	1.49	7.06
4.18	1.49	6.79	4.68	1.49	6.94	5.18	1.49	7.07
4.20	1.49	6.80	4.70	1.49	6.94	5.20	1.49	7.07
4.22	1.49	6.80	4.72	1.49	6.95	5.22	1.49	7.08
4.24	1.49	6.81	4.74	1.49	6.95	5.24	1.49	7.08
4.26	1.49	6.82	4.76	1.49	6.96	5.26	1.49	7.09
4.28	1.49	6.82	4.78	1.49	6.96	5.28	1.49	7.09
4.30	1.49	6.83	4.80	1.49	6.97	5.30	1.49	7.10
4.32	1.49	6.83	4.82	1.49	6.97	5.32	1.49	7.10
4.34	1.49	6.84	4.84	1.49	6.98	5.34	1.49	7.11
4.36	1.49	6.85	4.86	1.49	6.99	5.36	1.49	7.11
4.38	1.49	6.85	4.88	1.49	6.99	5.38	1.49	7.11
4.40	1.49	6.86	4.90	1.49	7.00	5.40	1.49	7.12
4.42	1.49	6.86	4.92	1.49	7.00	5.42	1.49	7.12
4.44	1.49	6.87	4.94	1.49	7.01	5.44	1.49	7.13
4.46	1.49	6.87	4.96	1.49	7.01	5.46	1.49	7.13
4.48	1.49	6.88	4.98	1.49	7.02	5.48	1.49	7.14
4.50	1.49	6.89	5.00	1.49	7.02	5.50	1.49	7.14

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
5.52	1.49	7.15	6.02	1.49	7.26	6.52	1.49	7.36
5.54	1.49	7.15	6.04	1.49	7.26	6.54	1.49	7.36
5.56	1.49	7.16	6.06	1.49	7.26	6.56	1.49	7.36
5.58	1.49	7.16	6.08	1.49	7.27	6.58	1.49	7.37
5.60	1.49	7.17	6.10	1.49	7.27	6.60	1.49	7.37
5.62	1.49	7.17	6.12	1.49	7.28	6.62	1.49	7.37
5.64	1.49	7.17	6.14	1.49	7.28	6.64	1.49	7.38
5.66	1.49	7.18	6.16	1.49	7.29	6.66	1.49	7.38
5.68	1.49	7.18	6.18	1.49	7.29	6.68	1.49	7.39
5.70	1.49	7.19	6.20	1.49	7.29	6.70	1.49	7.39
5.72	1.49	7.19	6.22	1.49	7.30	6.72	1.49	7.39
5.74	1.49	7.20	6.24	1.49	7.30	6.74	1.49	7.40
5.76	1.49	7.20	6.26	1.49	7.31	6.76	1.49	7.40
5.78	1.49	7.21	6.28	1.49	7.31	6.78	1.49	7.40
5.80	1.49	7.21	6.30	1.49	7.31	6.80	1.49	7.41
5.82	1.49	7.21	6.32	1.49	7.32	6.82	1.49	7.41
5.84	1.49	7.22	6.34	1.49	7.32	6.84	1.49	7.41
5.86	1.49	7.22	6.36	1.49	7.32	6.86	1.49	7.42
5.88	1.49	7.23	6.38	1.49	7.33	6.88	1.49	7.42
5.90	1.49	7.23	6.40	1.49	7.33	6.90	1.49	7.43
5.92	1.49	7.24	6.42	1.49	7.34	6.92	1.49	7.43
5.94	1.49	7.24	6.44	1.49	7.34	6.94	1.49	7.43
5.96	1.49	7.24	6.46	1.49	7.34	6.96	1.49	7.44
5.98	1.49	7.25	6.48	1.49	7.35	6.98	1.49	7.44
6.00	1.49	7.25	6.50	1.49	7.35	7.00	1.49	7.44

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
7.02	1.49	7.45	7.52	1.49	7.53	8.02	1.49	7.61
7.04	1.49	7.45	7.54	1.49	7.53	8.04	1.49	7.61
7.06	1.49	7.45	7.56	1.49	7.54	8.06	1.49	7.61
7.08	1.49	7.46	7.58	1.49	7.54	8.08	1.49	7.62
7.10	1.49	7.46	7.60	1.49	7.54	8.10	1.49	7.62
7.12	1.49	7.46	7.62	1.49	7.55	8.12	1.49	7.62
7.14	1.49	7.47	7.64	1.49	7.55	8.14	1.49	7.63
7.16	1.49	7.47	7.66	1.49	7.55	8.16	1.49	7.63
7.18	1.49	7.47	7.68	1.49	7.56	8.18	1.49	7.63
7.20	1.49	7.48	7.70	1.49	7.56	8.20	1.48	7.63
7.22	1.49	7.48	7.72	1.49	7.56	8.22	1.48	7.64
7.24	1.49	7.48	7.74	1.49	7.57	8.24	1.48	7.64
7.26	1.49	7.49	7.76	1.49	7.57	8.26	1.48	7.64
7.28	1.49	7.49	7.78	1.49	7.57	8.28	1.48	7.65
7.30	1.49	7.49	7.80	1.49	7.57	8.30	1.48	7.65
7.32	1.49	7.50	7.82	1.49	7.58	8.32	1.48	7.65
7.34	1.49	7.50	7.84	1.49	7.58	8.34	1.48	7.66
7.36	1.49	7.50	7.86	1.49	7.58	8.36	1.48	7.66
7.38	1.49	7.51	7.88	1.49	7.59	8.38	1.48	7.66
7.40	1.49	7.51	7.90	1.49	7.59	8.40	1.48	7.66
7.42	1.49	7.51	7.92	1.49	7.59	8.42	1.48	7.67
7.44	1.49	7.52	7.94	1.49	7.60	8.44	1.48	7.67
7.46	1.49	7.52	7.96	1.49	7.60	8.46	1.48	7.67
7.48	1.49	7.52	7.98	1.49	7.60	8.48	1.48	7.67
7.50	1.49	7.53	8.00	1.49	7.61	8.50	1.48	7.68

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
8.52	1.48	7.68	9.02	1.48	7.75	9.52	1.48	7.81
8.54	1.48	7.68	9.04	1.48	7.75	9.54	1.48	7.81
8.56	1.48	7.69	9.06	1.48	7.75	9.56	1.48	7.81
8.58	1.48	7.69	9.08	1.48	7.76	9.58	1.48	7.82
8.60	1.48	7.69	9.10	1.48	7.76	9.60	1.48	7.82
8.62	1.48	7.69	9.12	1.48	7.76	9.62	1.48	7.82
8.64	1.48	7.70	9.14	1.48	7.76	9.64	1.48	7.82
8.66	1.48	7.70	9.16	1.48	7.77	9.66	1.48	7.83
8.68	1.48	7.70	9.18	1.48	7.77	9.68	1.48	7.83
8.70	1.48	7.71	9.20	1.48	7.77	9.70	1.48	7.83
8.72	1.48	7.71	9.22	1.48	7.77	9.72	1.48	7.83
8.74	1.48	7.71	9.24	1.48	7.78	9.74	1.48	7.84
8.76	1.48	7.71	9.26	1.48	7.78	9.76	1.48	7.84
8.78	1.48	7.72	9.28	1.48	7.78	9.78	1.48	7.84
8.80	1.48	7.72	9.30	1.48	7.78	9.80	1.48	7.84
8.82	1.48	7.72	9.32	1.48	7.79	9.82	1.48	7.85
8.84	1.48	7.72	9.34	1.48	7.79	9.84	1.48	7.85
8.86	1.48	7.73	9.36	1.48	7.79	9.86	1.48	7.85
8.88	1.48	7.73	9.38	1.48	7.79	9.88	1.48	7.85
8.90	1.48	7.73	9.40	1.48	7.80	9.90	1.48	7.86
8.92	1.48	7.73	9.42	1.48	7.80	9.92	1.48	7.86
8.94	1.48	7.74	9.44	1.48	7.80	9.94	1.48	7.86
8.96	1.48	7.74	9.46	1.48	7.80	9.96	1.48	7.86
8.98	1.48	7.74	9.48	1.48	7.81	9.98	1.48	7.86
9.00	1.48	7.74	9.50	1.48	7.81	10.00	1.48	7.87

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
10.02	1.48	7.87	10.52	1.48	7.92	11.02	1.47	7.98
10.04	1.48	7.87	10.54	1.48	7.93	11.04	1.47	7.98
10.06	1.48	7.87	10.56	1.48	7.93	11.06	1.47	7.98
10.08	1.48	7.88	10.58	1.48	7.93	11.08	1.47	7.98
10.10	1.48	7.88	10.60	1.48	7.93	11.10	1.47	7.98
10.12	1.48	7.88	10.62	1.48	7.93	11.12	1.47	7.99
10.14	1.48	7.88	10.64	1.48	7.94	11.14	1.47	7.99
10.16	1.48	7.88	10.66	1.48	7.94	11.16	1.47	7.99
10.18	1.48	7.89	10.68	1.48	7.94	11.18	1.47	7.99
10.20	1.48	7.89	10.70	1.48	7.94	11.20	1.47	7.99
10.22	1.48	7.89	10.72	1.48	7.94	11.22	1.47	8.00
10.24	1.48	7.89	10.74	1.48	7.95	11.24	1.47	8.00
10.26	1.48	7.90	10.76	1.48	7.95	11.26	1.47	8.00
10.28	1.48	7.90	10.78	1.48	7.95	11.28	1.47	8.00
10.30	1.48	7.90	10.80	1.47	7.95	11.30	1.47	8.00
10.32	1.48	7.90	10.82	1.47	7.96	11.32	1.47	8.01
10.34	1.48	7.90	10.84	1.47	7.96	11.34	1.47	8.01
10.36	1.48	7.91	10.86	1.47	7.96	11.36	1.47	8.01
10.38	1.48	7.91	10.88	1.47	7.96	11.38	1.47	8.01
10.40	1.48	7.91	10.90	1.47	7.96	11.40	1.47	8.01
10.42	1.48	7.91	10.92	1.47	7.97	11.42	1.47	8.01
10.44	1.48	7.92	10.94	1.47	7.97	11.44	1.47	8.02
10.46	1.48	7.92	10.96	1.47	7.97	11.46	1.47	8.02
10.48	1.48	7.92	10.98	1.47	7.97	11.48	1.47	8.02
10.50	1.48	7.92	11.00	1.47	7.97	11.50	1.47	8.02

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
11.52	1.47	8.02	12.02	1.47	8.07	12.52	1.47	8.11
11.54	1.47	8.03	12.04	1.47	8.07	12.54	1.47	8.12
11.56	1.47	8.03	12.06	1.47	8.07	12.56	1.47	8.12
11.58	1.47	8.03	12.08	1.47	8.08	12.58	1.47	8.12
11.60	1.47	8.03	12.10	1.47	8.08	12.60	1.47	8.12
11.62	1.47	8.03	12.12	1.47	8.08	12.62	1.47	8.12
11.64	1.47	8.04	12.14	1.47	8.08	12.64	1.47	8.12
11.66	1.47	8.04	12.16	1.47	8.08	12.66	1.47	8.13
11.68	1.47	8.04	12.18	1.47	8.08	12.68	1.47	8.13
11.70	1.47	8.04	12.20	1.47	8.09	12.70	1.47	8.13
11.72	1.47	8.04	12.22	1.47	8.09	12.72	1.47	8.13
11.74	1.47	8.05	12.24	1.47	8.09	12.74	1.47	8.13
11.76	1.47	8.05	12.26	1.47	8.09	12.76	1.47	8.13
11.78	1.47	8.05	12.28	1.47	8.09	12.78	1.47	8.14
11.80	1.47	8.05	12.30	1.47	8.10	12.80	1.47	8.14
11.82	1.47	8.05	12.32	1.47	8.10	12.82	1.47	8.14
11.84	1.47	8.05	12.34	1.47	8.10	12.84	1.47	8.14
11.86	1.47	8.06	12.36	1.47	8.10	12.86	1.47	8.14
11.88	1.47	8.06	12.38	1.47	8.10	12.88	1.47	8.14
11.90	1.47	8.06	12.40	1.47	8.10	12.90	1.47	8.15
11.92	1.47	8.06	12.42	1.47	8.11	12.92	1.47	8.15
11.94	1.47	8.06	12.44	1.47	8.11	12.94	1.47	8.15
11.96	1.47	8.07	12.46	1.47	8.11	12.96	1.47	8.15
11.98	1.47	8.07	12.48	1.47	8.11	12.98	1.47	8.15
12.00	1.47	8.07	12.50	1.47	8.11	13.00	1.47	8.15

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
13.02	1.47	8.16	13.52	1.46	8.19	14.02	1.46	8.23
13.04	1.47	8.16	13.54	1.46	8.20	14.04	1.46	8.23
13.06	1.47	8.16	13.56	1.46	8.20	14.06	1.46	8.23
13.08	1.47	8.16	13.58	1.46	8.20	14.08	1.46	8.24
13.10	1.47	8.16	13.60	1.46	8.20	14.10	1.46	8.24
13.12	1.47	8.16	13.62	1.46	8.20	14.12	1.46	8.24
13.14	1.47	8.16	13.64	1.46	8.20	14.14	1.46	8.24
13.16	1.47	8.17	13.66	1.46	8.20	14.16	1.46	8.24
13.18	1.47	8.17	13.68	1.46	8.21	14.18	1.46	8.24
13.20	1.47	8.17	13.70	1.46	8.21	14.20	1.46	8.24
13.22	1.47	8.17	13.72	1.46	8.21	14.22	1.46	8.25
13.24	1.47	8.17	13.74	1.46	8.21	14.24	1.46	8.25
13.26	1.47	8.17	13.76	1.46	8.21	14.26	1.46	8.25
13.28	1.46	8.18	13.78	1.46	8.21	14.28	1.46	8.25
13.30	1.46	8.18	13.80	1.46	8.22	14.30	1.46	8.25
13.32	1.46	8.18	13.82	1.46	8.22	14.32	1.46	8.25
13.34	1.46	8.18	13.84	1.46	8.22	14.34	1.46	8.25
13.36	1.46	8.18	13.86	1.46	8.22	14.36	1.46	8.26
13.38	1.46	8.18	13.88	1.46	8.22	14.38	1.46	8.26
13.40	1.46	8.19	13.90	1.46	8.22	14.40	1.46	8.26
13.42	1.46	8.19	13.92	1.46	8.22	14.42	1.46	8.26
13.44	1.46	8.19	13.94	1.46	8.23	14.44	1.46	8.26
13.46	1.46	8.19	13.96	1.46	8.23	14.46	1.46	8.26
13.48	1.46	8.19	13.98	1.46	8.23	14.48	1.46	8.26
13.50	1.46	8.19	14.00	1.46	8.23	14.50	1.46	8.27

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
14.52	1.46	8.27	15.02	1.46	8.30	15.52	1.46	8.33
14.54	1.46	8.27	15.04	1.46	8.30	15.54	1.46	8.33
14.56	1.46	8.27	15.06	1.46	8.30	15.56	1.46	8.33
14.58	1.46	8.27	15.08	1.46	8.30	15.58	1.46	8.34
14.60	1.46	8.27	15.10	1.46	8.31	15.60	1.46	8.34
14.62	1.46	8.27	15.12	1.46	8.31	15.62	1.46	8.34
14.64	1.46	8.27	15.14	1.46	8.31	15.64	1.46	8.34
14.66	1.46	8.28	15.16	1.46	8.31	15.66	1.46	8.34
14.68	1.46	8.28	15.18	1.46	8.31	15.68	1.46	8.34
14.70	1.46	8.28	15.20	1.46	8.31	15.70	1.46	8.34
14.72	1.46	8.28	15.22	1.46	8.31	15.72	1.45	8.34
14.74	1.46	8.28	15.24	1.46	8.31	15.74	1.45	8.35
14.76	1.46	8.28	15.26	1.46	8.32	15.76	1.45	8.35
14.78	1.46	8.28	15.28	1.46	8.32	15.78	1.45	8.35
14.80	1.46	8.29	15.30	1.46	8.32	15.80	1.45	8.35
14.82	1.46	8.29	15.32	1.46	8.32	15.82	1.45	8.35
14.84	1.46	8.29	15.34	1.46	8.32	15.84	1.45	8.35
14.86	1.46	8.29	15.36	1.46	8.32	15.86	1.45	8.35
14.88	1.46	8.29	15.38	1.46	8.32	15.88	1.45	8.35
14.90	1.46	8.29	15.40	1.46	8.32	15.90	1.45	8.35
14.92	1.46	8.29	15.42	1.46	8.33	15.92	1.45	8.36
14.94	1.46	8.29	15.44	1.46	8.33	15.94	1.45	8.36
14.96	1.46	8.30	15.46	1.46	8.33	15.96	1.45	8.36
14.98	1.46	8.30	15.48	1.46	8.33	15.98	1.45	8.36
15.00	1.46	8.30	15.50	1.46	8.33	16.00	1.45	8.36

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
16.02	1.45	8.36	16.52	1.45	8.39	17.02	1.45	8.42
16.04	1.45	8.36	16.54	1.45	8.39	17.04	1.45	8.42
16.06	1.45	8.36	16.56	1.45	8.39	17.06	1.45	8.42
16.08	1.45	8.37	16.58	1.45	8.39	17.08	1.45	8.42
16.10	1.45	8.37	16.60	1.45	8.40	17.10	1.45	8.42
16.12	1.45	8.37	16.62	1.45	8.40	17.12	1.45	8.42
16.14	1.45	8.37	16.64	1.45	8.40	17.14	1.45	8.43
16.16	1.45	8.37	16.66	1.45	8.40	17.16	1.45	8.43
16.18	1.45	8.37	16.68	1.45	8.40	17.18	1.45	8.43
16.20	1.45	8.37	16.70	1.45	8.40	17.20	1.45	8.43
16.22	1.45	8.37	16.72	1.45	8.40	17.22	1.45	8.43
16.24	1.45	8.38	16.74	1.45	8.40	17.24	1.45	8.43
16.26	1.45	8.38	16.76	1.45	8.40	17.26	1.45	8.43
16.28	1.45	8.38	16.78	1.45	8.41	17.28	1.45	8.43
16.30	1.45	8.38	16.80	1.45	8.41	17.30	1.45	8.43
16.32	1.45	8.38	16.82	1.45	8.41	17.32	1.45	8.43
16.34	1.45	8.38	16.84	1.45	8.41	17.34	1.45	8.44
16.36	1.45	8.38	16.86	1.45	8.41	17.36	1.45	8.44
16.38	1.45	8.38	16.88	1.45	8.41	17.38	1.45	8.44
16.40	1.45	8.38	16.90	1.45	8.41	17.40	1.45	8.44
16.42	1.45	8.39	16.92	1.45	8.41	17.42	1.45	8.44
16.44	1.45	8.39	16.94	1.45	8.41	17.44	1.45	8.44
16.46	1.45	8.39	16.96	1.45	8.42	17.46	1.45	8.44
16.48	1.45	8.39	16.98	1.45	8.42	17.48	1.45	8.44
16.50	1.45	8.39	17.00	1.45	8.42	17.50	1.45	8.44

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
17.52	1.45	8.44	18.02	1.45	8.47	18.52	1.44	8.49
17.54	1.45	8.45	18.04	1.45	8.47	18.54	1.44	8.49
17.56	1.45	8.45	18.06	1.45	8.47	18.56	1.44	8.50
17.58	1.45	8.45	18.08	1.45	8.47	18.58	1.44	8.50
17.60	1.45	8.45	18.10	1.45	8.47	18.60	1.44	8.50
17.62	1.45	8.45	18.12	1.45	8.47	18.62	1.44	8.50
17.64	1.45	8.45	18.14	1.45	8.48	18.64	1.44	8.50
17.66	1.45	8.45	18.16	1.44	8.48	18.66	1.44	8.50
17.68	1.45	8.45	18.18	1.44	8.48	18.68	1.44	8.50
17.70	1.45	8.45	18.20	1.44	8.48	18.70	1.44	8.50
17.72	1.45	8.46	18.22	1.44	8.48	18.72	1.44	8.50
17.74	1.45	8.46	18.24	1.44	8.48	18.74	1.44	8.50
17.76	1.45	8.46	18.26	1.44	8.48	18.76	1.44	8.51
17.78	1.45	8.46	18.28	1.44	8.48	18.78	1.44	8.51
17.80	1.45	8.46	18.30	1.44	8.48	18.80	1.44	8.51
17.82	1.45	8.46	18.32	1.44	8.48	18.82	1.44	8.51
17.84	1.45	8.46	18.34	1.44	8.49	18.84	1.44	8.51
17.86	1.45	8.46	18.36	1.44	8.49	18.86	1.44	8.51
17.88	1.45	8.46	18.38	1.44	8.49	18.88	1.44	8.51
17.90	1.45	8.46	18.40	1.44	8.49	18.90	1.44	8.51
17.92	1.45	8.47	18.42	1.44	8.49	18.92	1.44	8.51
17.94	1.45	8.47	18.44	1.44	8.49	18.94	1.44	8.51
17.96	1.45	8.47	18.46	1.44	8.49	18.96	1.44	8.51
17.98	1.45	8.47	18.48	1.44	8.49	18.98	1.44	8.52
18.00	1.45	8.47	18.50	1.44	8.49	19.00	1.44	8.52

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
19.02	1.44	8.52	19.52	1.44	8.54	20.02	1.44	8.56
19.04	1.44	8.52	19.54	1.44	8.54	20.04	1.44	8.56
19.06	1.44	8.52	19.56	1.44	8.54	20.06	1.44	8.56
19.08	1.44	8.52	19.58	1.44	8.54	20.08	1.44	8.56
19.10	1.44	8.52	19.60	1.44	8.54	20.10	1.44	8.56
19.12	1.44	8.52	19.62	1.44	8.54	20.12	1.44	8.56
19.14	1.44	8.52	19.64	1.44	8.54	20.14	1.44	8.56
19.16	1.44	8.52	19.66	1.44	8.54	20.16	1.44	8.57
19.18	1.44	8.52	19.68	1.44	8.55	20.18	1.44	8.57
19.20	1.44	8.52	19.70	1.44	8.55	20.20	1.44	8.57
19.22	1.44	8.53	19.72	1.44	8.55	20.22	1.44	8.57
19.24	1.44	8.53	19.74	1.44	8.55	20.24	1.44	8.57
19.26	1.44	8.53	19.76	1.44	8.55	20.26	1.44	8.57
19.28	1.44	8.53	19.78	1.44	8.55	20.28	1.44	8.57
19.30	1.44	8.53	19.80	1.44	8.55	20.30	1.44	8.57
19.32	1.44	8.53	19.82	1.44	8.55	20.32	1.44	8.57
19.34	1.44	8.53	19.84	1.44	8.55	20.34	1.44	8.57
19.36	1.44	8.53	19.86	1.44	8.55	20.36	1.44	8.57
19.38	1.44	8.53	19.88	1.44	8.55	20.38	1.44	8.57
19.40	1.44	8.53	19.90	1.44	8.55	20.40	1.44	8.58
19.42	1.44	8.53	19.92	1.44	8.56	20.42	1.44	8.58
19.44	1.44	8.54	19.94	1.44	8.56	20.44	1.44	8.58
19.46	1.44	8.54	19.96	1.44	8.56	20.46	1.44	8.58
19.48	1.44	8.54	19.98	1.44	8.56	20.48	1.44	8.58
19.50	1.44	8.54	20.00	1.44	8.56	20.50	1.44	8.58

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
20.52	1.44	8.58	21.02	1.43	8.60	21.52	1.43	8.62
20.54	1.44	8.58	21.04	1.43	8.60	21.54	1.43	8.62
20.56	1.44	8.58	21.06	1.43	8.60	21.56	1.43	8.62
20.58	1.44	8.58	21.08	1.43	8.60	21.58	1.43	8.62
20.60	1.44	8.58	21.10	1.43	8.60	21.60	1.43	8.62
20.62	1.43	8.58	21.12	1.43	8.60	21.62	1.43	8.62
20.64	1.43	8.58	21.14	1.43	8.60	21.64	1.43	8.62
20.66	1.43	8.59	21.16	1.43	8.60	21.66	1.43	8.62
20.68	1.43	8.59	21.18	1.43	8.61	21.68	1.43	8.62
20.70	1.43	8.59	21.20	1.43	8.61	21.70	1.43	8.62
20.72	1.43	8.59	21.22	1.43	8.61	21.72	1.43	8.62
20.74	1.43	8.59	21.24	1.43	8.61	21.74	1.43	8.63
20.76	1.43	8.59	21.26	1.43	8.61	21.76	1.43	8.63
20.78	1.43	8.59	21.28	1.43	8.61	21.78	1.43	8.63
20.80	1.43	8.59	21.30	1.43	8.61	21.80	1.43	8.63
20.82	1.43	8.59	21.32	1.43	8.61	21.82	1.43	8.63
20.84	1.43	8.59	21.34	1.43	8.61	21.84	1.43	8.63
20.86	1.43	8.59	21.36	1.43	8.61	21.86	1.43	8.63
20.88	1.43	8.59	21.38	1.43	8.61	21.88	1.43	8.63
20.90	1.43	8.59	21.40	1.43	8.61	21.90	1.43	8.63
20.92	1.43	8.60	21.42	1.43	8.61	21.92	1.43	8.63
20.94	1.43	8.60	21.44	1.43	8.61	21.94	1.43	8.63
20.96	1.43	8.60	21.46	1.43	8.62	21.96	1.43	8.63
20.98	1.43	8.60	21.48	1.43	8.62	21.98	1.43	8.63
21.00	1.43	8.60	21.50	1.43	8.62	22.00	1.43	8.63

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
22.02	1.43	8.64	22.52	1.43	8.65	23.02	1.43	8.67
22.04	1.43	8.64	22.54	1.43	8.65	23.04	1.43	8.67
22.06	1.43	8.64	22.56	1.43	8.65	23.06	1.43	8.67
22.08	1.43	8.64	22.58	1.43	8.65	23.08	1.42	8.67
22.10	1.43	8.64	22.60	1.43	8.65	23.10	1.42	8.67
22.12	1.43	8.64	22.62	1.43	8.66	23.12	1.42	8.67
22.14	1.43	8.64	22.64	1.43	8.66	23.14	1.42	8.67
22.16	1.43	8.64	22.66	1.43	8.66	23.16	1.42	8.67
22.18	1.43	8.64	22.68	1.43	8.66	23.18	1.42	8.67
22.20	1.43	8.64	22.70	1.43	8.66	23.20	1.42	8.67
22.22	1.43	8.64	22.72	1.43	8.66	23.22	1.42	8.67
22.24	1.43	8.64	22.74	1.43	8.66	23.24	1.42	8.68
22.26	1.43	8.64	22.76	1.43	8.66	23.26	1.42	8.68
22.28	1.43	8.64	22.78	1.43	8.66	23.28	1.42	8.68
22.30	1.43	8.64	22.80	1.43	8.66	23.30	1.42	8.68
22.32	1.43	8.65	22.82	1.43	8.66	23.32	1.42	8.68
22.34	1.43	8.65	22.84	1.43	8.66	23.34	1.42	8.68
22.36	1.43	8.65	22.86	1.43	8.66	23.36	1.42	8.68
22.38	1.43	8.65	22.88	1.43	8.66	23.38	1.42	8.68
22.40	1.43	8.65	22.90	1.43	8.66	23.40	1.42	8.68
22.42	1.43	8.65	22.92	1.43	8.67	23.42	1.42	8.68
22.44	1.43	8.65	22.94	1.43	8.67	23.44	1.42	8.68
22.46	1.43	8.65	22.96	1.43	8.67	23.46	1.42	8.68
22.48	1.43	8.65	22.98	1.43	8.67	23.48	1.42	8.68
22.50	1.43	8.65	23.00	1.43	8.67	23.50	1.42	8.68

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
23.52	1.42	8.68	24.02	1.42	8.70	24.52	1.42	8.71
23.54	1.42	8.68	24.04	1.42	8.70	24.54	1.42	8.71
23.56	1.42	8.69	24.06	1.42	8.70	24.56	1.42	8.71
23.58	1.42	8.69	24.08	1.42	8.70	24.58	1.42	8.71
23.60	1.42	8.69	24.10	1.42	8.70	24.60	1.42	8.72
23.62	1.42	8.69	24.12	1.42	8.70	24.62	1.42	8.72
23.64	1.42	8.69	24.14	1.42	8.70	24.64	1.42	8.72
23.66	1.42	8.69	24.16	1.42	8.70	24.66	1.42	8.72
23.68	1.42	8.69	24.18	1.42	8.70	24.68	1.42	8.72
23.70	1.42	8.69	24.20	1.42	8.70	24.70	1.42	8.72
23.72	1.42	8.69	24.22	1.42	8.70	24.72	1.42	8.72
23.74	1.42	8.69	24.24	1.42	8.71	24.74	1.42	8.72
23.76	1.42	8.69	24.26	1.42	8.71	24.76	1.42	8.72
23.78	1.42	8.69	24.28	1.42	8.71	24.78	1.42	8.72
23.80	1.42	8.69	24.30	1.42	8.71	24.80	1.42	8.72
23.82	1.42	8.69	24.32	1.42	8.71	24.82	1.42	8.72
23.84	1.42	8.69	24.34	1.42	8.71	24.84	1.42	8.72
23.86	1.42	8.69	24.36	1.42	8.71	24.86	1.42	8.72
23.88	1.42	8.69	24.38	1.42	8.71	24.88	1.42	8.72
23.90	1.42	8.70	24.40	1.42	8.71	24.90	1.42	8.72
23.92	1.42	8.70	24.42	1.42	8.71	24.92	1.42	8.72
23.94	1.42	8.70	24.44	1.42	8.71	24.94	1.42	8.72
23.96	1.42	8.70	24.46	1.42	8.71	24.96	1.42	8.73
23.98	1.42	8.70	24.48	1.42	8.71	24.98	1.42	8.73
24.00	1.42	8.70	24.50	1.42	8.71	25.00	1.42	8.73

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**	**Volume factor**	**Calcite SI**	**Mg-silicateSI**
25.02	1.42	8.73	25.52	1.42	8.74	26.02	1.41	8.75
25.04	1.42	8.73	25.54	1.42	8.74	26.04	1.41	8.75
25.06	1.42	8.73	25.56	1.41	8.74	26.06	1.41	8.75
25.08	1.42	8.73	25.58	1.41	8.74	26.08	1.41	8.75
25.10	1.42	8.73	25.60	1.41	8.74	26.10	1.41	8.75
25.12	1.42	8.73	25.62	1.41	8.74	26.12	1.41	8.76
25.14	1.42	8.73	25.64	1.41	8.74	26.14	1.41	8.76
25.16	1.42	8.73	25.66	1.41	8.74	26.16	1.41	8.76
25.18	1.42	8.73	25.68	1.41	8.74	26.18	1.41	8.76
25.20	1.42	8.73	25.70	1.41	8.74	26.20	1.41	8.76
25.22	1.42	8.73	25.72	1.41	8.75	26.22	1.41	8.76
25.24	1.42	8.73	25.74	1.41	8.75	26.24	1.41	8.76
25.26	1.42	8.73	25.76	1.41	8.75	26.26	1.41	8.76
25.28	1.42	8.73	25.78	1.41	8.75	26.28	1.41	8.76
25.30	1.42	8.73	25.80	1.41	8.75	26.30	1.41	8.76
25.32	1.42	8.73	25.82	1.41	8.75	26.32	1.41	8.76
25.34	1.42	8.74	25.84	1.41	8.75	26.34	1.41	8.76
25.36	1.42	8.74	25.86	1.41	8.75	26.36	1.41	8.76
25.38	1.42	8.74	25.88	1.41	8.75	26.38	1.41	8.76
25.40	1.42	8.74	25.90	1.41	8.75	26.40	1.41	8.76
25.42	1.42	8.74	25.92	1.41	8.75	26.42	1.41	8.76
25.44	1.42	8.74	25.94	1.41	8.75	26.44	1.41	8.76
25.46	1.42	8.74	25.96	1.41	8.75	26.46	1.41	8.76
25.48	1.42	8.74	25.98	1.41	8.75	26.48	1.41	8.76
25.50	1.42	8.74	26.00	1.41	8.75	26.50	1.41	8.76

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
26.52	1.41	8.76	27.02	1.41	8.78	27.52	1.41	8.79
26.54	1.41	8.77	27.04	1.41	8.78	27.54	1.41	8.79
26.56	1.41	8.77	27.06	1.41	8.78	27.56	1.41	8.79
26.58	1.41	8.77	27.08	1.41	8.78	27.58	1.41	8.79
26.60	1.41	8.77	27.10	1.41	8.78	27.60	1.41	8.79
26.62	1.41	8.77	27.12	1.41	8.78	27.62	1.41	8.79
26.64	1.41	8.77	27.14	1.41	8.78	27.64	1.41	8.79
26.66	1.41	8.77	27.16	1.41	8.78	27.66	1.41	8.79
26.68	1.41	8.77	27.18	1.41	8.78	27.68	1.41	8.79
26.70	1.41	8.77	27.20	1.41	8.78	27.70	1.41	8.79
26.72	1.41	8.77	27.22	1.41	8.78	27.72	1.41	8.79
26.74	1.41	8.77	27.24	1.41	8.78	27.74	1.41	8.79
26.76	1.41	8.77	27.26	1.41	8.78	27.76	1.41	8.79
26.78	1.41	8.77	27.28	1.41	8.78	27.78	1.41	8.79
26.80	1.41	8.77	27.30	1.41	8.78	27.80	1.41	8.79
26.82	1.41	8.77	27.32	1.41	8.78	27.82	1.41	8.79
26.84	1.41	8.77	27.34	1.41	8.78	27.84	1.41	8.79
26.86	1.41	8.77	27.36	1.41	8.78	27.86	1.41	8.79
26.88	1.41	8.77	27.38	1.41	8.78	27.88	1.41	8.80
26.90	1.41	8.77	27.40	1.41	8.78	27.90	1.41	8.80
26.92	1.41	8.77	27.42	1.41	8.79	27.92	1.41	8.80
26.94	1.41	8.77	27.44	1.41	8.79	27.94	1.41	8.80
26.96	1.41	8.77	27.46	1.41	8.79	27.96	1.41	8.80
26.98	1.41	8.78	27.48	1.41	8.79	27.98	1.41	8.80
27.00	1.41	8.78	27.50	1.41	8.79	28.00	1.41	8.80

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
28.02	1.41	8.80	28.52	1.40	8.81	29.02	1.40	8.82
28.04	1.41	8.80	28.54	1.40	8.81	29.04	1.40	8.82
28.06	1.40	8.80	28.56	1.40	8.81	29.06	1.40	8.82
28.08	1.40	8.80	28.58	1.40	8.81	29.08	1.40	8.82
28.10	1.40	8.80	28.60	1.40	8.81	29.10	1.40	8.82
28.12	1.40	8.80	28.62	1.40	8.81	29.12	1.40	8.82
28.14	1.40	8.80	28.64	1.40	8.81	29.14	1.40	8.82
28.16	1.40	8.80	28.66	1.40	8.81	29.16	1.40	8.82
28.18	1.40	8.80	28.68	1.40	8.81	29.18	1.40	8.82
28.20	1.40	8.80	28.70	1.40	8.81	29.20	1.40	8.82
28.22	1.40	8.80	28.72	1.40	8.81	29.22	1.40	8.82
28.24	1.40	8.80	28.74	1.40	8.81	29.24	1.40	8.82
28.26	1.40	8.80	28.76	1.40	8.81	29.26	1.40	8.82
28.28	1.40	8.80	28.78	1.40	8.81	29.28	1.40	8.82
28.30	1.40	8.80	28.80	1.40	8.81	29.30	1.40	8.82
28.32	1.40	8.80	28.82	1.40	8.81	29.32	1.40	8.82
28.34	1.40	8.80	28.84	1.40	8.81	29.34	1.40	8.82
28.36	1.40	8.81	28.86	1.40	8.81	29.36	1.40	8.82
28.38	1.40	8.81	28.88	1.40	8.82	29.38	1.40	8.82
28.40	1.40	8.81	28.90	1.40	8.82	29.40	1.40	8.83
28.42	1.40	8.81	28.92	1.40	8.82	29.42	1.40	8.83
28.44	1.40	8.81	28.94	1.40	8.82	29.44	1.40	8.83
28.46	1.40	8.81	28.96	1.40	8.82	29.46	1.40	8.83
28.48	1.40	8.81	28.98	1.40	8.82	29.48	1.40	8.83
28.50	1.40	8.81	29.00	1.40	8.82	29.50	1.40	8.83

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
29.52	1.40	8.83	30.02	1.40	8.84	30.52	1.40	8.85
29.54	1.40	8.83	30.04	1.40	8.84	30.54	1.40	8.85
29.56	1.40	8.83	30.06	1.40	8.84	30.56	1.40	8.85
29.58	1.40	8.83	30.08	1.40	8.84	30.58	1.39	8.85
29.60	1.40	8.83	30.10	1.40	8.84	30.60	1.39	8.85
29.62	1.40	8.83	30.12	1.40	8.84	30.62	1.39	8.85
29.64	1.40	8.83	30.14	1.40	8.84	30.64	1.39	8.85
29.66	1.40	8.83	30.16	1.40	8.84	30.66	1.39	8.85
29.68	1.40	8.83	30.18	1.40	8.84	30.68	1.39	8.85
29.70	1.40	8.83	30.20	1.40	8.84	30.70	1.39	8.85
29.72	1.40	8.83	30.22	1.40	8.84	30.72	1.39	8.85
29.74	1.40	8.83	30.24	1.40	8.84	30.74	1.39	8.85
29.76	1.40	8.83	30.26	1.40	8.84	30.76	1.39	8.85
29.78	1.40	8.83	30.28	1.40	8.84	30.78	1.39	8.85
29.80	1.40	8.83	30.30	1.40	8.84	30.80	1.39	8.85
29.82	1.40	8.83	30.32	1.40	8.84	30.82	1.39	8.85
29.84	1.40	8.83	30.34	1.40	8.84	30.84	1.39	8.85
29.86	1.40	8.83	30.36	1.40	8.84	30.86	1.39	8.85
29.88	1.40	8.83	30.38	1.40	8.84	30.88	1.39	8.85
29.90	1.40	8.83	30.40	1.40	8.84	30.90	1.39	8.85
29.92	1.40	8.83	30.42	1.40	8.84	30.92	1.39	8.85
29.94	1.40	8.84	30.44	1.40	8.84	30.94	1.39	8.85
29.96	1.40	8.84	30.46	1.40	8.84	30.96	1.39	8.85
29.98	1.40	8.84	30.48	1.40	8.84	30.98	1.39	8.85
30.00	1.40	8.84	30.50	1.40	8.84	31.00	1.39	8.85

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
31.02	1.39	8.85	31.50	1.39	8.86	31.98	1.39	8.87
31.04	1.39	8.85	31.52	1.39	8.86	32.00	1.39	8.87
31.06	1.39	8.85	31.54	1.39	8.86	32.02	1.39	8.87
31.08	1.39	8.85	31.56	1.39	8.86	32.04	1.39	8.87
31.10	1.39	8.85	31.58	1.39	8.86	32.06	1.39	8.87
31.12	1.39	8.85	31.60	1.39	8.86	32.08	1.39	8.87
31.14	1.39	8.86	31.62	1.39	8.86	32.10	1.39	8.87
31.16	1.39	8.86	31.64	1.39	8.86	32.12	1.39	8.87
31.18	1.39	8.86	31.66	1.39	8.86	32.14	1.39	8.87
31.20	1.39	8.86	31.68	1.39	8.86	32.16	1.39	8.87
31.22	1.39	8.86	31.70	1.39	8.86	32.18	1.39	8.87
31.24	1.39	8.86	31.72	1.39	8.86	32.20	1.39	8.87
31.26	1.39	8.86	31.74	1.39	8.86	32.22	1.39	8.87
31.28	1.39	8.86	31.76	1.39	8.86	32.24	1.39	8.87
31.30	1.39	8.86	31.78	1.39	8.87	32.26	1.39	8.87
31.32	1.39	8.86	31.80	1.39	8.87	32.28	1.39	8.87
31.34	1.39	8.86	31.82	1.39	8.87	32.30	1.39	8.87
31.36	1.39	8.86	31.84	1.39	8.87	32.32	1.39	8.87
31.38	1.39	8.86	31.86	1.39	8.87	32.34	1.39	8.87
31.40	1.39	8.86	31.88	1.39	8.87	32.36	1.39	8.87
31.42	1.39	8.86	31.90	1.39	8.87	32.38	1.39	8.87
31.44	1.39	8.86	31.92	1.39	8.87	32.40	1.39	8.87
31.46	1.39	8.86	31.94	1.39	8.87	32.42	1.39	8.87
31.48	1.39	8.86	31.96	1.39	8.87	32.44	1.39	8.87

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
32.46	1.39	8.88	32.96	1.39	8.88	33.46	1.38	8.89
32.48	1.39	8.88	32.98	1.39	8.88	33.48	1.38	8.89
32.50	1.39	8.88	33.00	1.39	8.88	33.50	1.38	8.89
32.52	1.39	8.88	33.02	1.39	8.88	33.52	1.38	8.89
32.54	1.39	8.88	33.04	1.39	8.88	33.54	1.38	8.89
32.56	1.39	8.88	33.06	1.39	8.88	33.56	1.38	8.89
32.58	1.39	8.88	33.08	1.39	8.88	33.58	1.38	8.89
32.60	1.39	8.88	33.10	1.39	8.88	33.60	1.38	8.89
32.62	1.39	8.88	33.12	1.38	8.88	33.62	1.38	8.89
32.64	1.39	8.88	33.14	1.38	8.88	33.64	1.38	8.89
32.66	1.39	8.88	33.16	1.38	8.88	33.66	1.38	8.89
32.68	1.39	8.88	33.18	1.38	8.89	33.68	1.38	8.89
32.70	1.39	8.88	33.20	1.38	8.89	33.70	1.38	8.89
32.72	1.39	8.88	33.22	1.38	8.89	33.72	1.38	8.89
32.74	1.39	8.88	33.24	1.38	8.89	33.74	1.38	8.89
32.76	1.39	8.88	33.26	1.38	8.89	33.76	1.38	8.89
32.78	1.39	8.88	33.28	1.38	8.89	33.78	1.38	8.89
32.80	1.39	8.88	33.30	1.38	8.89	33.80	1.38	8.89
32.82	1.39	8.88	33.32	1.38	8.89	33.82	1.38	8.89
32.84	1.39	8.88	33.34	1.38	8.89	33.84	1.38	8.89
32.86	1.39	8.88	33.36	1.38	8.89	33.86	1.38	8.89
32.88	1.39	8.88	33.38	1.38	8.89	33.88	1.38	8.89
32.90	1.39	8.88	33.40	1.38	8.89	33.90	1.38	8.89
32.92	1.39	8.88	33.42	1.38	8.89	33.92	1.38	8.89
32.94	1.39	8.88	33.44	1.38	8.89	33.94	1.38	8.89

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
33.96	1.38	8.90	34.46	1.38	8.90	34.96	1.38	8.91
33.98	1.38	8.90	34.48	1.38	8.90	34.98	1.38	8.91
34.00	1.38	8.90	34.50	1.38	8.90	35.00	1.38	8.91
34.02	1.38	8.90	34.52	1.38	8.90	35.02	1.38	8.91
34.04	1.38	8.90	34.54	1.38	8.90	35.04	1.38	8.91
34.06	1.38	8.90	34.56	1.38	8.90	35.06	1.38	8.91
34.08	1.38	8.90	34.58	1.38	8.90	35.08	1.38	8.91
34.10	1.38	8.90	34.60	1.38	8.90	35.10	1.38	8.91
34.12	1.38	8.90	34.62	1.38	8.90	35.12	1.38	8.91
34.14	1.38	8.90	34.64	1.38	8.90	35.14	1.38	8.91
34.16	1.38	8.90	34.66	1.38	8.90	35.16	1.38	8.91
34.18	1.38	8.90	34.68	1.38	8.90	35.18	1.38	8.91
34.20	1.38	8.90	34.70	1.38	8.90	35.20	1.38	8.91
34.22	1.38	8.90	34.72	1.38	8.90	35.22	1.38	8.91
34.24	1.38	8.90	34.74	1.38	8.90	35.24	1.38	8.91
34.26	1.38	8.90	34.76	1.38	8.90	35.26	1.38	8.91
34.28	1.38	8.90	34.78	1.38	8.90	35.28	1.38	8.91
34.30	1.38	8.90	34.80	1.38	8.91	35.30	1.38	8.91
34.32	1.38	8.90	34.82	1.38	8.91	35.32	1.38	8.91
34.34	1.38	8.90	34.84	1.38	8.91	35.34	1.38	8.91
34.36	1.38	8.90	34.86	1.38	8.91	35.36	1.38	8.91
34.38	1.38	8.90	34.88	1.38	8.91	35.38	1.38	8.91
34.40	1.38	8.90	34.90	1.38	8.91	35.40	1.38	8.91
34.42	1.38	8.90	34.92	1.38	8.91	35.42	1.38	8.91
34.44	1.38	8.90	34.94	1.38	8.91	35.44	1.38	8.91

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI	Volume factor	Calcite SI	Mg-silicateSI
35.46	1.38	8.91	35.96	1.37	8.92	36.46	1.37	8.92
35.48	1.38	8.91	35.98	1.37	8.92	36.48	1.37	8.92
35.50	1.38	8.91	36.00	1.37	8.92	36.50	1.37	8.92
35.52	1.38	8.91	36.02	1.37	8.92	36.52	1.37	8.92
35.54	1.38	8.91	36.04	1.37	8.92	36.54	1.37	8.92
35.56	1.38	8.91	36.06	1.37	8.92	36.56	1.37	8.92
35.58	1.38	8.91	36.08	1.37	8.92	36.58	1.37	8.92
35.60	1.38	8.91	36.10	1.37	8.92	36.60	1.37	8.92
35.62	1.38	8.91	36.12	1.37	8.92	36.62	1.37	8.92
35.64	1.38	8.91	36.14	1.37	8.92	36.64	1.37	8.92
35.66	1.38	8.91	36.16	1.37	8.92	36.66	1.37	8.92
35.68	1.37	8.91	36.18	1.37	8.92	36.68	1.37	8.92
35.70	1.37	8.91	36.20	1.37	8.92	36.70	1.37	8.92
35.72	1.37	8.92	36.22	1.37	8.92	36.72	1.37	8.93
35.74	1.37	8.92	36.24	1.37	8.92	36.74	1.37	8.93
35.76	1.37	8.92	36.26	1.37	8.92	36.76	1.37	8.93
35.78	1.37	8.92	36.28	1.37	8.92	36.78	1.37	8.93
35.80	1.37	8.92	36.30	1.37	8.92	36.80	1.37	8.93
35.82	1.37	8.92	36.32	1.37	8.92	36.82	1.37	8.93
35.84	1.37	8.92	36.34	1.37	8.92	36.84	1.37	8.93
35.86	1.37	8.92	36.36	1.37	8.92	36.86	1.37	8.93
35.88	1.37	8.92	36.38	1.37	8.92	36.88	1.37	8.93
35.90	1.37	8.92	36.40	1.37	8.92	36.90	1.37	8.93
35.92	1.37	8.92	36.42	1.37	8.92	36.92	1.37	8.93
35.94	1.37	8.92	36.44	1.37	8.92	36.94	1.37	8.93

Appendix 2e- Results of E&M model simulation for average creek water in Mono Lake basin.

Volume factor	Calcite SI	Mg-silicateSI
36.96	1.37	8.93
36.98	1.37	8.93
37.00	1.37	8.93
37.02	1.37	8.93
37.04	1.37	8.93
37.06	1.37	8.93
37.08	1.37	8.93
37.10	1.37	8.93
37.12	1.37	8.93
37.14	1.37	8.93
37.16	1.37	8.93
37.18	1.37	8.93
37.20	1.37	8.93
37.22	1.37	8.93
37.24	1.37	8.93
37.26	1.37	8.93
37.28	1.37	8.93
37.30	1.37	8.93
37.32	1.37	8.93
37.34	1.37	8.93
37.36	1.37	8.93
37.38	1.37	8.93
37.40	1.37	8.93
37.42	1.37	8.93
37.44	1.37	8.93
37.46	1.37	8.93
37.48	1.37	8.93
37.50	1.37	8.93
37.52	1.37	8.93
37.54	1.37	8.93
37.56	1.37	8.93
37.58	1.37	8.93
37.60	1.37	8.93

References

Chapter-Introduction:

Anderson, R.F., Bacon M.P., Brewer P.G. (1982). Elevated Concentrations of Actinides in Mono Lake. *Science* **216**, 514-516.

Banfield, J.F., Jones B.F. and Veblen D.R. (1991) An AEM-TEM study of weathering and diagenesis, Abert Lake, Oregon: II. Diagenetic modification of the sedimentary assemblage. *Geochimica et Cosmochimica Acta,* **55**, 2795-2810.

Bailey, R. A., Dalrymple G.B. and Lanphere M. (1976). Volcanism, Structure, and Geochronology of Long Valley Caldera, Mono County, California. *Journal of Geophysical Research,* **81(5)**, 725-744.

Benson, L.V., Currey D.R., Lajoie K.R., Oviatt C.G., Robinson S.W., Smith G.I., Stine S. (1990). Chronology of expansion and contraction of four Great Basin lake systems during the past 35,000 years. *Palaeogeography, Palaeoclimatology and Palaeoecology,* **78(3-4)**, 241-286.

Benson, L.V., Lund S.P., Burdett J.W., Kashgarian M., Rose T.P., Smoot J.P. and Schwartz M. (1998). Correlation of Late-Pleistocene Lake-Level oscillations in Mono Lake, California, with North Atlantic Climate Events. *Quaternary Research,* **49**, 1-10.

Bethke, C.M. and Yeakel, S. (2008) The Geochemists' Workbench® Reference Manual, University of Illinois, 295p.

Bischoff, J.L., Fitts J.P., Fitzpatrick J.A. (1997). Responses of sediment geochemistry to climate change in Owens Lake sediment: In "An 800,000-year Palaeoclimate Recordfrom core Ol-92, Owens Lake, Southeast California" (In: Smith, G.I., Bischoff, J.L. Eds.),. *Geological Society of America Special Paper,* **317**, 37-47.

Bischoff, J.L., Stine S., Rosenbauer R. J., Fitzpatrick J. A., and Stafford T. W. Jr. (1993). Ikaite coprecipitation by mixing of shoreline springs and lake water, Mono Lake, California, USA. *Geochimica et Cosmochimica. Acta,* **57**, 3855-3865.

Bursik, Marcus and Sieh Kerry. (1989). Range Front Faulting and Volcanism in the Mono Basin, Eastern California. *Journal of Geophysical Research,* **94**(B11), 15,587-15,609.

Chen, Y., Evensen, N.M., York D., and Lajoie K.R. (1996) The Edge of Time: Dating Young Volcanic Ash Layers with Ar^{40}-Ar^{39} Ar Laser Probe. *Science*, **274**, 1176-1178.

Conell, T.L. and Dreiss S. J. (1995). Chemical Evolution of Shallow Groundwater Along the Northeast Shore of Mono Lake, California. *Water Resources Research*, 31(12), 3171-3182.

Eugster, H.P., and Hardie L.A. (1978). Saline Lakes In: A. Lerman (Ed.), Lakes- Chemistry, Geology, Physics (pp. 237-293), New York: Springer-Verlag.

Eugster, H.P., Harvie C.E. and Weare J.H. (1980). Mineral equilibria in the six- component seawater system, Na-K-Mg-Ca-Cl-SO_4-H_2O at 25°C. *Geochimica et Cosmochimica Acta*, **44**, 1335-1347.

Eugster, H.P., and Jones B.F. (1979). Behavior of major solutes during closed-basin brine evolution. American Journal of Science, **279**, 609-631.

Eugster, H.P. and Maglione G. (1979). Brines and evaporates of the Lake Chad basin, Africa. *Geochimica et Cosmochimica Acta,* **43**, 973-982.

Gac, J. Y., Al Droubi A., Fritz B. and Tardy Y. (1977) Geochemical behavior of silica and magnesium during the evaporation of waters in Chad. *Chemical Geology,* **19**, 215-228.

Garrels, R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Gilbert, C.M., Christensen M.N., Al-Rawi, Lajoie K.R .(1968) Structural and volcanic history of Mono Basin, California-Nevada, in Studies in Volcanology, edited by R.R. Coates, R.L. Hay and C.A. Anderson. *Memoir Geological Society of America,* **116**, 275-329.

Hardie, L.A. and Eugster H.P. (1970). The evolution of closed-basin brines. *Mineralogical Society of America. Special Publication,* **3**, 273-290.

Harvie, C.E., Eugster H.P. and Weare J.H. (1982) Mineral equilibria in the six-component seawater system , Na-K-Mg-Ca-Cl-SO_4-H_2O at 25°C. II: Compositions of the saturated solutions. *Geochimica et Cosmochimica Acta,* **46**, 1603-1618.

Harvie, C.E., Moller N. and Weare J.H. (1984). The prediction of mineral solubilities in natural waters : The Na-K-Mg-Ca-H-Cl-SO_4-OH-HCO_3-CO_3-CO_2—H_2O system to high ionic strengths at 25°C. *Geochimica et Cosmochimica Acta*, **48**, 723-752.

Harvie, C.E. and Weare J.H. (1980). The prediction of mineral solubilities in natural waters: The Na-K-Mg-Ca-Cl-SO_4-H_2O system from zero to high concentrations at 25°C. *Geochimica et Cosmochimica Acta,* **44**, 981-997.

Harvie, C.E., Weare J.H., Hardie L.A., and Eugster H.P. (1980). Evaporation of seawater: Calculated mineral sequences. *Science,* **208**, 498-500.

Johannesson, K. H. and Lyons W.B. (1994). The rare earth element geochemistry of Mono Lake water and the importance of carbonate complexing. *Limnology and Oceanography,* **39(5)**, 1141-1154.

Johannesson, K.H., Lyons W.B. and Bird D.A. (1994). Rare earth element concentrations and speciation in alkaline lakes from the western U.S.A. *Geophysical Research Letters,* **21**, 773-776.

Jones, B. F. and Weir A. H. (1983) Clay minerals of Lake Abert, an alkaline saline lake. *Clays and Clay Minerals,* **31**, 161-172.

Lajoie, K.R. (1968). Quaternary Stratigraphy and geologic History of Mono Basin, Eastern California. PhD thesis, University of California, Berkeley.

Neumann, K. and Dreiss S.J. (1995). Strontium 87/Strontium 86 Ratios as Tracers in Groundwater and Surface Waters in Mono Basin, California. *Water Resources Research,* **31(12)**, 3183-3193.

Parkhurst, D.L. and Appelo, C.A.J. (1999) User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.

Reheis, M.C., Stine S., and Sarna-Wojcicki A.M. (2002). Drainage reversals in Mono Basin during the late Pliocene and Pleistocene. *Geological Society of America Bulletin,* **114(8)**, 991-1006.

Russell, I.C. (1889). Quaternary History of the Mono Valley, California. Artemisia Press, Lee Vining, CA.

Sahajpal, R., Zimmerman S.R.H., Datta S., Hemming N.G., and Hemming S.R. (2011) Assesing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA). *Geochimica et Cosmochimica Acta*, **75**, 7855-7863.

Simpson, H.J., Trier R.M., Toggweiler J.R., Mathieu G., Deck B.L., Olsen C.R. (1980). Fallout Plutonium in an Alkaline, Saline Lake. *Science*, **207**, 1071-1073.

Simpson, H.J., Trier R.M., Olsen C.R., Hammond D.E., Ege A., Miller L., Melack J.M. (1982). Radionuclides in Mono Lake, California. *Science*, **216**, 512-514.

Singer Arieh (1984) The Paleoclimatic Interpretation of Clay Minerals in Sediments. *Earth-Science Reviews*, **21**, 251-293

Stine, S. (1991). Geomorphic, geographic and hydrographic basis for resolving the Mono Lake controversy. *Environmental Geology and Water Sciences,* **17**, 67-83.

Tomascak, P.B., N.G. Hemming., Hemming S. R. (2003). The lithium isotopic composition of waters of the Mono Basin, California. *Geochimica et Cosmochimica. Acta,* **67(4)**, 601- 611.

Zimmerman, S.H., Hemming S., Kent D.V., Searle S. (2006) Revised chronology for late Pleistocene Mono Lake sediments based on paleointensity correlation to the global reference curve. *Earth and Planetary Science Letters,* **252**, p. 94-106

Zimmerman, S.H. (2006) Chronology and Paleoclimate Records of the Late Pleistocene Wilson Creek Formation at Mono Lake, California. PhD. Thesis. Columbia University, p 203.

Zimmerman, S.R.H., Pearl C., Hemming S.R., Tamulonis K., Hemming N.G. and Searle S.Y. (2011a) Freshwater control of ice rafted-debris in the last glacial period at Mono Lake, California, USA. *Quaternary Research*, **76**, 264-271.

Zimmerman, S.R.H., Hemming S.R., Hemming N.G., Tomascak P.B. and Pearl C. (2011b) High-resolution chemostratigraphic record of late Pleistocene lake-level variability, Mono Lake, California. *Geological Society of America Bulletin*, **123**, 2320-2334.

Chapter-1:

Anderson R.F., Bacon M.P., Brewer P.G. (1982). Elevated Concentrations of Actinides in Mono Lake. *Science*, **216**, 514-516.

Bacon S.N., Burke R.M., Pezzopane S.K. and Jayko A.S. (2006) Last glacial maximum and Holocene lake levels of Owens Lake, eastern California, USA. *Quaternary Science Reviews,* **25,** 1264–1282

Banfield J.F., Jones B.F. and Veblen D.R. (1991) An AEM-TEM study of weathering and diagenesis, Abert Lake, Oregon: II. Diagenetic modification of the sedimentary assemblage. *Geochimica et Cosmochimica Acta*, **55**, 2795-2810.

Bailey R. A., Dalrymple G.B. and Lanphere M. (1976). Volcanism, Structure, and Geochronology of Long Valley Caldera, Mono County, California. *Journal of Geophysical Research*, **81(5**), 725-744.

M. Battaglia, M.J. Williams, D.Y. Venezky, D.P. Hill, J.O. Langbein, C.D. Farrar, J.F. Howle, M. Sneed *and* P. Segall (2003). The Long Valley Caldera GIS Database. Digital Data Series DDS-81 Version 1.0.

Benson L.V., Currey D.R., Lajoie K.R., Oviatt C.G., Robinson S.W., Smith G.I., Stine S. (1990). Chronology of expansion and contraction of four Great Basin lake systems during the past 35,000 years. *Palaeogeography, Palaeoclimatology and Palaeoecology*, ***78*****(3-4)**, 241-286.

Benson L.V., Thompson R.S. (1987) Lake-level variation in the Lahontan basin for the past 50,000 years. *Quaternary Research*, **28**, 69–85.

Benson L.V., Burdett J.W., Kashgarian M., Lund S.P., Phillips F.M. and Rye R.O. (1996) Climatic and hydrologic oscillations in the Owens Lake basin and adjacent Sierra Nevada, California. *Science,* **274,** 746–749.

Benson L.V., Lund S.P., Burdett J.W., Kashgarian M., Rose T.P., Smoot J.P. and Schwartz M. (1998). Correlation of Late-Pleistocene Lake-Level oscillations in Mono Lake, California, with North Atlantic Climate Events. *Quaternary Research*, **49**, 1-10.

Bischoff J.L., Cummins K. (2001) Wisconsin glaciation of the Sierra Nevada (79,000–15,000 yr B.P.) as recorded by rock flour in sediments of Owens Lake, California. *Quaternary Research*, **55** , 14–24.

Bischoff J.L., Fitts J.P., Fitzpatrick J.A. (1997a). Responses of sediment geochemistry to climate change in Owens Lake sediment: In "An 800,000-year Palaeoclimate Recordfrom core Ol-92, Owens Lake, Southeast California" (In: Smith, G.I., Bischoff, J.L. Eds.),. *Geological Society of America Special Paper*, **317**, 37-47.

Bischoff J. L., Menking K. M., Fitts J. P., Fitzpatrick J.A. (1997b). Climatic oscillations 10,000-155,000 yr B.P. at Owens Lake, California reflected in glacial rock flour abundance and lake salinity in core OL-92. *Quaternary Science Reviews*, **48**, 313-325.

Bischoff J.L., Stine S., Rosenbauer R. J., Fitzpatrick J. A., and Stafford T. W. Jr. (1993). Ikaite coprecipitation by mixing of shoreline springs and lake water, Mono Lake, California, USA. *Geochimica et Cosmochim. Acta*, **57**, 3855-3865.

Blevins M. L., Coufal E. L., Pagan R. J., Haw R. D., Smith V.J., McKeown D. S., Garcia M.R. and Edwards B.R. Background Report on Mono Basin Geology and Hydrology (1984). Los Angeles Department of Water and Power, Aqueduct Division, Hydrology Section, Los Angeles, California.

Broecker W.S., Wanninkhof R., Mathieu G., Peng T. H., Stine S., Robinson S., Herczeg A., Stuiver M. (1988). The radiocarbon budget for Mono Lake : an unsolved mystery. *Earth and Planetary Science Letters*, **88**, 16-26.

Bursik M. I., Gillespie A.R., (1993). Late Pleistocene Glaciation of Mono Basin, California. *Quaternary Research*, **39(1)**, 24-35.

Bursik Marcus and Sieh Kerry. (1989). Range Front Faulting and Volcanism in the Mono Basin, Eastern California. *Journal of Geophysical Research*, **94(B11)**, 15,587-15,609.

Conell T.L. and Dreiss S. J. (1995). Chemical Evolution of Shallow Groundwater Along the Northeast Shore of Mono Lake, California. *Water Resources Research*, **31(12)**, 3171-3182.

Crowley J.L., Schoene B, Bowring S.A. (2007). U–Pb dating of zircon in the Bishop Tuff at the millennial scale. *Geology*, **35(12)**, 1123-1126.

Davis J. O. (1983). Level of Lake Lahontan during deposition of the Trego Hot Springs tephra about 23,400 years ago. *Quaternary Research*, **19**, 312–324.

Drever J.I. (1997) The Geochemistry of Natural Waters Prentice Hall Inc. Upper Saddle River New Jersey.

Gac J. Y., Al Droubi A., Fritz B. and Tardy Y. (1977) Geochemical behavior of silica and magnesium during the evaporation of waters in Chad. Chemical Geology, **19**, 215-228.

Garrels R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Hildreth W., and Mahood G. A. (1986). Geological Society of America Bulletin Ring-fracture eruption of the Bishop Tuff. *Geological Society Of America Bulletin*, **97(4)**, 396-403. doi: 10.1130/0016-7606(1986)97<396.

Hostetler S.W., Benson L.V. (1990), Paleoclimatic implications of the high stand of Lake Lahontan derived from models of evaporation and lake level. *Climate Dynamics,* **4**, 207–217.

Johannesson K. H. and Lyons W.B. (1994). The rare earth element geochemistry of Mono Lake water and the importance of carbonate complexing. *Limnology and Oceanography*, **39(5)**, 1141-1154.

Johannesson K.H., Lyons W.B. and Bird D.A. (1994). Rare earth element concentrations and speciation in alkaline lakes from the western U.S.A. *Geophysical Research Letters*, **21**, 773-776.

Jones B. F. and Weir A. H. (1983) Clay minerals of Lake Abert, an alkaline saline lake. *Clays Clay Mineral*. **31,** 161-172.

Lajoie K.R. (1968). Quaternary Stratigraphy and geologic History of Mono Basin, Eastern California. PhD thesis, University of California, Berkeley.

Li C. H., Stott L.D., and Hammond D.E., (1997). Temperature and salinity effects on ^{18}O fractionation for rapidly precipitated carbonates: Laboratory experiments with alkaline lake water. Episodes **20 (3)**, 193-198.

Lin J. C., Broecker W. S., Anderson R. F., Hemming S.R., Rubenstone J. L., Bonani, G. (1996) New ^{230}Th/U and ^{14} C ages from Lake Lahontan carbonates, Nevada, USA, and a discussion of the origin of initial thorium. *Geochim.Cosmochim.Acta,* **60**, 2817-2832.

Moore D. and Reynolds R.C. (1997) X-Ray Diffraction and the Identification and Analysis of Clay Minerals, 2nd ed.: Oxford University Press, New York

Neumann K. and Dreiss S.J. (1995). Strontium 87/Strontium 86 Ratios as Tracers in Groundwater and Surface Waters in Mono Basin, California. *Water Resources Research*, **31(12)**, 3183-3193.

Phillips F. M., Rogers D. B., Dreiss S. J., Jannik N. O., and Elmore D.(1995) Chlorine 36 in Great Basin waters: Revisited. *Water Res. Res.*
31, 3195–3204.

Russel I.C. (1889). Quaternary History of the Mono Valley, California. Artemisia Press, Lee Vining, CA.

Simpson H.J., Trier R.M., Toggweiler J.R., Mathieu G., Deck B.L., Olsen C.R. (1980). Fallout Plutonium in an Alkaline, Saline Lake. *Science*, **207**, 1071-1073.

Simpson H.J., Trier R.M., Olsen C.R., Hammond D.E., Ege A., Miller L., Melack J.M. (1982). Radionuclides in Mono Lake, California. *Science*, **216**, 512-514.

Singer Arieh (1984) The Paleoclimatic Interpretation of Clay Minerals in Sediments. *Earth-Science Reviews,* **21**, 251-293

Smith G.I., Bischoff J.L. (1997) An 800,000-Year Paleoclimatic record from core OL-92, Owens Lake, Southeast California. *Geological Society of America Special Paper*, **317**, 165.

Stine S. (1990). Late Holocene fluctuations of Mono Lake, eastern California. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **78**, 333-381.

Tomascak P.B., N.G. Hemming., Hemming S. R. (2003). The lithium isotopic composition of waters of the Mono Basin, California. *Geochimica. Cosmochimica. Acta.*, **67(4)**, 601- 611.

Zimmerman S., Hemming S., Kent D.V., Searle S. (2006) Revised chronology for late Pleistocene Mono Lake sediments based on paleointensity correlation to the global reference curve. *Earth and Planetary Science Letters* **252**, p. 94-106

Zimmerman S.H. (2006) Chronology and Paleoclimate Records of the Late Pleistocene Wilson Creek Formation at Mono Lake, California. Thesis. Columbia University, p 203.

Chapter 2:

Bischoff, J. L., Menking K. M., Fitts J. P. and Fitzpatrick J. A. (1997a) Climatic oscillations 10, 000–155, 000 yr B.P. at Owens Lake, California reflected in glacial rock flour abundance and lake salinity in core OL-92. *Quaternary Science Review*. **48**, 313–325.

Bischoff, J.L., Fitts J.P., Fitzpatrick J.A. (1997b). Responses of sediment geochemistry to climate change in Owens Lake sediment: In "An 800,000-year Palaeoclimate Recordfrom core Ol-92, Owens Lake, Southeast California" (In: Smith, G.I., Bischoff, J.L. Eds.). *Geological Society of America Special Paper*, **317**, 37-47.

Bischoff, J.L., Stine S., Rosenbauer R. J., Fitzpatrick J. A., and Stafford T. W. Jr. (1993). Ikaite coprecipitation by mixing of shoreline springs and lake water, Mono Lake, California, USA. *Geochimica et Cosmochimica. Acta*, **57**, 3855-3865.

Eugster, H.P., and Jones B.F. (1979). Behavior of major solutes during closed-basin brine evolution. *American Journal of Science*, **279**, 609-631.

Eugster, H.P. and Maglione G. (1979). Brines and evaporates of the Lake Chad basin, Africa. Geochimica et Cosmochimica Acta, **43**, 973-982.

Garrels, R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Hardie, L.A. and Eugster H.P. (1970). The evolution of closed-basin brines. *Mineralogical Society of America. Special Publication*, **3**, 273-290.

Menking, K.M., Bischoff J.L., Fitzpatrick J.A., Burdette J.W. and Rye R.O. (1997). Climatic/Hydrologic oscillations since 155,000 yr B.P. at Owens Lake, California, reflected in abundance and stable isotope composition of sediment carbonate. *Quaternary Research*, **48**, 58-68.

Sahajpal R., Zimmerman S.R.H., Datta S., Hemming N.G., and Hemming S.R. (2011) Assesing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA*). Geochimica et Cosmochimica Acta*, **75**, 7855-7863.

Schrag, D.P. (1999) Rapid analysis of high precision Sr/Ca ratios in corals and other marine carbonates. *Paleoceanography*, **14**, 97-103.

Zimmerman, S., Hemming S., Kent D.V., Searle S. (2006) Revised chronology for late Pleistocene Mono Lake sediments based on paleointensity correlation to the global reference curve. *Earth and Planetary Science Letters*, **252**, p. 94-106

Zimmerman, S.H. (2006) Chronology and Paleoclimate Records of the Late Pleistocene Wilson Creek Formation at Mono Lake, California. PhD Thesis. Columbia University, p 203.

Zimmerman, S.R.H., Pearl C., Hemming S.R., Tamulonis K., Hemming N.G. and Searle S.Y. (2011a) Freshwater control of ice rafted-debris in the last glacial period at Mono Lake, California, USA. *Quaternary Research*, **76**, 264-271.

Zimmerman, S.R.H., Hemming S.R., Hemming N.G., Tomascak P.B. and Pearl C. (2011b) High-resolution chemostratigraphic record of late Pleistocene lake-level variability, Mono Lake, California. *Geological Society of America Bulletin*, **123**, 2320-2334.

Chapter 3:

Benson, L.V., Currey D.R., Lajoie K.R., Oviatt C.G., Robinson S.W., Smith G.I., Stine S. (1990). Chronology of expansion and contraction of four Great Basin lake systems during the past 35,000 years. *Palaeogeography, Palaeoclimatology and Palaeoecology,* **78(3-4)**, 241-286.

Bethke, C.M. and Yeakel, S. (2008) The Geochemists' Workbench® Reference Manual, University of Illinois, 295p.

Bischoff, J.L., Stine S., Rosenbauer R. J., Fitzpatrick J. A., and Stafford T. W. Jr. (1993). Ikaite coprecipitation by mixing of shoreline springs and lake water, Mono Lake, California, USA. *Geochimica et Cosmochimica Acta,* **57**, 3855-3865.

Bischoff, J.L., Fitts J.P., Fitzpatrick J.A. (1997). Responses of sediment geochemistry to climate change in Owens Lake sediment: In "An 800,000-year Palaeoclimate Recordfrom core Ol-92, Owens Lake, Southeast California" (In: Smith, G.I., Bischoff, J.L. Eds.), *Geological Society of America Special Paper,* **317**, 37-47.

Blevins, M. L., Coufal E. L., Pagan R. J., Haw R. D., Smith V.J., McKeown D. S., Garcia M.R. and Edwards B.R. Background Report on Mono Basin Geology and Hydrology (1984). Los Angeles Department of Water and Power, Aqueduct Division, Hydrology Section, Los Angeles, California.

Broecker, W.S. (1996). The Once and Future Climate. *Natural History,* **105**, 29-39.

Eugster, H.P., and Hardie L.A. (1978). Saline Lakes In A. Lerman (Ed.), Lakes- Chemistry, Geology, Physics (pp. 237-293), New York: Springer-Verlag.

Eugster, H.P., and Jones B.F. (1979). Behavior of major solutes during closed-basin brine evolution. *American Journal of Science,* **279**, 609-631.

Eugster, H.P. and Maglione G. (1979). Brines and evaporates of the Lake Chad basin, Africa. *Geochimica et. Cosmochimica Acta,* **43**, 973-982.

Garrels, R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Hardie, L.A. and Eugster H.P. (1970). The evolution of closed-basin brines. *Mineralogical Society of America. Special Publication,* **3**, 273-290.

Harvie, C.E., Moller N. and Weare J.H. (1984). The prediction of mineral solubilities in natural waters : The Na-K-Mg-Ca-H-Cl-SO4-OH-HCO3-CO3-CO2—H2O system to high ionic strengths at 25°C. *Geochimica et. Cosmochimica Acta*, **48**, 723-752.

Harvie, C.E. and Weare J.H. (1980). The prediction of mineral solubilities in natural waters: The Na-K-Mg-Ca-Cl-SO4-H2O system from zero to high concentrations at 25°C. *Geochimica et. Cosmochimica Acta,* **44**, 981-997.

Garrels, R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Lajoie, K.R. (1968). Quaternary Stratigraphy and geologic History of Mono Basin, Eastern California. PhD thesis, University of California, Berkeley.

Mono Lake committee, Lee vining, C.A. http://www.monolake.org/about/stats

Neumann, K. and Dreiss S.J. (1995). Strontium 87/Strontium 86 Ratios as Tracers in Groundwater and Surface Waters in Mono Basin, California. *Water Resources Research,* **31(12)**, 3183-3193.

Parkhurst, D.L. and Appelo, C.A.J. (1999) User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.

Russell, I.C. (1889). Quaternary History of the Mono Valley, California. Artemisia Press, Lee Vining, CA.

Sahajpal, R., Zimmerman S.R.H., Datta S., Hemming N.G., and Hemming S.R. (2011) Assesing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA). *Geochimica et. Cosmochimica Acta*, **75**, 7855-7863.

Sahajpal, R., Hemming N.G., Hemming S.R., Zimmerman S.R.H., Sahajpal R. (in prep) Developing evaporation and mixing models for mineral stability and validating geochemical proxy record for paleolake level and paleosalinity in Mono Lake basin, CA.

Stine, S. (1990) Late Holocene fluctuations of Mono Lake, eastern California. *Palaeogeography, Palaeoclimatology, Palaeoecology,* **78**, 333-381.

Stine, S. (1991). Geomorphic, geographic and hydrographic basis for resolving the Mono Lake controversy. *Environmental Geology and Water Sciences,* **17**, 67-83.

Stine, S. (1994). Extreme and persistent drought in Californiaand Patagonia during Mediaeval time. *Nature,* **369**,546–549

Tomascak, P.B., N.G. Hemming., Hemming S. R. (2003). The lithium isotopic composition of waters of the Mono Basin, California. *Geochimica et Cosmochimica. Acta,* **67(4)**, 601- 611.

Vorster, P.T. (1985) "A water balance forecast model for Mono Lake, California." California State University.

Zimmerman, S., Hemming S., Kent D.V., Searle S. (2006) Revised chronology for late Pleistocene Mono Lake sediments based on paleointensity correlation to the global reference curve. *Earth and Planetary Science Letters,* **252**, 94-106

Zimmerman, S.R.H., Pearl C., Hemming S.R., Tamulonis K., Hemming N.G. and Searle S.Y. (2011a) Freshwater control of ice rafted-debris in the last glacial period at Mono Lake, California, USA. *Quaternary Research,* **76**, 264-271.

Zimmerman, S.R.H., Hemming S.R., Hemming N.G., Tomascak P.B. and Pearl C. (2011b) High-resolution chemostratigraphic record of late Pleistocene lake-level variability, Mono Lake, California. *Geological Society of America Bulletin*, **123**, 2320-2334.

Chapter 4:

Garrels, R.M. and Mackenzie F.T. (1967) Origin of the chemical compositions of some springs and lakes. In: R.F. Gould, Editor, Equilibrium Concepts in Natural Water Systems, American Chemical Society Publication, Washington, DC, pp. 222–242

Hardie, L.A. and Eugster H.P. (1970). The evolution of closed-basin brines. *Mineralogical Society of America. Special Publication.* **3**, 273-290.

Harvie, C.E., Moller N. and Weare J.H. (1984). The prediction of mineral solubilities in natural waters : The Na-K-Mg-Ca-H-Cl-SO_4-OH-HCO_3-CO_3-CO_2—H_2O system to high ionic strengths at 25°C. *Geochimica et Cosmochimica Acta*, **48**, 723-752.

Harvie, C.E. and Weare J.H. (1980). The prediction of mineral solubilities in natural waters: The Na-K-Mg-Ca-Cl-SO_4-H_2O system from zero to high concentrations at 25°C. *Geochimica et Cosmochimica Acta*, **44**, 981-997.

Parkhurst, D.L. and Appelo, C.A.J. (1999) User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: U.S. Geological Survey Water-Resources Investigations Report 99-4259, 310 p.

Sahajpal, R., Zimmerman S.R.H., Datta S., Hemming N.G., and Hemming S.R. (2011) Assesing Li and other leachable geochemical proxies for paleo-salinity in lake sediments from the Mono Basin, CA (USA). *Geochimica et. Cosmochimica Acta*, **75**, 7855-7863.

Sahajpal R., Hemming N.G., Hemming S.R., Zimmerman S.R.H., Sahajpal R. (in prep) Developing evaporation and mixing models for mineral stability and validating geochemical proxy record for paleolake level and paleosalinity in Mono Lake basin, CA.