EPITHERMAL ALTERATION IN TUFF OF SULPHUR CREEK,

YELLOWSTONE NATIONAL PARK, WYOMING

By

JENNIFER LEIGH MANION

A thesis submitted in partial fulfillment of
the requirements for the degree of

MASTERS OF SCIENCE IN GEOLOGY

WASHINGTON STATE UNIVERSITY
School of Earth and Environmental Sciences

AUGUST 2010

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of JENNIFER LEIGH MANION find it satisfactory and recommend that it be accepted.

____

Peter B. Larson, Chair

____

John A. Wolff

____

Frank (Nick) F. Foit

ACKNOWLEDGEMENT

Foremost, I would like to acknowledge my parents, Dale and Karen Manion, who have supported me throughout my academic career. They have been steadfast through my complaints, concerns, and jargon. I would like to thank my brother, Jeremy, for his sound advice and unwavering faith in my ability. I would like to thank Eric E. Baar for his patience, encouragement, and support during my time at WSU and (hopefully) for many years to come. I would like to thank Ashley Tefft for her assistance and bear management skills while in the field; Allen Andersen for his field assistance as well as for his insightful conversations; Kamilla Fellah for allowing me to stay in her home while completing this project. I would like to extend a special thanks to Chad Pritchard for allowing me access to his unpublished data and for allowing me to pick his brain from time to time.

I would like to thank Peter B. Larson, John Wolff, and Nick Foit for constructive criticism, advice, and for serving on my committee. I want also to thank Charles Knaack, Rick Conrey, and Scotty Cornelius in the Geoanalytical Lab at WSU. Special thanks to park services for allowing me to perform my research in Yellowstone National Park. This research was supported by NSF grant EAR-0609475. It was also supported in part by the WSU School of Earth and Environmental Sciences, the Tobacco Root Geological Society, and the Colorado Scientific Society.

EPITHERMAL ALTERATION IN TUFF OF SULPHUR CREEK,

YELLOWSTONE NATIONAL PARK, WYOMING

Abstract

By Jennifer Leigh Manion, M.S.
Washington State University
August 2010

Chair: Peter B. Larson

The Tuff of Sulphur Creek (480 ka) is well exposed in the Seven Mile Hole area of the Grand Canyon of the Yellowstone River, Yellowstone National Park, Wyoming. The rhyolitic tuff erupted after the collapse of the Yellowstone Caldera (640 ka) and hosts more than 350 vertical meters of hydrothermal alteration. This work focused on shallow epithermal alteration in the south fork of Sulphur Creek. Two epithermal alteration subtypes with varying mineral assemblages and alteration styles have been identified in the area: a low-sulfidation subtype containing silica-illite-sulfides (including pyrite, marcasite, galena, and sphalerite) and a high sulfidation subtype containing silica-alunite-kaolinite-sulfides (including pyrite and marcasite) as well as various amounts of diaspore and pyrophyllite. Most alteration higher in the canyon displays alteration typical of the high-sulfidation subtype, such as advanced argillic alteration, silicification, and vuggy silica. Alteration the base of the canyon is typical of the low-sulfidation subtype, including veins, stockwork veinlets, and brecciation. Boiling along the hydrostatic curve caused a low-sulfidation system to generate and supply acidic fluids to a hot spring environment located in the south fork of Sulphur Creek. These acidic fluids also yielded subsurface mineral associations typical of high-sulfidation subtypes, overprinting the already present low-sulfidation alteration. Oxygen isotope ratios support boiling in the system. The alteration in Tuff of Sulphur Creek is compared to other, better known epithermal systems.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Yellowstone National Park (YNP), in the northwest corner of Wyoming, has drawn the attention of visitors, politicians, environmentalists, and scientists for more than a century (**Figure 1**). Geoscientists flock to YNP to study an active volcano; its past, present, and future. Studies of the thousands of active hot springs in the region have been extensive and are ongoing. These hot springs are the result of meteoric fluids being heated and convectively driven in a vapor-dominated system by the underlying magma chamber, creating a hydrothermal environment (Fournier, 1989). However, YNP contains an older phase of hydrothermal alteration that seemingly goes unnoticed and unstudied. This older alteration includes an ostensibly barren epithermal assemblage, beautifully displayed in Tuff of Sulphur Creek (480 ka), a post Yellowstone Caldera collapse (640 ka) pyroclastic deposit. With the world's increasing appetite for commodities, the need to understand why some epithermal systems are barren and others are productive has become increasingly important for exploration.

Hydrothermal Systems

A hydrothermal system occurs when heated fluids move through and react with wall rocks. An epithermal system is a hydrothermal system developing between the paleo-water table and 1.5 km below it (Taylor, 2007); fluid temperatures can range up to 300ºC (Simmons et al., 2005). Often, epithermal systems are linked to paleo-hot springs (White et al., 1992). Though any rock can host an epithermal system, they commonly occur in calc-alkaline to alkaline rocks in volcanic arc systems. Mineralization is found below the paleo-water table in areas of high paleo-permeability by wall rock replacement or in steeply dipping veins. These systems often produce economic Au-Ag mineralization. They typically contain a base metal suite (such as Cu, Pb, and Zn) linked to trace elements such as Au, Ag, Hg, As, Sb, Tl, etc. (White et al., 1992). Oxygen isotope ratios measured from epithermal minerals suggest they are derived from both magmatic sources as well as fluid interaction with the country rock (Faure and Mensing, 2005). Heald et al. (1987) acknowledge the importance of caldera settings for younger epithermal deposits because of extensive fracturing.

Field Area

Tuff of Sulphur Creek (TSC) is located on the northeast rim of the Yellowstone Caldera (**Figures 2** and **3**). Most of TSC was deposited inside the Yellowstone Caldera, although some of the tuff is located outside of the caldera. The field area for this study was along the south fork of Sulphur Creek (**Figure 5**). Sulphur Creek is a tributary to the Yellowstone River and flows from west to east, parallel to the caldera margin, into the Grand Canyon of the Yellowstone River. Sulphur Creek canyon, which has been (and is actively being) eroded by Sulphur Creek, slopes gently to the east, steepening dramatically towards the confluence of the north and south forks (**Figure 4**). Outcrops in the canyon consist of large, discontinuous whitish-yellow walls except for Outcrops 2 and 5, which are small, grey, silicified outcrops (**Figure 15**).

Purpose

There are two main purposes for studying Tuff of Sulphur Creek (TSC) in and adjacent to the Grand Canyon of the Yellowstone River. The first is to study a low $\delta^{18}O$ post-caldera pyroclastic flow from an unaltered deposit through hydrothermal alteration.

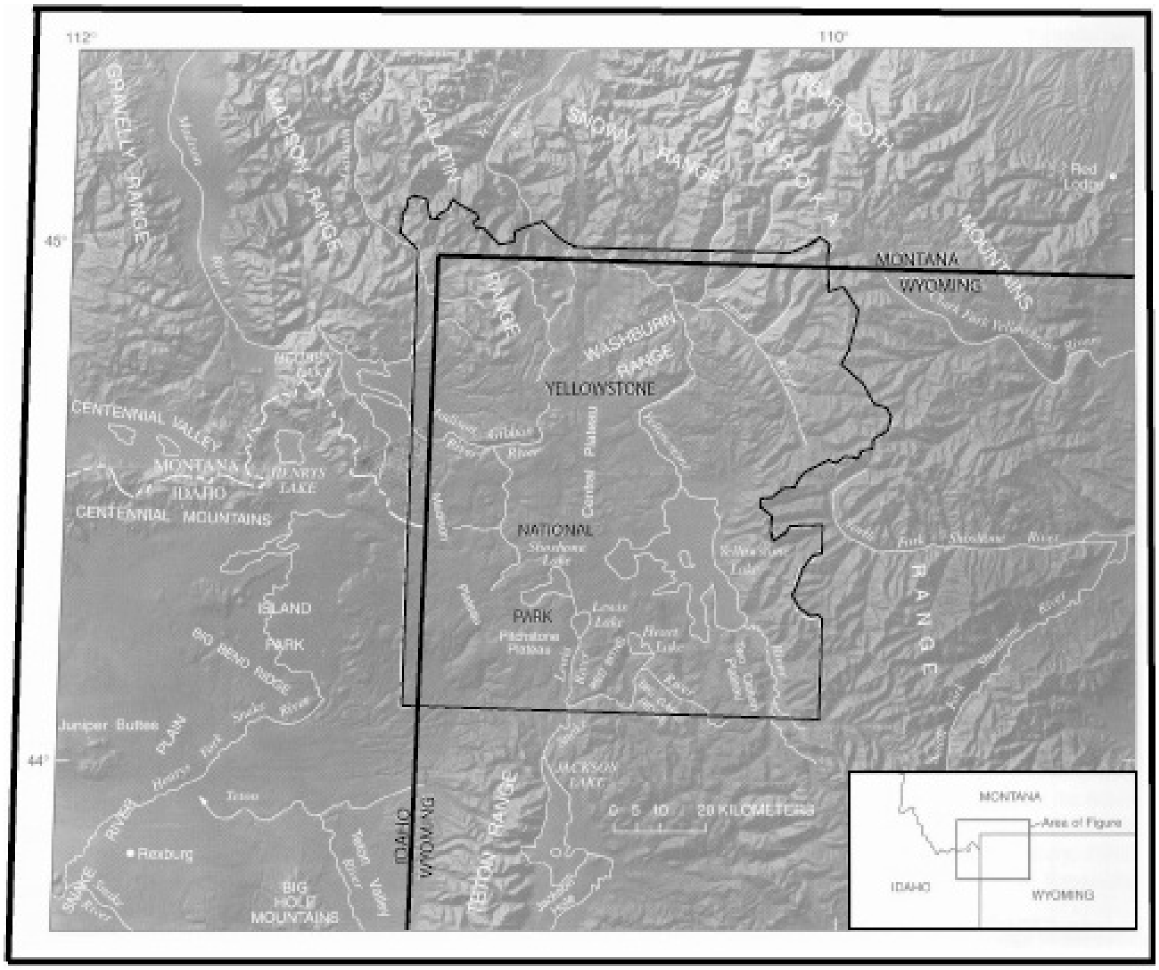


Figure 1: Location map of the Yellowstone Plateau region. Figure from Christiansen (2001).

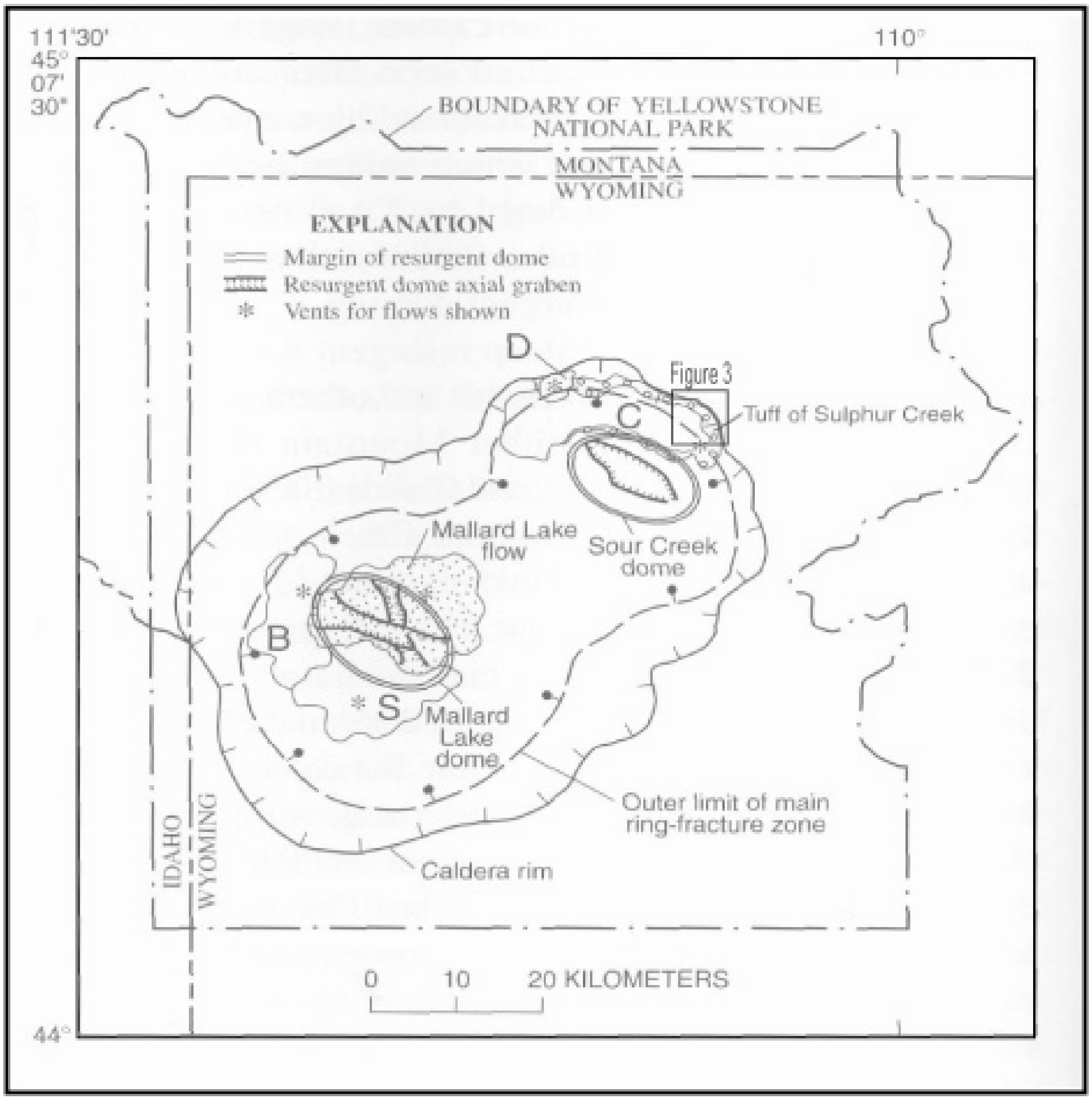


Figure 2: Yellowstone Caldera including resurgent domes and the Upper Basin Member of the Plateau Rhyolites, Yellowstone Plateau. C- Canyon Flow, D- Dunraven Road Flow, B- Biscuit Basin Flow, S- Scaup Lake Flow. Tuff of Sulphur Creek is located on the northeast rim of the caldera. The box encloses the area of **Figure 3**. Figure from Christiansen (2001).

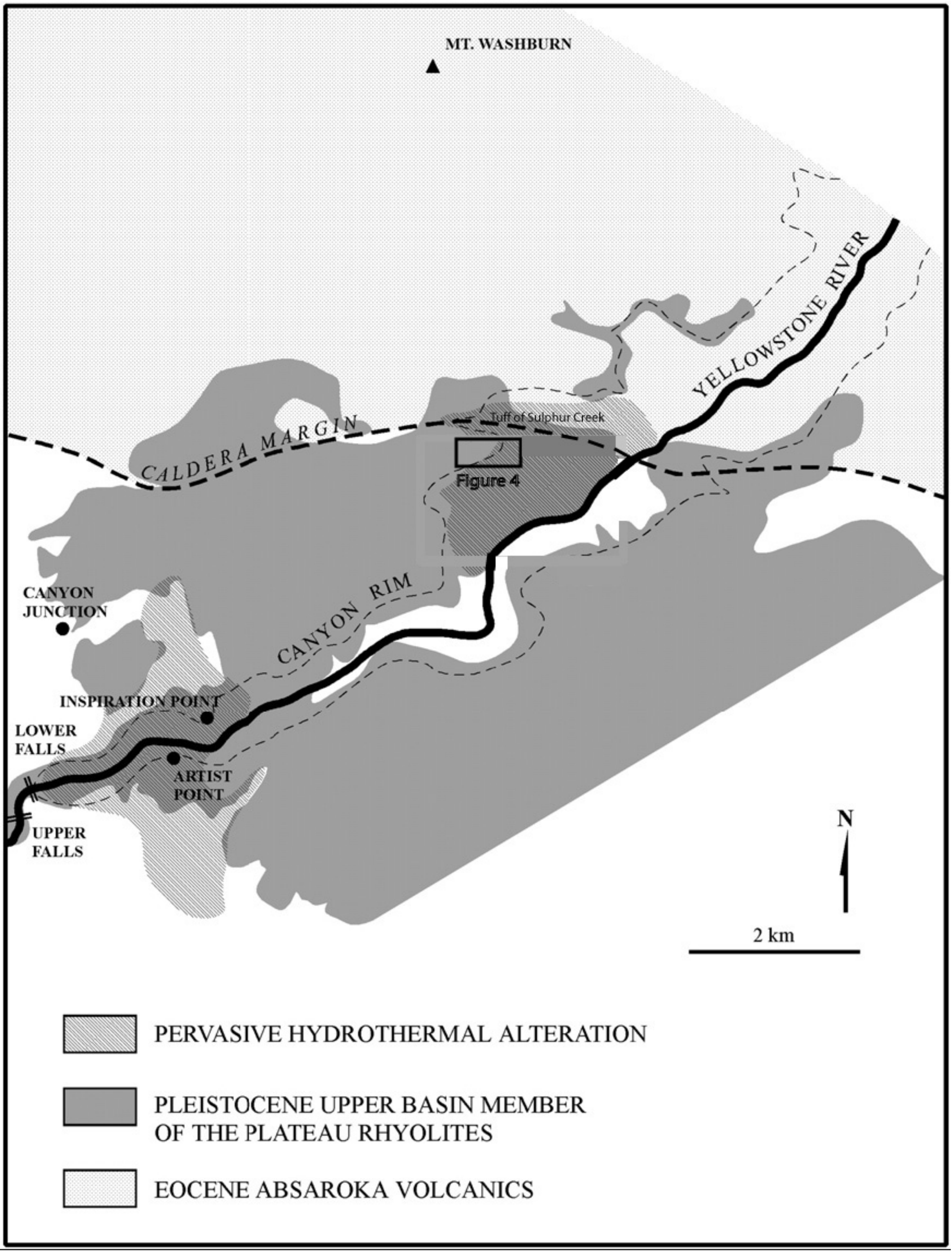


Figure 3: General geologic map of the Grand Canyon of the Yellowstone River. The box encloses the area of **Figure 4**. Modified from Larson et al. (2009).

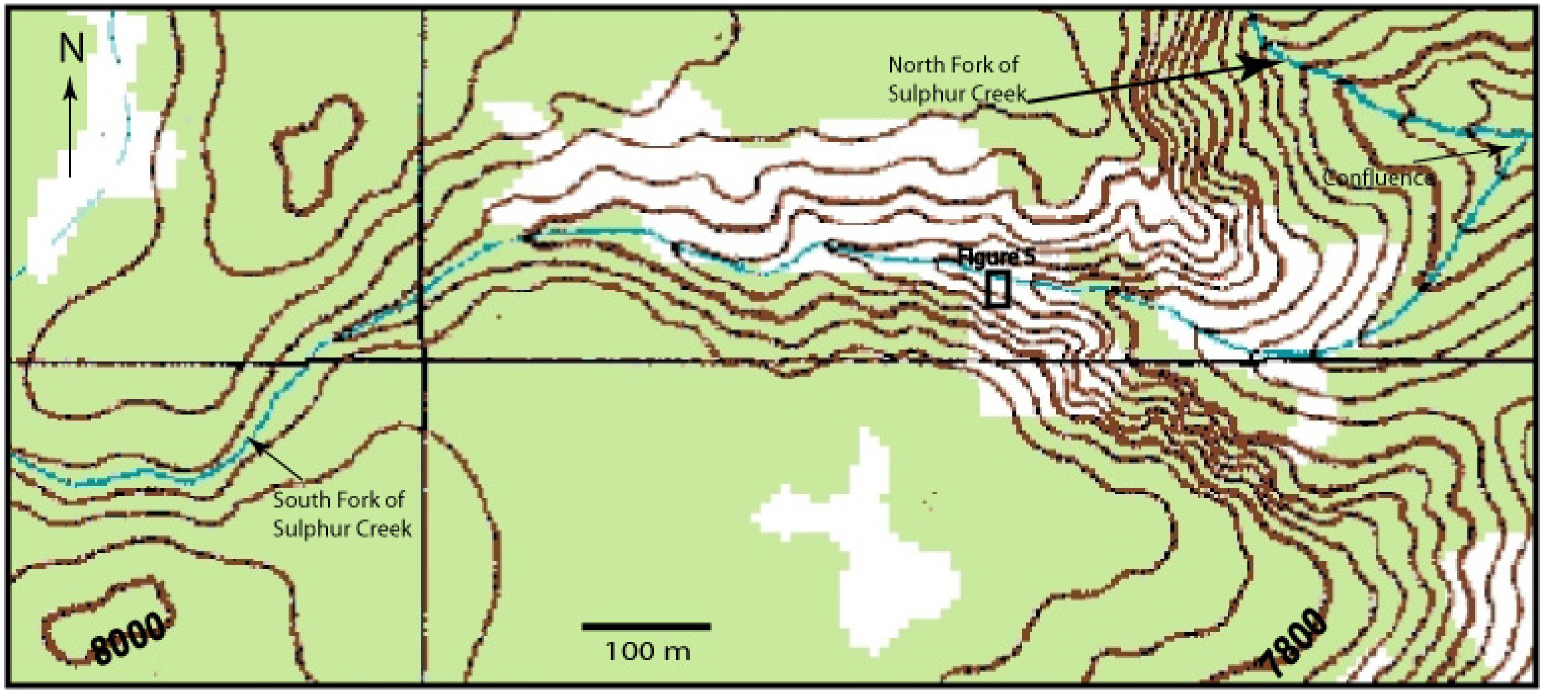


Figure 4: Topographic map of the south branch of Sulphur Creek. North and south forks are labeled. Box encloses the area of **Figure 5**. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

This includes studying chemical gains and losses during hydrothermal alteration, controls on hydrothermal fluid flow, hydrothermal fluid chemistry, and the extent of hydrothermal alteration. This study also provides a comparison between the active hydrothermal system and an older hydrothermal system. The active hydrothermal system in YNP is currently precipitating sinter and causing alteration. The older hydrothermal system is an inactive, preserved system. Although there are active hot springs in the field area, these hot springs are the result of the current hydrothermal system as opposed to the older system. Research performed on Tuff of Sulphur Creek is part of an interdisciplinary study being completed by Washington State University graduate students. Chad Pritchard is studying the unaltered TSC, Allison Phillips and I are studying the extent of the alteration within altered TSC, and Allen Andersen is studying the active hot springs rising through TSC.

My role in the study is to determine the nature of the epithermal system hosted within altered TSC by observing hydrothermal minerals and their distribution, the extent of alteration, geochemistry, fluid temperature gradients, and structural controls on the hydrothermal system.

The second purpose of this study is to compare altered TSC to other epithermal system to determine why altered TSC is barren of economic mineralization. Barren epithermal systems are rarely noted or studied to their full potential (Taylor, 2007). Although various amounts of gold have been found throughout YNP (White et al., 1992), altered TSC is barren of Au-mineralization. Our goal is to determine whether this lack of mineralization is related to erosion, lack of Au present in the system, or, possibly, of a lack of precipitation due to fluid chemistry. As a poorly-mineralized terrain, altered TSC should be studied to better define characteristics and/or regional features which could be used as predictors of Au-bearing epithermal ore deposits.

Figure 5: South fork of Sulphur Creek Canyon. Note pervasively altered outcrop walls. View of south wall, looking east. Photo taken by Caroline Larson.

CHAPTER TWO

GEOLOGIC HISTORY

The Yellowstone super-volcano is considered the surficial expression of a mantle plume. Many theories are focused on the origin of the plume; lower mantle (Pierce and Morgan, 1992) verses upper mantle (Christiansen et al., 2002). The origin of Yellowstone Plateau volcanism is not the topic of this paper. With that being said, Yellowstone volcanism may be herein referred to as hotspot-related. Hotspot refers to the “melting anomaly” creating the Yellowstone volcano and not the source of the volcanism (Shaw and Jackson, 1974).

There have been three caldera forming events in the Yellowstone Plateau volcanic field, all related to magmatism due to the Yellowstone hotspot (Christiansen et al., 2002). Distribution of the deposits associated with the three calderas is shown in **Figure 6**. A summary of the geologic history can be found in Christiansen (2001); the following is a brief overview of the information found therein.

First Volcanic Cycle

The first volcanic cycle associated with Yellowstone volcanism occurred in the west-southwest part of the Park (**Figure 7**). No ring fractures have been identified with this event, though Christiansen (2001) deduced that magma caused regional swelling and fracturing, followed by the eruption of Huckleberry Ridge Tuff (HRT), and eventual collapse. The collapsed areas were buried by subsequent volcanism and sedimentation. At least one rhyolitic flow preceded the Huckleberry Ridge Tuff, the Rhyolite of Snake River Butte.

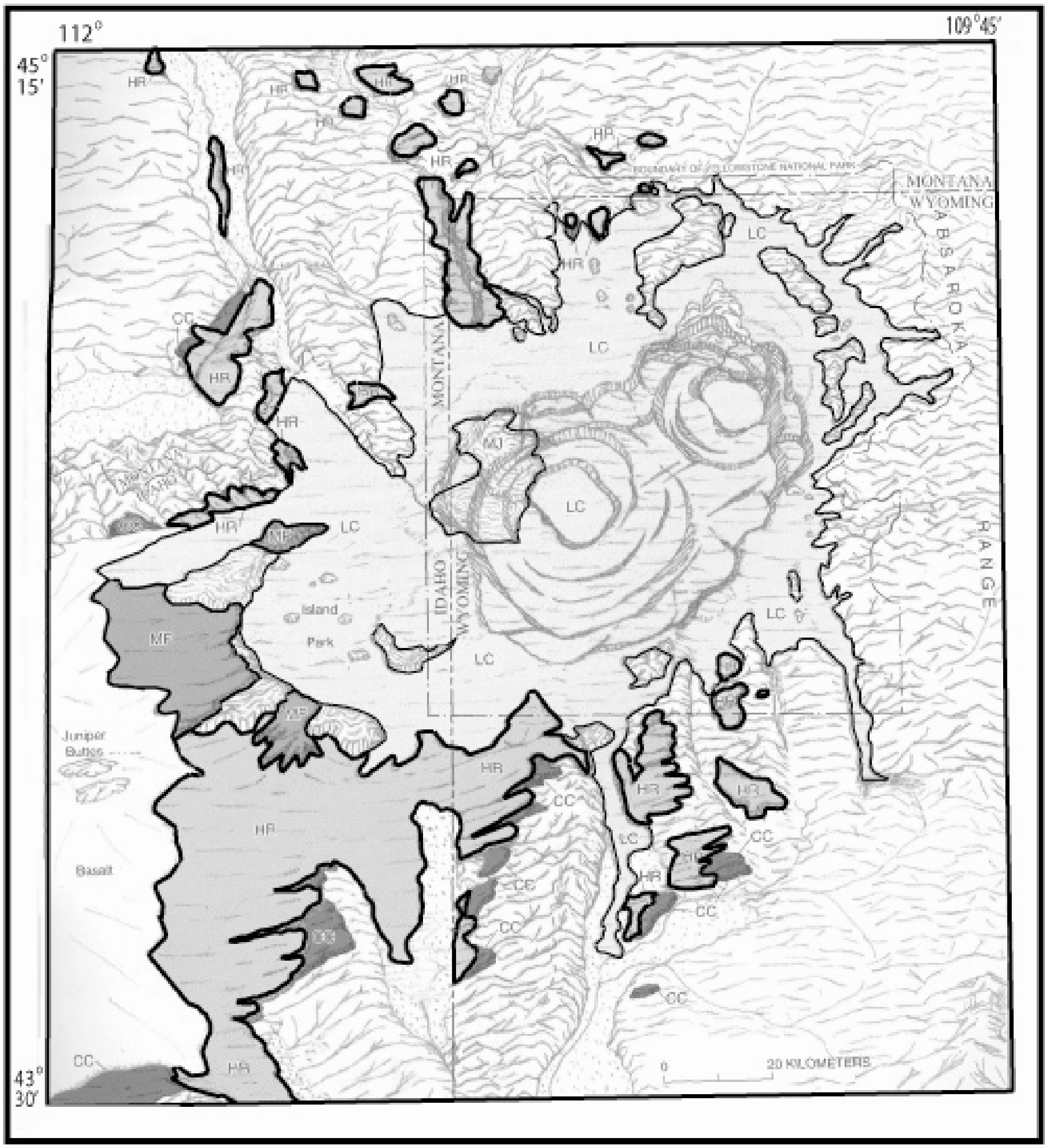


Figure 6: The deposits for the Huckleberry Ridge tuff (gray), Mesa Falls Tuff (darkest gray), and Lava Creek Tuff (lightest gray) are outlined above. HR- Huckleberry Ridge Tuff, MF- Mesa Falls Tuff, LC- Lava Creek Tuff. Also included in figure: CC- Kilgore Tuff and Conant Creek Tuff. Figure from Christiansen (2001).

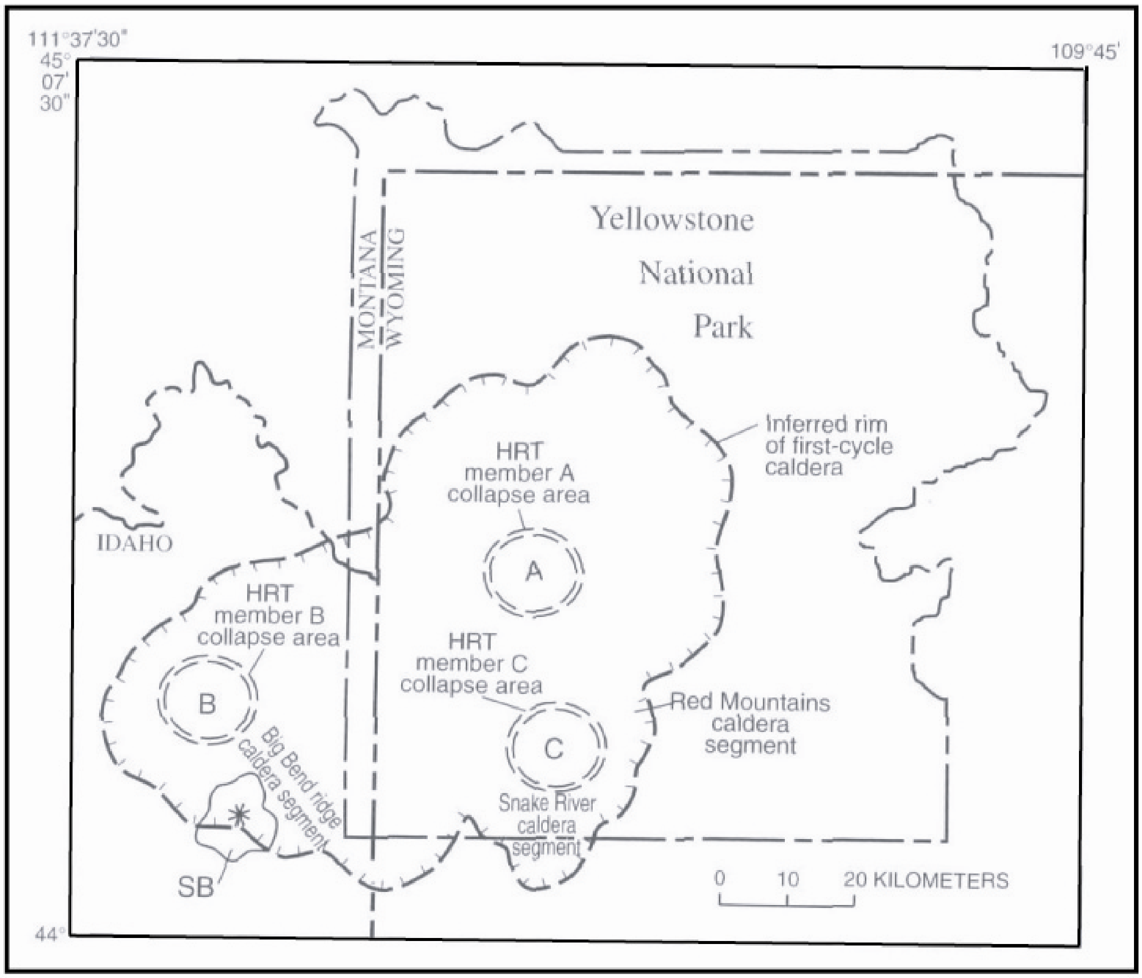


Figure 7: Vents and distribution of Huckleberry Ridge Tuff. HRT- Huckleberry Ridge Tuff. Also included in figure: SB- Snake River Butte Flow. Figure from Christiansen (2001).

The Huckleberry Ridge Tuff contains a basal fallout, followed by three ash flow tuffs. Eruption of two of the three tuffs are responsible for the first caldera collapse. Sanidine from HRT was dated by $^{40}Ar/^{39}Ar$ at 2.053±0.096 Ma (Christiansen, 2001). At least four post-collapse rhyolitic lava flows have been associated with the first volcanic cycle.

Second Volcanic Cycle

The second volcanic cycle truncates the post-collapse rhyolites of the first cycle and erupted in the west-southwest part of the Park and in Park Island, west of YNP (**Figure 8**). Eruption of the Mesa Falls Tuff (MFT) was the smallest of the three caldera forming events. The MFT contains a basal fallout with a single ash flow mostly contained within the boundaries of the first caldera. Ring fractures associated with MFT were buried by subsequent volcanism and sedimentation. The MFT was dated by $^{40}Ar/^{39}Ar$ at 1.292±0.005 Ma (Christiansen, 2001). Five post-collapse rhyolitic domes are associated with the eruption of the MFT. The Basalt of the Narrows of the Grand Canyon of Yellowstone River is also associated with post-collapse volcanism of the second volcanic cycle.

Third Volcanic Cycle

The third volcanic cycle began with rhyolitic and basaltic flows in the central to central-southwest of the park (**Figure 6**). The Yellowstone Caldera formed after magmatic expansion triggered regional fracturing, the eruption of Lava Creek Tuff (LCT), and finally, collapse. Welded ash flow sheets erupted throughout what is now the Yellowstone Caldera. Third cycle volcanism ejected the most material and lead to the largest caldera associated with the Yellowstone hotspot.

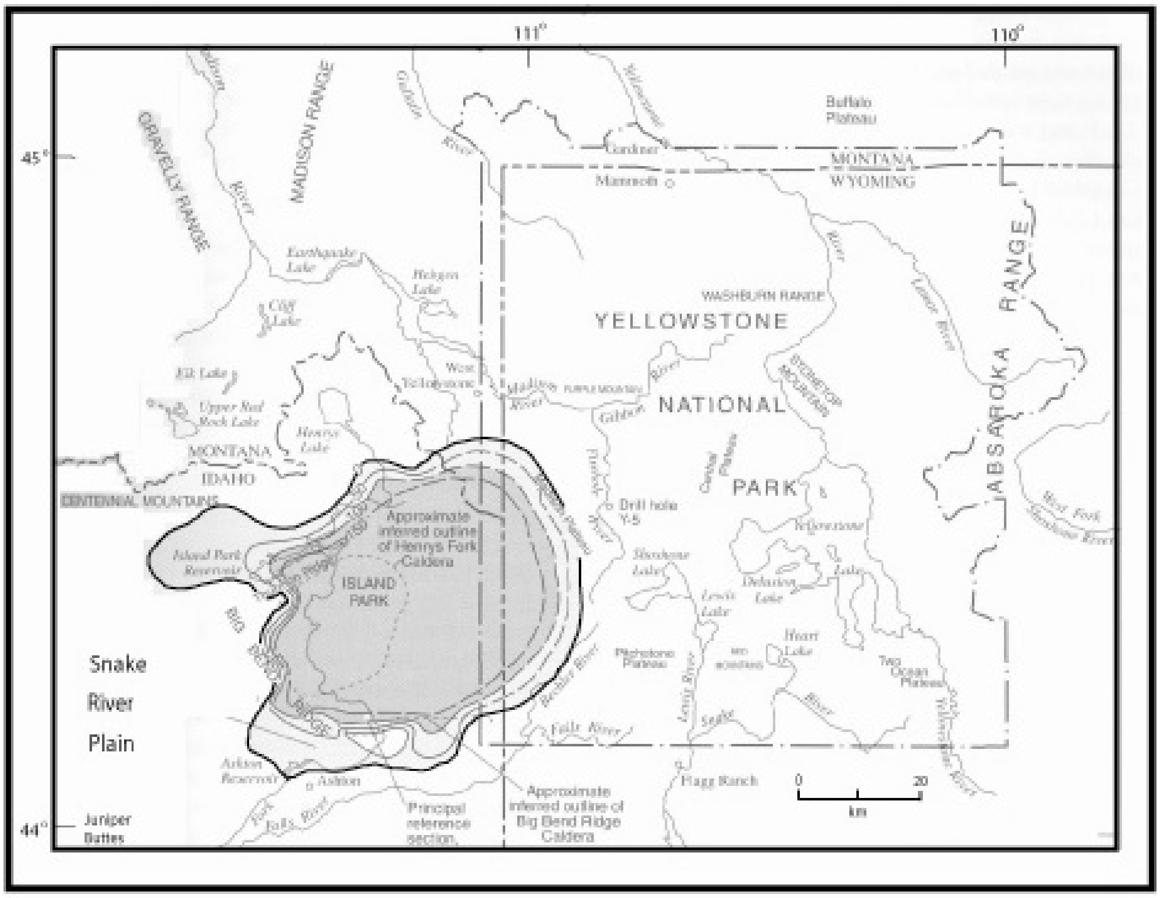


Figure 8: Distribution of Mesa Falls Tuff is shown in gray. Figure from Christiansen (2001).

There are two principal units in the LCT deposit: member A and B. Member A is associated with a vent to the west of the center of activity; it is the "basal unit" of LCT. A basal fallout, bedded ash horizon (the lower portion of member B) separates member A from B. Member B is sourced out of the eastern portion of activity. $^{40}Ar/^{39}Ar$ dating of sanidine yields an age of 640±0.002 ka (Christiansen, 2001).

Two post-collapse structural uplift domes formed soon after collapse of the Yellowstone Caldera: the Mallard Lake dome and the Sour Creek dome (**Figure 2**). While the domes were being generated, subsequent volcanism, known as the Plateau

Rhyolites, were erupting elsewhere within the caldera (Christiansen, 2001). The Upper Basin Member (UBM) of the Plateau Rhyolites consists of five intracaldera, low $\delta^{18}O$ rhyolitic flows, emplaced between 516 ka and 480 ka (Hildreth et al., 1984; 1991). Extracaldera flows, erupting at the same time as the Plateau Rhyolites, include the Obsidian Creek Member and the Roaring Mountain Member (Christiansen, 2001).

Post-collapse basalts are more prevalent than pre-collapse basalts. These flows are found outside the margins of the Yellowstone Caldera, within prominent tectonic zones, and are all similar in chemistry (olivine tholeiites). No basalts have extruded directly within the Yellowstone Caldera (Christiansen, 2001).

Intracaldera Rhyolites

The nature of the low $\delta^{18}O$ rhyolitic flows associated with the Yellowstone hotspot has been the subject of some debate (e.g., Bindeman et at., 2007; Boroughs et al., 2005). Boroughs et al. (2005) studied depleted rhyolites in the Central Snake River Plain. They suggest a mechanism of assimilation of hydrothermally altered crust within the underlying magma chamber. In the Yellowstone Plateau volcanic field, post-collapse rhyolites associated with the Huckleberry Ridge Tuff and the Lava Creek Tuff eruptions also display low $\delta^{18}O$ values. Intracaldera rhyolites associated with the third volcanic cycle contain low $\delta^{18}O$ flows.

The Plateau Rhyolites are divided into members based on location within the caldera, geochemistry, and age. Collectively, these intracaldera rhyolites have been erupting intermittently from 516 ka through ~70 ka (Christiansen, 2001).

The Upper Basin Member of the Plateau Rhyolites includes five flows (**Figure 2**). Biscuit Basin Flow (~516 ka) is a glassy rhyolite overlain by the plagioclase-rich Scaup

Lake Flow (~198 ka). The Tuff of Sulphur Creek is a welded tuff overlain by Canyon Flow, which appears to have erupted from the same vents as the Tuff of Sulphur Creek and is compositionally similar to it. The Dunraven Road Flow overlies Canyon Flow (Christiansen, 2001). Dunraven Road Flow, compositionally discernible from Canyon Flow, has a glassy unit grading to a dense vitrophyre, which grades into a devitrified tuff (Chad Pritchard, Pers. Comm.). The mean age for the Tuff of Sulphur Creek, Canyon Flow, and Dunraven Road Flow averages about 481 ka (Gansecki et al, 1996).

The Central Plateau Member of the Plateau Rhyolites includes eight flows, occurring about 70,000 years apart (Christiansen, 2001). These high silica rhyolites began erupting approximately 560 ka. The flows are mostly restricted to the caldera; however, there is some overflow. Individual flows are petrographically similar to each other and contain moderate abundances of quartz and sanidine phenocrysts (Christiansen, 2001).

Extracaldera Rhyolites

Two rhyolitic members are found outside of the Yellowstone Caldera margin: Obsidian Creek and Roaring Mountain (**Figure 9**). Both members are found along the Norris-Mammoth Corridor, a linear zone beginning at the caldera rim near Norris Geyser Basin and stretching north 43 km to Mammoth Hot Springs (Christiansen, 2001).

The Obsidian Creek Member (OCM) is a porphyritic rhyolite, geochemically similar to Scaup Lake Flow of the UBM (Christiansen, 2001). Five domes are associated with OCM, which conformably overlies Lava Creek Tuff outside of the caldera rim. Two domes have been dated: Willow Park (~316 ka) and Gibbon Hill (~116 ka) (Obradovich, 1992).

The Roaring Mountain Member includes four flows, which began erupting approximately 400 ka continuing through 80 ka. The rhyolites are aphyric to very sparsely porphyritic (Christiansen, 2001).

Tuff of Sulphur Creek

Tuff of Sulphur Creek (TSC) is the protolith for the altered rocks investigated in this study. TSC was emplaced to the northeast of the Yellowstone Caldera along the ring fracture (**Figure 2**). TSC is an agglutinated pyroclastic fallout tuff about 75 m thick (Christiansen, 2001). It contains, for the most part, undeformed bedded sequences with sorted pumice and phenocrysts. Phenocryst abundance is between 5-10% and include rounded quartz (quartz eyes) and sodic plagioclase, with minor amounts of sanidine, clinopyroxene, magnetite, and fayalite. The base of the section is brittle grading into a densely welded tuff which is covered by a devitrified zone (Chad Pritchard, Pers. Comm.). Fumarolic vertical pipes (or spires) display rheomorphic deformation (**Figure 10**). The spires are limonite cemented (Christiansen, 2001).

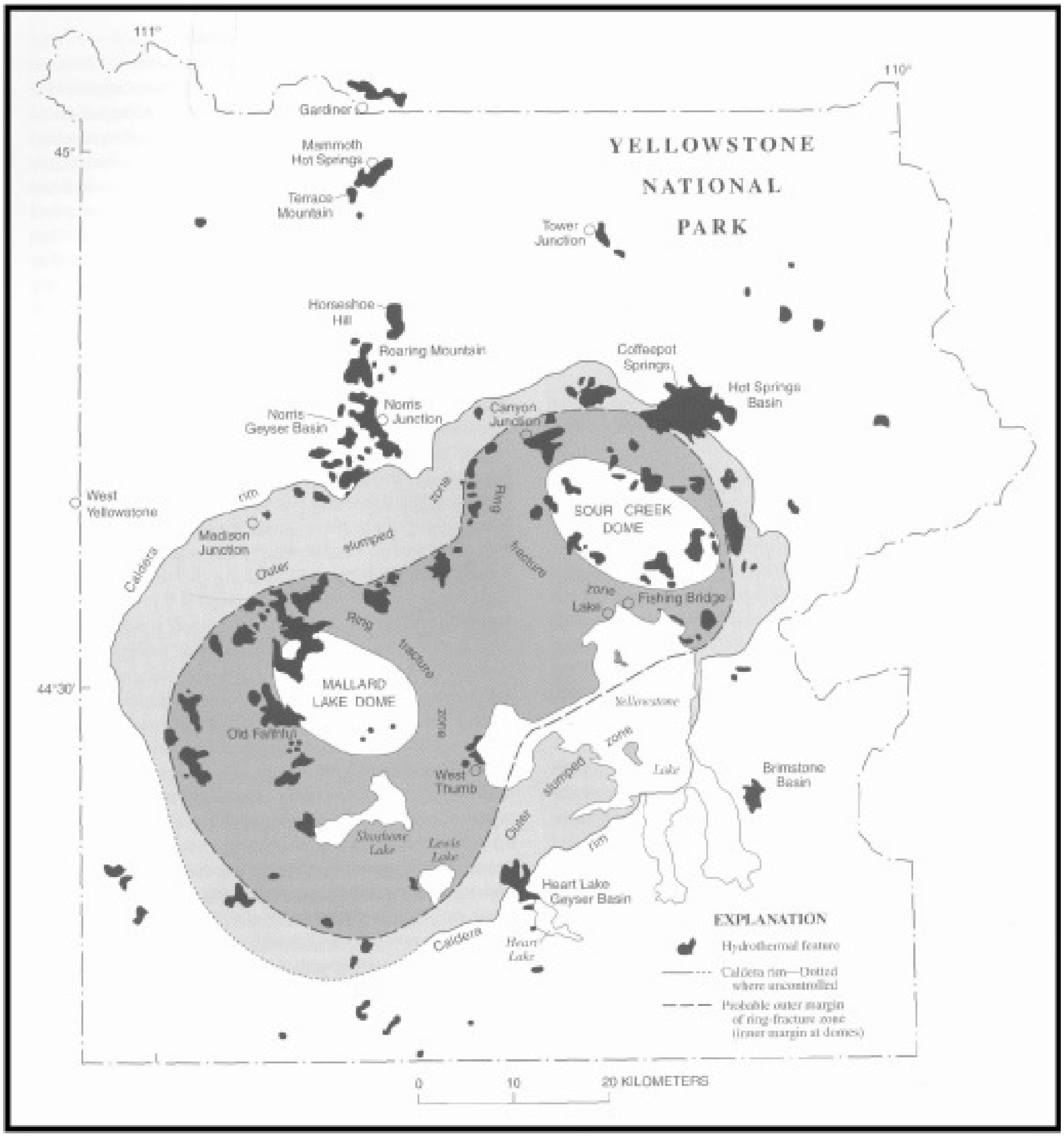


Figure 9: Hydrothermal activity in Yellowstone National Park. Dark gray area represents the Yellowstone Caldera and the light gray area represents the slumped region outside of the Caldera. Note: Obsidian Creek Member is adjacent to Roaring Mountain Member. Figure from Christiansen (2001).

TSC is a high silica, rhyolitic tuff with SiO_2 weight percentages between 76.30-76.59 (Christiansen, 2001). **Tables 5** and **6** give averaged compositional data from 40 unaltered TSC samples ("Fresh TSC") collected and analyzed by Chad Pritchard (Pritchard, unpublished data). The averaged protolith data were used as a comparison for altered samples.

Figure 10: TSC fumarolic pipes or spires. Photo taken by Caroline Larson.

CHAPTER THREE

GEOLOGIC BACKGROUND

Epithermal Alteration

Many of the features common in epithermal deposits suggest their shallow emplacement. Sinter, boiling features (e.g., quartz replacement of calcite), and an increase in $\delta^{18}O$ values toward the paleo-surface, are evidence of shallow emplacement (Taylor, 2007). The most obvious link to shallow emplacement of epithermal systems is the connection with permeable extrusive rocks.

Mineral epithermal assemblages reflect the pH of the mineralizing fluids (Simmons et al., 2005). Alteration occurs below the water table in areas of high paleo-permeability. Alteration minerals associated with epithermal systems are often vertically zoned throughout a deposit. Massive opal deposits occur at the horizon of the paleo-water table (Simmons et al., 2005). As mentioned earlier, this zoning often helps in identifying depth of emplacement at the time of alteration (Taylor, 2007).

There are two main subtypes associated with epithermal systems (high-sulfidation/acid-sulfate and low-sulfidation/adularia-sericite) as well as two minor subtypes (intermediate-sulfidation and hot spring). The term sulfidation refers to the potential oxidation state and fugacity of sulfur in mineralizing fluids depositing sulfides (Barton and Skinner, 1979).

Any rock type can play host to an epithermal system, though the most common hosts are calc-alkaline volcanic rocks. Tectonic settings also play a role in determining the presence and type of epithermal alteration. Most high-sulfidation systems occur in volcanic arcs while many low-sulfidation systems occur in areas with widespread extension (Simmons et al., 2005; Taylor, 2007).

Epithermal alteration occurs as open-space filling or replacement below the paleo-water table in areas of high permeability (Simmons et al., 2005). Open-space filling is the result of hydrothermal fluids depositing minerals and/or gelatinous mixtures (such as, opaline gels). Open-space filling can occur in many ways, the most common being vug filling, veining, and space filling in breccia pipes (Taylor, 2007). Alteration replacement features occur when heated fluids come in contact with surrounding wall rock and hydrothermal reactions occur. Individual style of alteration for each subtype will be discussed in more detail below.

High-Sulfidation/Acid-Sulfate

The high-sulfidation subtype (commonly known as acid-sulfate) is typically formed by water-rock interaction between acidic, magmatic waters and calc-alkaline volcanic rocks (typically, andesitic to dacitic rocks). High-sulfidation fluids are commonly less evolved than low-sulfidation fluids. This subtype generally produces smaller deposits than the low-sulfidation subtype (Taylor, 2007).

If a high-sulfidation system is the product of less evolved, magmatic fluids, alteration will occur proximal to the source which heats the fluids (**Figure 11**). This does not suggest that alteration occurs directly adjacent to a magmatic body; rather, that the alteration occurs closer to the convecting fluids than to the surface (up to ~700 m below the paleo-water table) (Hedenquist et al., 2000). Magmatic fluids with a minor meteoric component can generate high-sulfidation alteration (Simmons et al., 2005). High-sulfidation fluids are acidic and contain many volatiles including S, C, and Cl. Alteration in a system begins when magmatic SO_2, CO_2, and HCl break down under the influence of the hot waters, then interact with the surrounding wall rock resulting in the oxidation of magmatic H_2S (Taylor, 2007).

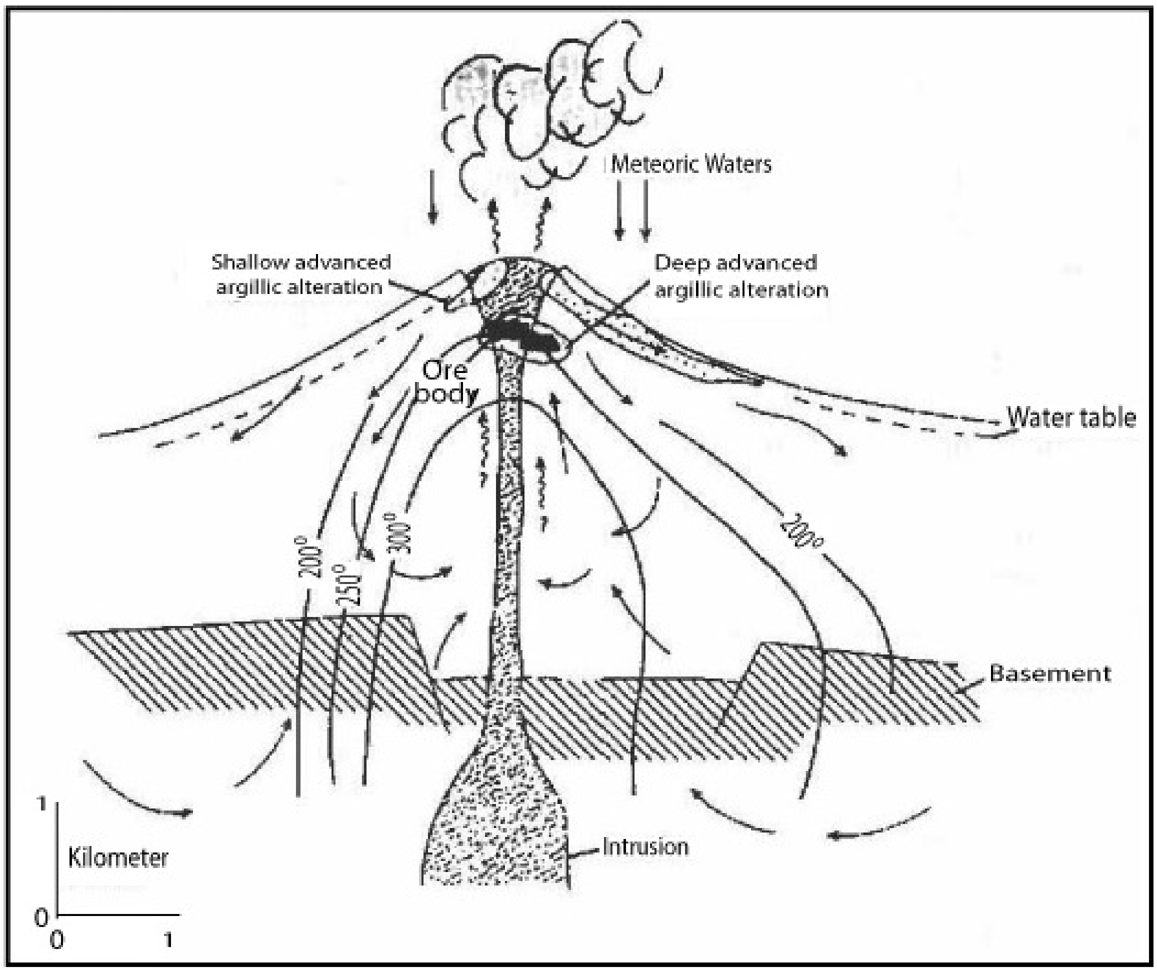


Figure 11: High-sulfidation/Acid-sulfate alteration model. Figure from Heald et al. (1987).

Fluid inclusion data show that the salinity of high-sulfidation hydrothermal fluids is between 5 to 40 weight percent NaCl equivalent, though most high-sulfidation salinities fall between 5 to 10 weight percent NaCl equivalent (Simmons et al., 2005). If a system is buffered by these high saline, low pH waters, a high-sulfidation mineral assemblage suite will be generated.

The most common mineral in both high- and low-sulfidation systems is silica (SiO_2), namely quartz. This is due to elevated Si content in ascending fluids which saturate the system. Also prominent, and indicative of a high-sulfidation system, are alunite, kaolinite, and dickite. Other typical minerals include pyrophyllite, sericite, chlorite, barite, diaspore, and native sulfur (Simmons et al., 2005; Taylor, 2007).

Cu, Au, Ag, and As are abundant in high-sulfidation systems while Pb, Hg, Sb, Te, Sn, Mo, Bi are often present in lesser amounts. Pyrite and enargite are the main sulfides found in this system. Many Cu-bearing minerals, sulfosalts, and tellurides are associated with high-sulfidation; these include covellite, bornite, chalcocite, orpiment, tetrahedrite, tennantite, and bismuthinite (Simmons et al., 2005; Taylor, 2007). If base metal sulfides are present, Cu can be sporadic or even absent in the system (Taylor, 2007). There are two Au-bearing minerals: native gold and electrum.

The most prominent alteration associated with high-sulfidation is silicification due to massive silica replacement of groundmass (Taylor, 2007). Ore is often disseminated throughout silicified groundmass. Silicified wall rocks often contain vuggy silica. Brecciation and veining (including stockwork veins) are typical but do not dominant this system. Coarse-grained alunite is indicative of hypogene high-sulfidation enrichment while fine-grained alunite suggests supergene replacement of sulfide minerals (Simmons et al., 2005; Taylor, 2007).

The center of a high-sulfidation system is dominated by silicified wall rock and advanced argillic alteration. If there is ore, it will be prevalent in the center (Taylor, 2007). Surrounding the center of the deposit is a shell of propylitic alteration surrounded by quartz+ alunite+ kaolinite/dickite+ pyrophyllite± illite or smectite (Simmons et al., 2005). Topography may influence the location and extent of each alteration shell.

Low-Sulfidation/Adularia-Sericite

The low-sulfidation subtype (commonly known as adularia-sericite) is formed by water-rock interaction between nearly neutral, meteoric waters and calc-alkaline or alkaline volcanic rocks (typically, basaltic to rhyolitic rocks) (Simmons et al., 2005). Low-sulfidation fluids are more evolved than high-sulfidation fluids and are reducing. This subtype generally produces larger deposits than the high-sulfidation subtype (Taylor, 2007).

The low-sulfidation subtype occurs near surface, up to 50 m below the paleo-water table (Hedenquist et al., 2000). Meteoric fluids with a minor (if any) magmatic component generate low-sulfidation alteration (**Figure 12**). These fluids are near-neutral and contain limited amounts of the volatiles S and C (Taylor, 2007). Alteration in a system begins when meteoric fluids with Cl, H_2S, and CO_2 interact with the surrounding wall rock causing wall rock-buffered hydrolysis. Fluid inclusion data show that the salinity of low-sulfidation hydrothermal fluids is less than 10 weight percent NaCl equivalent, although most Au and Ag deposits have salinities less than 5 weight percent NaCl equivalent (Simmons et al., 2005). Most metals are mobile in fluids with salinities between 10 and 20 weight percent NaCl equivalent, which may explain why low-sulfidation deposits are not as endowed in metallic minerals as high-sulfidation systems. Lower density fluids are typically closer to the surface and are a product of boiling (Taylor, 2007). If a system is buffered by low saline, neutral pH fluids, a low-sulfidation mineral assemblage suite with associated textures will be generated.

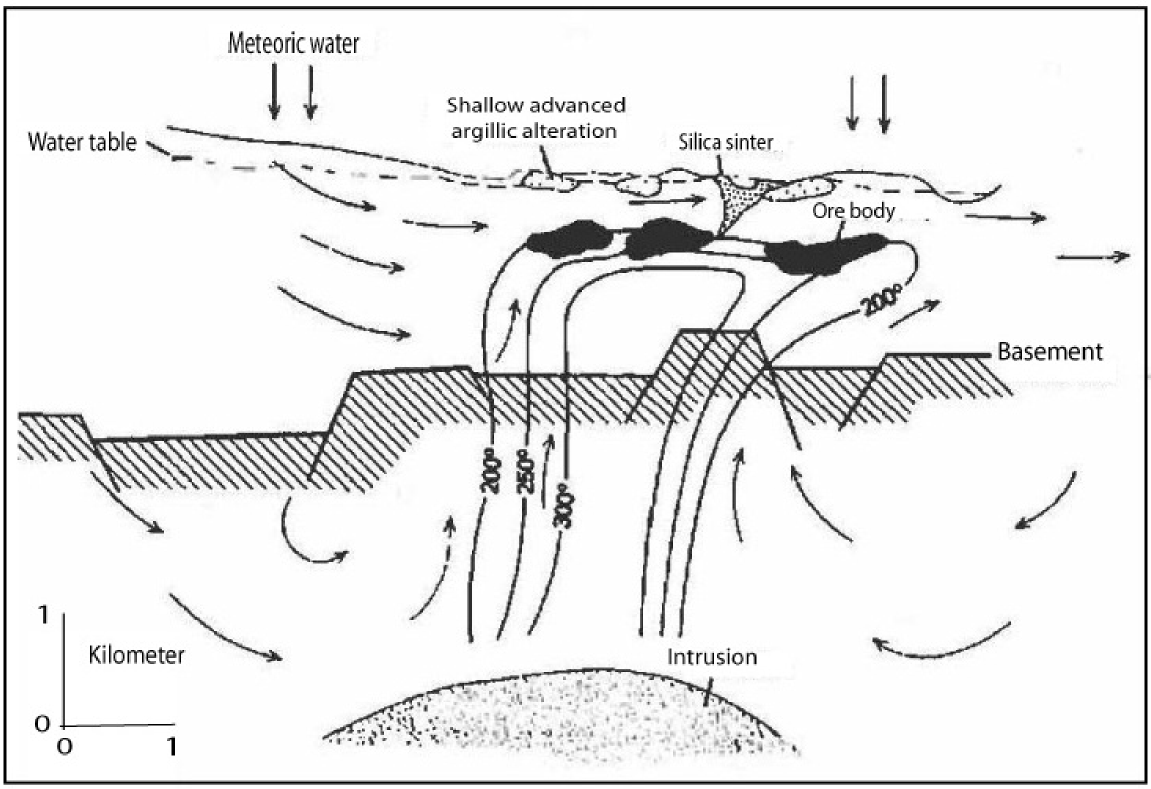


Figure 12: Low-sulfidation/Adularia-sericite alteration. Figure from Heald et al. (1987).

Quartz is the most common gangue mineral. Also prominent, and indicative of a low-sulfidation system, are the minerals calcite, adularia, and illite. Though adularia is the typical feldspar associated with low-sulfidation, it is not always present (Taylor, 2007). Other minerals typical of near-neutral fluids are chalcedony, chlorite, barite, rhodochrosite, and various other carbonates (Simmons et al., 2005; Taylor, 2007).

Au, Ag, Zn, and Pb are abundant in low-sulfidation systems while Cu, Sb, As, Hg, and Se can be found in lesser amounts. Pyrite is the most common gangue sulfide (Taylor, 2007). Although low-sulfidation systems have fewer sulfides than high-sulfidation systems, common base metal sulfides include chalcopyrite, tetrahedrite, galena, sphalerite, and arsenopyrite may be present (Simmons et al., 2005; Taylor, 2007). Ore-bearing minerals associated with low-sulfidation include electrum, native gold, and possibly sphalerite and galena.

Low-sulfidation systems are noted by their prominent structural control. Ore is often found associated with veining (including stockwork veins) and brecciation. Cavity fillings, such as drusy quartz and colloform banding are most likely to contain higher grade ore (Taylor, 2007). Ore disseminated throughout altered groundmass is less common (Simmons et al., 2005).

The core of alteration surrounds veining and contains quartz, adularia, illite, and pyrite as well as ore-bearing minerals (Simmons et al., 2005); the core is silicified with either quartz or chalcedony. Surrounding the core is a shell of phyllic alteration followed by argillic alteration (Taylor, 2007). Shell overprinting may occur due to cyclic pulses of hydrothermal water in the system. Regionally, an area can experience propylitic alteration with clays, carbonates and zeolite minerals (Simmons et al., 2005).

Intermediate-Sulfidation

Intermediate-sulfidation is a term used to describe a system that is typically dominated by a low-sulfidation gangue mineral assemblage but has the sulfide characteristics of both high- and low-sulfidation systems (Hedenquist et al., 2000). Intermediate-sulfidation systems well endowed in base metal and Fe-sulfides are thought to be the product of highly saline fluids that are less acidic than high-sulfidation systems. Fluids from both high- and low-sulfidation systems are capable of fluctuating in sulfidation states thus becoming an intermediate-sulfidation system. Fluids which deposit ore-bearing sulfides in low-sulfidation systems average between intermediate- and low-sulfidation states.

Minerals associated with intermediate-sulfidation are tennantite, tetrahedrite, hematite-pyrite-magnetite, pyrite, and chalcopyrite (Simmons et al., 2005). Intermediate-sulfidation does not occur in altered TSC. For a full description of this subtype, refer to Hedenquist et al. (2000).

Hot Spring Subtype/Steam-heated deposits

The hot spring subtype (also known as steam-heated deposits) forms in near surface environments from steam-heated waters. These systems can be produced by either acidic (high-sulfidation) or near-neutral (low-sulfidation) fluids (Taylor, 2007), though it is common to see low-sulfidation style mineralization (Hedenquist et al., 2000). Hot spring deposits can overlay a deeper economic or barren system containing either low- or high-sulfidation alteration. This subtype is often associated with sinter, surficial alteration lenses and/or brecciated root zones. The deposits are easily eroded because of their proximity to the surface (Taylor, 2007).

Sulfate and clay minerals and minor amounts of pyrite are typical of the hot spring subtype. Coarse-grained alunite can be indicative of a hot spring system if found in association with the aforementioned minerals and features. Alunite can be present, regardless of what subtype lays beneath a hot spring system. This system can be barren or bulk minable (Taylor, 2007).

As these are topography-directed systems, there is no notable alteration halo. Alteration can occur in lenticular spaces along zones of high permeability or as an apron draping over an underlying system (Taylor, 2007).

High-Sulfidation verses Low-Sulfidation

Why is one system dominated by high-sulfidation alteration while another by low? Since all subtypes are capable of producing similar gangue minerals and fine-grained gold (Taylor, 2007), the answer lies deeper than rock type or fluid source. The proportion of magmatic verses meteoric water available to the system plays a large role in the pH of water. Water-rock interaction and fluid mixing can cause the fluid chemistry to change (Taylor, 2007). Reducing verses oxidizing fluids will determine the type of the mineralogy. Boiling in the system will change the chemistry of a fluid and an increase in fluid temperature can yield varying mineral assemblages (Simmons et al., 2005). The type of country rock will, also, determine the type of alteration as will the depth of emplacement. High-sulfidation systems hosted in rhyolites or andesites tend to settle topographically above low-sulfidation alteration; the opposite of what is expected (Taylor, 2007). The confining pressure of the water table will determine the overall pressure and temperature gradients in the system (Simmons et al., 2005).

Alteration Minerals

Simmons et al. (2005) generated a list of temperatures and depths associated with mineral phases (**Tables 10-12**). Mineral emplacement verses temperature and depth is important for mineral exploration. If temperatures and depths can be inferred based on mineralogy, then approximate paleo-depth and temperature can be used to infer mineral proximity within a system. Fluid inclusion and stable isotope data of epithermal economic minerals suggest that epithermal ore minerals begin to precipitate from solution between 150 and 300ºC at depths between 50 to 1500 m (respectively) (Simmons et al., 2005). Trace elements are also an effective means of locating and establishing economic mineral abundances (White et al., 1992).

<u>Stable Isotope Ratios</u>

Standard Mean Ocean Water has a $\delta^{18}O$ value of 0.0‰. Most igneous rocks have $\delta^{18}O$ values between 5.0‰ (basalts) and 10.0‰ (granites). As a general rule, extrusive rocks have smaller fractionations than intrusive rocks (Taylor, 1968). Caldera related, continental rhyolites, like those associated with the Yellowstone Caldera, may have lower $\delta^{18}O$ values than non-caldera related, extrusive rocks. Lower values are the result of the collapse of hydrothermally altered rocks which have assimilated in the magma chamber and are re-extruded (Taylor and Sheppard, 1986).

Meteoric water and rocks which have interacted with meteoric water are the only materials with a $\delta^{18}O$ value less than 0.0‰ (Faure and Mensing, 2005). There are only a few published values for the $\delta^{18}O$ signature from the hydrothermally altered rocks in the Yellowstone Plateau (Larson et al., 2009).

Isotope fractionation is a temperature dependant function; as temperature increases, fractionation decreases. Oxygen and hydrogen isotopes can be specifically used to determine the nature of fluids reacting in a hydrothermal system. Temperature fractionation should be recognizable between veins and altered wall rocks, as well as in a vertical profile; deeper alteration should have a lower $\delta^{18}O$ value than alteration topographically higher. The resulting ratios can be used to determine water sources.

Water/rock interactions cause a "$\delta^{18}O$ shift" because as heated fluids react with country rocks, oxygen exchange occurs between the fluids and the rocks (Craig, 1963). The more fluid that interacts with a rock, the more the rock moves into equilibrium with the fluid. These wall rocks will have lower $\delta^{18}O$ ratios as they buffer to the fluids (which will have increased $\delta^{18}O$ ratios). This reaction is seen in a variety of ways: mineral alteration (in which the alteration product forms in equilibrium with the fluid), oxygen exchange in unaltered minerals, the dissolving of minerals, or the precipitation of minerals in pore spaces. Stable isotope ratios reported by Taylor (1974) show that most hydrothermal systems are fueled by meteoric waters.

Hydrothermal Activity in the Yellowstone Caldera

The extent of the hydrothermal activity in the Yellowstone Caldera is evident in the widespread geysers, hot springs, and mud pots throughout the region (**Figure 9**). Heated fluids are mobile along the ring fracture zones of the caldera margin. The fractures localize the fluids yielding a structurally controlled hydrothermal system. Locally, intense centers of activity occur beyond the caldera margin in the Norris-Mammoth Corridor. The oldest dated hydrothermal activity in the Yellowstone Caldera is ~373 ka (Sturchio et al, 1994).

The fluids supplied to fractures are generated from two sources, a meteoric component and a magmatic component. Meteoric waters at Yellowstone account for at least 95% of the final hydrothermal fluids (White, 1969); Fournier (1989) suggests the fluids are between 99.6 and 99.8% meteoric. The magma body and the magmatic fluids act as the heating mechanisms for meteoric waters. Magmatic fluids are heated, making them less dense and allowing them to convect through permeable rocks or fissures. When the hydrothermal fluids reach groundwater, they heat it as well. The hydrothermal mixture interacts with surrounding country rocks, causing hydrothermal alteration. White et al. (1975) suggested that the current alteration in YNP is forming due to boiling fluids.

Gold in Yellowstone

The presence of gold in Yellowstone is not a new observation; its presence has been noted by many. Gottfried et al. (1972) and Tilling et at. (1973) reported Au values from unaltered volcanic rocks in YNP. Their results show a Au content between 0.1 and 60 ppb with an average concentration ~0.5 ppb. White et al. (1992) studied gold particles in actively depositing sinter. Their results show a Au content between 0.5 and 10 ppm in selected areas.

Though gold is found throughout Yellowstone, Gibbon Geyser Basin (GGB) and adjacent areas contain the highest concentration of sinter-deposited gold in YNP (White et al., 1992). The gold content in GGB is as high as 10 ppm in some locations (Beryl Spring). GGB is situated within two prominent faulting zones, near the caldera rim and along the Norris-Mammoth Corridor. Because of its proximity to both, it is possible its fluids have a deeper source than those fluids affecting other hot springs and basins in

YNP. Neither Norris Geyser Basin nor Crater Hills displayed anomalous gold (White et al., 1992).

Hydrothermal Activity in Tuff of Sulphur Creek

Tuff of Sulphur Creek covers the collapsed Yellowstone Caldera ring fracture to the northeast. A combination of extensional faults and the ring fracture in and around the caldera acted as conduits for the upwelling hydrothermal fluids. Ponce and Glen (2002) note the importance of large scale faulting and the occurrence of epithermal deposits.

Larson et al. (2009) performed a preliminary study on the features and alteration in altered TSC. They concluded there are two assemblages: quartz (opal)+ kaolinite± dickite± alunite and quartz+ illite± adularia. The quartz (opal)+ kaolinite assemblage is found in the upper 100 m of the canyon, thus, it is assumed that these minerals formed directly below the paleo-surface. The assemblage was generated from lower temperature, acid-sulfate fluids. The quartz + illite assemblage is found deeper in the canyon, ~100 m below the canyon rim. This assemblage was generated from high temperature, alkali-chloride fluids. Both assemblages have various amounts of pyrite and marcasite. $^{40}Ar/^{39}Ar$ dating was performed on hydrothermal alunite yielding an alteration date of 154± 16 ka.

TSC is actively being downcut by Sulphur Creek. Canyon formation caused the water table to lower and a steady lowering of the water table lead to the overprinting of mineral assemblages and features (Larson et al., 2009). This thesis will expand upon the hydrothermal features and the epithermal alteration of TSC.

CHAPTER FOUR

METHODS

Field Methods

One preliminary field season and two technical seasons were spent in Yellowstone National Park. Summer of 2007 was used to locate the boundaries of the field area and get a feel for the rugged terrain. 7 samples were collected (YS-07-JM01 through 07) along the south ridge of the south fork of Sulphur Creek. Field assistants were Eric Baar, Allison Phillips, and Brian Pauley.

The second field season took place in summer, 2008; 156 samples were collected. Little mapping was done at this time. Field assistants were Eric Baar and Ashley Tefft.

The third field season (summer, 2009) was devoted to mapping structures, active thermal areas inside the canyon, and outcrops. Field assistant was Eric Baar.

From the creek, Outcrop 1 to note is on the south wall and is white. Moving east along the south wall, Outcrops 3, 5, 6, and 7 are encountered. Along the north wall (from west to east), Outcrop 2 is located on the north ridge. Moving east, Outcrops 4 A (west) through C (east) make up the north wall. The north wall is a large, whitish-yellow with almost continuous exposure and stretches for a majority of the field area. **Figure 13** shows the distribution of outcrops.

Sampling

Samples were collected from west to east beginning from the bottom of the outcrop and working up the walls toward the ridges. Within an outcrop, samples were collected every ~7.5 m (where possible). However, if a vein or "interesting" rock occurred between the intervals, it was sampled as well. Each sample was given a brief field description, a GPS location, bagged and numbered accordingly. Notes were taken as to the distance and direction between two samples for clarification on a higher resolution map. The distribution of samples is noted in **Appendix I**, **Figure I-2**. In total, 164 samples were collected during the 2007 and 2008 field seasons. See **Appendix IV**, **Table IV-1** for sample locations.

Upon returning from the field and prior to lab work, each sample was split to reveal a fresh, unweathered surface. For each sample, groundmass replacement, veining, protolith and alteration phenocrysts, sulfides, vuggy silica, drusy quartz, and any other distinguishing characteristics were described (**Appendix IV**, **Table IV-2**). After thorough descriptions were completed for each sample, all samples were laid out according to outcrop and location within the outcrop to distinguish any visible patterns.

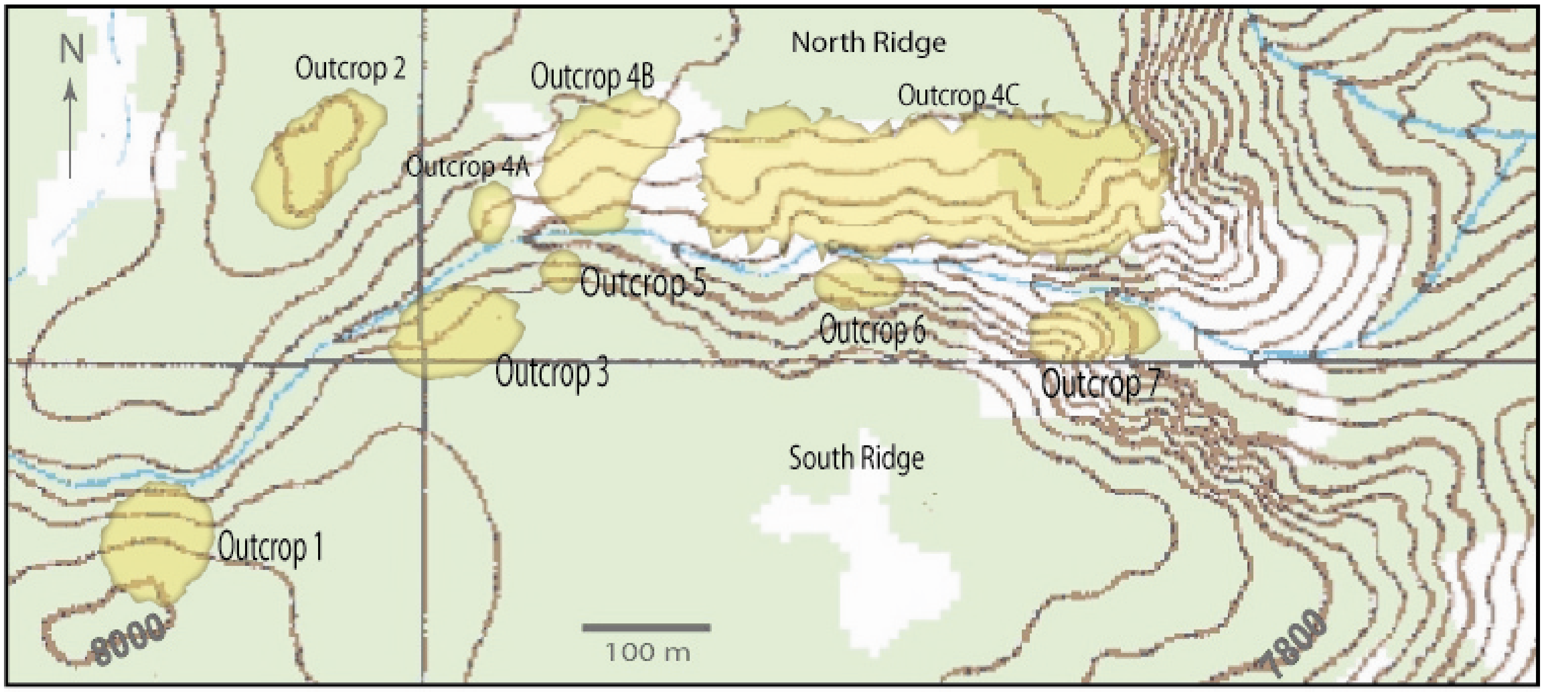


Figure 13: Outcrop Map. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Mapping

Field mapping of structures and outcrops was done during the third field season. Structures included large veins, spires, and active thermal features in the canyon. Mapping focused on the location of thermal features (**Appendix II**, **Figure II-1**), the strikes and dips of veins (**Appendix II**, **Figure II-2**), and linear measurements between veins, active thermal features, and inactive thermal features (spires) (**Appendix II**, **Figure II-3**).

X-Ray Diffraction

X-ray diffraction (XRD) is the most common way to identify both bulk mineralogy and clay mineralogy. Clay-size crystalline particles, placed on a slide and loaded into the diffractometer, are exposed to directed X-rays. The goniometer moves around the sample at prespecified angles and steps. The directed X-rays reflect the atomic spacing of crystalline material. X-rays will scatter in a specific pattern, unique to a mineral.

Methods

Samples were chosen for basic mineralogy identification. Part of a sample (i.e., vein, wall rock, or whole rock) was broken off with a hammer on a steel disk, ground into a powder with a mortar and pestle, placed in a vial and labeled with the sample number and type of sample.

Individual powders were randomly oriented on a glass slide and set with acetone. After completely drying, the slide was placed in the Siemens D-500 X-Ray Diffractometer. The diffractometer was set to operate at 35 kV and 30 mA. Scan range

(2-80º 2θ), step interval (0.04), and dwell time (5.0 seconds) were set in the MDI DataScan 4.0 software. These parameters yielded a total scan time of 2:42:35 (hours).

Once the sample was scanned, the resulting diffractogram was analyzed with Jade 8.0 software (Materials Data Corporation). All available mineral database libraries were searched for peak matches. Minerals were identified by comparing known diffraction patterns to the unknown sample. The diffractometer has a detection limit of 5%, therefore, all minerals reported were in abundance of ~5% or more in a sample.

The largest peak was the first to be matched to a known mineral. Once the peak was matched, other, smaller, peaks for the same mineral where matched. A peak was only used once; once it had been associated with a mineral, it was no longer available for other minerals.

Since this was a basic mineralogy scan, clays were not separated, heated, and oriented on the slide.

Thin Sections

Thin sections were made for a further investigation of alteration and vein paragenesis, vein-type analyses, and alteration-type classifications. They were also used for sulfide identification.

Methods

A billet was cut from a slabbed sample for an approximate fit to a non-frosted glass slide (~1.3 cm). Billets were attached to slides with epoxy and allowed to dry for at least 30 minutes. Some billets were set with epoxy for about 2 hours before they were cemented to a slide because they were too porous to adhere to the slide. (Epoxy ingredients are as follows: 5 mL of resin plus 5 cc of curing reagent. The epoxy mixture was heated for one minute and stirred for five minutes.) A set billet was cut and shaved, then sanded using 600 μm grit. Slides were not ground to 30 μm because they were not being used to determine mineralogy. Sections were then polished using a 3 μ grit and a dab of oil on a sheet of paper.

X-ray Fluorescence

X-ray fluorescence (XRF) provides a compositional analysis of major and trace elements. X-rays release fluorescent radiation on a sample without destroying it.

Inductively Coupled Plasma Mass Spectroscopy

Inductively coupled plasma mass spectroscopy (ICP-MS) is used as a more precise method of analyzing trace elements. Instead of X-rays, this instrument induces ionization by adding argon gas to a sample then vaporizing the sample (Jarvis et al., 1992). ICP-MS has a lower detection limit than that of the XRF.

Methods

Whole rock major and trace element XRF and ICP-MS analyses were measured at the Washington State University (WSU) GeoAnalytical Lab using the methods of Johnson et al. (1999) and Knaack et al. (1994), respectively. Weathered material was sifted during the crushing stage of sample preparation for XRF and ICP-MS.

Assays

Assays were performed by Activation Laboratories Ltd. (ActLabs) in Ontario, Canada. These samples were sent out for analyses because they contained large amounts of sulfides and sulfates which require back calculation on the XRF. These analyses are necessary because they provide elemental data not typically performed by the WSU GeoAnalytical Lab.

Methods

Assay samples were crushed then sent to ActLabs to be analyzed. The 48+Au assay package was preformed on 8 samples. See the ActLabs website (www.actlabs.com) for procedural methods on each of the tests listed below.

The following 29 elements were analyzed by Instrumental Neutron Activation Analysis (INAA): Au, As, Ba, Br, Ce, Co, Cr, Cs, Eu, Fe, Hf, Hg, Ir, La, Lu, Na, Nd, Rb, Sb, Sc, Se, Sm, Sn, Ta, Th, Tb, U, W, Yb. 17 elements were analyzed with four acid ICP, a near total digestion employing HF, $HClO_4$, HNO_3, and HCl with released metals determined by ICP/OES (optical emission spectrometry): Cu, Cd, Mo, Pb, S, Al, Be, Bi, Ca, K, Mg, Mn, P, Sr, Ti, V, Y. Three elements were analyzed by both INAA and Total Digestion ICP: Ag, Ni, and Zn. Silica was not measured due to volatilization. **Table III-5** (**Appendix III**) lists methods and detection limits for each element analyzed.

Stable Isotope Ratios

Because different stable isotopes have various atomic masses with different vibrational energies in molecular sites, isotope fractionation occurs. Fractionation occurs when lighter isotopes are preferentially segregated or partitioned from heavier isotopes of the same element during a chemical or physical reaction. For example, because ^{16}O is the lightest oxygen isotope, it preferentially evaporates from seawater and falls as precipitation (Dansgaard, 1964).

Fractionation is generally reported as the difference between the δ values of two species, where:

$$\delta = \left(\frac{R_{sample}}{R_{standard}} - 1 \right) x\ 1000.$$

R_{sample} is the ratio between isotopes in the sample ($^{18}O/^{16}O$) and $R_{standard}$ is the ratio of the same isotopes in the standard. Stable isotope ratios always display the lightest isotope in the denominator (i.e., ^{16}O). The product is recorded in parts per thousand (per mil or ‰). Oxygen isotope δ values are usually measured relative to the standard VSMOW (Vienna Standard Mean Ocean Water). This research reports the stable isotope ratios for hydrothermal quartz because, once formed, oxygen exchange with subsequent hydrothermal fluids is very slow and quartz tends to preserve its initial O ratio in these environments (Criss and Taylor, 1983).

Methods

Hydrothermal quartz and opal samples were crushed and picked based on the physical integrity of clean quartz crystals. After picking, samples were weighed out to the nearest 2 mg (not to exceed 3 mg) and placed in the metal sample holder. Color and sample clarity were noted for all weighed samples. A full sample holder was loaded into the sample chamber of the laser-fluorination line at the WSU GeoAnalytical Lab. Loading the sample holder exposed the oxygen line to the atmosphere, so the vacuum line was pumped down for ~5 hours to clean it.

Samples were slowly heated with a 20W CO_2 laser. Samples were exposed to bromine-pentafluride (BrF_5) causing a chemical reaction, releasing oxygen from its chemical bond from Si (Clayton and Mayeda, 1963; Sharp, 1990). Released oxygen was then passed through a steel line and again through a glass line. Each line contained a cold trap with zeolite pellets where gas was cleaned from the sample. The oxygen was released into the Finnigan™ Delta S Isotope Ratio Mass Spectrometer, where it was measured against a standard gas. Please refer to Sharp (1990) and Takeuchi and Larson (2005) for detailed methods. The mass spectrometer is operated by ISODAT NT software. Isotope ratios were normalized to $\delta^{18}O$= 5.8‰ verses VSMOW from the UWG-2 standard (Valley et al., 1995). The first three samples were standards, followed by three unknowns, one standard, three unknowns, etc.

Electron Microprobe

Preliminary microprobe data were collected from 3 thin sections from brecciated vein samples. These analyses were preformed on the Cameca Camebax at Washington State University.

CHAPTER FIVE

RESULTS

Hand Sample Descriptions

One float sample and 163 outcrop hand samples were collected; YS-08-JM01, the float sample, has not been included in any of the descriptions below. These samples have both groundmass (matrix) alteration and wall rock alteration (**Table 1**). Groundmass alteration involves changing the geochemistry of the protolith, rhyolitic groundmass. Wall rock alteration includes veining, vuggy silica, drusy quartz, argillization of phenocrysts, and the production of sulfides (**Appendix IV**).

Groundmass Alteration

Altered Tuff of Sulphur Creek (TSC) contains three types of groundmass or matrix alteration: silicification, argillization, and leaching. Silicification is defined as the replacement of rhyolitic groundmass by hydrothermal silica (**Figure 14**). Silicified samples are harder than argillized and leached samples. Argillization is defined as the replacement of rhyolitic groundmass by hydrothermal clay and sulfate minerals (**Figure 15**). Argillized samples are softer than silicified samples but harder than leached samples. Leaching occurs when acidic fluids move through a rock dissolving groundmass and phenocrysts, leaving behind a pockmarked texture (**Figure 16**). These rocks have extremely high SiO_2 contents (>99%) yet are NOT silicified; they are extremely soft.

Of the 163 hand samples, 116 samples are silicified. Silicification is widespread throughout the canyon walls (**Appendix I**, **Figure I-3**). Of the 59 samples collected from stream outcrop (which includes the lower 7.5 m of the canyon walls) 27 samples are not silicified. 21 of the non-silicified samples have silica veins, veinlets and/or brecciation associated with veining. Of the 54 samples collected from wall outcrop (beginning 7.5 m

Sample	Silicified: Major	Argilization: Major	Argilization: Overprint	Leached-unaltered	Brecciated Veins	Silica Veins	Sulfide Veins	Silica Veinlets	Clay Veinlets	Sulfide Veinlets	Empty Veinlets	Vuggy Silica	Leached-Altered	Drusy Quartz	Sulfides	Altered Phenocrysts	Unaltered Phenocrysts	Oxidized
YS-07-JM01	x		x						x		x							x
YS-07-JM02	x		x					x	x	x					x			
YS-07-JM03	x		x						x									
YS-07-JM04	x		x						x			x			x			
YS-07-JM05	x								x					x	x	x		
YS-07-JM06	x		x									x		x				
YS-07-JM07	x					x												
YS-08-JM02	x		x					x			x							
YS-08-JM03	x													x				
YS-08-JM04	x							x				x		x		x		
YS-08-JM05	x													x				
YS-08-JM06	x		x					x								x		
YS-08-JM07	x		x					x										
YS-08-JM08		x			x			x		x					x			
YS-08-JM09		x			x			x		x					x			
YS-08-JM10		x													x			
YS-08-JM11	x		x					x	x					x				
YS-08-JM12		x				x												
YS-08-JM13		x				x		x	x	x					x	x		x
YS-08-JM14		x			x			x		x					x			
YS-08-JM15	x							x										
YS-08-JM16	x		x												x			
YS-08-JM17		x											x		x	x	x	
YS-08-JM18	x							x		x		x			x			
YS-08-JM19	x		x			x			x						x			
YS-08-JM20	x				x										x			
YS-08-JM21	x				x			x	x	x					x			
YS-08-JM22	x		x				x	x	x						x	x		
YS-08-JM23		x						x	x						x			x
YS-08-JM24	x	x						x	x	x					x	x	x	
YS-08-JM25		x						x	x							x	x	
YS-08-JM26		x											x					
YS-08-JM27	x	x						x		x					x	x	x	
YS-08-JM28		x							x		x					x	x	
YS-08-JM29	x	x						x	x		x	x					x	
YS-08-JM31		x						x	x	x					x	x	x	
YS-08-JM32	x	x						x	x					x				
YS-08-JM33	x	x						x	x			x				x		
YS-08-JM34		x																
YS-08-JM35		x						x	x				x					
YS-08-JM36				x														
YS-08-JM37	x		x					x				x				x		
YS-08-JM38						x				x				x	x			
YS-08-JM39		x				x			x						x			
YS-08-JM40				x				x			x							
YS-08-JM41				x														
YS-08-JM42	x		x					x	x		x			x	x	x		
YS-08-JM43		x						x			x		x					
YS-08-JM44	x							x		x		x			x	x		
YS-08-JM45	x							x				x		x				
YS-08-JM46	x					x												
YS-08-JM47	x							x				x		x				x
YS-08-JM48	x		x			x		x				x						
YS-08-JM49				x				x										
YS-08-JM50				x				x						x				
YS-08-JM51				x				x										
YS-08-JM52	x							x				x						x
YS-08-JM53	x							x				x						x
YS-08-JM54	x							x										
YS-08-JM55	x											x						
YS-08-JM56	x		x					x	x			x						

Table 1: Summary of groundmass and wall rock alteration based on hand sample descriptions for each sample.

Sample	Silicified: Major	Argilization: Major	Argilization: Overprint	Leached-unaltered	Brecciated Veins	Silica Veins	Sulfide Veins	Silica Veinlets	Clay Veinlets	Sulfide Veinlets	Empty Veinlets	Vuggy Silica	Leached-Altered	Drusy Quartz	Sulfides	Altered Phenocrysts	Unaltered Phenocrysts	Oxidized
YS-08-JM57	x											x		x				
YS-08-JM58	x							x				x		x				
YS-08-JM59	x	x												x	x			
YS-08-JM60	x																	
YS-08-JM61	x											x						
YS-08-JM62	x							x										
YS-08-JM65	x											x		x				
YS-08-JM66	x											x		x				
YS-08-JM67	x										x	x		x				
YS-08-JM68						x					x				x			
YS-08-JM69	x																	
YS-08-JM70		x						x	x						x			
YS-08-JM71	x							x		x					x			
YS-08-JM72		x						x	x							x		
YS-08-JM73	x					x		x										
YS-08-JM74	x		x					x	x	x					x	x		
YS-08-JM75				x				x										
YS-08-JM76	x							x				x		x	x			x
YS-08-JM77	x		x			x		x				x		x				
YS-08-JM78	x					x		x	x						x	x	x	
YS-08-JM79				x														
YS-08-JM80	x						x								x			
YS-08-JM81	x							x		x					x			
YS-08-JM82				x				x										
YS-08-JM83				x		x		x						x	x			
YS-08-JM84				x				x		x				x	x			
YS-08-JM85	x					x		x		x				x	x			
YS-08-JM86	x		x					x		x	x				x			
YS-08-JM87	x				x	x		x		x				x	x			
YS-08-JM88						x												
YS-08-JM89				x				x		x				x	x			
YS-08-JM90		x							x									
YS-08-JM91	x							x										
YS-08-JM92				x				x										
YS-08-JM93		x						x							x			
YS-08-JM94	x		x													x		x
YS-08-JM95		x																x
YS-08-JM96	x		x					x	x									
YS-08-JM97	x		x					x	x					x	x	x		
YS-08-JM98	x						x	x							x	x		
YS-08-JM99	x					x		x										
YS-08-JM100		x							x									
YS-08-JM101		x			x			x	x						x			
YS-08-JM102	x		x					x	x									
YS-08-JM103				x		x								x				
YS-08-JM104	x							x							x			
YS-08-JM105	x					x			x									x
YS-08-JM106	x		x					x	x									x
YS-08-JM107	x		x					x	x						x			x
YS-08-JM108	x		x					x				x						
YS-08-JM109	x					x		x	x	x					x			
YS-08-JM110					x	x		x	x						x			
YS-08-JM111	x		x															
YS-08-JM112	x	x						x	x	x					x	x		
YS-08-JM113		x				x												
YS-08-JM114		x						x		x		x			x			
YS-08-JM115		x						x						x				
YS-08-JM116	x		x					x	x					x	x	x		
YS-08-JM117	x							x			x	x		x				
YS-08-JM118		x			x			x		x					x			
YS-08-JM119		x					x	x							x			
YS-08-JM120A	x	x													x			

Table 1: Continued.

Sample	Silicified: Major	Argillization: Major	Argillization: Overprint	Leached-unaltered	Brecciated Veins	Silica Veins	Sulfide Veins	Silica Veinlets	Clay Veinlets	Sulfide Veinlets	Empty Veinlets	Vuggy Silica	Leached-Altered	Drusy Quartz	Sulfides	Altered Phenocrysts	Unaltered Phenocrysts	Oxidized
YS-08-JM120B	x													x				
YS-08-JM121	x		x					x	x						x	x		
YS-08-JM122	x		x													x		x
YS-08-JM123	x		x					x	x			x			x	x		
YS-08-JM124	x		x						x							x		
YS-08-JM125	x											x		x				x
YS-08-JM126	x													x				
YS-08-JM127	x							x				x		x				x
YS-08-JM128	x							x				x						
YS-08-JM129	x							x				x						
YS-08-JM130	x					x		x						x	x			x
YS-08-JM131	x							x				x						
YS-08-JM132	x	x																x
YS-08-JM133	x													x	x			
YS-08-JM134	x													x				
YS-08-JM135	x					x								x				
YS-08-JM136	x					x		x				x			x			
YS-08-JM137	x		x					x	x	x					x	x		
YS-08-JM138	x		x											x		x		
YS-08-JM139	x													x				
YS-08-JM140	x									x		x			x			
YS-08-JM141	x							x										
YS-08-JM142	x		x					x	x						x	x		x
YS-08-JM143	x							x										
YS-08-JM144	x											x						
YS-08-JM145	x		x					x	x							x		
YS-08-JM146	x		x									x						
YS-08-JM147	x		x															
YS-08-JM148	x							x				x						
YS-08-JM149	x				x	x		x		x				x	x			
YS-08-JM150	x					x									x			
YS-08-JM151	x				x										x			
YS-08-JM152							x	x		x					x			
YS-08-JM153	x					x				x					x			
YS-08-JM154	x	x			x										x			
YS-08-JM155#1	x	x				x				x					x	x		
YS-08-JM155#2	x						x	x		x					x			x
YS-08-JM155#3	x									x					x	x		
YS-08-JM156	x													x		x	x	
YS-08-JM157	x														x			

Table 1: Continued.

Figure 14: Silicified hand sample YS-08-JM125. Sample contains vuggy silica and the large vug contains drusy quartz.

Figure 15: Argillized hand sample YS-08-JM115. Sample contains argillized phenocrysts.

above the stream, ending ~24 m below the ridges) 20 samples are not silicified. 15 of those samples have silica veins, veinlets, or silica healed brecciation. Of the 52 samples collected from outcrop along the ridges (starting ~24 m below the ridges) 1 sample is not silicified; however, this sample was taken from a silica vein.

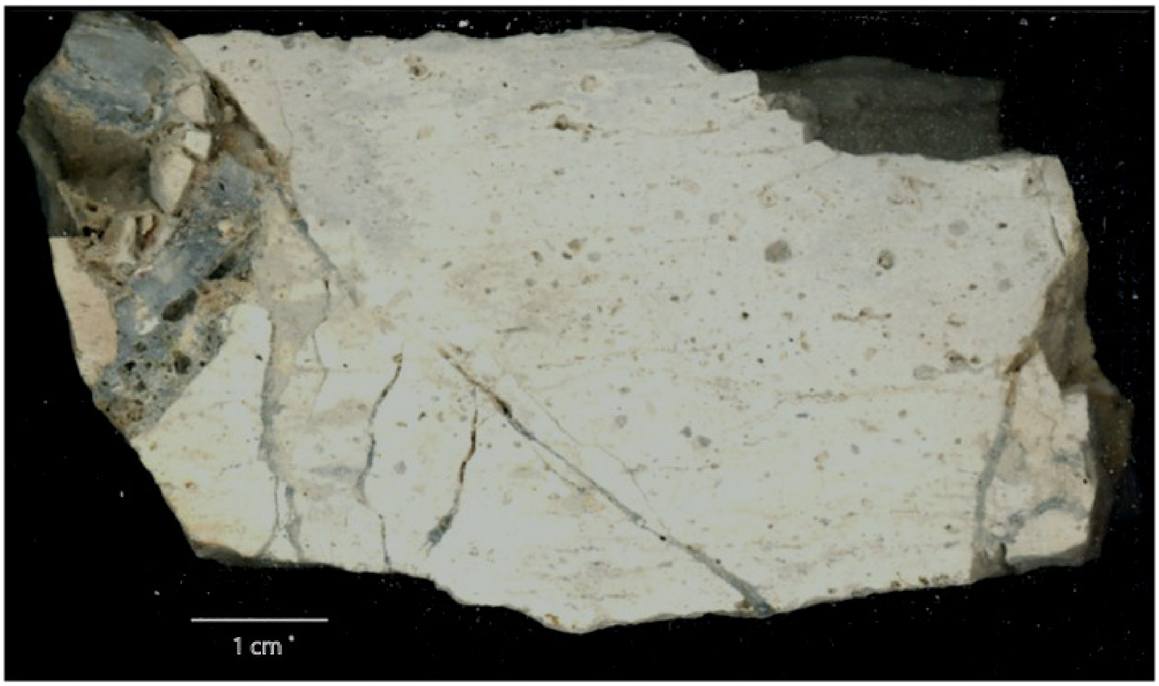


Figure 16: Leached hand sample YS-08-JM51. Sample contains silica veins and veinlets and brecciation healed by silica.

Of the total samples collected, 76 are argillized. Argillization, for the most part, is found at the base and middle of the canyon (**Appendix I**, **Figure I-4**). Of the 59 samples collected from stream outcrop, 31 samples are not argillized. 14 of those samples have clay or sulfate replacement minerals and/or clay veinlets. Of the 54 samples collected from wall outcrop, 23 samples are not argillized. 8 of those samples have clay or sulfate replacement minerals and/or clay veinlets. Of the 52 samples collected from outcrop along the ridges, 33 samples are not argillized. 9 of those samples have clay or sulfate minerals present.

49 hand samples display both silicification and argillization. Samples must display groundmass replacement by both hydrothermal silica and hydrothermal clay and/or sulfate minerals to be included in the alteration overlap. There are other samples which have phenocryst replacement but not groundmass replacement; those are not included here. **Figure I-6** (**Appendix I**) shows the distribution of both silicified and argillized samples.

It is difficult to define the paragenesis between the silicification and argillization in TSC. Hand samples and thin sections suggest that silicification is overprinted by argillization. The relationship is vague, but it appears as if argillization encroaches on or replaces silicification. This is mainly based on color variations in hand samples.

Of the total samples collected, 15 samples are high silica, leached tuff. The leached samples create a linear feature on the sample map, which begins near the base of the canyon to the west, crosses the stream, gains elevation and continues halfway through the canyon to the east (**Appendix I**, **Figure I-7**). None of the samples collected from the ridges are leached, however, 19 samples displayed internal leaching. Leaching is hard to specify in silicified and argillized samples because it is difficult to interpret if a pockmarked sample was leached then altered or if the texture represents vuggy silica (described below).

Wall Rock Alteration

Groundmass alteration is often accompanied by veining, brecciation, vuggy silica, drusy quartz, argillization of phenocrysts, and the presence of sulfides.

There are two veining styles in the study area, veins and veinlets. Veining in TSC formed by one or more open-space filling events. Veins are a common product of fluid flow, where fluids move through a fracture and deposit minerals. Veins heal as they are being fractured (Berg, 1932). Material will begin to deposit symmetrically along the walls (or selvage) of a vein, crystallizing toward the center. If the fluids cease flowing before a fissure is completely filled, a vug will remain; often, vugs are lined with drusy quartz. Wall rocks adjacent to veins are dominated by silicification and advanced argillic alteration; there is little to no potassium feldspar and no chlorite to note.

A veinlet is a small (<0.5 cm), even microscopic, tightly sealed fracture (Berg, 1932). Altered TSC contains microscopically zoned or colloform veinlets.

Veins

Silica Veins: Silica veins are the most prevalent veins in altered TSC because hot fluids remobilized ions from the high silica rhyolites. Silica veins hosted in altered TSC can be ~0.5 cm or larger (**Figure 17**). The silica veins pinch and swell throughout the stream bed, canyon walls, and along both ridges. Silica veins are the most difficult structures to recognize in the canyon because the south branch of Sulphur Creek is pervasively silicified. The veins are found both parallel and perpendicular to the direction

Figure 17: Silica vein sub-perpendicular to bedding with minor brecciation in the center.

of compression within the tuff. Many silica veins are colloform and/or crustiform (vuggy with druses) (**Figures 18** and **19**).

29 samples were collected which contain silica veins or were directly from a silica vein (**Appendix I**, **Figure I-8**). 16 silica veins were recovered from the base of the section, 8 from the walls, and 5 from the ridges. 19 of the vein samples are associated with silicified rocks.

Figure 18: Colloform silica vein. Saunders (1990) noted in the Sleeper deposit Au is often associated with the lighter bands, while the darker bands are barren.

Figure 19: Hand sample YS-08-JM38. Colloform vein sampled from vein in **Figure 18**.

Sulfide Veins: Sulfides are abundant in altered TSC, both visibly and microscopically. In all instances, including veining, the presence of sulfides is closely correlated to that of silica. Sulfides are found in silicified groundmass and silica veins, just as hydrothermal silica is found in sulfide veins (**Figures 20** and **21**). Marcasite and pyrite are the main sulfides.

The sulfide veins are similar in size to the silica veins (**Figure 22**). These veins also pinch and swell throughout the canyon floor although they are not as abundant as the silica veins. Vein orientation, strictly based on field observations, is perpendicular to sub-parallel to compaction foliation in the tuff. Rarely (if ever) do silica and sulfide veins cross-cut or occur directly adjacent to each other. No overlap of silica and sulfide veins has been noted in this study.

6 samples were collected with sulfide veins. **Appendix I**, **Figure I-10** shows the distribution of the non-brecciated sulfide veins. 5 sulfide veins were recovered from the base of the section and 1 sample from the wall. 4 of these samples are associated with silicified rocks.

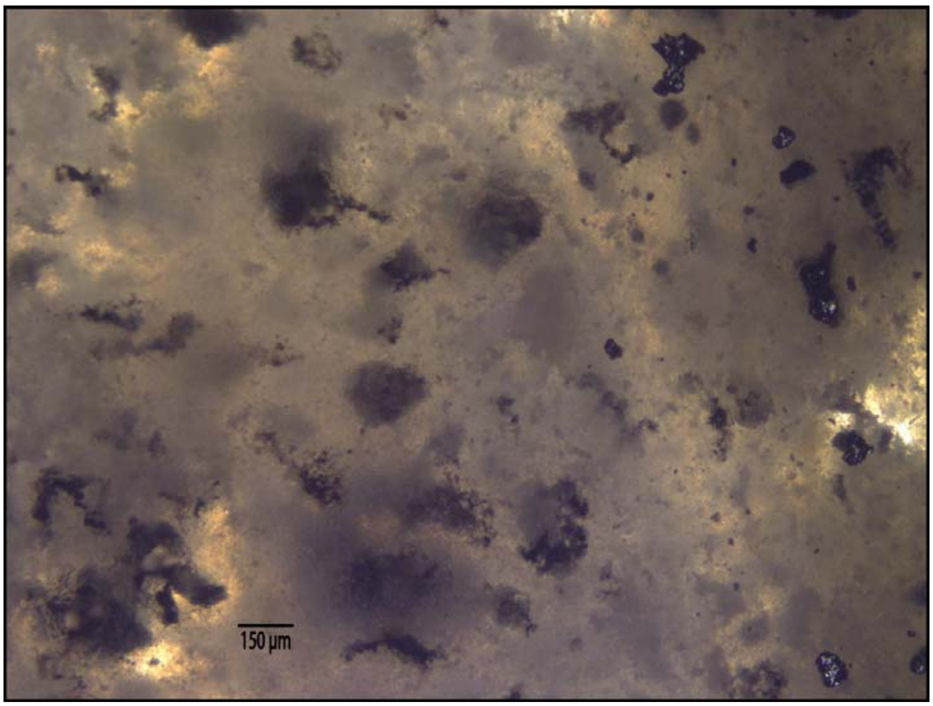


Figure 20: Micrograph from YS-08-JM38. Sulfides scattered throughout silicified matrix. Transmitted; plane-polarized light.

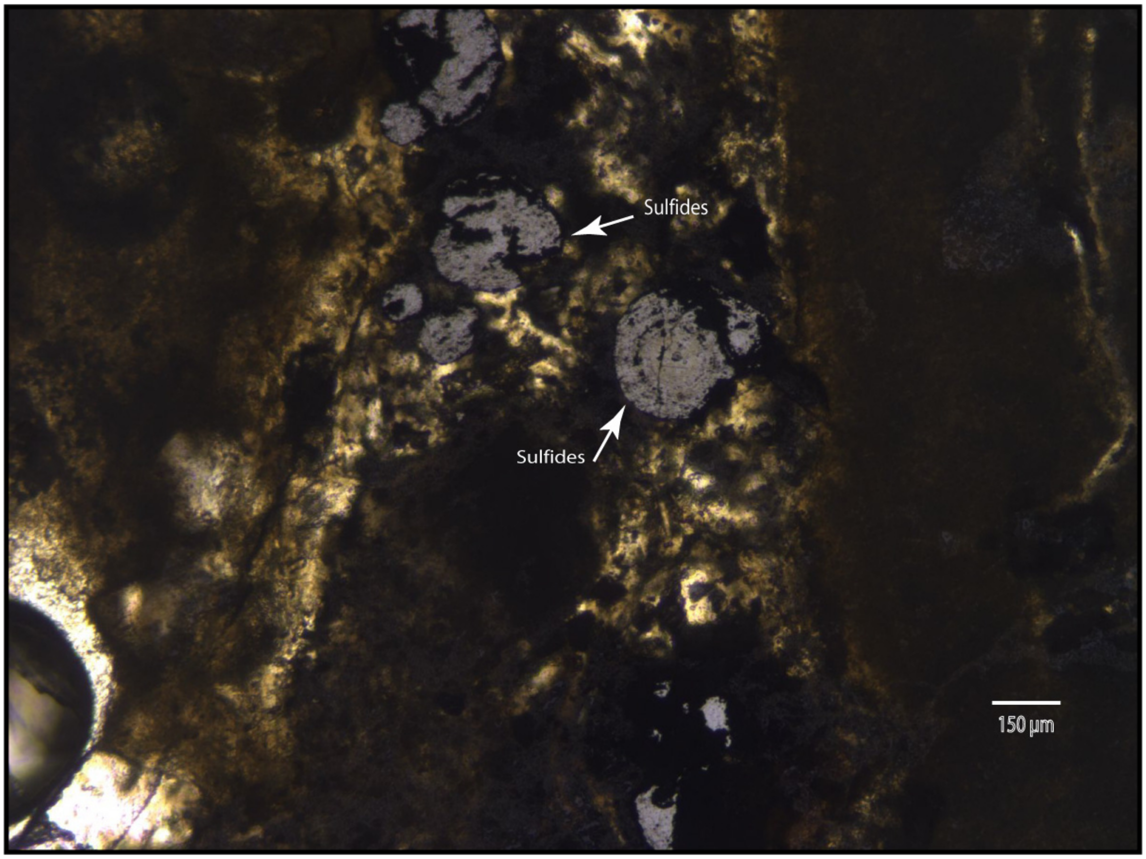


Figure 21: Micrograph from YS-08-JM09. Sulfides nucleating in a silica matrix. Reflected; plane-polarized light.

Figure 22: Sulfide vein subparallel to the primary igneous textures with minor brecciation.

Veinlets

Silica Veinlets: Silica veinlets are the most common style of fracture fill in altered TSC (**Figure 23**). They are readily abundant in almost every sample. Sometimes these veinlets occur with sulfide and/or clay veinlets. A single veinlet can contain a silica core surrounded by clay with a sulfide selvage. Along the same veinlet, the three phases can reorder to any sequence of zoning. The immense number of veinlets, which may or may not cross-cut, makes the order of deposition based on veinlets difficult to determine.

Of the 163 samples collected, 96 contain silica veinlets. **Figure I-9** (**Appendix I)** shows the distribution of silica veinlets. 37 samples from the base of the section contain silica veinlets, 39 from the walls, and 20 from the ridges. 67 of the samples are associated with silicified rocks and 14 samples are associated with silica veins.

Clay Veinlets: Clay veinlets are the second most abundant veinlets in altered TSC (**Figure 24**). Clay and/or possibly sulfates infill these tiny fractures; the infill minerals are too fine-grained to determine mineralogy. Often, clay veinlets link argillized phenocrysts (**Figure 50**).

45 samples contain clay veinlets. **Figure I-13** (**Appendix I**) shows the distribution of those samples. 15 samples from the base of the canyon contain clay veinlets, 18 from the walls, and 12 from the ridges. Of those samples with clay veinlets, 39 are associated with argillized rocks.

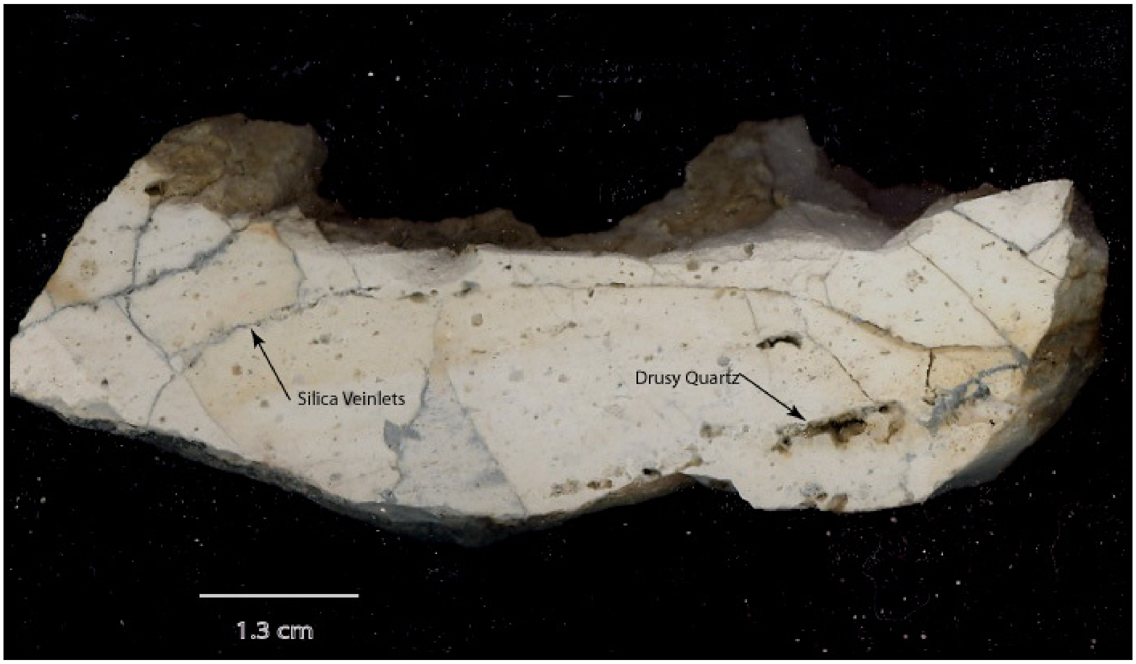


Figure 23: Silica veinlets in sample YS-08-JM43. Note the random orientation and cross-cutting relations of the veinlets.

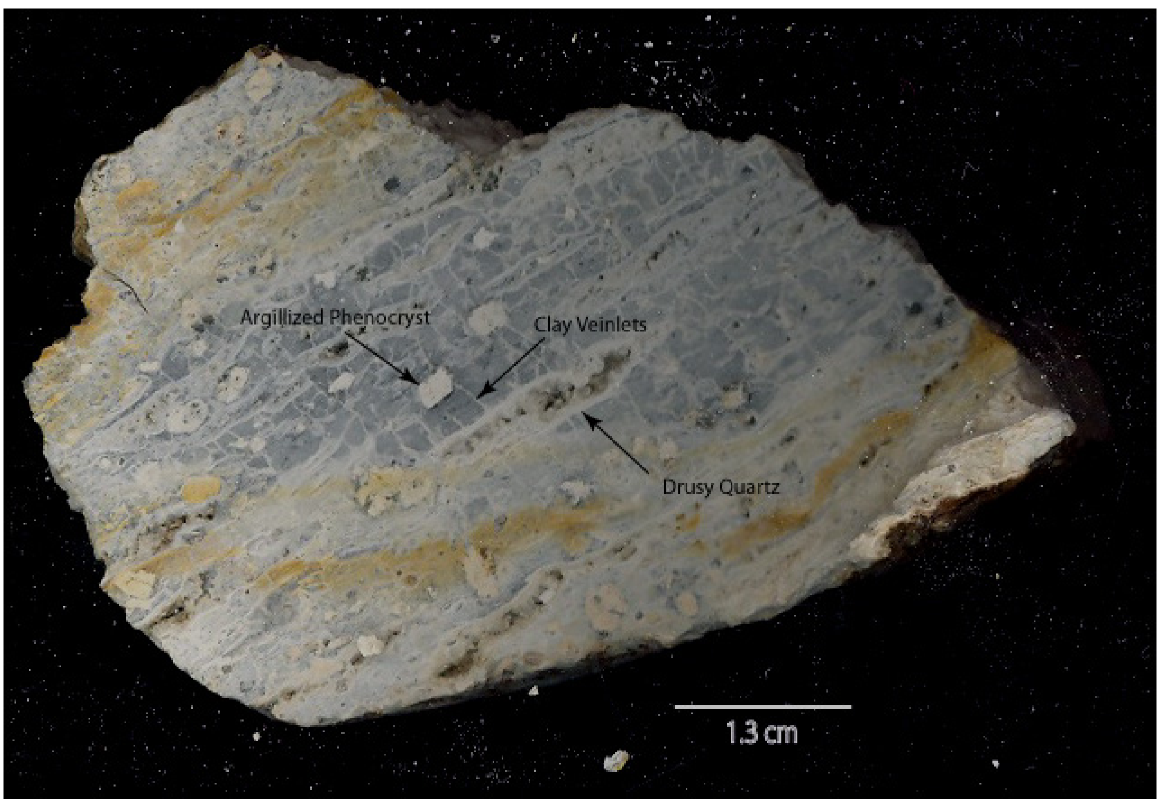


Figure 24: Clay veinlets in sample YS-08-JM116. Most veinlets are perpendicular to sub-perpendicular and some veinlets connect argillized phenocrysts. The vugs in this sample contain drusy quartz.

Sulfide Veinlets: Sulfide veinlets are the least common type of veinlet in the system, yet they are still abundant (**Figures 25** and **26**). These veinlets are closely associated with silica veinlets, though they can also be found near clay veinlets. Like their larger counterparts, sulfide veinlets often have a silica component.

32 samples contain sulfide veinlets. **Figure I-11** (**Appendix I**) shows the distribution of those samples. 22 samples from the base of the section contain clay veinlets, 7 from the walls, and 3 from the ridges. Of those samples with clay veinlets, 20 are associated with silicified rocks and 2 samples are associated with sulfide veins.

Empty Veinlets: Hairline linear fractures that have no mineral infill are named empty veinlets (**Figure 27**). There are 11 samples containing empty veinlets. 5 samples were from the base of the section, 3 from the walls and 3 from the ridges (**Appendix I**, **Figure I-14**).

Veinlet Overlap: Veinlet overlap is common. Of all the samples containing veinlets, 25 samples have both silica and clay veinlets, 18 samples have silica and sulfide veinlets, and 9 samples contain silica, sulfide, and clay veinlets. 4 samples have silica and empty veinlets, 2 samples have clay and empty veinlets, and 2 samples contain silica, clay, and empty veinlets; 1 sample contains silica, sulfide, and empty veinlets.

Breccia

A sudden release of pressure on confined fluids will lead to brecciation (Taylor, 2007). Most of the brecciation in the altered TSC system is hydrothermal deduced from a lack of systematic layering of the breccia and also because the breccia are healed by hydrothermal minerals (Sillitoe et al., 1985). There is a minor amount of phreatic brecciation seen in the wall rock. (Phreatic brecciation occurs when heated groundwater expands.) Brecciated veins are exposed in the stream bed (**Figure 28**). All of the brecciated veins pinch and swell (**Figure 29**). A single vein can be as wide as the stream bed (about 4.5 m), although most of the brecciated veins stretch are about 0.6-0.9 m wide. Veins can be much smaller, as well.

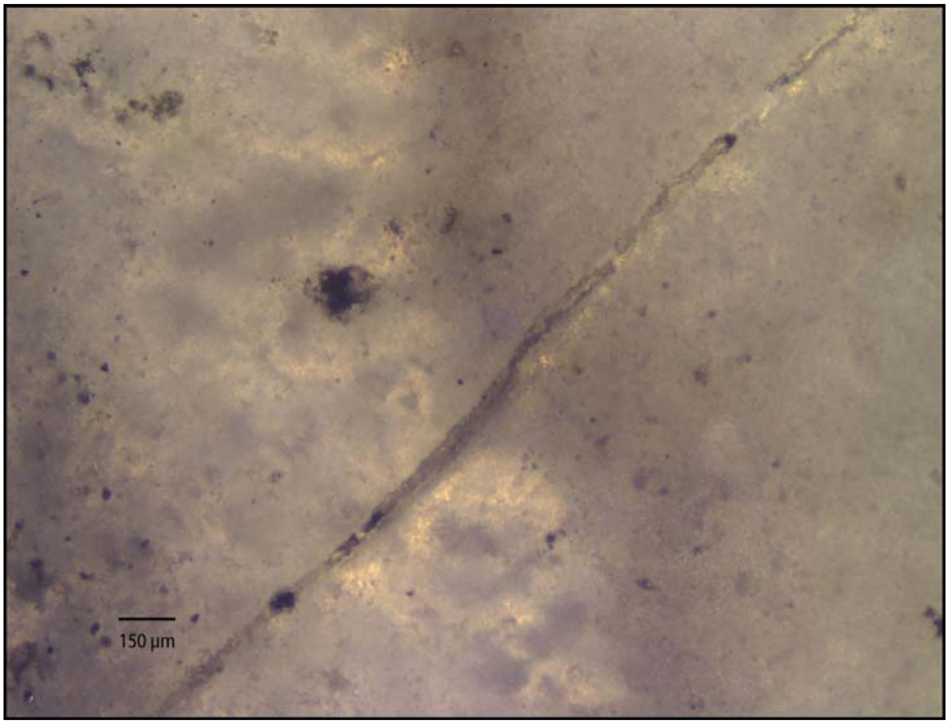


Figure 25: Micrograph of sample YS-08-JM38. Sulfide veinlet in a colloform silica vein with disseminated sulfides. Transmitted; plane-polarized light.

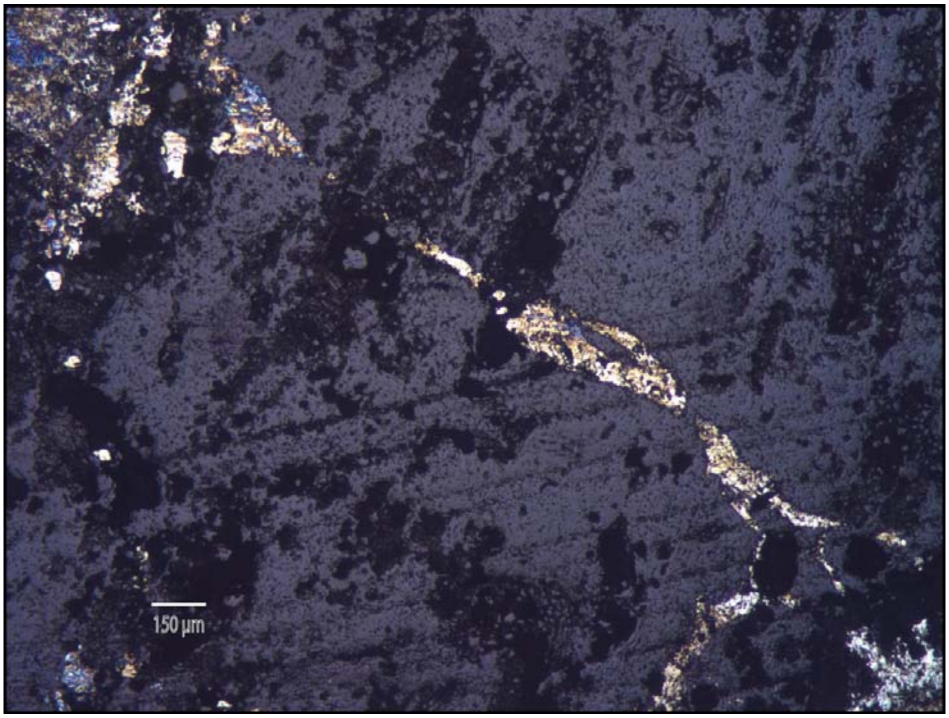


Figure 26: Micrograph of sample YS-08-JM152. Sulfide veinlet with disseminated sulfides. Reflected; cross-polarized light.

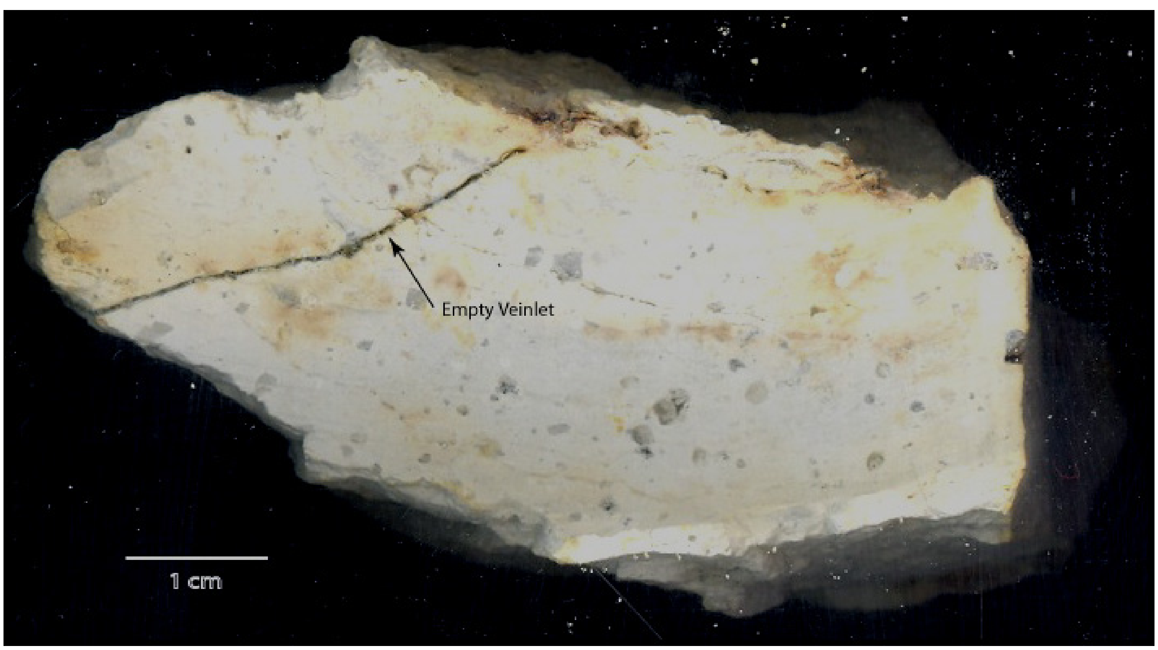


Figure 27: Empty veinlet in sample YS-08-JM86.

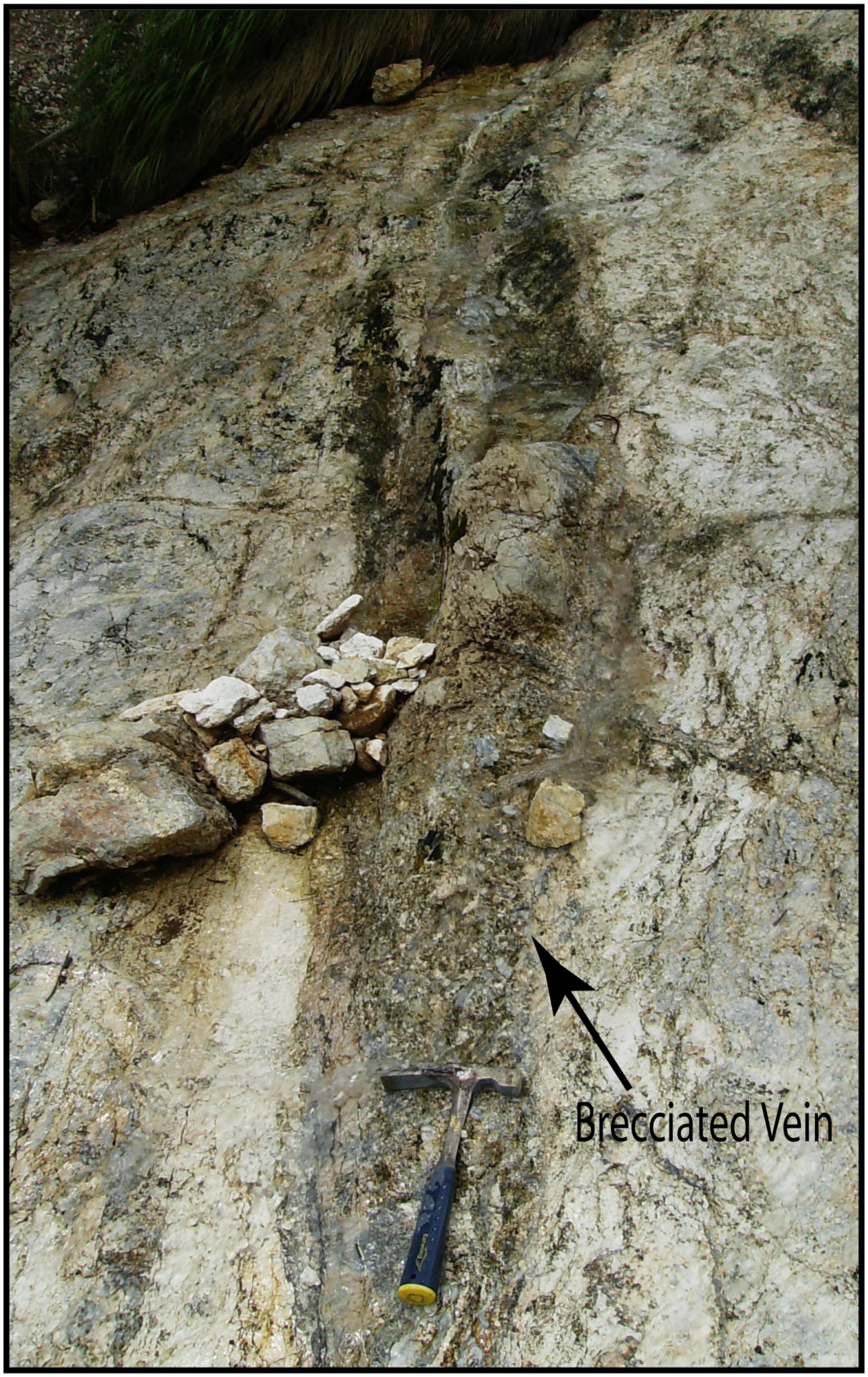


Figure 28: Brecciated vein perpendicular to stream bed.

Figure 29: Swell of brecciated vein. Crackle to mosaic breccia with sub-angular to sub-rounded mostly clast-supported clasts with a sulfide and silica matrix.

There are three general forms of brecciation. *Crackle breccia* forms when interconnected veinlets fracture a rock but do not transport the fractured material (**Figure 30**). The rock is literally “cracked”. Crackle breccia is clast-supported with angular fragments. *Mosaic breccia* forms when fluids fracture wall rocks and begin to transport the fractured material (**Figure 29**). It has angular to sub-rounded clasts and can be clast or matrix-supported. *Milled breccia* forms when fluids transport fragments “far” from source (farther than mosaic) (**Figure 31**). The fragments are sub-rounded to rounded and can be clast or matrix-supported.

The brecciated fragments are pieces of TSC wall rock and phenocrysts as well as pieces of broken-up, colloform silica veins (**Figure 32**). Some wall rock fragments contain silica and sulfide veinlets which terminate at the edge of the fragmented piece, indicating the veinlets occurred prior to brecciation. Brecciated wall rock fragments include unaltered, argillized, and/or silicified TSC; it is possible to have all three lithologies in one hand sample. The fragments vary in size from >10 cm to <1 mm. Breccias are healed a siliceous matrix with a major sulfide component. Some of the veins appear to be completely healed by sulfides; however, there is always a silica component.

Brecciated veins are surrounded by phyllic alteration (quartz+ sericitic illite+ pyrite), similar to veins in the Kelian Gold Mine, Indonesia (Davies et al., 2008). According to the Kelian model (**Figure 33**), alteration should include carbonates and chlorite (propylitic alteration), however, exposure in TSC is limited to the canyon walls and neither of these alterations are visible.

Figure 30: Micrograph of crackle breccia in sample YS-08-JM155 #2. Sample contains angular, clast-supported fragments (dark) healed by sulfides. Reflected; cross-polarized light.

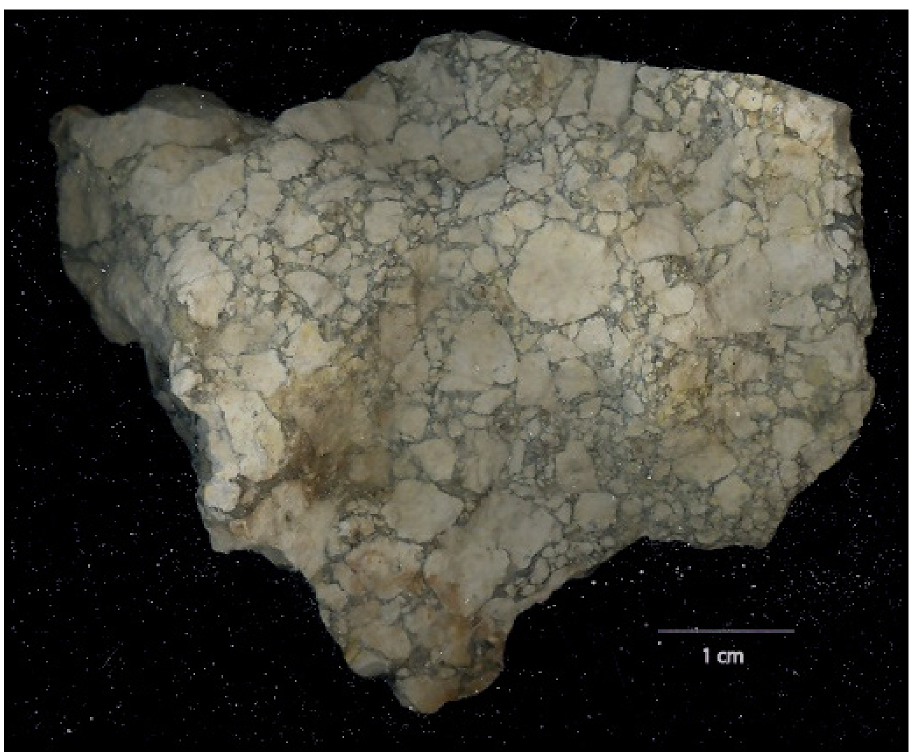


Figure 31: Milled breccia in sample YS-08-JM149. Breccia are sub-rounded to rounded in a matrix of sulfide and silica. Sample changes from clast- to matrix-supported.

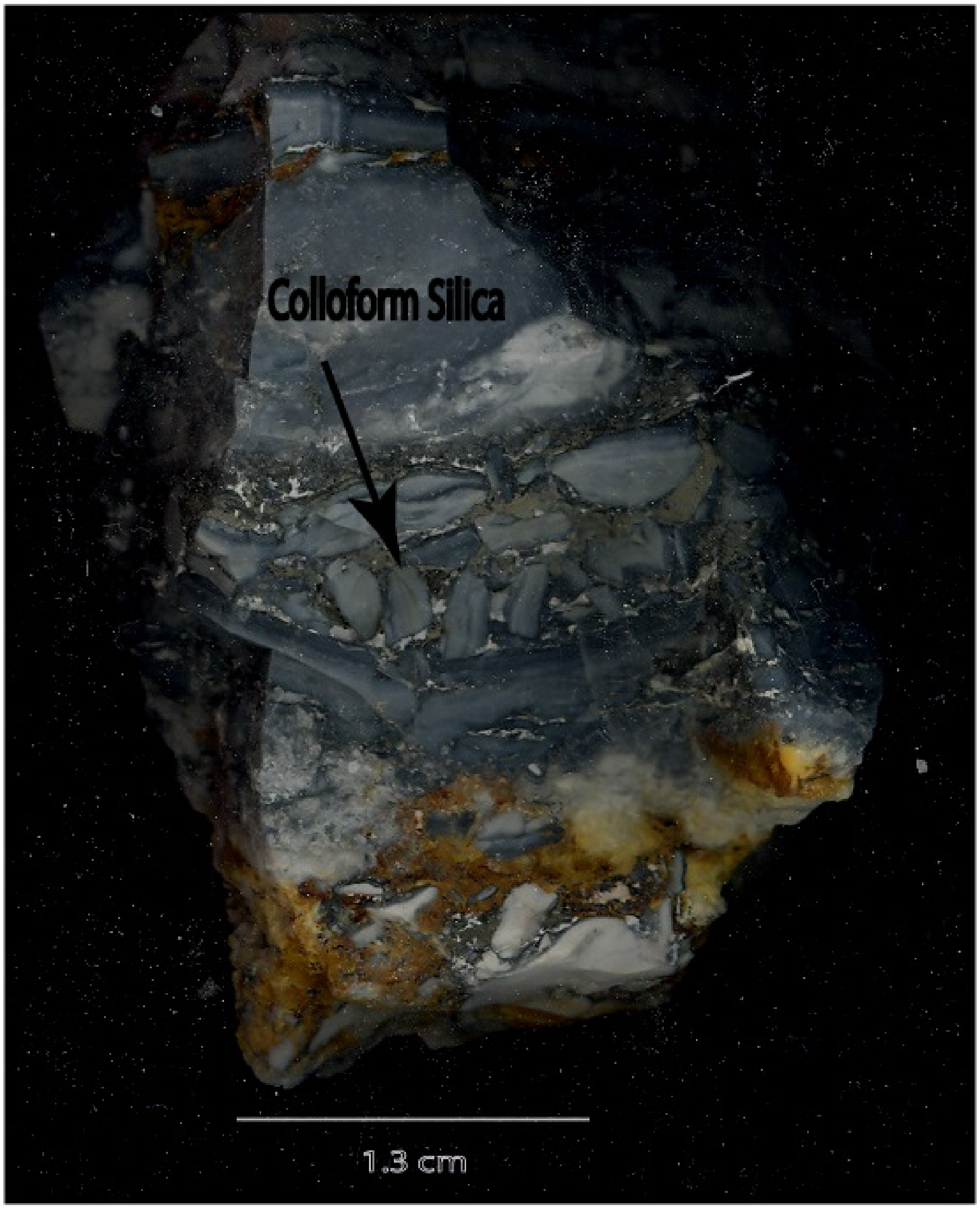


Figure 32: Brecciated hand sample YS-08-JM20. Breccia include milled fragments of colloform silica.

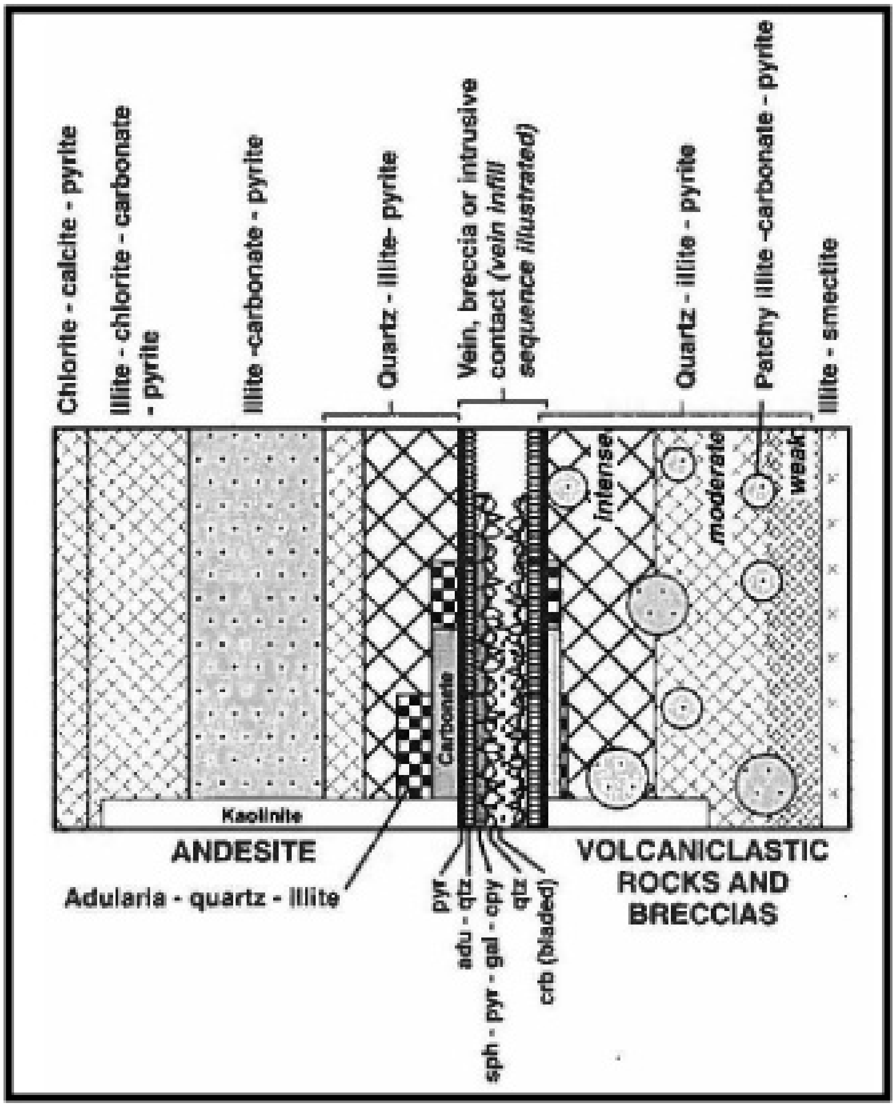


Figure 33: Figure showing idealized spatial distributions of alteration surrounding a vuggy vein. Note: Altered TSC does not contain carbonate or propylitic alteration. Figure from Davies et al. (2008).

12 brecciated vein samples were collected. **Figure I-15** (**Appendix I)** shows the distribution of those samples along the stream bed.

Vuggy Silica and Drusy Quartz

Vuggy silica is a textural component associated with low pH epithermal systems. It is commonly seen in outcrops that were under the influence of highly acidic, heated fluids. Wall rocks exposed to acidic hydrothermal fluids have siliceous groundmass replacement as well as leached phenocrysts leaving behind a matrix of siliceous residue with a pockmarked or vuggy texture (**Figure 14**).

If silica-rich fluids move through the vugs, cooling quickly, a blanket of prismatic, millimeter-sized quartz crystals can encrust the vug (**Figure 34**). These tiny crystals are referred to as drusy quartz and are often associated with gold deposition.

For this research, vuggy silica is only called such if it is accompanied by matrix silicification. There are leached samples (noted above) and argillized samples with leached groundmass and phenocrysts; these are not included as vuggy silica samples. 36 samples have vuggy silica. **Figure I-16** (**Appendix I**) shows the distribution of vuggy silica. 2 samples from the base of the section contained vuggy silica, 10 from the walls, and 24 from the ridges.

42 samples contain drusy quartz. **Figure I-17** (**Appendix I**) shows the distribution of drusy quartz. 13 samples from the base of the section contain drusy quartz, 10 from the walls, and 19 from the ridges. 13 samples have both vuggy silica and drusy quartz.

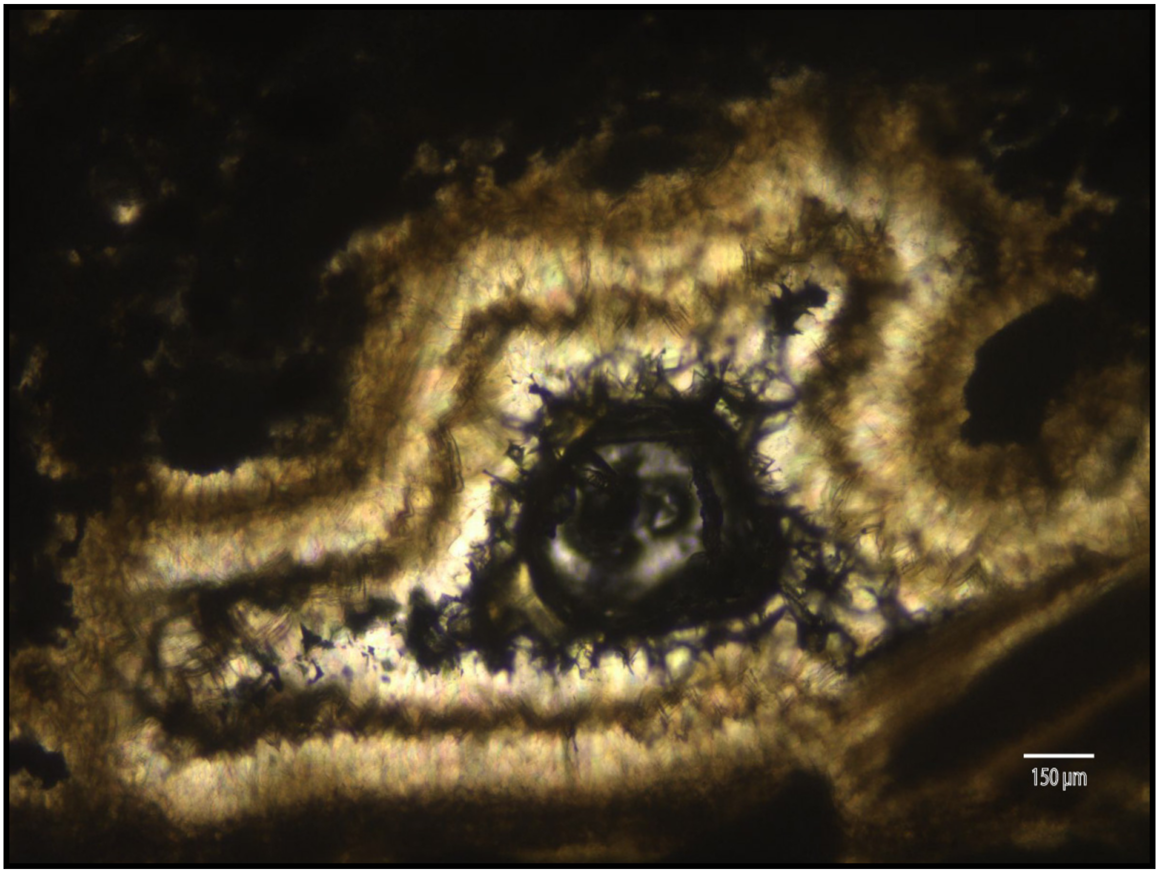


Figure 34: Micrograph from sample YS-08-JM59. Colloform silica with drusy quartz crystals in the center. Transmitted; cross-polarized light.

Argillized Phenocrysts

Argillized phenocrysts occur when hydrothermal fluids move through a rock and primary phenocrysts (such as feldspars) undergo a reaction with the fluids to become new minerals (**Figure 35**). Product minerals include phyllosilicates and sulfates. Not all secondary phenocrysts are the result of altered primary minerals; secondary minerals, such as adularia, can precipitate from the fluids and infill vugs. **Figure I-19** (**Appendix I**) shows the distribution of fresh and argillized phenocrysts.

Sulfides

Sulfides are widespread in altered TSC. Most of the sulfides in the wall rock are pyrite and marcasite (both FeS_2). Most sulfides are visible only in polished thin sections, showing the fine-grain nature and dissemination of the sulfides in this particular epithermal system (**Figure 21**). Sulfides and silica are closely linked; where silica is found, sulfides are close by.

70 samples have disseminated, massive, or veined sulfides. **Figure I-20** (**Appendix I**) shows the distribution of sulfides. 42 samples from the base of the section contain sulfides, 15 from the walls, and 13 from the ridges. 48 of the samples containing sulfides are associated with silicified rocks and 36 samples are associated with sulfide veins or veinlets.

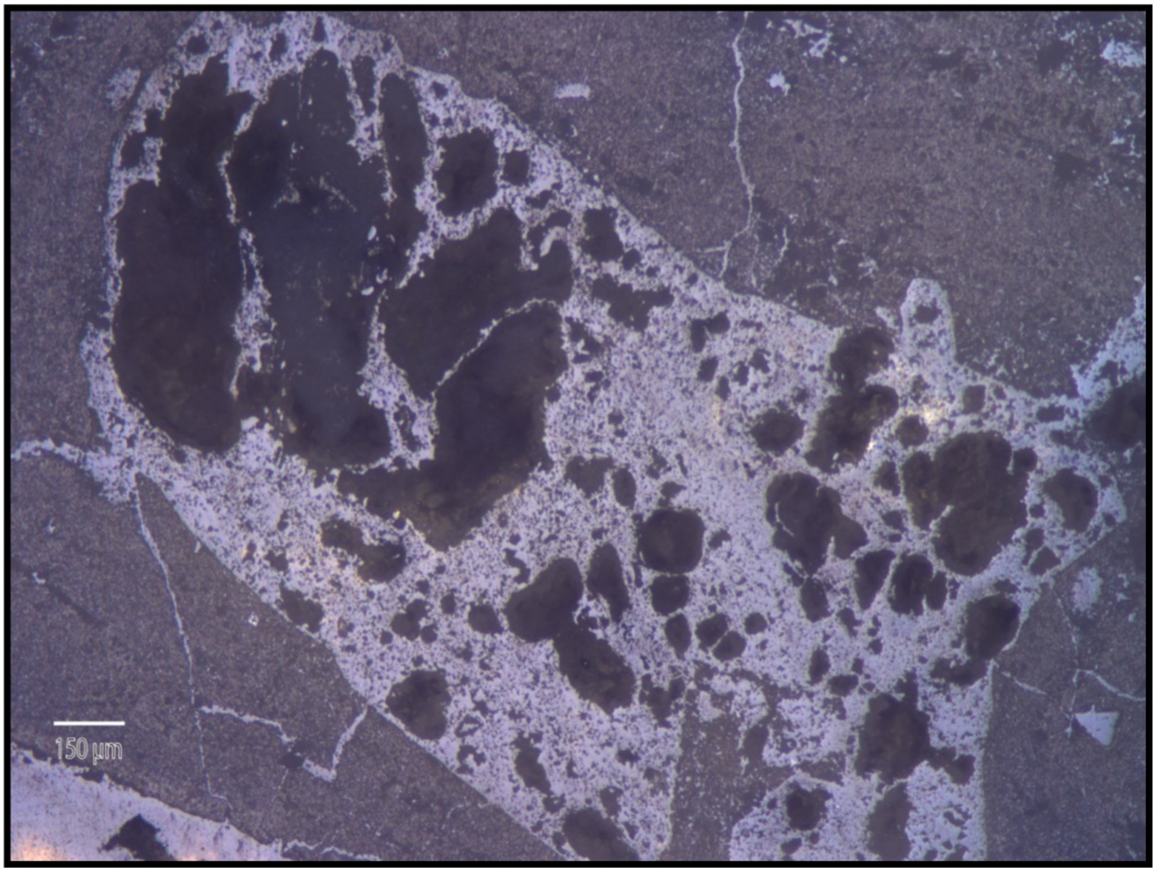


Figure 35: Micrograph from sample YS-08-JM42. Argillized phenocryst with clay veinlets and internal brecciation. Transmitted; plane-polarized light.

Other features

The stream bed contains rounded nodules filled with silica and sulfides (**Figures 36** and **37**). Silica are not associated with veining, rather with silicification. Saunders (1990) found that anomalous Au precipitated in opaline samples in the Sleeper low-sulfidation epithermal deposit, therefore, the silica nodules and opaline hand samples should be tested for Au and trace element abundances. Iron oxidation is not widespread in the canyon, but does occur. 19 samples were heavily oxidized (**Figure 38**). It is uncertain if the oxidation is the product of hydrothermal fluids or if it is due to supergene processes (weathering).

Figure 36: Silica nodule in stream bed. Surrounding wall rock is silicified.

Figure 37: Sulfide nodule from stream bed. Note proximity of milled breccia healed by sulfides. Surrounding wall rock is silicified.

Figure 38: Oxidized hand sample YS-08-JM95. Note the primary igneous texture is preserved.

Mapping

Most faulting in the region trends N-NW (Christiansen, 2001). Similarly, some structures in altered TSC follow a general N-NW trend, although many structures have a N-NE trend. **Appendix II** contains active thermal locations and various structures and their orientations.

X-Ray Diffraction

Minerals

Hydrothermal silica (SiO_2) polymorphs are the most common gangue found in hydrothermal and epithermal systems, thus, hydrothermal silica is prevalent in almost all samples in altered TSC. Fluids in epithermal systems can become silica saturated when hydrothermal fluids boil, cool rapidly or react with volcanic glass (Drummand and Ohmoto, 1985; Fournier, 1985). Hydrothermal silica forms when heated fluids, containing dissolved silica, begin to cool, and precipitate SiO_2 (White et al., 1992). The presence of hydrothermal silica polymorphs leads to a better understanding of alteration conditions. **Figure 39** shows temperature conditions for some polymorphs of silica.

Amorphous silica (opal A), the least crystalline of the silica polymorphs, can precipitate from supersaturated fluids at any temperature (White et al., 1992). Silica saturated fluids will form amorphous silica when the temperature of the fluids drop considerably below the temperature at which quartz forms. In epithermal systems under pressure, higher temperature fluids are more saturated with amorphous silica than are lower temperature fluids (Gunnarsonn and Arnórsson, 2000). Amorphous silica solubility decreases as temperature decreases. As amorphous silica is slowly buried in high temperature systems, it can undergo diagenetic changes; opal A will begin to crystallize into cristobalite, then chalcedony, and finally quartz (White et al., 1992). Although only one XRD sample showed clear evidence for amorphous silica, it is visibly abundant in altered TSC.

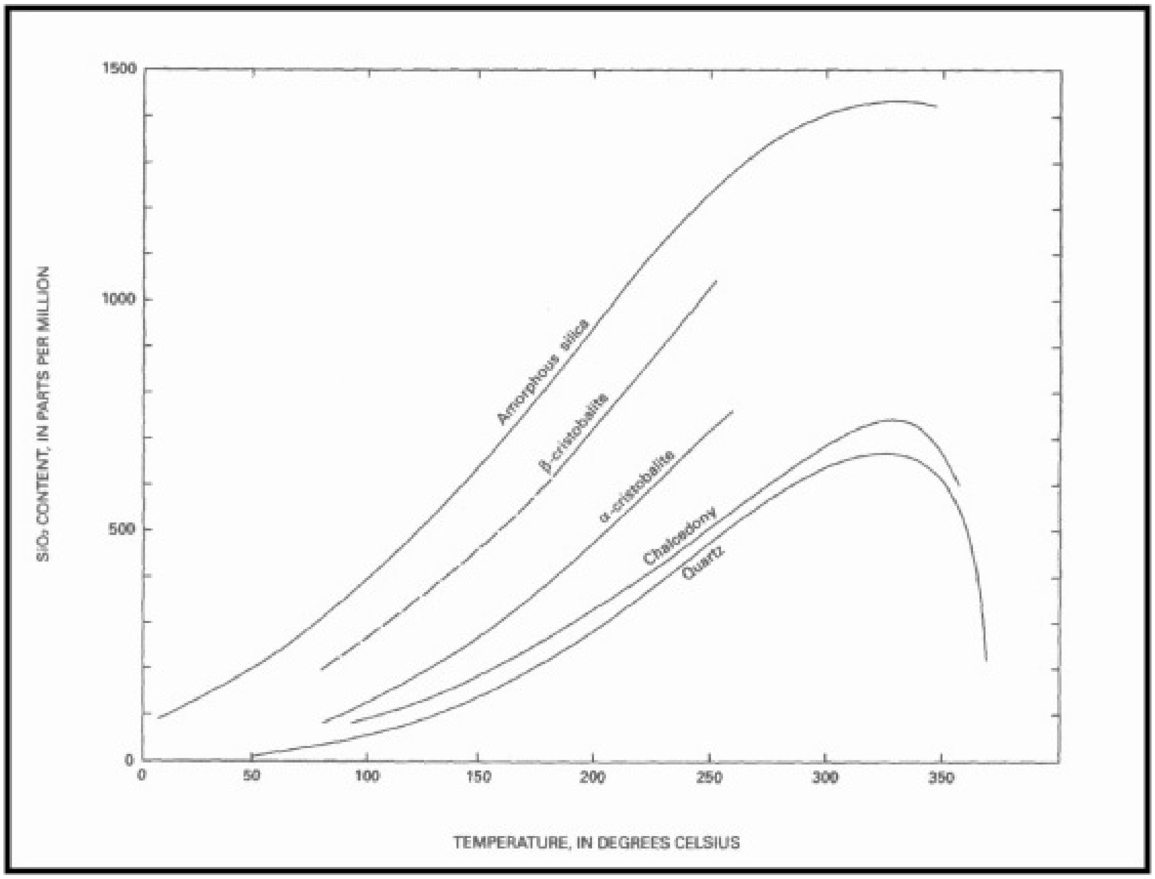


Figure 39: Silica polymorph solubility as a function of temperature. Figure from White et al., 1992.

Quartz is the most crystalline polymorph of silica and the most common form of silica in the study area. The boundary between the formation of opal and the formation of quartz is temperature and saturation dependent (White et al., 1992). Although the solubility of amorphous silica decreases with temperature, generally, the solubility of quartz increases (Gunnarsson and Arnórsson, 2000). **Figure 40** is the diffractogram for sample YS-08-JM128, which contains major quartz peaks. 65 samples were X-rayed based on whole rock, wall rock, and/or vein material. Of those, 46 samples contain major quartz peaks and 11 have minor quartz peaks. Based on the diffractograms, quartz is prevalent throughout the canyon (**Appendix I**, **Figure I-23**).

Opal cristobalite-tridymite, or *opal C-T* (and varieties therein) is the second most abundant polymorph of silica in TSC. Opal C-T is less crystalline than quartz and will form more readily than quartz if fluids are over saturated in silica (White et al., 1992). **Figures 41** and **42** show the diffractogram for sample YS-08-JM27, which contains opal C-T peaks. 23 samples contain dominant opal C-T peaks and 19 have minor opal C-T peaks. Though opal C-T is present throughout the canyon, it is dominant in the base (**Appendix I**, **Figure I-24**).

Chalcedony is not observed in the diffractograms. Chalcedony was found in areas adjacent to the study area. It is possible that much of the chalcedony in the field area has undergone diagenetic recrystallization.

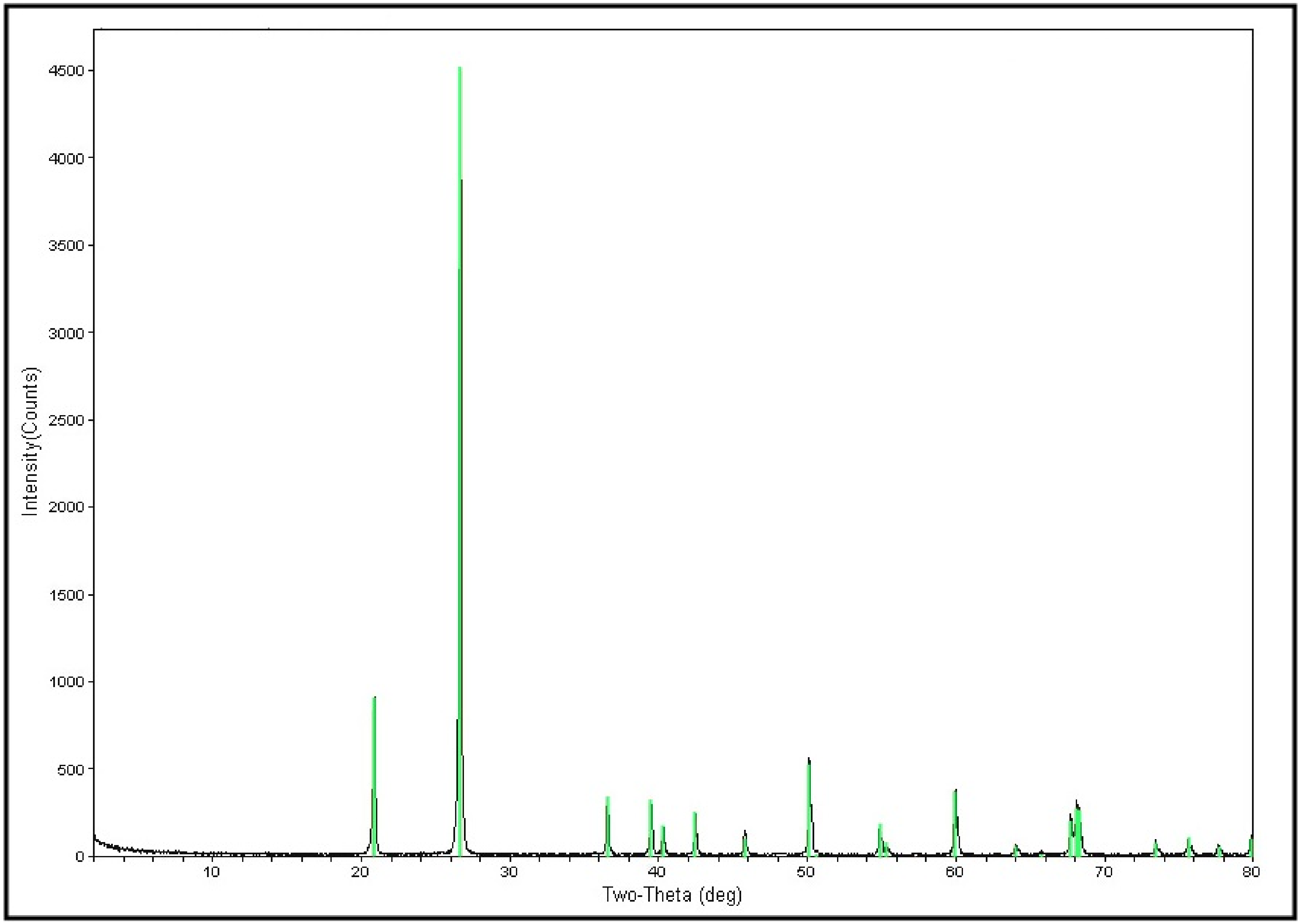


Figure 40: Diffractogram from sample YS-08-JM128. The green markers indicate the 2θ and relative intensity of quartz (SiO_2) peaks.

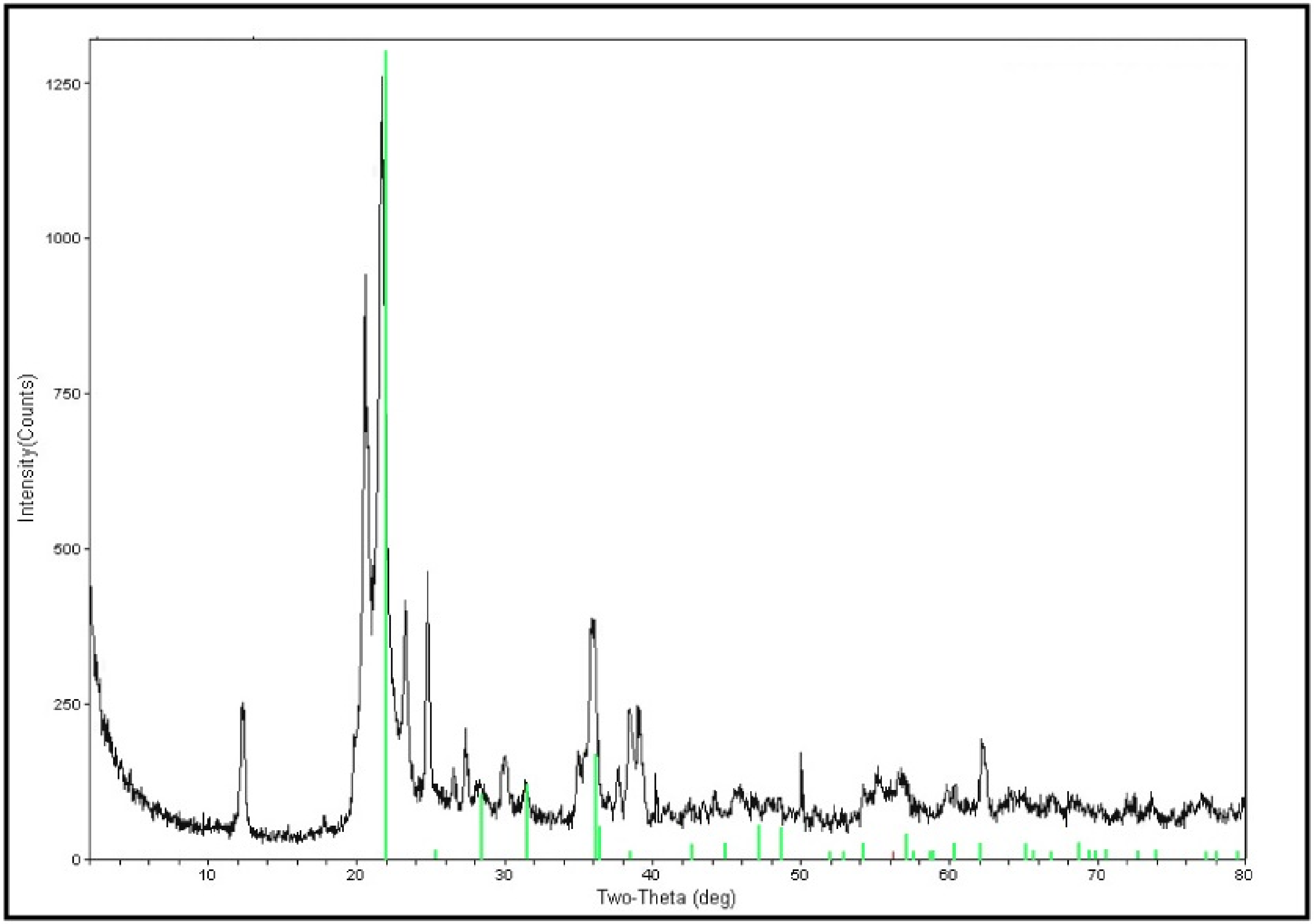


Figure 41: Diffractogram from sample YS-08-JM27. The green markers indicate the 2θ and relative intensity of cristobalite (SiO_2) peaks.

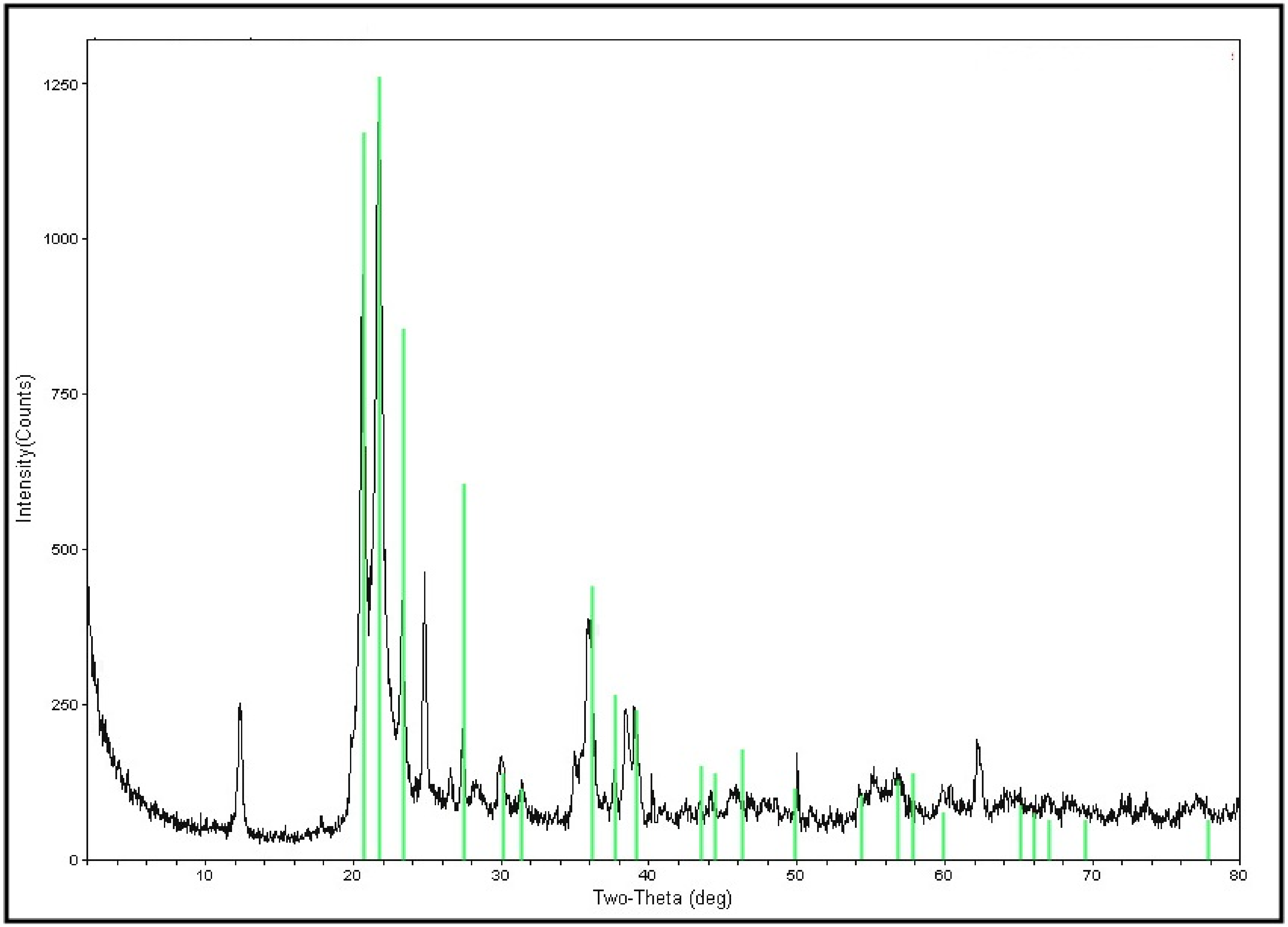


Figure 42: Diffractogram from sample YS-08-JM27. The green markers indicate the 2θ and relative intensity of tridymite (SiO_2) peaks.

Phyllosilicates are minerals with platy or sheet-like structures. Hydrothermal phyllosilicates are the product of feldspars reacting with hydrothermal fluids. Kaolinite is the most abundant phyllosilicate in altered TSC. The kaolinite group includes the clay minerals kaolinite and dickite, both $Al_2Si_2O_5(OH)_4$. Dickite, a polymorph of kaolinite, typically occurs in hydrothermal veins suggesting it is a higher temperature form of kaolinite. **Figure 43** is the diffractogram for sample YS-08-JM28, which contains major kaolinite. Of the 65 samples x-rayed, 46 samples contain kaolinite and 8 samples contain both kaolinite and dickite. 28 samples contain major kaolinite peaks and 18 have minor kaolinite peaks. Dickite occurs as a minor component in the samples in which it is present. Kaolinite is present throughout the canyon but is more abundant at the base of the canyon (**Appendix I**, **Figure I-25**).

Illite is another phyllosilicate in altered TSC. Illite can be a general term for non-expanding, clay-sized minerals or can be a specific mineral. Here, the term illite will be used in reference to the mineral with the formula $KAl_2(Si_3Al)O_{10}(OH)_2$. **Figure 44** is the diffractogram for sample YS-08-JM121, which contains minor illite. 51 samples contain illite; 5 samples have major illite peaks. **Appendix I**, **Figure I-26** shows the distribution of those samples.

Sulfates are a mineral group with the anionic complex SO_4^{2-}. Alunite group minerals are Al-sulfates, including alunite ($KAl_3(SO_4)_2(OH)_6$), walthierite ($Ba_{0.5}Al_3(SO_4)_2(OH)_6$), huangite ($Ca_{0.5}Al_3(SO_4)_2(OH)_6$), and rostite ($AlSO_4(OH,F)\cdot 5(H_2O)$). It is possible other alunite group minerals are present in the study area. **Figures 45** and **46** show the diffractogram for sample YS-08-JM22, which contains major alunite and walthierite. Barite ($BaSO_4$) is another prominent sulfate.

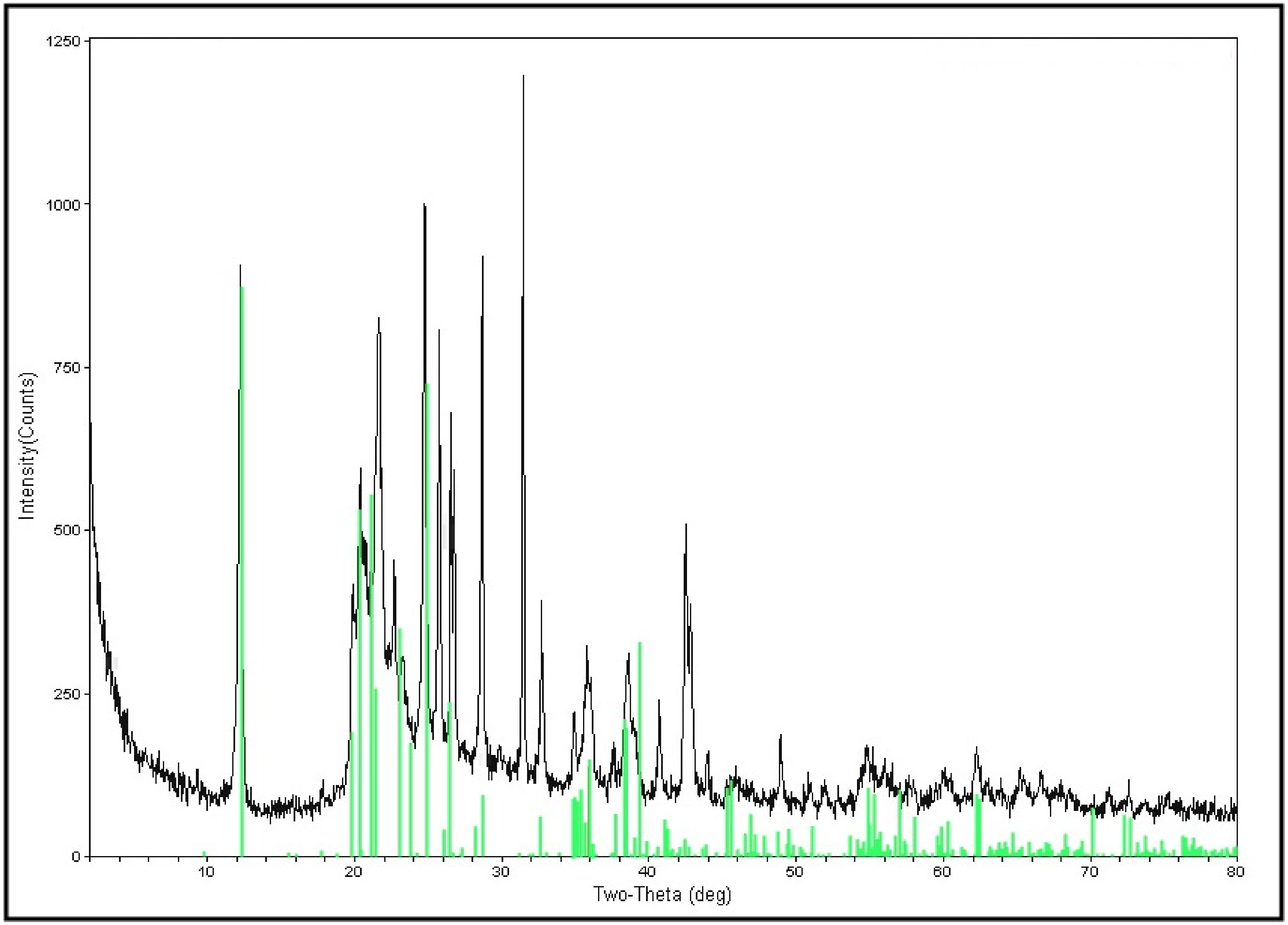


Figure 43: Diffractogram from sample YS-08-JM28. The green markers indicate the 2θ and relative intensity of kaolinite ($Al_2Si_2O_5(OH)_4$) peaks.

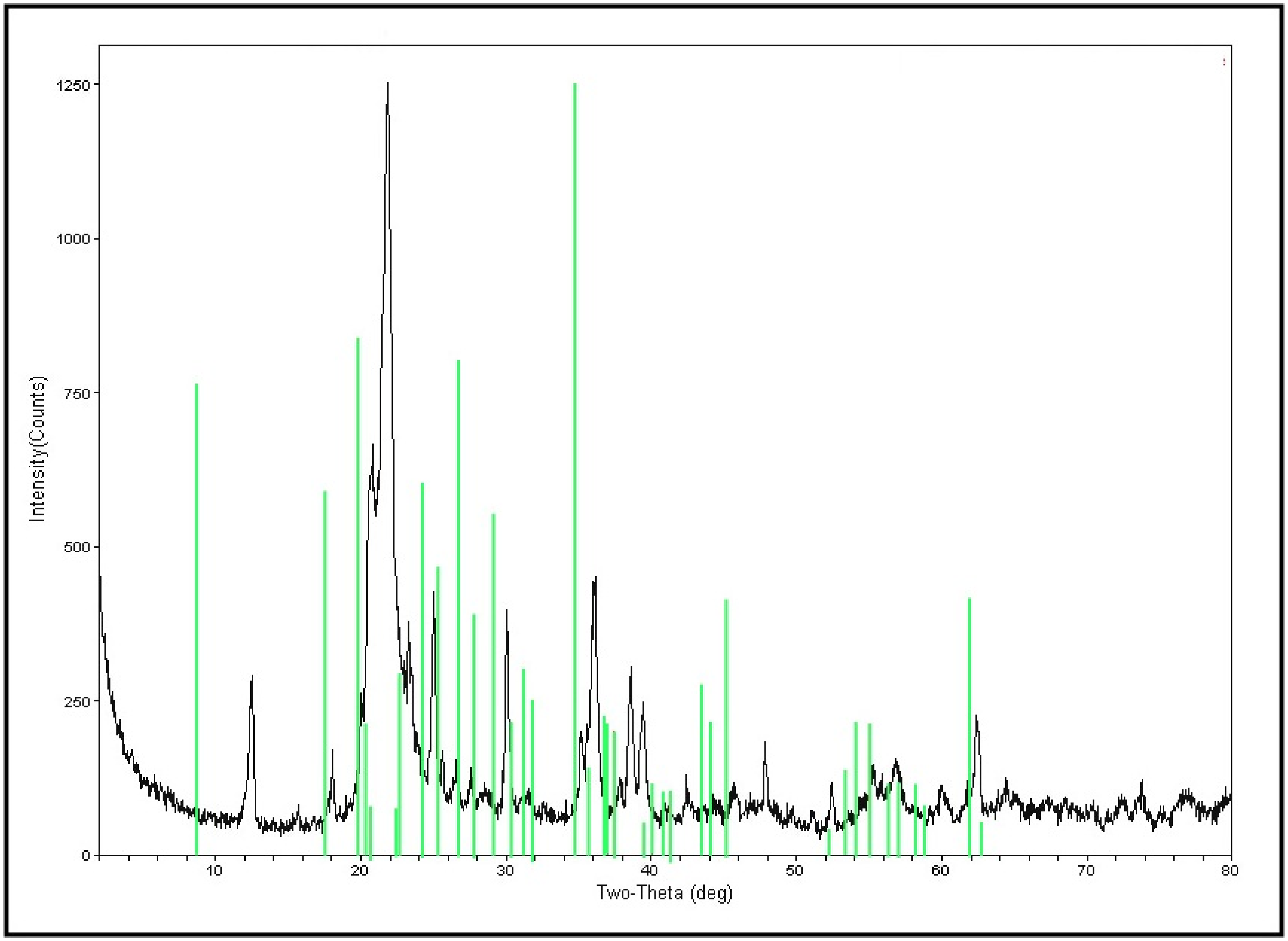


Figure 44: Diffractogram from sample YS-08-JM121. The green markers indicate 2θ and relative intensity of illite ($KAl_2(Si_3Al)O_{10}(OH)_2$) peaks.

Figure 47 is the diffractogram for sample YS-08-JM28, which contains major barite. 52 samples contain sulfates. Many samples contain multiple types of sulfates, the most frequent combination being alunite and walthierite; most samples with major alunite also contain walthierite. If alunite is a major mineral, barite (if it occurs) is present in minor amounts. It is rare for one sample to contain more than two major sulfate minerals. **Appendix I**, **Figures I-27** through **I-31** show the distribution of sulfates in the canyon.

Sulfides are extremely abundant in epithermal systems, though they typically constitute <5% of the minerals present in a single hand sample. Most sulfides in TSC are microscopic and disseminated throughout the hydrothermal silica. For this reason, sulfide peaks are rare in diffractograms.

Pyrite and marcasite are the most abundant sulfides in both X-rayed samples and polished thin sections. Marcasite is a polymorph of pyrite and its formation requires an acidic, low temperature (<160 ^{o}C) solution (Grønvold and Westrum, 1976). Marcasite will preferentially precipitate over pyrite in a hydrothermal solution with pH <4.5 (Schoonen and Barnes, 1991). If the fluid S species is H_2S, then marcasite will dominate in solutions with pH <5 at any temperature (Murowchich and Barnes, 1986). Pyrite, on the other hand, will form under more variable conditions, typically in neutral to slightly basic fluids at a variety of temperatures. Other sulfide minerals that have been found in altered TSC include sphalerite (ZnS), galena (PbS), and cinnabar (HgS).

Of the 65 samples X-rayed, 19 samples contained measurable sulfides. Most of the sulfides are concentrated in the base of the canyon (**Appendix I**, **Figure I-32**).

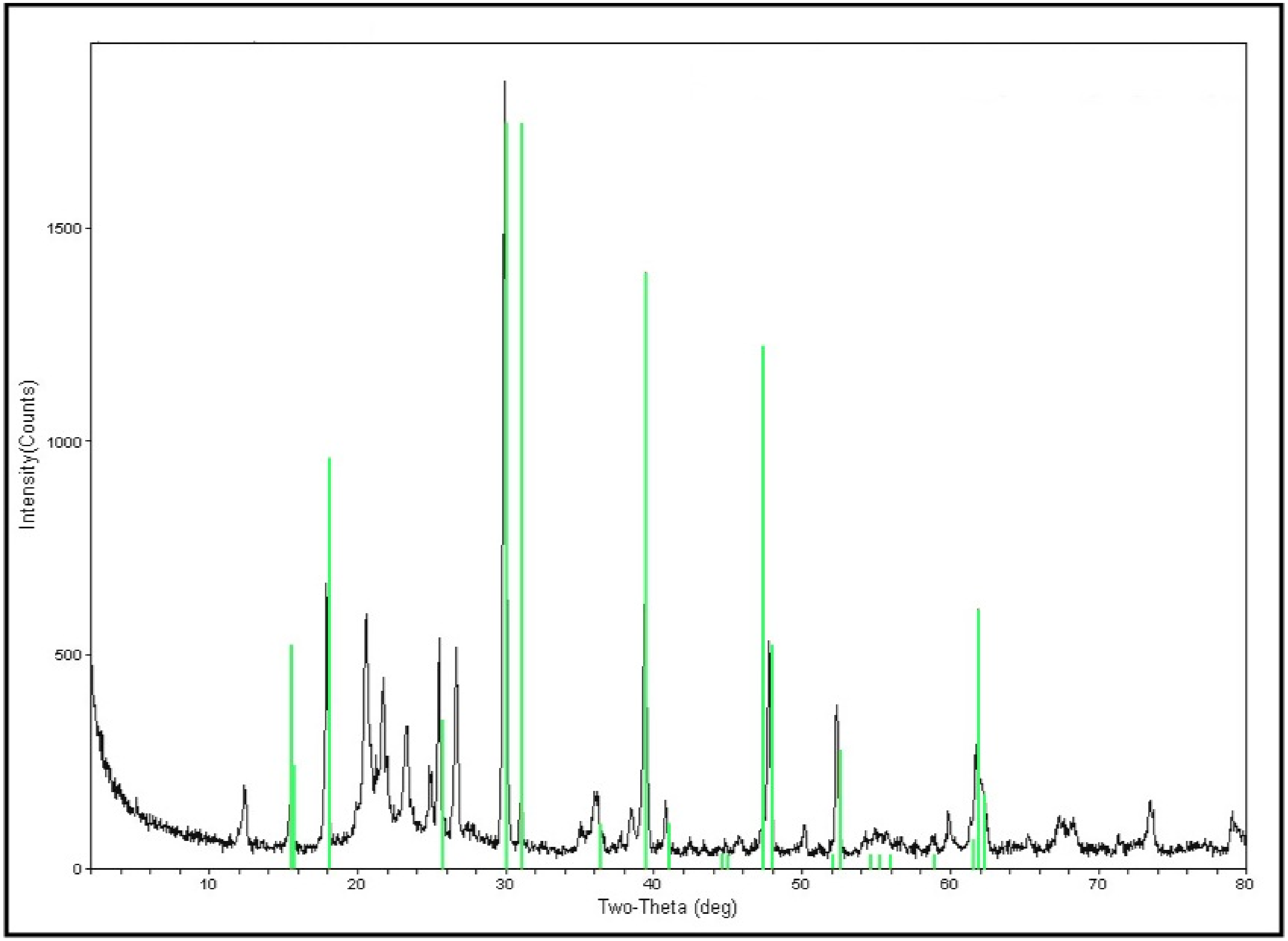


Figure 45: Diffractogram from sample YS-08-JM22. The green markers indicate the 2θ and relative intensity of alunite ($(KAl_3(SO_4)_2(OH)_6)$) peaks.

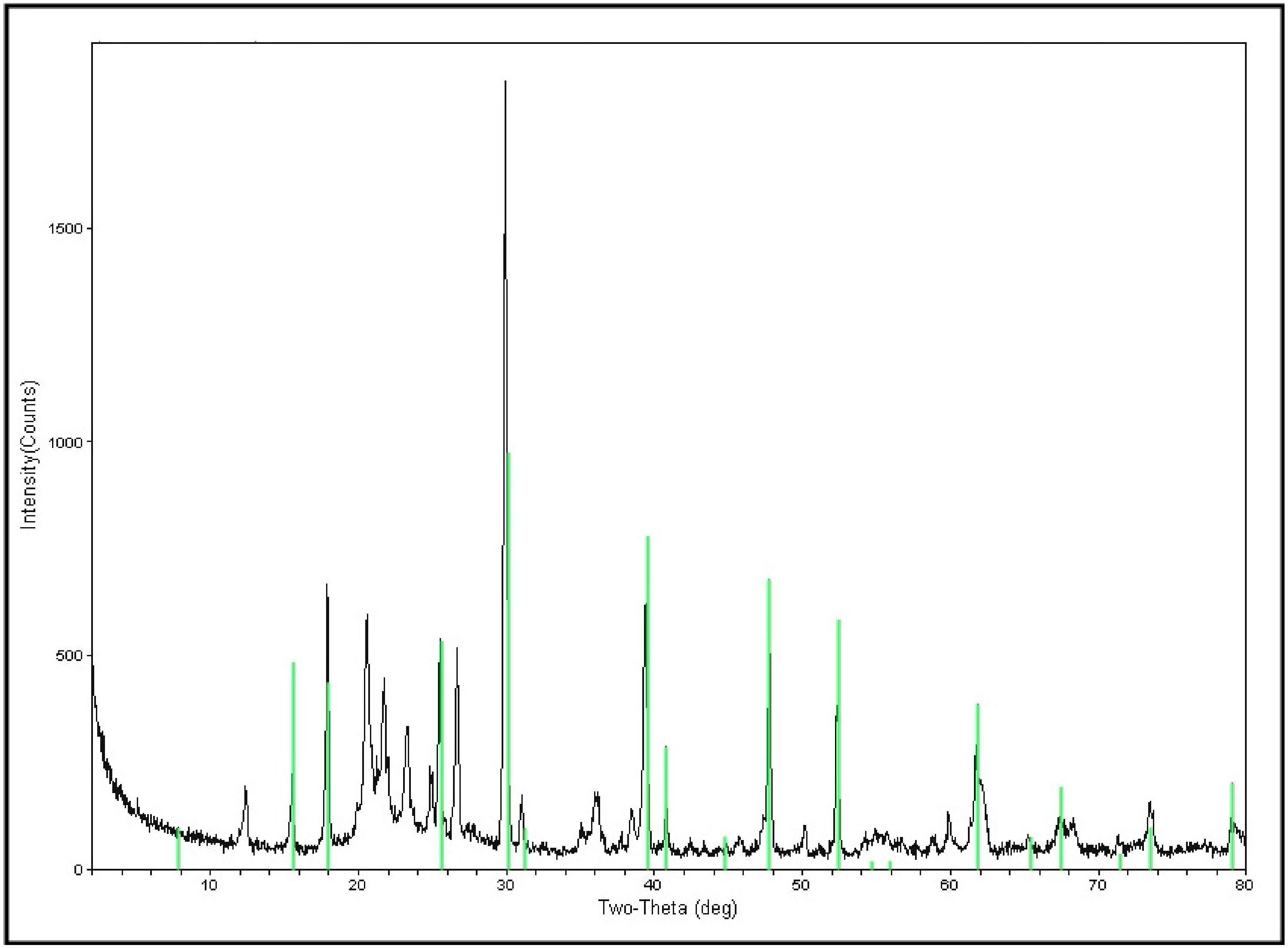


Figure 46: Diffractogram from sample YS-08-JM22. The green markers indicate 2θ and relative intensity of walthierite ($(Ba_{0.5}Al_3(SO_4)_2(OH)_6)$) peaks.

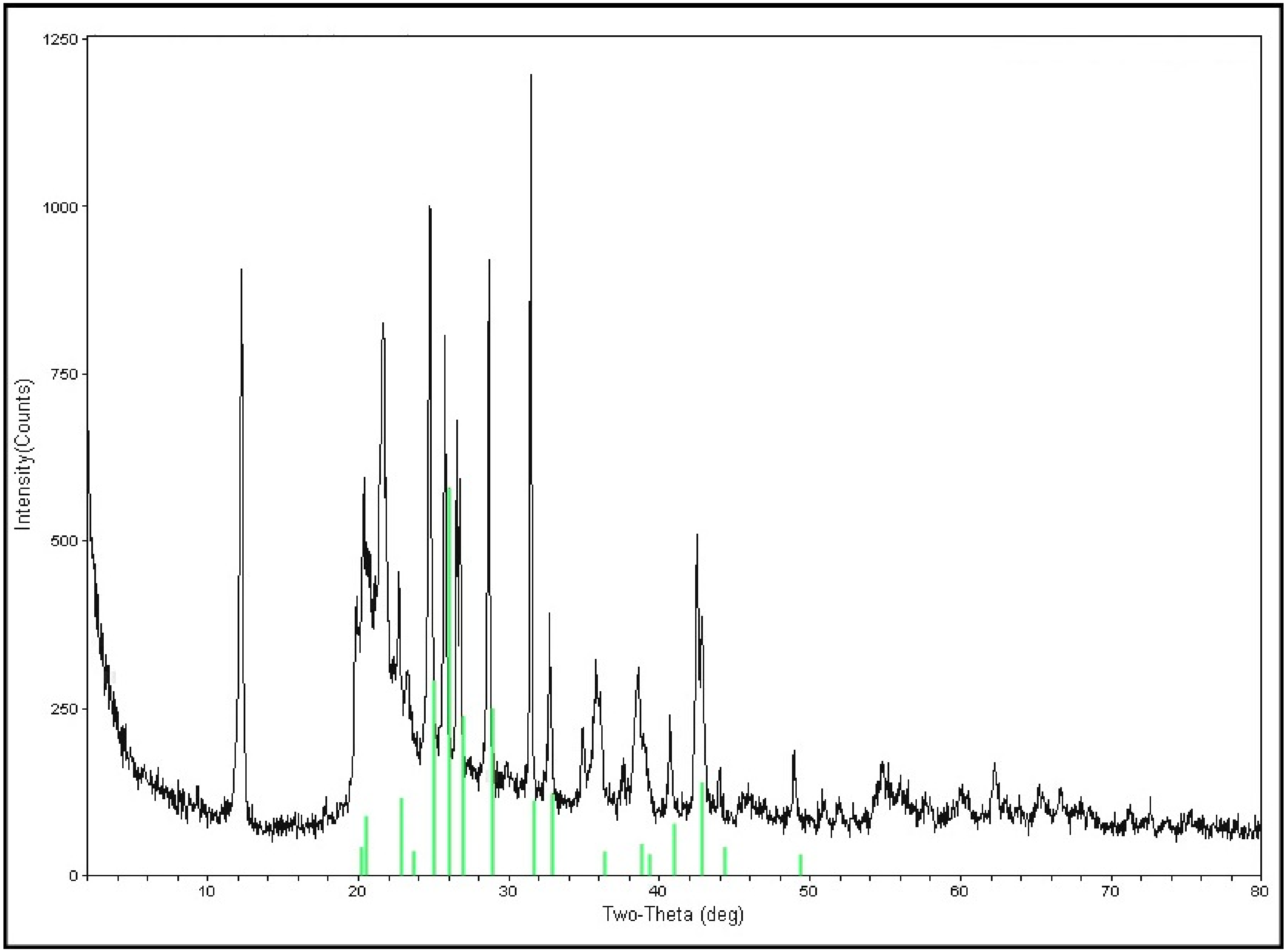


Figure 47: Diffractogram from sample YS-08-JM28. The green markers indicate the 2θ and relative intensity of barite ($BaSO_4$) peaks.

Mineral Assemblages

There are four hydrothermal mineral assemblages in the south fork of Sulphur Creek (**Tables 2** and **3**). Mineral assemblages are based mostly on whole rock XRD analyses, although some vein and wall rock samples were specifically separated for analyses. Mineral assemblages are numbered in order of abundance; for instance, Mineral Assemblage 1 is the most abundant assemblage while Mineral Assemblage 4 is the least. (Minerals are listed in order of abundance as well.) **Table 4** is an overview of the following.

Mineral Assemblage 1 consists of silica+ kaolinite+ illite± sulfate± smectite± diaspore± sulfide± pyrophyllite± zunyite± zeolite. Silica occurs as quartz (most abundant), variations of opal C-T, and opal A. Kaolinite appears as both kaolinite and dickite, though kaolinite is more common. Sulfate is absent in 3 of the 39 samples associated with Mineral Assemblage 1 and occurs as alunite, walthierite, barite, huangite, and rostite. Smectite occurs as montmorillanite and beidellite. Sulfide occurs as marcasite, pyrite, galena, and sphalerite. The zeolite is edingtonite. Albite and sanidine are the primary feldspars. **Figure I-35** (**Appendix I**) shows the distribution of Mineral Assemblage 1.

Mineral Assemblage 2 consists of silica+ illite± sulfate± sulfide± pyrophyllite. Silica occurs as quartz and opal C-T. Sulfate occurs as barite, alunite, walthierite, and rostite and is in 8 out of 11 samples. Sulfide occurs as marcasite, pyrite and minor cinnabar. Albite is the primary feldspar. **Figure I-36** (**Appendix I**) shows the distribution of Mineral Assemblage 2.

Sample	Outcrop	Type	Mineral Assemblage
	Top of Section		
YS-07-JM02	South Ridge	WR	1
YS-07-JM05	South Ridge	WR	3
YS-08-JM45	Outcrop 3	WR	1
YS-08-JM59	Outcrop 2	WR	1
YS-08-JM61	Outcrop 2	WR	1
YS-08-JM62	Outcrop 2	WR	1
YS-08-JM121	South Ridge	WR	1
YS-08-JM128	South Ridge	WR	1
YS-08-JM130	Outcrop 3	2 Samples: WR/ Si Vein	1
YS-08-JM131	South Ridge Float	WR	2
YS-08-JM132	South Ridge	WR	1
YS-08-JM133	North Ridge	WR	4
YS-08-JM135	North Ridge	Si Vein	4
YS-08-JM136	Outcrop 4B	WR	2
YS-08-JM136	Outcrop 4B	Si Vein	4
YS-08-JM137	Outcrop 4B	WR	1
YS-08-JM144	North Ridge/OC4	WR	2
YS-08-JM146	North Ridge	WR	1
	Middle of Section		
YS-08-JM04	Outcrop 7	WR	2
YS-08-JM23	Outcrop 1	2 WR samples	3
YS-08-JM24	Outcrop 1	2 samples	1
YS-08-JM27	Outcrop 1	WR	1
YS-08-JM28	Outcrop 1	White Clays	1
YS-08-JM31	Outcrop 1	White Clays	1
YS-08-JM32	Outcrop 1	White Clays	1
YS-08-JM35	Outcrop 1	WR	1
YS-08-JM36	Outcrop 3	WR	1
YS-08-JM37	Outcrop 3	White Clays	1
YS-08-JM43	Outcrop 3	WR	1
YS-08-JM44	Outcrop 3	WR	1
YS-08-JM70	Outcrop 4B	WR	1
YS-08-JM74	Outcrop 4B	WR	2
YS-08-JM81	Outcrop 4A	WR	2
YS-08-JM82	Outcrop 4A	WR	1
YS-08-JM97	Outcrop 6	WR	4
YS-08-JM107	Outcrop 6	WR	1
YS-08-JM156	Outcrop 4C	WR	1
	Bottom of Section		
YS-08-JM08	Outcrop 7	WR	3
YS-08-JM17	Outcrop 4C	WR	1
YS-08-JM22	Outcrop 4C	WR	1
YS-08-JM38	Outcrop 3	White Clays	1
YS-08-JM39	Outcrop 3	2 samples	4
YS-08-JM42	Outcrop 3	White Clays	1
YS-08-JM83	Outcrop 4B	WR	2
YS-08-JM85	Outcrop 4B	WR	2
YS-08-JM89	Outcrop 4B	WR	2
YS-08-JM115	Outcrop 4C	WR	2
YS-08-JM117	Outcrop 4C	WR	2
YS-08-JM149	Stream	Wall Rock	1
YS-08-JM149	Stream	Vein: Silica, sulfide, clay	3
YS-08-JM150	Stream	WR	1
YS-08-JM150	Stream	Si Vein	4
YS-08-JM151	Stream	Si Vein	3
YS-08-JM152	Stream	Vein: silica and clays	1
YS-08-JM152	Stream	Sulf Vein	1
YS-08-JM153	Stream	Si Vein	1
YS-08-JM153	Stream	WR	1
YS-08-JM154	Stream	Wall Rock	1
YS-08-JM154	Stream	Sulf Vein 1: sulfides minor clays	1
YS-08-JM154	Stream	Sulf Vein 2: clays minor sulfides	1
YS-08-JM155#1	Stream	Si Vein	1
YS-08-JM155#2	Stream/Outcrop 4C	Sulf Vein	3
YS-08-JM155#3	Stream/Outcrop 4C	Wall Rock	1

Table 2: Overview of mineral assemblages based on XRD analyses.
WR: Whole Rock; Si Vein: Silica Vein; White Clays: White phenocrysts in matrix;
Sulf Vein: Sulfide Vein.
Note: Some samples were scanned more than once based on alteration.

Sample	Type	Quartz	Opal C-T	Kaolinite	Illite	Alunite	Waltherite	Barite	Pyrite	Marcasite	Other
					Top of Section						
YS-07-JM02	WR	x	X	X	x	X	X	x			**Albite**
YS-07-JM05	WR		X	x				X			diaspore
YS-08-JM45	WR	X		x	x	x					
YS-08-JM59	WR	X		x	x						
YS-08-JM61	WR	X		x	x						
YS-08-JM62	WR	X		x	x	x	x				montmorillanite
YS-08-JM121	WR	x	X	X	x	X	X				**Diaspore**, dickite
YS-08-JM128	WR	X	x	x	x			x			
YS-08-JM130	2 Samples: WR/ Si Vein	X		x	x	x					
YS-08-JM131	WR	x	X		x			X			
YS-08-JM132	WR	x	X	X	x	x		X			zunyite
YS-08-JM133	WR	X									
YS-08-JM135	Si Vein	X									albite
YS-08-JM136	WR	X			x				x	x	albite
YS-08-JM136	Si Vein	X									albite
YS-08-JM137	WR	x	X	X	x	X	X				rostite, diaspore
YS-08-JM144	WR	x	X		x			x			
YS-08-JM146	WR		X	X	x	X	X				**Sanidine**, montmorillanite, opal A
					Middle of Section						
YS-08-JM04	WR	X			X	x		x			
YS-08-JM23	†2 WR samples	Xx	Xx	X		X	X				dickite
YS-08-JM24	** 2 samples	x	X	X	Xx	X	X				dickite, montmorillanite
YS-08-JM27	WR	x	X	X	x	x	x				beidellite, dickite, montmorillanite
YS-08-JM28	White Clays		X	X	x	x	x	X			dickite, pyrophyllite
YS-08-JM31	White Clays		X	x	X						montmorillanite, albite, diaspore
YS-08-JM32	White Clays		X	x	x			X			montmorillanite
YS-08-JM35	WR		X	x	x	X	X				diaspore, albite, edingtonite
YS-08-JM36	WR	X		x	x	x	x				montmorillanite
YS-08-JM37	*White Clays	X		x	x	X	X				**Albite**
YS-08-JM43	WR	X	x	x	x	X	X				montmorillanite, albite, pyrophyllite, diaspore
YS-08-JM44	WR	X		X	x	X	X		X	x	montmorillanite, albite, galena, sphalerite, zunyite
YS-08-JM70	WR	X		X	x	X	X				**Albite**, huangite
YS-08-JM74	WR		X		x	X	X				pyrophyllite
YS-08-JM81	WR	X			x				x	x	
YS-08-JM82	WR	X	x	x	x	x		x			albite
YS-08-JM97	WR	X				x		x			huangite, tridymite
YS-08-JM107	WR	X		X	x	X	X				**Huangite**, dickite, diaspore
YS-08-JM156	WR	x	X	X	x	X	X				**Albite**, diaspore
					Bottom of Section						
YS-08-JM08	WR	X	x	X		X	X		x	x	**Albite**
YS-08-JM17	WR	X	x	X	x	X	X				**Sanidine**, dickite
YS-08-JM22	WR	x	x	X	x	X	X				montmorillanite, huangite, albite
YS-08-JM38	White Clays	X	x	x	x	X	X				**Albite**, montmorillanite
YS-08-JM39	†† 2 samples	X	x			x	x	x			
YS-08-JM42	* White Clays	X	x	x	x	X	X				**Huangite**
YS-08-JM83	WR	X			X	X	X		X	x	pyrophyllite
YS-08-JM85	WR	X			x				X	X	pyrophyllite
YS-08-JM89	WR	X			x			x			cinnabar
YS-08-JM115	WR	X	x		X	X	X				
YS-08-JM117	WR	X	X		x			X			rostite
YS-08-JM149	Wall Rock	X		X	x	x	x		x		**Huangite**, diapsore, albite
YS-08-JM149	Vein: Silica, sulfide, clay	X		X		x	x		X	x	montmorillanite, albite
YS-08-JM150	Wall Rock	X	X	X	x	X	X				**Albite**, montmorillanite
YS-08-JM150	Si Vein	X							x	x	**Pyrophyllite**
YS-08-JM151	Si Vein	X	x	X		x	x		x		diaspore, albite, pyrophyllite
YS-08-JM152	Vein: silica and clays	X	x	X	x	X	X		x	x	**Albite**, montmorillanite
YS-08-JM152	Sulf Vein	X		X	x	x	x		X	X	**Galena**, **Albite**, sphalerite
YS-08-JM153	Si Vein	X	x	x	x	x		x			
YS-08-JM153	WR	X		X	x				x	X	sanidine, tridymite
YS-08-JM154	Wall Rock	X	x	X	x	X	X				**Albite**, dickite
YS-08-JM154	Sulf Vein 1: sulfides minor clays	X	x	X	x	x	x		X	X	montmorillanite, albite, galena, sphalerite
YS-08-JM154	Sulf Vein 2: clays minor sulfides	X	x	X	x	X	X		x	x	**Albite**, galena
YS-08-JM155#1	Si Vein	X	x	X	x	x	x			x	diaspore, pyrophyllite, sanidine
YS-08-JM155#2	Sulf Vein	X	x	x		x	x		X	X	**Albite**, galena, sphalerite
YS-08-JM155#3	Wall Rock	X	x	X	x	X	X			X	**Albite**, phyrophyllite, dickite, diaspore

Table 3: XRD summary of minerals present in analyzed samples.

Samples are arranged according to relative height in the canyon. **Bold**/Capitalized: Sample contains major peaks for mineral; non-bold/lower-case: sample contains minor peaks for mineral; WR: Whole Rock; Si Vein: Silica Vein; White Clays: White phenocrysts in matrix; Sulf Vein: Sulfide Vein.

*Clays with minor silica; **Whole Rock (kaolinite) and Clays (illite); †Sample 1 (opal C-T); Sample 2 (quartz); ††Sample 1: clays minor silica; Sample 2: silica minor clays

Note: Samples YS-08-JM 117 and 150 contain major peaks of both quartz and opal C-T.

Minerals	Mineral Assemblage 1	Mineral Assemblage 2	Mineral Assemblage 3	Mineral Assemblage 4
Quartz	x	x	x	x
Opal C-T	x	x	x	x
Opal A	x			
Kaolinite	x		x	
Dickite	x		x	
Illite	x	x		
Alunite	x	x	x	x
Walthierite	x	x	x	x
Huangite	x			x
Rostite	x	x		
Barite	x	x	x	x
Monmorillanite	x		x	
Beidellite	x			
Diaspore	x		x	
Pyrite	x	x	x	x
Marcasite	x	x	x	x
Galena	x		x	
Sphalerite	x		x	
Cinnabar		x		
Pyrophyllite	x	x	x	x
Zunyite	x			
Edingtonite	x			
Albite	x	x	x	x
Sanidine	x			

Table 4: Mineral summary of Mineral Assemblages 1-4.

Mineral Assemblage 3 consists of silica+ kaolinite+ sulfate± sulfide± diaspore± smectite± pyrophyllite. Silica occurs as quartz and opal C-T. Kaolinite appears as both kaolinite and dickite, though kaolinite is more abundant. Sulfate occurs as alunite, walthierite, and barite. Sulfide occurs as pyrite and marcasite with minor sphalerite and galena. Smectite occurs as montmorillanite. Albite is the primary feldspar. **Figure I-37** (**Appendix I**) shows the distribution of Mineral Assemblage 3.

Mineral Assemblage 4 consists of silica± sulfate± sulfide± pyrophyllite. Silica is present mostly as quartz with minor opal C-T and tridymite. Sulfate occurs as alunite, barite, walthierite, and huangite. Sulfides occur as marcasite and pyrite. Albite is the primary feldspar. **Figure I-38** (**Appendix I**) shows the distribution of Mineral Assemblage 4.

<u>Thin Sections</u>

Paragenesis

Alteration paragenesis in Sulphur Creek is not overtly apparent. Alteration styles in the study area, though pervasive, do not typically display clear paragenesis relative to other alteration events. Sample YS-08-JM11 (**Figure 48**) contains an apparent overprinting of silicification by argillization, suggesting, at least locally, that silicification occurred prior to argillization.

Cross-cutting veinlets aid in distinguishing vein paragenesis when off-set veinlets are present, two veinlets with different mineralogy intersect, or if the intersection of two veinlets is crisp. However, veining in this system is extremely pervasive and individual veinlet boundaries are often vague and discontinuous. Off sets are not continuous and often change directions. Veinlet mineralogies are generally distinguishable. One veinlet can contain three types of minerals which branch and weave through other veinlets with no recognizable pattern. Veinlets pinch and swell too often to distinguish any formidable paragenesis among them.

Many samples, such as YS-08-JM112 and YS-08-JM42, contain clearly defined clay veinlets dissecting altered phenocrysts (**Figures 49** and **50**). This phenomenon also (but rarely) occurred with sulfide and silica veinlets (**Figures 51** and **52**). Veinlets also lead to unaltered phenocrysts. Sometimes veinlets "wet" or encrust a phenocryst but do not alter it (**Figures 53** and **54**).

Vein Type Analyses

Thin sections aided in the identification of veinlets, thus increasing their distribution throughout the canyon. In hand samples, only those veinlets large enough to see with an unaided eye (or handlens) were described, limiting the appearance of both sulfide and clay veinlets. However, thin sections gave a microscopic view into the sheer number and distribution of both veins and veinlets. Microbreccia and micro-collforming within veinlets was also seen in thin sections (**Figures 55** and **56**). Colloforms imply veins were generated incrementally (Nagayama, 1993a).

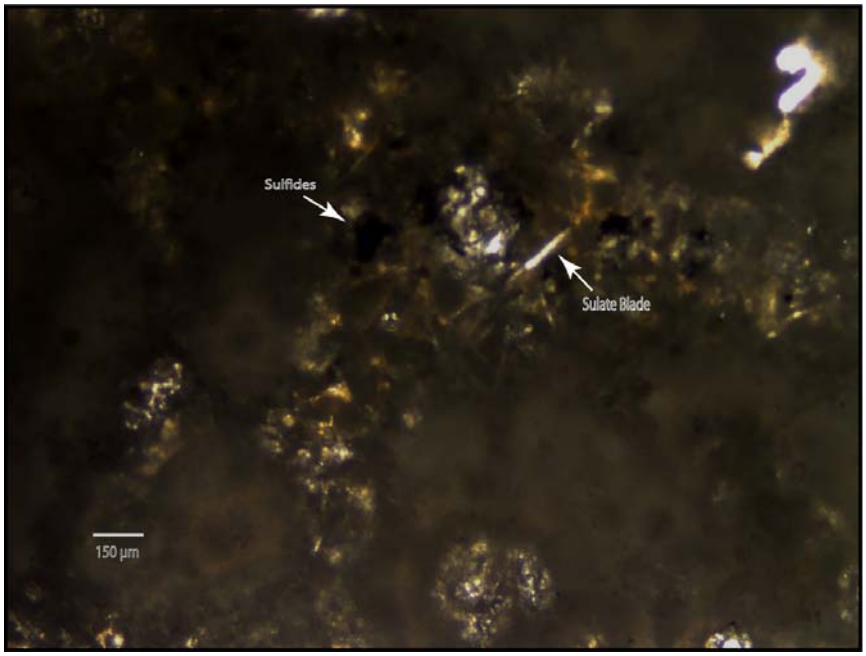


Figure 48: Micrograph from sample YS-08-JM11. Argillization (cloudy, whitish texture) overprints silicification (non-cloudy texture). Note the presence of bladed sulfates and globular sulfides. Transmitted; plane-polarized light.

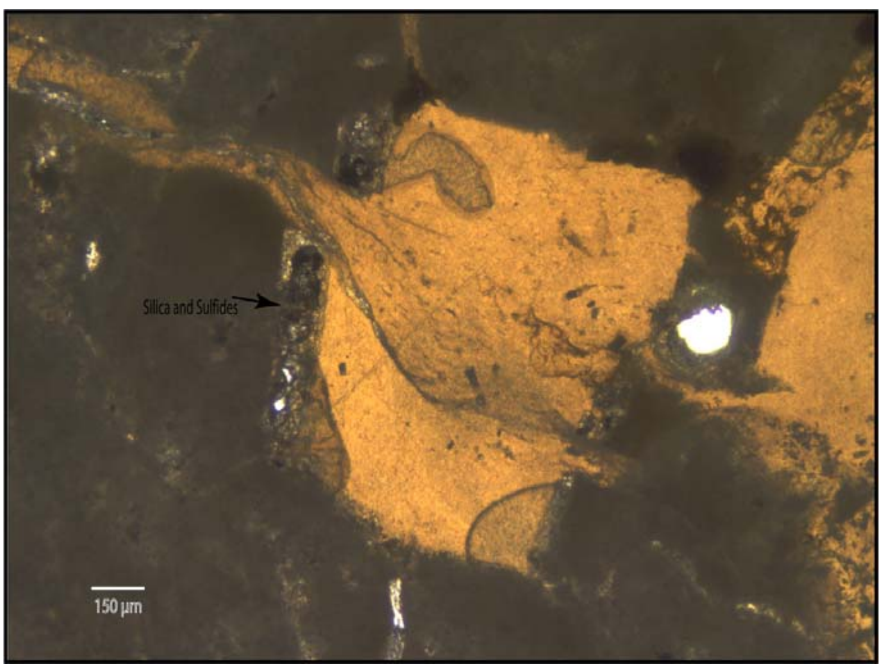


Figure 49: Micrograph from sample YS-08-JM112. Argillized phenocrysts dissected by a clay-silica veinlet. Phenocryst edge is "wetted" by silica and sulfides. Transmitted; plane-polarized light.

Figure 50: Micrograph from sample YS-08-JM42. Argillized phenocrysts dissected by clay veinlets. Transmitted; plane-polarized light.

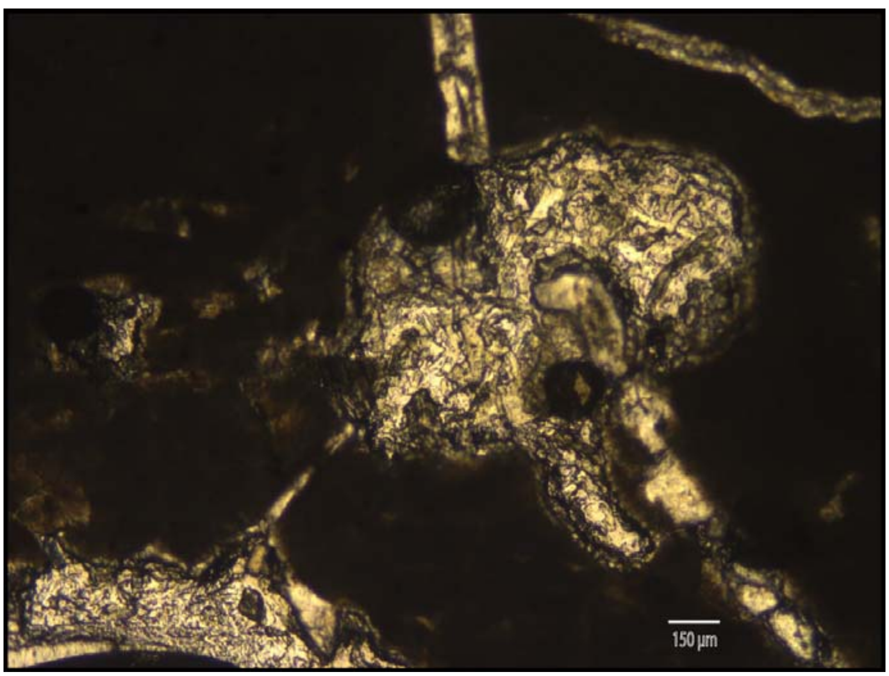


Figure 51: Micrograph from sample YS-08-JM107. Highly fractured quartz eye dissected by a silica veinlet. Transmitted; cross-polarized light.

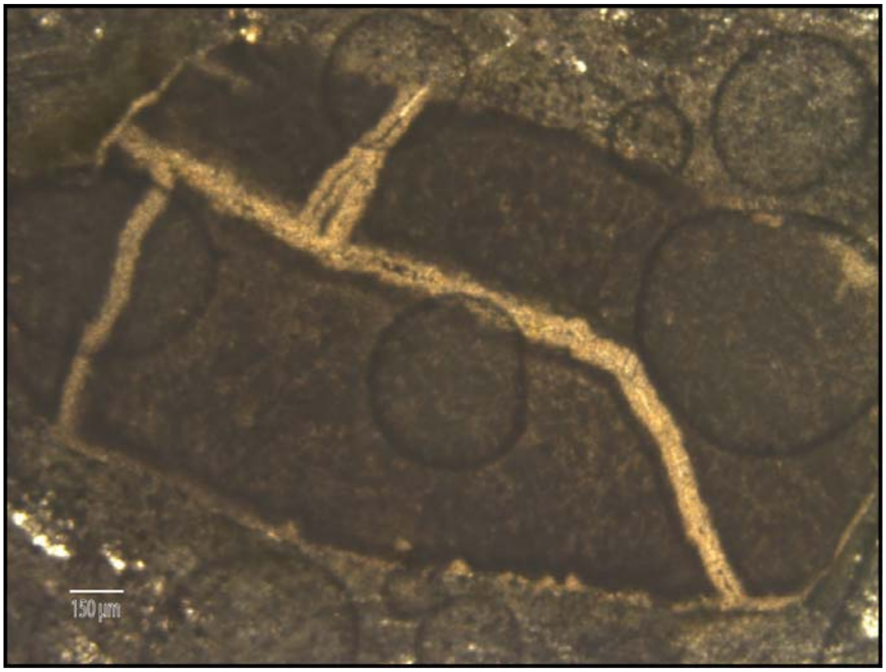


Figure 52: Micrograph from sample YS-08-JM72. Phenocryst fractured by silica veinlet with clay selvage. Note wetting of phenocryst by clay minerals. Transmitted; plane-polarized light.

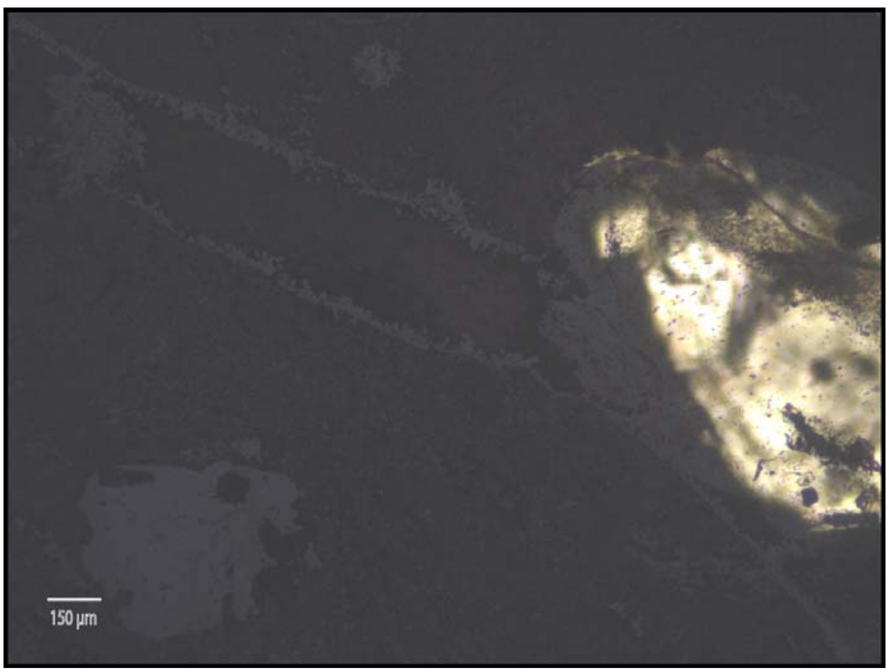


Figure 53: Micrograph from sample YS-08-JM42. Unfractured quartz eye with clay veinlets and minor wetting of grain rim by clay minerals. Transmitted; plane-polarized light.

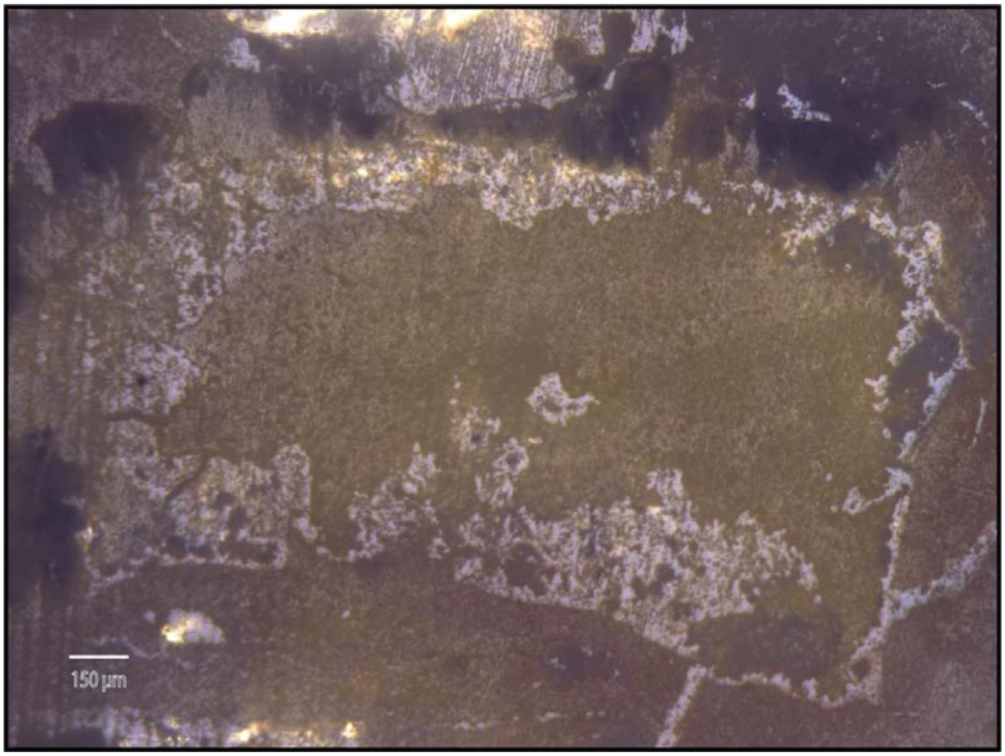


Figure 54: Micrograph from sample YS-08-JM42. Unaltered feldspar with clay veinlet. Grain rim is wetted by clay minerals.

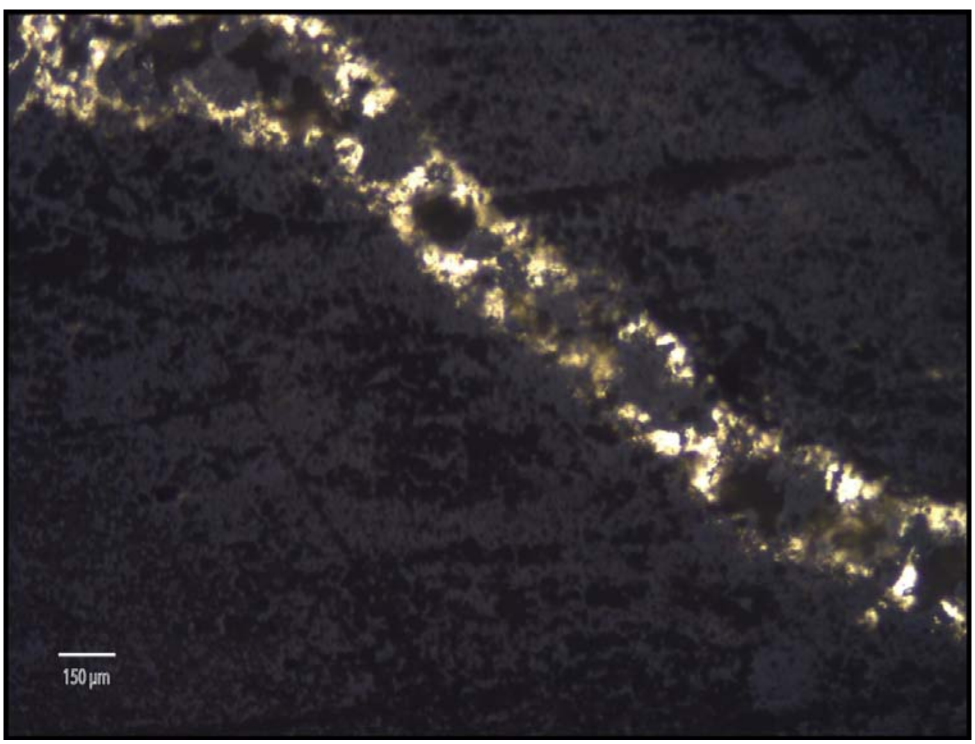


Figure 55: Micrograph from sample YS-08-JM149. Silica veinlet with microbreccia.

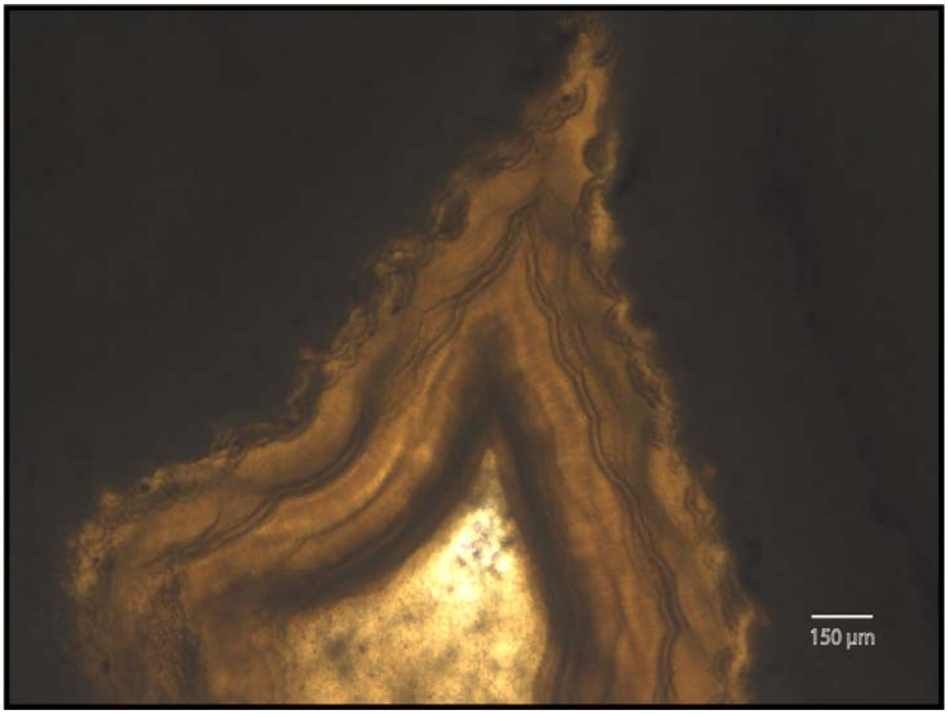


Figure 56: Micrograph from sample YS-08-JM38. Colloform silica veinlet.

Alteration-type analyses

Silicification is the most pervasive alteration in TSC. Almost every sample is silicified. There are rocks so pervasively altered by advanced argillic alteration that silicification is no longer visible except in thin section. Silicification appears as fused "grains" in thin section.

Argillization, though pervasive, is more difficult to identify in hand sample than silicification. Often, the extent of alteration is so thorough that alteration types are unidentifiable. With the use of a microscope, the distribution and extent of argillization was easily recognized. Argillization appears as a fuzzy white to tan "grains" in thin section.

In slightly altered samples, primary igneous textures are easily observed. In more altered samples, the textures are silicified or argillized. The most altered samples are internally structureless, both in hand sample and in thin section. This phenomenon occurs most often in completely silicified samples.

Sulfide Mineralogy

Sulfide minerals were identifiable in polished sections. The distinction between marcasite (FeS_2) and pyrite (FeS_2) was made based on color as well as the botryoidal texture and highly fractured nature of marcasite (**Figures 57** and **58**). Thin sections aided in identifying a local paragenesis between marcasite to pyrite; marcasite, locally, occurred prior to pyrite. Marcasite wedges between pyrite grains (**Figure 59**) and pyrite heals brecciated marcasite (**Figure 60**); this could not occur if marcasite was not already present.

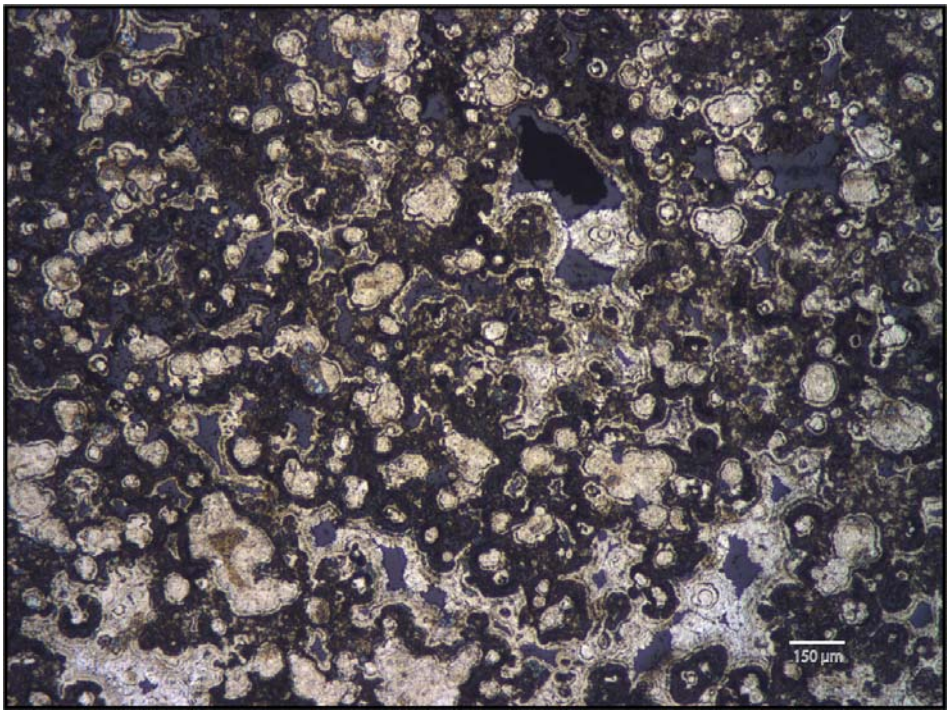


Figure 57: Micrograph from sample YS-08-JM155 #2. Botryoidal marcasite. Reflected; cross-polarized light.

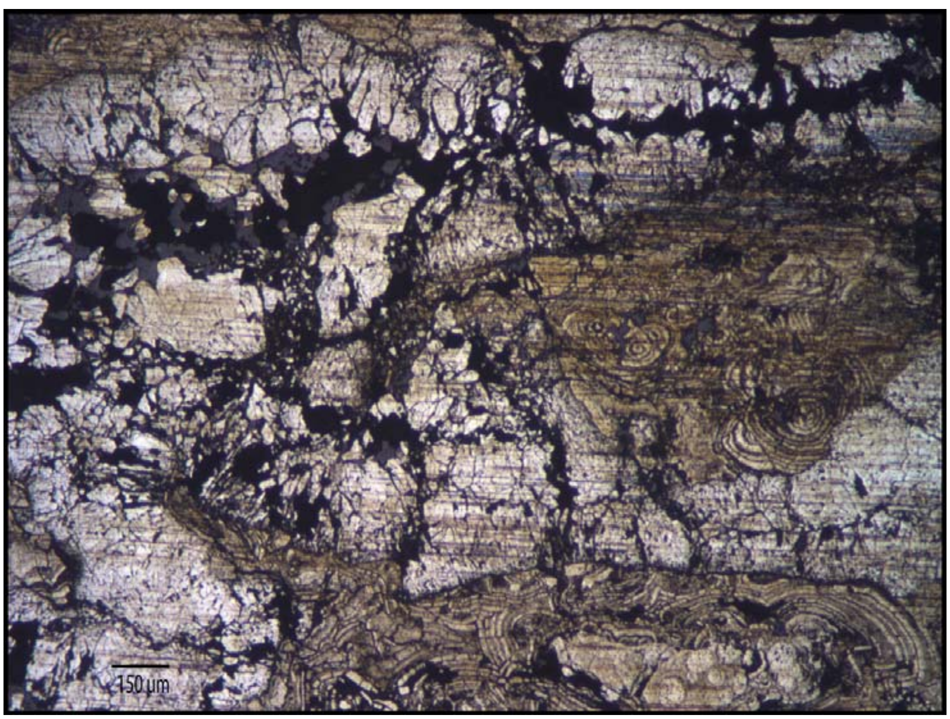


Figure 58: Micrograph from sample YS-08-JM152. Botryoidal, fractured marcasite (gray-copper, colloform mineral) healed by pyrite (grayish tan infill). Note: Pyrite is brecciated. Reflected; cross-polarized light.

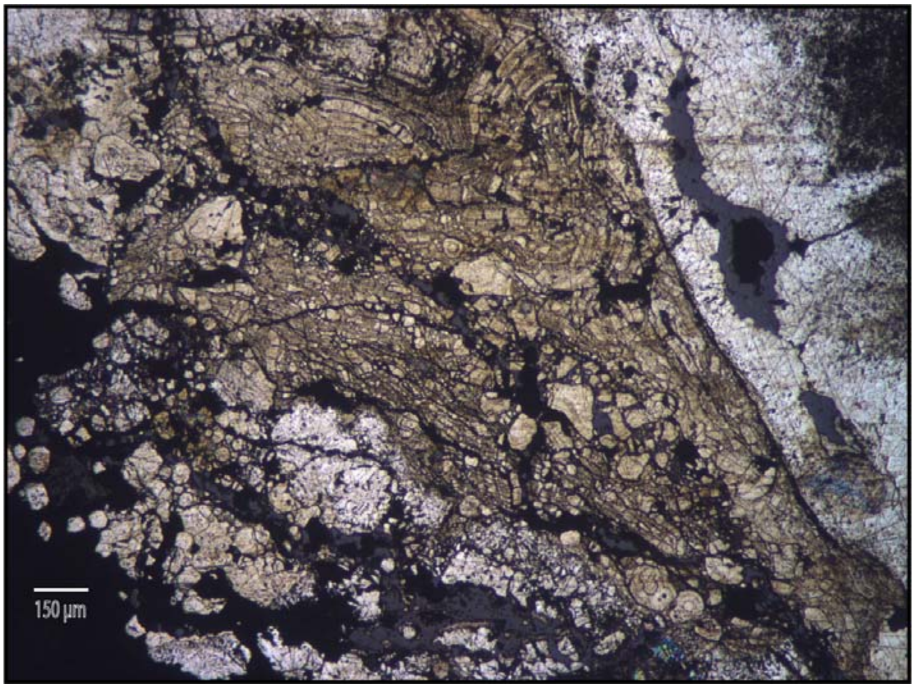


Figure 59: Micrograph from sample YS-08-JM152. Botryoidal, fractured marcasite (gray-copper, colloform mineral) with pyrite contact. Reflected; cross-polarized light.

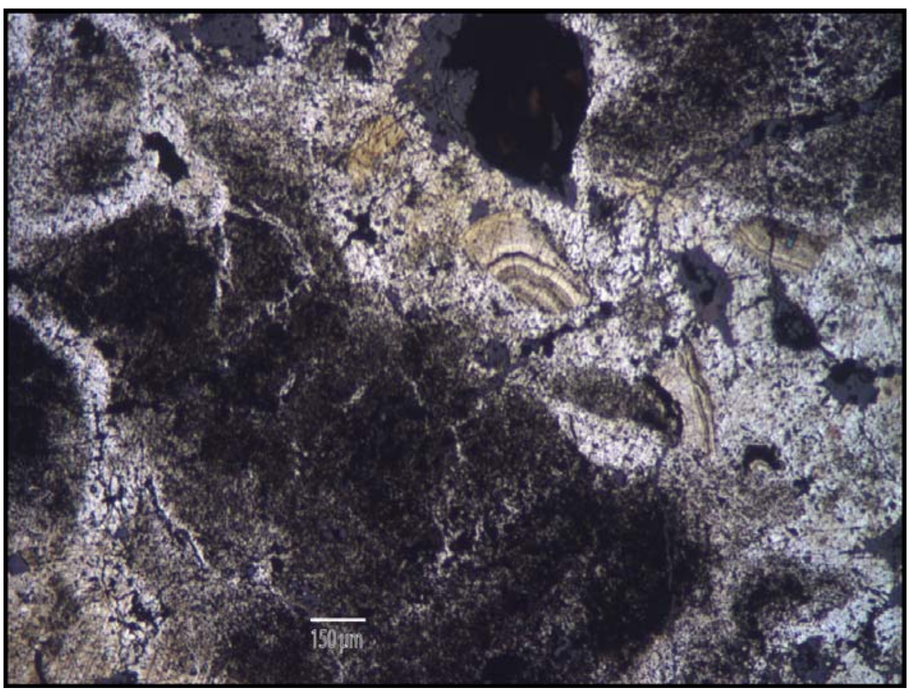


Figure 60: Micrograph from sample YS-08-JM152. Brecciated marcasite (botryoidal, copper grains) healed by fine-grained pyrite. Reflected; cross-polarized light.

Geochemistry

X-ray Fluorescence

Table III-2 (**Appendix III**) lists major element (normalized to oxides) results while **Table III-3** (**Appendix III**) lists results for the trace element analyses. 30 samples were analyzed via XRF.

Inductively coupled plasma mass spectroscopy

Table III-4 (**Appendix III**) lists the results for ICP-MS trace element analyses. 29 samples were analyzed via ICP-MS.

Assays

Table III-6 (**Appendix III**) lists major element (unnormalized) results while **Table III-7** (**Appendix III**) lists the results for the trace element analyses and assays. 8 samples were assayed.

Combined analyses

A complete list of results from XRF, ICP-MS, and assays, as well as, fresh (unaltered) TSC data (Pritchard, Unpublished) is given in **Table 5** (major elements, normalized to oxides) and **Table 6** (trace elements). Results were not normalized to BSE.

Sample	SiO2 (%)	Al2O3 (%)	FeO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	TiO2 (%)	P2O5 (%)	MnO (%)	SO3 (%) >/=	Cl (%) >/=
Fresh TSC	78.11	11.90	1.25	0.06	0.62	2.95	4.75	0.30	0.03	0.02	--	--
YS-08-JM44	--	21.50	5.09	0.08	0.03	0.27	12.48	0.30	0.04	--	--	--
YS-08-JM78	--	16.59	1.69	0.08	0.03	0.46	14.58	0.30	0.03	--	--	--
YS-08-JM155 #2	--	15.61	18.65	0.03	0.15	2.75	6.29	0.20	0.03	--	--	--
YS-08-JM149	--	14.13	10.63	0.02	0.08	1.02	2.99	0.22	0.03	--	--	--
YS-08-JM21	--	14.10	8.01	0.05	0.10	1.02	2.84	0.18	0.28	--	--	--
YS-08-JM118	--	13.38	10.79	0.07	0.08	0.67	1.86	0.17	0.25	--	--	--
YS-08-JM20	--	20.48	2.47	< 0.01	0.04	0.05	0.17	0.22	0.04	--	--	--
YS-08-JM152	--	6.76	33.58	0.03	0.04	0.67	1.73	0.07	0.01	--	--	--
YS-08-JM23	79.87	14.24	0.45	0.03	0.10	0.66	4.28	0.29	0.08	0.002	5.36	0.01
YS-08-JM36	97.76	1.51	0.14	0.00	0.07	0.02	0.13	0.33	0.04	0.002	0.04	0.01
YS-08-JM38*	94.83	2.48	1.09	0.00	0.06	0.04	1.27	0.21	0.02	0.002	0.04	0.01
YS-08-JM42	80.42	14.69	0.36	0.00	0.04	0.30	3.89	0.26	0.04	0.002	5.88	0.01
YS-08-JM43	77.17	15.33	0.36	0.00	0.02	0.06	6.62	0.38	0.05	0.001	5.15	0.01
YS-08-JM130	98.10	1.32	0.09	0.00	0.06	0.03	0.07	0.30	0.01	0.002	0.05	0.01
YS-08-JM62	98.99	0.45	0.03	0.03	0.02	0.13	0.11	0.23	0.01	0.002	0.00	0.01
YS-08-JM133	99.59	0.18	0.04	0.00	0.01	0.03	0.06	0.10	0.01	0.002	0.07	0.01
YS-08-JM82	98.52	0.66	0.26	0.00	0.02	0.00	0.20	0.31	0.02	0.001	0.04	0.01
YS-08-JM70	89.49	8.28	0.79	0.00	0.02	0.04	1.16	0.20	0.02	0.001	2.65	0.01
YS-08-JM74	78.03	16.64	0.08	0.00	0.02	0.36	4.44	0.34	0.10	0.001	5.82	0.01
YS-08-JM83	92.57	3.40	1.59	0.00	0.10	0.17	1.82	0.28	0.06	0.002	1.07	0.01
YS-08-JM85	93.12	3.50	1.20	0.00	0.05	0.13	1.88	0.12	0.01	0.002	0.49	0.01
YS-08-JM89	98.37	0.88	0.26	0.00	0.04	0.00	0.06	0.37	0.02	0.001	0.12	0.01
YS-08-JM137	71.67	21.59	0.84	0.00	0.01	0.32	5.15	0.38	0.04	0.001	5.73	0.01
YS-08-JM97	82.45	11.65	0.19	0.00	0.06	0.56	4.77	0.30	0.02	0.001	2.97	0.01
YS-08-JM107	72.63	22.98	0.19	0.00	0.04	0.08	3.60	0.46	0.03	0.001	5.18	0.01
YS-08-JM22	79.84	15.33	0.33	0.00	0.06	0.58	3.55	0.28	0.02	0.001	4.61	0.01
YS-08-JM115	63.65	26.18	2.10	0.00	0.02	0.24	7.24	0.47	0.08	0.001	6.15	0.01
YS-08-JM117	93.38	3.76	0.04	0.00	0.09	0.88	1.55	0.29	0.02	0.001	0.12	0.01
YS-08-JM144	98.07	0.71	0.08	0.02	0.04	0.19	0.20	0.64	0.04	0.002	0.06	0.01
YS-08-JM146	79.35	12.26	0.45	0.01	0.22	2.44	4.81	0.42	0.02	0.007	0.08	0.02
YS-08-JM156	78.82	12.38	0.42	0.00	0.26	2.74	5.08	0.28	0.03	0.001	0.08	0.01
YS-08-JM04	89.17	7.84	0.04	0.00	0.01	0.12	2.23	0.53	0.06	0.001	4.88	0.01
YS-08-JM08	80.75	12.38	1.12	0.02	0.18	1.64	3.60	0.29	0.03	0.001	0.06	0.01
YS-08-JM13	70.66	21.19	0.72	0.00	0.09	0.86	6.07	0.38	0.03	0.001	5.82	0.01
YS-08-JM17	78.79	12.56	0.36	0.02	0.26	2.48	5.26	0.24	0.02	0.001	0.05	0.01
YS-08-JM121	92.08	6.67	0.07	0.01	0.03	0.16	0.51	0.43	0.05	0.001	2.45	0.02
YS-07-JM02	80.76	12.69	0.57	0.00	0.11	1.32	4.17	0.35	0.02	0.003	3.20	0.01
YS-07-JM05	98.27	0.76	0.29	0.00	0.01	0.10	0.10	0.45	0.02	0.001	0.00	0.01

Table 5: Major and minor elements normalized to oxides from XRF and assay analyses.

Si was not measured in assay analyses due to the volatilization of Si.

SO3 and Cl are back calculated (XRF) and are greater than or equal to the values shown.

*Averaged with repeat bead

Sample	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Ba (ppm)	Th (ppm)	Nb (ppm)	Y (ppm)	Hf (ppm)	Ta (ppm)	U (ppm)	Pb (ppm)	Rb (ppm)	Cs (ppm)	Sr (ppm)
Fresh TSC	70.60	135	15.00	56.09	11.52	1.67	10.37	1.77	10.44	2.14	5.65	0.85	5.26	0.80	961	22.36	45.31	53.79	9.87	3.19	5.47	27.54	165	4.46	65.65
YS-08-JM44	39.3	63	--	25	4.6	1.4	--	< 0.5	--	--	--	--	2.5	0.37	500	13.1	--	31	5	1.7	5.6	106	334	11	48
YS-08-JM78	52	80	--	28	6.4	1.3	--	< 0.5	--	--	--	--	4.5	0.69	1260	13.8	--	47	6	2.4	6	17	405	8	84
YS-08-JM155 #2	42.7	58	--	23	3.4	0.6	--	< 0.5	--	--	--	--	1.9	0.26	400	14.5	--	14	4	1.8	6.4	25	139	< 1	20
YS-08-JM149	32	32	--	6	1.8	< 0.2	--	< 0.5	--	--	--	--	2	0.45	< 50	8.4	--	26	4	< 0.5	68.9	31	41	2	30
YS-08-JM21	223	248	--	57	11.4	1.5	--	< 0.5	--	--	--	--	3.9	0.51	410	23.9	--	52	4	3.4	6.1	108	51	3	211
YS-08-JM118	204	223	--	55	11	1.5	--	1	--	--	--	--	3.5	0.54	510	17.5	--	57	3	< 0.5	4.2	72	< 15	< 1	169
YS-08-JM20	28.8	39	--	6	2.1	< 0.2	--	< 0.5	--	--	--	--	2.4	0.37	300	10.3	--	21	6	2.3	4	19	< 15	3	36
YS-08-JM152	9.1	16	--	< 5	1	< 0.2	--	< 0.5	--	--	--	--	0.8	0.14	< 50	3.8	--	9	1	< 0.5	< 0.5	33	< 15	2	7
YS-08-JM23*	59.90	96.25	10.09	35.56	7.49	1.16	6.61	1.20	7.61	1.50	3.91	0.55	3.27	0.48	704	19.35	36.28	38.38	7.66	2.46	4.74	32.29	56.23	9.57	110
YS-08-JM36	33.10	51.00	4.93	16.52	2.92	0.33	2.12	0.37	2.64	0.60	2.06	0.36	2.52	0.43	243	26.54	55.33	16.17	11.73	4.07	7.87	22.54	7.08	5.42	68.01
YS-08-JM38*	17.60	33.91	3.73	14.62	2.93	0.53	2.30	0.39	2.20	0.39	0.99	0.14	0.85	0.12	248	9.33	18.23	10.91	1.87	0.43	30.27	5.52	76	4.45	125.11
YS-08-JM42	25.88	49.49	5.55	17.62	3.63	0.43	3.07	0.56	3.69	0.78	2.35	0.38	2.41	0.39	1521	23.65	32.75	19.56	7.28	2.40	9.48	24.38	83.96	6.11	38.01
YS-08-JM43	33.77	46.55	5.26	18.00	4.05	0.68	3.90	0.74	4.99	1.13	3.51	0.57	3.79	0.62	1258	25.25	67.24	28.12	14.87	5.17	8.23	41.16	108	0.84	44.84
YS-08-JM130	10.93	22.49	2.53	9.68	2.08	0.21	1.96	0.41	2.90	0.64	2.03	0.33	2.30	0.38	559	22.56	52.90	15.83	10.24	3.78	6.46	4.92	5.48	5.81	21.58
YS-08-JM62	3.10	1.69	0.42	1.39	0.44	0.04	0.49	0.11	0.90	0.22	0.76	0.14	1.00	0.17	74	5.04	40.33	6.33	7.54	2.83	1.49	1.26	8.03	4.28	16.40
YS-08-JM133	4.31	5.89	0.64	2.39	0.22	0.02	0.23	0.05	0.38	0.10	0.35	0.06	0.44	0.08	109	3.18	19.97	2.58	4.04	1.93	0.39	1.64	4.72	2.39	11.95
YS-08-JM82	35.57	63.37	7.10	24.09	4.92	0.56	4.51	0.88	6.01	1.28	3.66	0.56	3.49	0.51	277	22.66	60.48	35.17	10.32	4.41	5.94	11.52	11.91	4.41	22.14
YS-08-JM70	17.10	29.84	3.09	9.12	1.92	0.35	1.75	0.32	2.14	0.46	1.44	0.24	1.62	0.25	1125	13.29	30.22	11.35	6.53	2.05	3.10	27.97	5.01	1.35	30.57
YS-08-JM74	95.44	151	15.66	48.94	8.52	1.37	6.04	0.84	4.07	0.69	1.83	0.30	2.02	0.33	609	27.32	42.97	14.93	9.19	2.99	5.28	24.38	13.97	1.79	185
YS-08-JM83	47.75	93.19	10.53	36.27	7.69	0.98	6.86	1.17	7.29	1.44	3.97	0.59	3.74	0.58	431	23.34	39.81	38.05	8.59	2.85	5.08	23.75	56.39	4.39	66.29
YS-08-JM85	33.64	58.49	5.97	19.59	3.42	0.50	2.60	0.41	2.31	0.49	1.39	0.23	1.55	0.26	264	11.86	17.97	11.55	4.55	1.37	3.58	15.15	92.07	5.81	18.65
YS-08-JM89	33.62	52.02	4.94	15.85	3.38	0.57	4.05	0.98	7.37	1.59	4.57	0.69	4.28	0.65	2775	24.91	59.23	40.48	12.35	4.31	6.65	24.75	3.22	2.30	41.49
YS-08-JM137	27.12	43.52	3.99	14.33	2.70	0.27	2.22	0.40	2.61	0.55	1.67	0.27	1.84	0.30	558	19.27	37.20	13.86	8.41	2.46	4.30	21.77	25.47	2.06	48.24
YS-08-JM97	44.59	80.99	8.82	28.90	5.57	1.09	4.32	0.74	4.37	0.83	2.23	0.34	2.28	0.36	927	25.56	45.17	16.78	9.40	3.18	5.20	24.70	132.29	3.12	30.94
YS-08-JM107	43.88	70.75	7.03	21.83	3.73	0.58	3.73	0.78	5.92	1.31	3.93	0.61	3.83	0.59	764	27.41	45.68	34.74	10.92	3.09	5.87	35.61	9.01	0.67	42.71
YS-08-JM22	26.97	51.41	5.81	20.84	4.53	0.58	3.99	0.69	4.35	0.90	2.54	0.40	2.68	0.42	675	17.49	40.44	24.35	8.39	2.87	7.13	27.49	38.74	0.52	34.79
YS-08-JM115	73.18	114	11.05	35.59	5.15	0.58	3.55	0.63	4.47	1.02	3.00	0.47	3.04	0.49	553	20.90	50.95	25.72	10.77	3.46	5.89	34.34	13.78	0.32	99.44
YS-08-JM117	50.45	107	12.80	46.90	10.28	1.17	8.79	1.36	7.77	1.53	4.23	0.64	4.11	0.67	833	31.17	50.07	40.47	10.44	3.54	6.88	33.87	49.76	1.10	25.00
YS-08-JM144	67.82	127	13.13	53.39	9.95	0.59	8.60	1.53	9.53	1.97	5.46	0.84	5.32	0.84	1364	35.10	66.71	51.40	16.93	4.57	11.55	37.00	5.44	1.43	65.93
YS-08-JM146	47.01	86.47	10.08	34.60	7.57	1.11	6.59	1.14	7.09	1.46	4.07	0.63	4.01	0.62	1130	32.56	54.03	36.58	13.09	3.77	6.47	28.09	163	4.16	36.16
YS-08-JM156	76.08	155	17.86	64.63	13.12	1.56	11.03	1.80	10.38	1.94	5.06	0.73	4.56	0.68	839	25.29	46.97	48.20	9.60	3.27	5.26	27.88	173	2.39	33.99
YS-08-JM04	61.21	108	11.02	35.63	5.85	0.66	4.14	0.78	5.33	1.18	3.56	0.56	3.67	0.60	1334	27.15	64.13	30.10	14.76	4.46	7.13	41.84	10.20	0.42	53.09
YS-08-JM08	58.25	116	12.41	43.79	9.23	1.44	8.20	1.39	8.51	1.68	4.61	0.68	4.30	0.66	665	21.40	42.51	44.36	8.74	2.96	5.02	35.52	120	4.96	32.52
YS-08-JM13	43.40	87.01	10.38	38.62	8.11	1.04	6.58	1.11	6.61	1.28	3.59	0.54	3.40	0.52	762	27.20	44.67	30.25	9.81	3.09	5.92	25.54	57.74	0.71	50.66
YS-08-JM17	61.85	123	14.70	51.33	10.27	1.33	7.44	1.13	6.11	1.08	2.82	0.42	2.63	0.41	806	26.48	45.12	23.99	9.12	3.22	5.81	26.37	176	2.36	32.76
YS-08-JM121**	34.50	58.60	--	20.80	--	--	--	--	--	--	--	--	--	--	2203	20.00	106.90	42.30	--	--	11.70	26.20	17.70	10.30	105
YS-07-JM02	45.95	86.65	10.14	35.92	7.61	1.14	7.03	1.12	6.83	1.40	3.85	0.57	3.75	0.59	788	24.58	44.91	34.69	10.14	3.08	5.30	24.01	108	2.92	31.67
YS-07-JM05	26.01	47.65	5.50	18.40	3.54	0.30	3.26	0.67	4.91	1.12	3.36	0.53	3.55	0.59	1233	12.75	55.79	31.21	13.35	4.02	5.46	28.73	8.06	0.95	20.81

Table 6: Trace elements from XRF, ICP-MS and assay analyses.

If elements were analyzed by both XRF and ICP-MS, values were averaged.

*Averaged with repeat bead **Sample was not measured with ICP-MS

Sample	Sc (ppm)	Zr (ppm)	Ni (ppm)	Cr (ppm)	V (ppm)	Ga (ppm)	Cu (ppm)	Zn (ppm)	Be (ppm)	Cd (ppm)	Mo (ppm)	S (%)	Bi (ppm)	Au (ppb)	Ag (ppm)	As (ppm)	Br (ppm)	Co (ppm)	Hg (ppm)	Ir (ppb)	Mn (ppm)	Sb (ppm)	Se (ppm)	W (ppm)	Sn (ppm)
Fresh TSC	5.28	334	0.59	4.09	3.85	21.10	1.87	69.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM44	5.3	–	25	12	29	–	11	115	< 1	2.7	15	5.91	< 2	969	0.3	103	< 0.5	16	4	< 5	48	74.8	13	8	< 0.01
YS-08-JM78	7.1	–	5	9	12	–	8	14	1	< 0.3	8	0.99	< 2	257	1.3	104	< 0.5	3	< 1	< 5	27	13	5	< 1	< 0.01
YS-08-JM155 #2	2.7	–	82	< 2	9	–	13	44	3	1.8	45	19	< 2	56	0.5	429	< 0.5	26	7	< 5	79	89.3	< 3	< 1	< 0.01
YS-08-JM149	3.6	–	24	< 2	42	–	6	36	3	0.6	28	10.8	< 2	17	< 0.3	2540	< 0.5	11	< 1	< 5	32	34.2	< 3	< 1	< 0.01
YS-08-JM21	4.8	–	28	< 2	11	–	16	76	4	0.4	36	7.69	< 2	2	0.7	319	< 0.5	11	4	< 5	47	4.8	< 3	< 1	< 0.01
YS-08-JM118	4.4	–	59	6	13	–	31	109	3	0.8	72	11.4	< 2	< 2	0.7	660	< 0.5	15	2	< 5	27	7.8	< 3	< 1	< 0.01
YS-08-JM20	3.7	–	3	< 2	6	–	6	7	1	< 0.3	5	2.08	< 2	< 2	0.4	225	< 0.5	2	< 1	< 5	19	35.8	< 3	17	< 0.01
YS-08-JM152	1.7	–	182	13	10	–	14	106	1	3	30	> 20.0	< 2	< 2	< 0.3	568	< 0.5	62	19	< 5	79	24.6	< 3	< 1	< 0.01
YS-08-JM23*	4.89	271	4.10	7.80	6.20	28.30	1.00	10.80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM36	3.99	392	1.60	7.20	6.30	13.50	0.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM38*	2.14	39	2.25	9.60	7.70	10.45	2.05	4.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM42	4.69	243	6.20	12.70	8.60	13.80	0.90	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM43	5.35	445	2.10	15.90	32.70	71.10	2.30	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM130	3.43	341	0.20	5.80	4.70	2.70	0.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM62	1.20	236	1.40	7.20	5.30	9.10	0.00	1.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM133	0.46	122	1.10	15.40	5.80	4.30	0.40	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM82	5.73	324	0.70	6.30	10.20	5.10	1.50	7.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM70	3.73	226	2.20	5.10	4.40	13.30	4.60	2.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM74	6.70	316	1.60	6.80	7.40	19.70	2.50	2.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM83	4.96	295	0.40	13.00	3.10	10.30	4.80	5.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM85	3.16	154	0.00	11.60	3.50	6.20	5.00	1.60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM89	3.99	407	2.30	5.90	3.70	0.50	4.90	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM137	7.63	319	1.20	7.70	9.80	16.20	0.70	2.80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM97	3.32	314	6.10	2.60	5.40	12.90	1.20	0.40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM107	6.53	409	0.70	7.60	9.70	15.20	0.00	3.70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM22	7.61	288	1.80	5.60	9.80	18.90	0.10	1.80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM115	5.13	399	2.30	20.90	18.30	36.90	0.00	0.30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM117	2.95	344	0.00	1.90	2.50	5.00	0.00	0.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM144	3.71	612	0.70	8.20	5.40	3.10	0.30	0.50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM146	3.45	471	2.50	5.90	9.10	26.10	0.60	8.30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM156	3.75	322	2.60	2.10	3.40	20.40	1.60	8.90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM04	5.59	530	0.00	12.80	10.10	26.30	0.00	0.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM08	5.52	288	6.30	11.20	11.20	16.80	3.10	9.50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM13	11.76	350	5.30	21.90	11.80	14.40	3.70	4.30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM17	3.22	290	4.10	4.90	6.40	18.30	0.00	9.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-08-JM121**	10.40	830	21.30	42.20	22.70	47.40	2.50	2.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-07-JM02	5.60	363	0.70	3.60	5.70	17.50	3.70	11.10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
YS-07-JM06	3.78	480	15.30	3.80	0.00	0.00	3.70	0.80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 6: Continued.

Stable Isotope Ratios

23 hydrothermal quartz samples and 3 hydrothermal opal samples were analyzed for oxygen stable isotope data. The range of isotopic values was between -3.01‰ and 6.44‰. **Table 7** lists sample number, outcrop, elevation, type of alteration, and per mil results for all samples. **Figure 61** shows the type of alteration sampled plotted against per mil data. With the exception of the opal samples, isotope ratios from vein samples range from -2.0 to 2.0‰ and matrix and drusy quartz samples have a wide range of values (-3.0 to 6.0‰) depending on the elevation from which they were collected. Opal tends to have higher $\delta^{18}O$ ratios because of the inherent water in this mineraloid; the water in opal exchanges readily with atmospheric water. **Figure 63** shows the distribution of samples analyzed with associated per mil data. **Figure 62** shows elevation verses per mil data; in general, a decrease in elevation yields lower $\delta^{18}O$ values.

Sample	Outcrop	Elevation (ft)	Type of sample	δ 18O (‰)
YS-08-JM136	Outcrop 4B	8120	Vein (opal)	6.44
YS-08-JM124	South Ridge	8040	Float	-2.48
YS-08-JM128	South Ridge	8080	Matrix	5.87
YS-07-JM05	South Ridge	8020	Drusy Quartz	4.27
YS-08-JM125	South Ridge	8040	Matrix	3.06
YS-08-JM133	North Ridge	8200	Matrix	5.99
YS-08-JM59	Outcrop 2	8200	Matrix	1.22
YS-08-JM77*	Outcrop 5	8040	Drusy Quartz	-0.35
YS-08-JM77*	Outcrop 5	8040	Vein	1.3
YS-08-JM12	Outcrop 7	7860	Vein	0.25
YS-08-JM13	Outcrop 7	7880	Matrix	-3.01
YS-08-JM13	Outcrop 7	7880	Vein (opal)	2.03
YS-08-JM13	Outcrop 7	7880	Vein	-0.51
YS-08-JM20	Stream	7960	Vein	-0.18
YS-08-JM120A	Stream	7940	Opal Nodule	3.92
YS-08-JM150	Stream	7850	Vein	-0.3
YS-08-JM153	Stream	7840	Vein	0
YS-08-JM98	Outcrop 6	7970	Matrix	-0.33
YS-08-JM09**	Outcrop 7	7860	Vein	0.47
YS-08-JM38	Outcrop 3	8030	Vein	-0.05
YS-08-JM39	Outcrop 3	8030	Vein	0.25
YS-08-JM42	Outcrop 3	8030	Vein	-1.46
YS-08-JM78	Outcrop 4A	8020	Matrix	0.57
YS-08-JM83	Outcrop 4B	8000	Matrix	-0.95
YS-08-JM85	Outcrop 4B	8000	Vein	-1.41
YS-08-JM113	Outcrop 4C	7940	Drusy Quartz	0.97

Table 7: Overview of samples prepared for stable isotope ratio analyses.
Vein, unless otherwise stated, includes quartz veins and veinlets;
matrix=silicified altered groundmass; drusy quartz lines vugs in wall rock.
*Vein with drusy quartz **Quartz from breccia healing

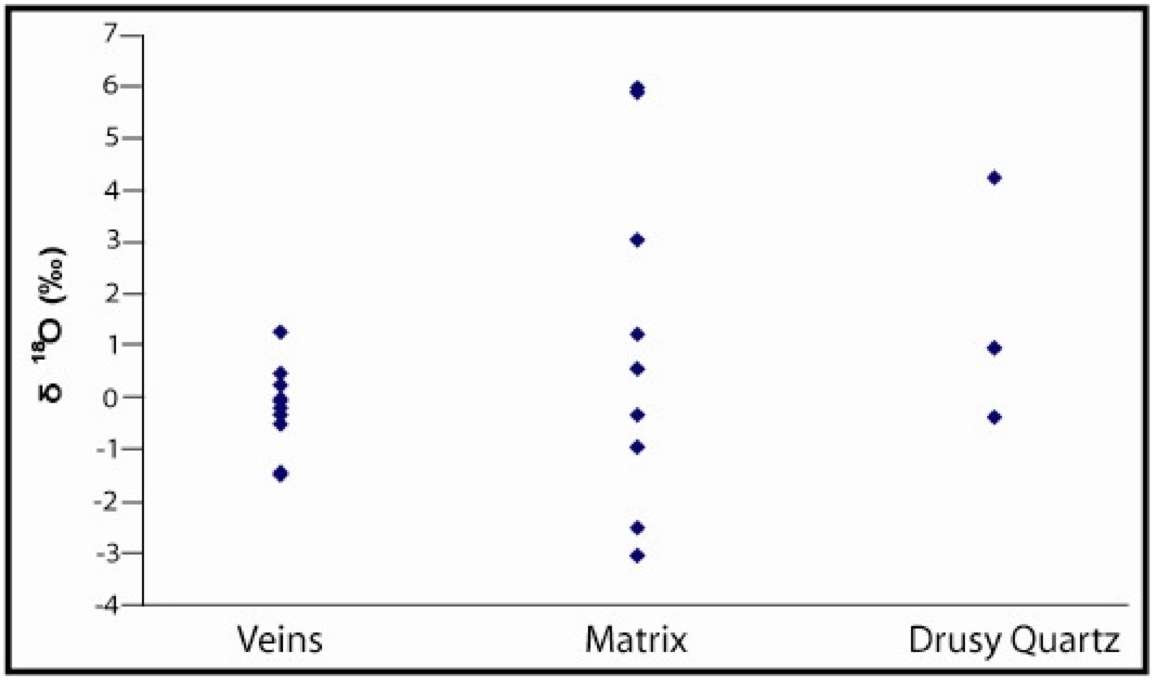


Figure 61: Type of alteration plotted against oxygen isotope ratios (per mil).
Note: Opal samples have been omitted.

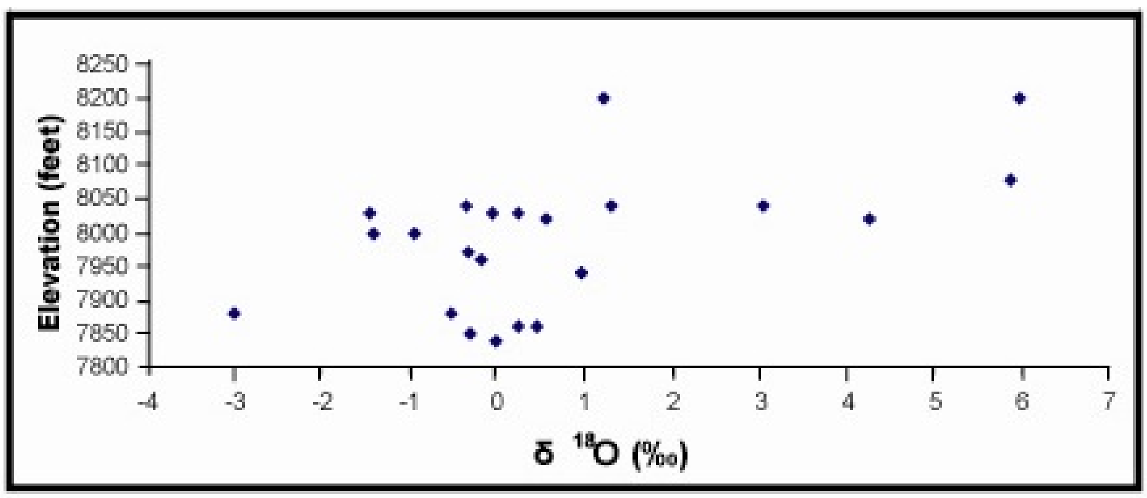


Figure 62: Oxygen isotope ratios (per mil) plotted against elevation (in feet) in Sulphur Creek canyon- south fork. Note: Opal samples have been omitted.

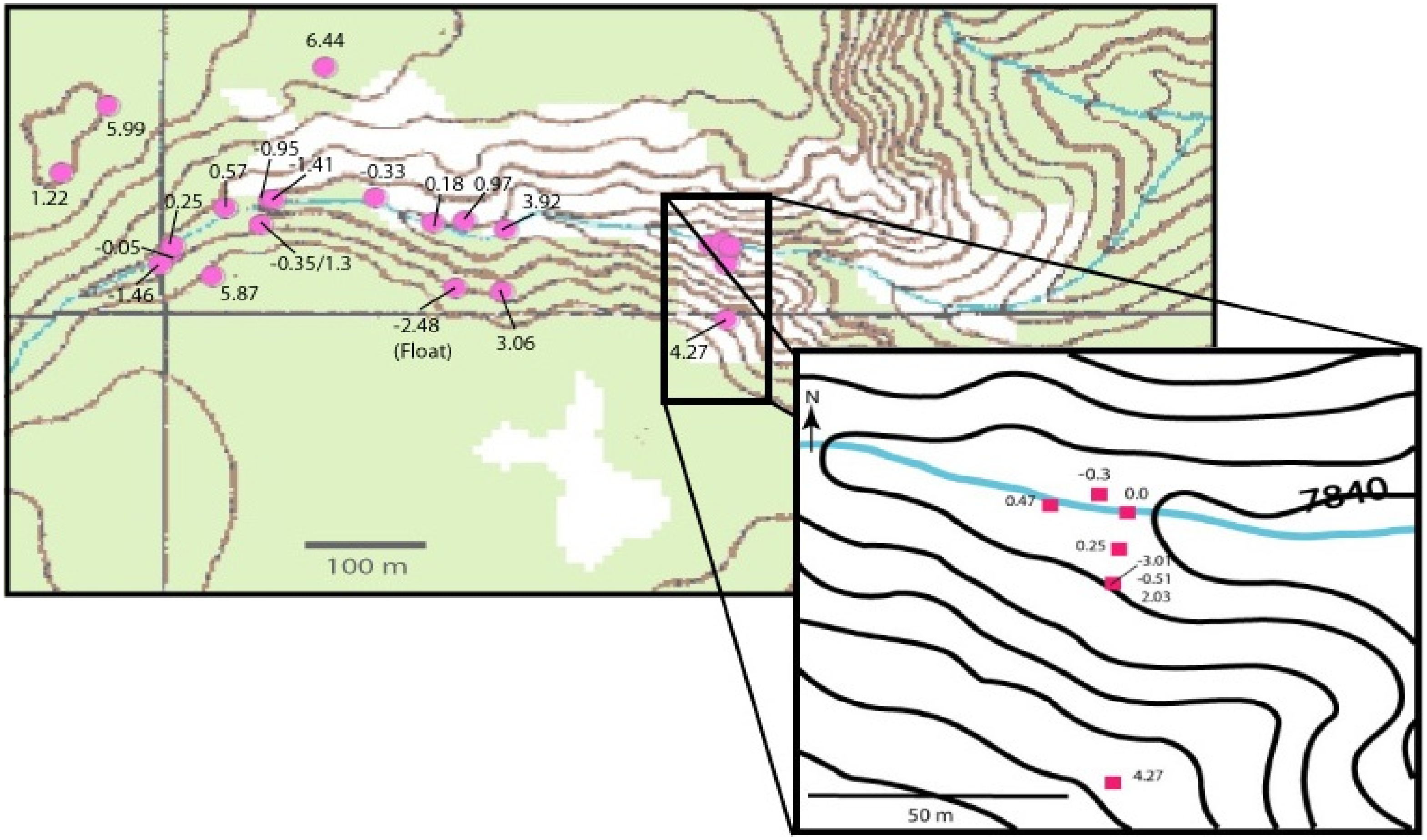


Figure 63: Distribution map of samples used for oxygen isotope studies and per mil values. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Electron Microprobe

Microprobe work was completed to confirm mineralogy in a few samples and to ensure no gold flakes were being overlooked; none were found. Pyrite/marcasite were the key components in the thin sections probed and interestingly enough, most FeS_2 grains were not pure iron sulfides. Many contained various amounts of As and Ni (as well as a few other metals). This could be an explanation for no visible sulfide minerals with these metals, yet they are elevated above protolith concentrations based on XRF data.

Unidentified clays were noted as well. Some of the clays were bright to pale pink, white, or various shades of blue in thin section. Analysis indicated silicate minerals with various amounts of Ti, Al, Na, K, Mg, P, and Fe. Along with various clays, sample YS-08-JM118 contains andalusite, which was not detected in hand sample or XRD.

CHAPTER SIX

DISCUSSION

Alteration in the South Fork of Sulphur Creek

The primary objective of this study was to define the epithermal alteration in Tuff of Sulphur Creek (TSC), which was emplaced along the collapsed Yellowstone Caldera ring fracture to the northeast and subsequently altered. Larson et al. (2009) define the hydrothermal nature of altered TSC as epithermal based on the deposit's proximity to the surface, mineral assemblages, and mineral geothermometry. Altered TSC has been exposed in the Grand Canyon of the Yellowstone River and in a tributary canyon incised by Sulphur Creek. Interestingly enough, it would seem that hydrothermal alteration in TSC and the incision of Sulphur Creek canyon are coeval (Larson et al., 2009). These conclusions are consistent with the investigations of this thesis.

Summary of alteration in TSC

Hydrothermal alteration in Sulphur Creek canyon is pervasive. The canyon ridges are silicified, the canyon walls show silicification overprinted by advanced argillic alteration with pervasive stockwork veinlets, and the stream bed is dominated by brecciated veins surrounded by silicification. Advanced argillic alteration is a type of hydrothermal alteration dominated by kaolinite and quartz with altered or replaced feldspars.

It is inconclusive as to whether the older hydrothermal system (preserved in Sulphur Creek canyon) was continuously inundated by hydrothermal fluids or had intermittent fluids. Alteration and vein paragenesis were clouded by extensively altered groundmass.

Geochemical data aided in alteration identification. In general, samples with silica weight percentages between 90 and 99 were silicified and samples containing 10 weight percent or higher Al_2O_3 were argillized. These are very generalized interpretations, however. In hydrothermal systems, fluids are capable of scavenging minerals from the groundmass without the accumulation of additional components in that rock. For example, leaching yields high silica weight percentages (>99%) but such samples are not necessarily silicified. Because of this, caution should be used when comparing geochemical data to alteration if no sample density studies have been performed. Geochemical data should only be used as a secondary reference for alteration; hand sample descriptions and mineral identification should always be primary. With that being said, the correlation between SiO_2 and Al_2O_3 is a negative linear trend, suggesting that the lowering of SiO_2 concentrations in the system is proportional to the increasing of Al_2O_3 concentrations (**Appendix III**, **Figure III-1**). This could support advanced argillic overprinting. Al^{3+} is remobilized and re-deposited to form alteration minerals typical of advanced argillic alteration.

SiO_2 data was plotted against major, minor, and trace element data (**Appendix III**). Al_2O_3 and K_2O plot negative linear trends with SiO_2. All trace elements (as well as FeO, TiO_2, and P_2O_5) plot nearly identical patterns featuring weak negative correlations. These patterns suggest, in general, that a decrease in silica is complemented by an increase in these elements, most of which are rare earth elements (REE). Trace elements that do not follow this pattern include high field strength elements (HFSE), most large-ion lithophile elements (LILE), and transition metals (including Y). LILEs were plotted against K_2O, only Rb has a distinguishably positive correlation; no other correlations were found between the elements (**Appendix III**). Hydrothermally mobile alkali trace elements were plotted against Th; Rb, Ba, and Sr show vague positive correlations (**Appendix III**).

Lewis et al. (1997) noted depleted REE in sinter from acid-sulfate and acid-sulfate-chloride hot springs located in the Yellowstone Caldera caused by REE mobility during water-rock interaction. Interestingly enough, altered TSC contains depleted REE relative to fresh TSC (**Table 8**).

Two of the eight samples sent to ActLabs for assay analyses have Au concentrations greater than 0.1 ppm. (White et al. (1992) noted Au concentrations >0.1 ppm were anomalous in actively precipitating sinter in the Yellowstone Caldera.) Both of these sample have high K concentrations and relatively low percentages of other total oxides. These samples are relatively depleted or the same as trace element concentrations found in unaltered TSC, except for elevated concentrations of: Ba (YS-08-JM78), Pb (YS-08-JM44), Rb (both), minor Cs (both), Ni (both), Cr (both), V (both), Cu (both), and Zn (YS-08-JM44). Bi was not detected in Au-bearing samples. Se is another notable trace element that often occurs when Au is present in the system (Saunders, 1990). The two samples in altered TSC with anomalous Au (>0.1 ppm) contain higher Se concentrations relative to the samples without anomalous Au. **Table 9** compares five samples with decreasing Au values in altered TSC.

Sample	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Total REE
Fresh TSC	70.60	135	15.00	56.09	11.52	1.67	10.37	1.77	10.44	2.14	5.65	0.85	5.26	0.80	326.95
YS-08-JM44	39.3	63	--	25	4.6	1.4	--	< 0.5	--	--	--	--	2.5	0.37	>136.17
YS-08-JM78	52	80	--	28	6.4	1.3	--	< 0.5	--	--	--	--	4.5	0.69	>172.89
YS-08-JM155 #2	42.7	58	--	23	3.4	0.6	--	< 0.5	--	--	--	--	1.9	0.26	>129.86
YS-08-JM149	32	32	--	6	1.8	< 0.2	--	< 0.5	--	--	--	--	2	0.45	>74.25
YS-08-JM21	223	248	--	57	11.4	1.5	--	< 0.5	--	--	--	--	3.9	0.51	>545.31
YS-08-JM118	204	223	--	55	11	1.5	--	1	--	--	--	--	3.5	0.54	>499.54
YS-08-JM20	28.8	39	--	6	2.1	< 0.2	--	< 0.5	--	--	--	--	2.4	0.37	>78.67
YS-08-JM152	9.1	16	--	< 5	1	< 0.2	--	< 0.5	--	--	--	--	0.8	0.14	>27.04
YS-08-JM23*	59.90	96.25	10.09	35.56	7.49	1.16	6.61	1.20	7.61	1.50	3.91	0.55	3.27	0.48	235.58
YS-08-JM36	33.10	51.00	4.93	16.52	2.92	0.33	2.12	0.37	2.64	0.60	2.06	0.36	2.52	0.43	119.91
YS-08-JM38*	17.60	33.91	3.73	14.62	2.93	0.53	2.30	0.39	2.20	0.39	0.99	0.14	0.85	0.12	80.70
YS-08-JM42	25.88	49.49	5.55	17.62	3.63	0.43	3.07	0.56	3.69	0.78	2.35	0.38	2.41	0.39	116.22
YS-08-JM43	33.77	46.55	5.26	18.00	4.05	0.68	3.90	0.74	4.99	1.13	3.51	0.57	3.79	0.62	127.55
YS-08-JM130	10.93	22.49	2.53	9.68	2.08	0.21	1.96	0.41	2.90	0.64	2.03	0.33	2.30	0.38	58.85
YS-08-JM62	3.10	1.69	0.42	1.39	0.44	0.04	0.49	0.11	0.90	0.22	0.76	0.14	1.00	0.17	10.87
YS-08-JM133	4.31	5.89	0.64	2.39	0.22	0.02	0.23	0.05	0.38	0.10	0.35	0.06	0.44	0.08	15.15
YS-08-JM82	35.57	63.37	7.10	24.09	4.92	0.56	4.51	0.88	6.01	1.28	3.66	0.56	3.49	0.51	156.49
YS-08-JM70	17.10	29.84	3.09	9.12	1.92	0.35	1.75	0.32	2.14	0.46	1.44	0.24	1.62	0.25	69.65
YS-08-JM74	95.44	151	15.66	48.94	8.52	1.37	6.04	0.84	4.07	0.69	1.83	0.30	2.02	0.33	336.73
YS-08-JM83	47.75	93.19	10.53	36.27	7.69	0.98	6.86	1.17	7.29	1.44	3.97	0.59	3.74	0.58	222.05
YS-08-JM85	33.64	58.49	5.97	19.59	3.42	0.50	2.60	0.41	2.31	0.49	1.39	0.23	1.55	0.26	130.83
YS-08-JM89	33.62	52.02	4.94	15.85	3.38	0.57	4.05	0.98	7.37	1.59	4.57	0.69	4.28	0.65	134.56
YS-08-JM137	27.12	43.52	3.99	14.33	2.70	0.27	2.22	0.40	2.61	0.55	1.67	0.27	1.84	0.30	101.79
YS-08-JM97	44.59	80.99	8.82	28.90	5.57	1.09	4.32	0.74	4.37	0.83	2.23	0.34	2.28	0.36	185.44
YS-08-JM107	43.88	70.75	7.03	21.83	3.73	0.58	3.73	0.78	5.92	1.31	3.93	0.61	3.83	0.59	168.51
YS-08-JM22	26.97	51.41	5.81	20.84	4.53	0.58	3.99	0.69	4.35	0.90	2.54	0.40	2.68	0.42	126.12
YS-08-JM115	73.18	114	11.05	35.59	5.15	0.58	3.55	0.63	4.47	1.02	3.00	0.47	3.04	0.49	256.03
YS-08-JM117	50.45	107	12.80	46.90	10.28	1.17	8.79	1.36	7.77	1.53	4.23	0.64	4.11	0.67	257.59
YS-08-JM144	67.82	127	13.13	53.39	9.95	0.59	8.60	1.53	9.53	1.97	5.46	0.84	5.32	0.84	305.67
YS-08-JM146	47.01	86.47	10.08	34.60	7.57	1.11	6.59	1.14	7.09	1.46	4.07	0.63	4.01	0.62	212.44
YS-08-JM156	76.08	155	17.86	64.63	13.12	1.56	11.03	1.80	10.38	1.94	5.06	0.73	4.56	0.68	364.23
YS-08-JM04	61.21	108	11.02	35.63	5.85	0.66	4.14	0.78	5.33	1.18	3.56	0.56	3.67	0.60	241.74
YS-08-JM08	58.25	116	12.41	43.79	9.23	1.44	8.20	1.39	8.51	1.68	4.61	0.68	4.30	0.66	271.47
YS-08-JM13	43.40	87.01	10.38	38.62	8.11	1.04	6.58	1.11	6.61	1.28	3.59	0.54	3.40	0.52	212.18
YS-08-JM17	61.85	123	14.70	51.33	10.27	1.33	7.44	1.13	6.11	1.08	2.82	0.42	2.63	0.41	284.03
YS-08-JM121**	34.50	58.60	--	20.80	--	--	--	--	--	--	--	--	--	--	113.90
YS-07-JM02	45.95	86.65	10.14	35.92	7.61	1.14	7.03	1.12	6.83	1.40	3.85	0.57	3.75	0.59	212.56
YS-07-JM05	26.01	47.65	5.50	18.40	3.54	0.30	3.26	0.67	4.91	1.12	3.36	0.53	3.55	0.59	119.38

Table 8: Rare earth elements in altered TSC samples.

Sample	Au (ppb)	Al (%)	Fe (%)	Mg (%)	Ca (%)	Na (%)	K (%)	Ti (%)	P (%)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Ba (ppm)	Th (ppm)	Y (ppm)	Hf (ppm)	Ta (ppm)	U (ppm)
YS-JM-44	969	5.69	3.96	0.05	0.02	0.1	5.18	0.18	0.009	39.3	63	25	4.6	1.4	< 0.5	2.5	0.37	500	13.1	31	5	1.7	5.6
YS-JM-78	257	4.39	1.31	0.05	0.02	0.17	6.05	0.18	0.006	52	80	26	6.4	1.3	< 0.5	4.5	0.69	1260	13.6	47	6	2.4	6
YS-JM-155 #2	56	4.13	14.5	0.02	0.11	1.02	2.61	0.12	0.006	42.7	58	23	3.4	0.6	< 0.5	1.9	0.26	400	14.5	14	4	1.8	6.4
YS-JM-149	17	3.74	8.26	0.01	0.06	0.38	1.24	0.13	0.007	32	32	6	1.8	< 0.2	< 0.5	2	0.45	< 50	6.4	26	4	< 0.5	66.9
YS-JM-21	2	3.73	6.23	0.03	0.07	0.38	1.18	0.11	0.062	223	248	57	11.4	1.5	< 0.5	3.9	0.51	410	23.9	52	4	3.4	6.1

Table 9: Comparative geochemistry for samples containing Au above detection limit.

Sample	Pb (ppm)	Rb (ppm)	Cs (ppm)	Sr (ppm)	Sc (ppm)	Ni (ppm)	Cr (ppm)	V (ppm)	Cu (ppm)	Zn (ppm)	Be (ppm)	Cd (ppm)	Mo (ppm)	S (%)	Bi (ppm)	Ag (ppm)	As (ppm)	Br (ppm)	Co (ppm)	Hg (ppm)	Ir (ppb)	Mn (ppm)	Sb (ppm)	Se (ppm)	W (ppm)	Sn (ppm)
YS-JM-44	106	334	11	46	5.3	25	12	29	11	115	< 1	2.7	16	5.91	< 2	0.3	103	< 0.5	16	4	< 5	48	74.8	13	8	< 0.01
YS-JM-78	17	405	8	84	7.1	5	9	12	8	14	1	< 0.3	8	0.99	< 2	1.3	104	< 0.5	3	< 1	< 5	27	13	5	< 1	< 0.01
YS-JM-155 #2	25	139	< 1	20	2.7	42	< 2	9	13	44	3	1.8	45	19	< 2	0.5	429	< 0.5	26	7	< 5	79	89.3	< 3	< 1	< 0.01
YS-JM-149	31	41	2	30	3.6	24	< 2	42	6	36	3	0.6	28	10.8	< 2	< 0.3	2540	< 0.5	11	< 1	< 5	32	34.2	< 3	< 1	< 0.01
YS-JM-21	108	51	3	211	4.8	28	< 2	11	16	76	4	0.4	36	7.69	< 2	0.7	319	< 0.5	11	4	< 5	47	4.8	< 3	< 1	< 0.01

Table 9: Continued.

In general, stable isotope ratios in altered TSC show lower ratios at the base of the canyon and higher ratios at the top of the canyon. The canyon walls display a wide range of intermediate values, relative to elevation in the canyon (**Figure 62**). This is consistent with the isotope fractionation boiling model proposed by Larson and Taylor (1987). According to the model, boiling in a system will cause larger isotope fractionations at higher elevations and smaller fractionations at lower elevations.

Altered TSC Epithermal Subtyping

Mineralogy, based on XRD and field observations, in the study area approximates a high-sulfidation mineral assemblage; silica+ alunite+ kaolinite± diaspore± pyrophyllite are common high-sulfidation gangue minerals. Silica+ illite are common low-sulfidation minerals. Minor amounts of illite can be associated with acidic fluids, however, in altered TSC illite is so widespread that a majority of the illite is likely due to near-neutral fluids. Pyrite+ marcasite are common in both high- and low-sulfidation systems. Galena+ sphalerite are common in low-sulfidation systems. Heald et al. (1987) noted that low-sulfidation deposits are typically Cu-poor. Veins are lacking in adularia (a feldspar common in low-sulfidation veins), however, kaolinite and dickite are common byproducts of altered adularia.

Silicification is a common high-sulfidation alteration as is advanced argillic alteration. Veins, stockwork veinlets, and brecciation are common in low-sulfidation systems (Davies et al., 2008), although a brecciated root zone is typical of hot spring deposits (Taylor, 2007). In the field area, the large brecciated veins are strictly associated with the stream bed. Vuggy silica and leaching, common high-sulfidation textures, are widespread in the higher elevations in the canyon.

Explanation

The current hydrothermal setting in Yellowstone Plateau volcanic field is characteristic of a system associated with a low-sulfidation deposit. The Plateau is located in an extensional setting with active faulting and the system is dominated by near-neutral waters. So, why does the altered TSC epithermal system contain pervasive high-sulfidation minerals and textures?

Altered Tuff of Sulphur Creek contains high-sulfidation alteration overprinting a poorly developed low-sulfidation system due to boiling in the canyon and subsequent, localized, canyon incision lowering the water table. TSC originally contained a low-sulfidation deposit, with alkaline-chloride fluids similar to those found in the current hydrothermal system (Fournier, 1985). It is possible the Bull Lake Glaciation, 155-130 ka, (Licciardi and Pierce, 2008) regionally displaced the paleo-water table causing it to locally rise directly below what is now the canyon rim in Sulphur Creek. Because of the added pressure, water began to rise and boil along the hydrostatic boiling curve in zones of upwelling (Barger and Fournier, 1988; Haas, 1971) changing the fluid chemistry from a near-neutral solution to an acidic solution. Boiling, acidic water was spewed onto the surface, forming a hot spring epithermal deposit. Directly below the paleo-water table high-sulfidation alteration began to form as well. Below the high-sulfidation deposit, the low-sulfidation system may have continued to form in more saline, lower temperature waters; however, the low-sulfidation system was poorly developed based on minor visible crustiform-colloform textures and the absence of lattice textures. Boiling continued until the glaciers receded and pressure was lifted from the system. As the glaciers receded locally, the water table lowered and continued to lower as canyon incision deepened (Larson et al., 2009). With a lowering water table, the acidic fluids were lowered, re-altering the low-sulfidation deposit beneath the hot spring/high-sulfidation alteration. This was the cause of overprinting (**Figure 64**).

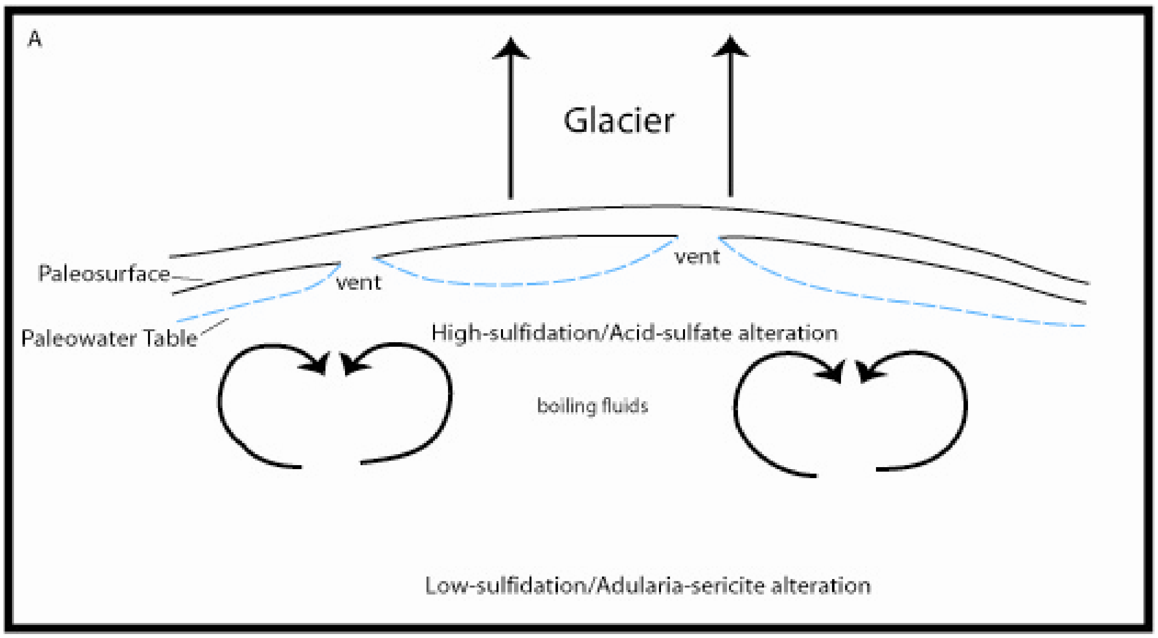


Figure 64A: Schematic showing an elevated water table due to regional glaciation. Added pressure caused groundwater to boil along the hydrostatic boiling curve, which rises in zones of upwelling. Deeper in the system, a low-sulfidation system had formed from near-neutral fluids; boiling caused these near-neutral fluids to become acidic. Acidic fluids form a high-sulfidation deposit topographically higher than the low-sulfidation deposit. Also, vents formed in the zones of upwelling, depositing sinter along the paleo-surface.

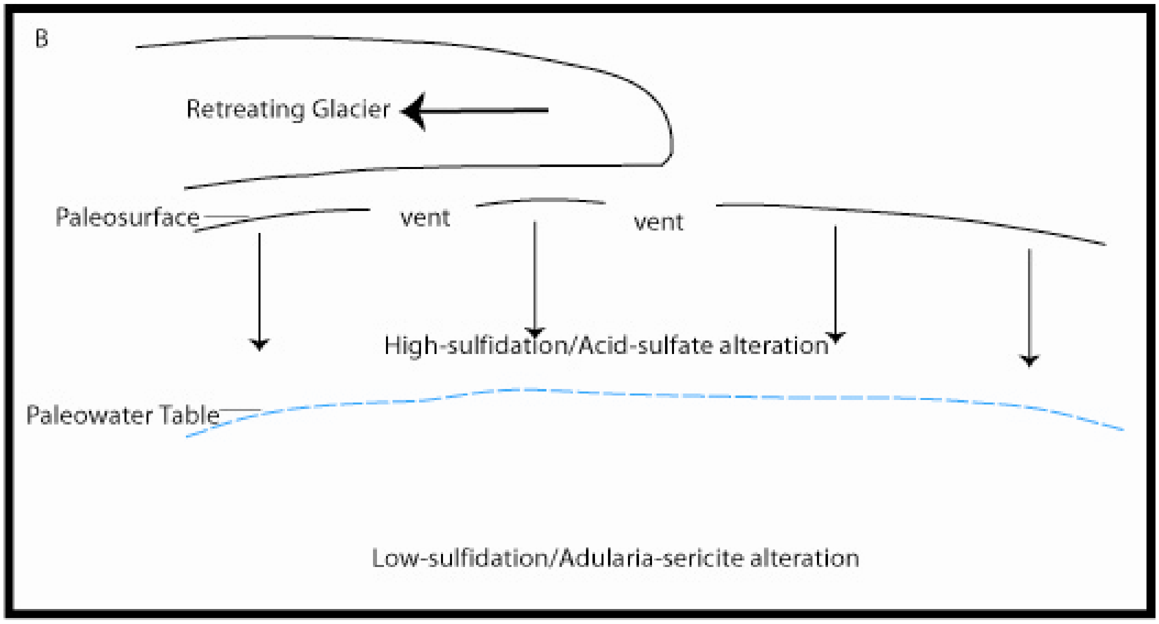


Figure 64B: Schematic showing the water table lowering due to regional glacial retreat.

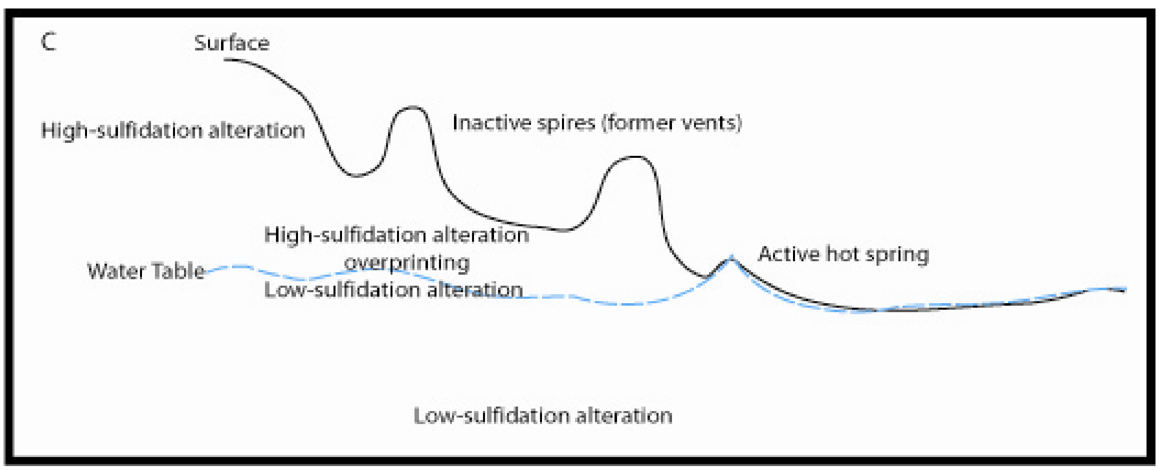


Figure 64C: Schematic showing the present-day water table and alteration in the canyon. The ridges in the canyon feature sinter (massive opaline silica) from a hot spring deposit; there is high-sulfidation alteration high in the canyon walls; in the middle of the canyon walls, there is a high-sulfidation system overprinting a low-sulfidation system. The spires represent zones of upwelling, which are now silicified. Active thermals or hot springs appear in the canyon where the water table intersects the surface.

Overprinting in the canyon is supported by geothermometry from Simmons et al. (2005). They generated a list of common epithermal minerals and the temperatures and paleo-depths at which those minerals typically form (**Tables 10**, **11** and **12**). Epithermal alteration usually forms below the water table with massive opaline silica at the water table. Generally, kaolinite forms at shallow levels in an epithermal system, but **Figure I-25** (**Appendix I**) shows that kaolinite is well distributed throughout the canyon. However, kaolinite forms at shallow levels relative to the water table; therefore, its presence at various elevations throughout the canyon supports a change in water table at the time kaolinite was being deposited. Illite commonly occurs deeper than kaolinite in an epithermal system, and a vast majority of the illite in altered TSC occurs at relatively low elevations in the canyon (**Appendix I**, **Figure I-26**). The kaolinite-illite transition seen by Larson et al. (2009) in altered TSC in adjacent field areas does not occur in the south fork of Sulphur Creek. Rather, illite and kaolinite can be found in a single hand sample at various elevations in the canyon. This, again, can be explained by overprinting caused by lowering the paleo-water table.

Mineral	Temperature (°C)
Smectite	100-160
Kaolinite	100-200
Laumontite	125-225
Interlayered Clays	~130-230
Dickite	~125-300
Pyrophyllite	210-300
Illite	~225-300
Chlorite	~225-300
Epidote	~240-300
Andalusite	~250-300
Biotite	~280-300

Table 10: Hydrothermal minerals compared to fluid temperatures at time of emplacement (Simmons et al., 2005).

Mineral	Depth below water table (m)
Cristobalite	Above water table
Sulfur	Above water table
Massive Opal	At water table
Alunite	~5-20
Kaolinite	~5-35
Smectite	~35-40

Table 11: Hydrothermal minerals compared to depth of emplacement below the water table (Simmons et al., 2005).

Mineral	Temperature (°C)	Depth of emplacement (m)
Kaolinite	180	Surface
Smectite	230	<50
Interlayered Clays	250	30-200
Illite	280	~300- >1000
Chlorite	280	~300- >1000
Epidote	325	~400- >1000
Biotite	350	~850->1000

Table 12: Hydrothermal minerals compared to temperature and depth of emplacement below the water table (Simmons et al., 2005).

Metal Concentrations

The second objective of this research was to compare altered TSC to other, better known epithermal systems to evaluate why this system contains very low concentrations of metals that are ore-grade in similar epithermal systems. In an epithermal deposit, economic minerals will precipitate at temperatures between 150 and 300 ^{o}C at depths ranging from 50 and 1500 m below the water table (Simmons et al., 2005). High- and low-sulfidation environments can produce very fine-grained Au. This is especially common in environments which form above a boiling hydrothermal system (such as a hot spring) (Taylor, 2007). What is the difference, then, between the altered TSC and Au-producing systems? From a mineralogical standpoint, the altered TSC system contains gangue minerals typically present in productive epithermal deposits (Taylor, 2007; Simmons et al, 2005). The system also has low Cu-concentrations, a low-sulfidation phenomenon described by Heald et al. (1987). TSC groundmass and wall rock alteration are characteristic for epithermal systems; there is simply no Au. Au has been detected in Yellowstone National Park in various amounts. Unaltered rocks from the Yellowstone Plateau volcanic field can have Au values up to 60 ppb (Gottfried et al., 1972; Tilling et at., 1973), and Au is currently precipitating in the active hydrothermal system in Gibbon Geyser Basin (White et al., 1992).

Timing of emplacement

Heald et al. (1987) studied 16 epithermal deposits of various styles. Their work suggested that viable low-sulfidation deposits form >1 m.y. after host rock deposition while high-sulfidation deposits occur <0.5 m.y. after host rock deposition. If TSC (~480 ka) was initially altered by alkaline-chloride fluids (~154 ka), then, according to the

Heald et al. model, alteration occurred too quickly after host rock emplacement for the system to be economic. However, Kodĕra et al. (2005) found that the intermediate-sulfidation epithermal Au-veins near the Rozalia base metal deposit, Banská Hodruša, Slovakia, formed quickly after the Stiavnica stratovolcano caldera collapse.

Of the deposits Heald et al. (1987) tabulated, many occurred in the final stages of a volcano's life cycle. If any volcanism occurred following ore deposition, then the volcanism was minor. One major difference between the TSC epithermal system and similar, economic systems is that the Yellowstone hotspot is still supplying magma to an active volcano. It is possible that the TSC epithermal system occurred too soon relative to the third volcanic cycle to have been economic, according to this model. However, Bindeman et al. (2007) suggested that the low $\delta^{18}O$ Yellowstone post-caldera collapse rhyolitic flows are associated with a decline in the current volcanic cycle. So, it is also possible that alteration timing is not relevant to the lack of economic mineralization in this system.

Element Mobility

In paleo-hot spring epithermal systems Au, Ag, Hg, As, and Sb are common trace metals (White et al., 1992); the trace elements Cu, Pb, Zn, and Ag are often found in deeper epithermal systems. Buchanan (1981) stated that Au precipitates in the upper portions of a vapor-dominated or boiling system, whereas base metals often precipitate in more saline, fluid dominated systems. White et al. (1992) suggested abundant Au-mineralization is often associated with elevated base metal assemblages, below the horizon where volatile elements deposit, while Taylor (2007) made the exception that

Au-mineralization can be associated with volatiles in hot spring deposits as well as other shallow epithermal deposits.

Altered TSC base metal concentrations are elevated relative to protolith concentrations (**Table 6**). Tuff of Sulphur Creek regionally overlies units of the Yellowstone Plateau and Absorka volcanics (Feely et al., 2002); locally, these units (**Figure 65**) have high base metal concentrations (Ni, Cr, V, Pb, Cu, etc.). Pritchard (unpublished) obtained two samples from Lava Creek Tuff from which he collected base metal data; Cu values were very low compared to other base metals present (for example, the average Cr in LCT is 14.51 ppm while the average Cu in LCT is 0.5 ppm). It is possible that altered TSC has higher base metal percentages than unaltered TSC because the hydrothermal fluids scavenged elements from the underlying units. With an apparent lack of Cu in the unaltered system, it is not surprising that high Cu-concentrations are not present in altered TSC.

Fluid Chemistry

Taylor (2007) noted that mineralizing fluids in a hydrothermal system can be derived from either magma degassing or meteoric waters. Fluid chemistry determines which elements are precipitated in a system, therefore, which minerals form in that system. Saline fluids are essential in base metal transportation (Taylor, 2007) and play a large role in the active precipitation of Au in Gibbon Geyser Basin (White et al., 1992).

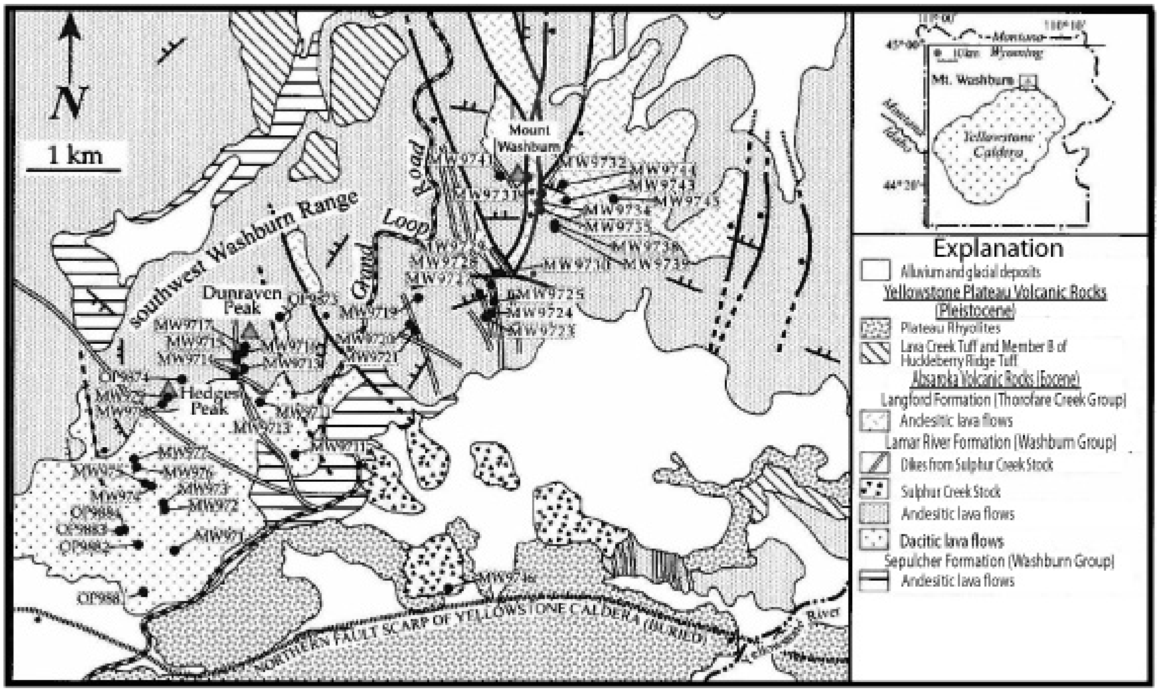


Figure 65: Units underlying TSC, including Yellowstone Plateau and Washburn Volcanics. Figure from Feely et al. (2002).

Metals are released in an epithermal system when hydrothermal fluids interact with unstable minerals (Faure and Mensing, 2005). Those metals can then be deposited in fractures or as groundmass replacement. Metal precipitation and Au deposition in epithermal environments is frequently the result of fluid mixing; low saline fluids combining with evolved or more saline fluids (Taylor, 2007). According to Simmons et al. (2005) intermediate sulfur states are required for the precipitation of native Au from hydrothermal fluids in epithermal systems. Stable isotope ratios suggest that both country rock and magma are responsible for metal generation in hydrothermal systems (Faure and Mensing, 2005). Au concentrations in hydrothermal fluids are affected by sulfur fugacity and the oxidation state of magmatic vapor. Taylor (2007) notes that S must be in excess to Fe in a Au-bearing hydrothermal system in order for Au to be mobile and precipitate. Au can be the depositional product of many events such as rapid cooling, boiling, fluid mixing, water-rock interaction, and decompression (Taylor, 2007). Near the Rozália base metal mine, Slovakia, Au precipitation was directly associated with sustained boiling of mixed fluids, which caused the solubility of Au in the fluids to decrease (Kodĕra et al., 2005).

Silica

Hydrothermal silica is essential to understanding gold transport and deposition because the two minerals often occur together in epithermal deposits; Au is often found in silica veins (White et al., 1992). Saunders (1990) suggested that gold and silica travel and deposit together in a colloidal "gel" in boiling epithermal systems; this process is triggered by an excess of Al^{3+} in the fluids. Fournier (1985) noted that Au in YNP was deposited with silica colloids. Lindgren (1936) stated that silica colloids are important in Au deposition because they protect the Au during transportation and against weathering and erosion. If silica colloids are present, Saunders (1990) notes that equilibrium thermodynamic processes in the system are not necessary for the precipitation of Au. Altered TSC displays colloidal silica closely associated with disseminated, botryoidal iron sulfides (pyrite and/or marcasite) (**Figure 21**). Colloform or botryoidal silica textures are seen in the micro-colloform banding in YS-08-JM59 (**Figure 66**). Botryoidal textures are typically considered corroboration of colloids in the system (Sander and Black, 1988), suggesting freely circulating fluids in the system. It is plausible that further investigation of vein and silicified samples would yield a connection between colloidal silica and disseminated gold.

So, where's the Gold?

White et al. (1992) stated that although the currently active Yellowstone hydrothermal system has the proper ingredients for economic mineralization, the system has been inundated by fluids which have diluted and flushed out many of the necessary particulates. They applied their concept to the current hydrothermal system in YNP; however, it is unknown how much water was involved during alteration of the older hydrothermal system in TSC. If Au was present in the fluids, dilution would only account for dissemination, not a complete lack of Au. In the dilution model, White et al. (1992) do not explain where the Au might be. The Gibbon Geyser Basin (GGB) is possibly analogous to TSC. Au has been found as high as 10 ppm at GGB while one sample of altered TSC has yielded ~1 ppm Au.

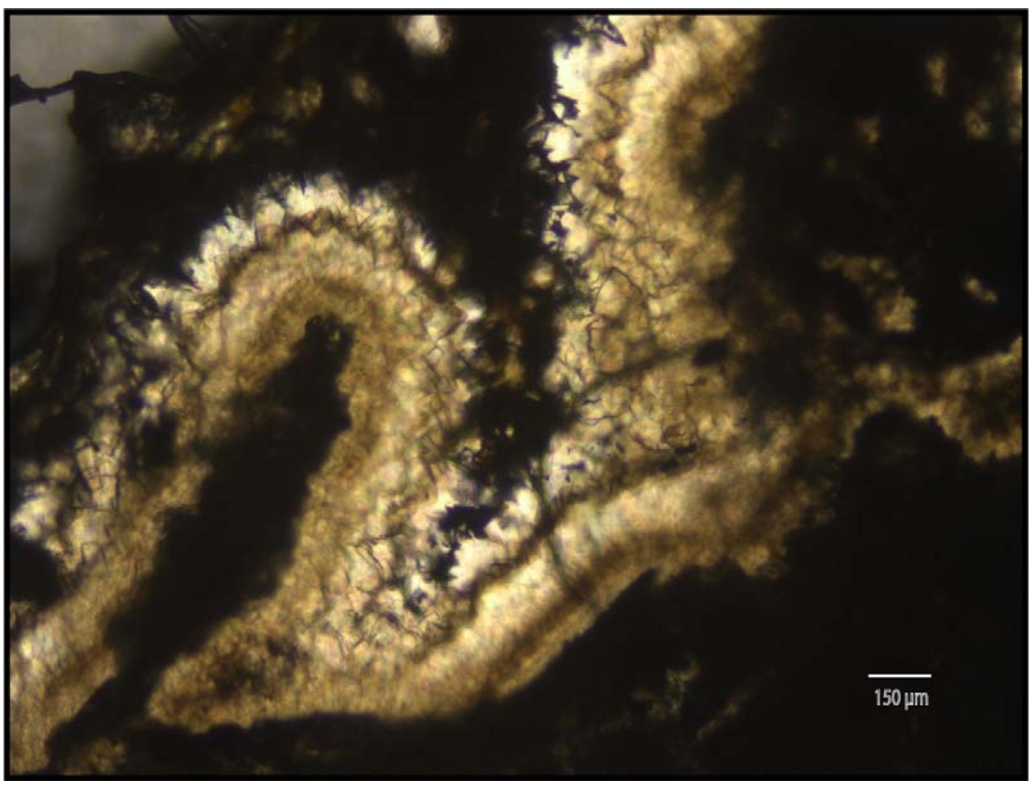


Figure 66: Micrograph from sample YS-08-JM59. Colloform silica veinlet with botryoidal texture. Note drusy quartz. Transmitted; cross-polarized light.

But GGB is located on both the margin of the Yellowstone Caldera and on the Norris-Mammoth Corridor. It is possible that the confluence of the structures associated with both faulting systems has been the cause of anomalous Au at GGB. It still does not explain what is missing in the TSC epithermal system.

Landtwig et al. (2002) determined that multiple phases of hydrothermal brecciation redistributed or diluted Au in veins at the Agua Rica porphyry deposit, Argentina. This is a possibility in TSC; however, without knowing if brecciation occurred in response to one event or multiple events makes this a difficult hypothesis to prove.

White et al. (1992) speculated that precipitating silica can clog conduits in the system, redirecting fluids and mineralization; this occurs as the temperature of the fluids decreases, decreasing the solubility of silica. Clogged conduits and redirected fluids are a possible solution to the question of missing mineralization. The spires in the canyon are presumably the major conduits to the hot spring deposit and they are presumably silicified, which is why they are still standing while most of the canyon has been eroded.

When a hot spring deposit is the result of boiling, it is typical for the sinter and proximal wall rock to be rich in metals, but Taylor (2007) explains that some hot spring epithermal deposits represent barren gaps, with widespread alteration but no metal mineralization; the system is barren. These deposits are often associated with discordant lenses of permeability in the system. A barren gap seems an unlikely scenario since TSC is located on the caldera ring fault and all samples for this research were collected from that area. Structures are abundant in Sulphur Creek canyon (**Appendix II**) and alteration is pervasive.

Erosion in TSC could also explain the lack of economic mineralization. If the system represents a hot spring epithermal subtype deposit, proximity to the surface would put the system at risk of being eroded. If economic mineralization was laid down as an apron with the sinter, then possibly it has been eroded. However, some of the apron remains and there is no sign of Au, disseminated or otherwise, in those outcrops. Therefore, it seems unlikely that Au-mineralization in TSC has altogether been eroded, rather that Au was never prevalent in the altered system.

Future Work

Trace elements

Quantifying trace element variations can be helpful in determining fluid flow patterns throughout the canyon (Guha et al., 1991). A full suite of geochemical assays on protolith and altered samples should be performed; special emphasis should be given to vein samples. Alkali element mobility can be used to measure fluid flow associated with Au-bearing hydrothermal systems. All in all, more geochemistry should be preformed on the existing samples to clearly determine, within an outcrop, water-rock interactions and the alteration effects.

Fluid Inclusions

Taylor (2007) suggests Au is precipitated when low saline hydrothermal fluids mix with higher salinity fluids. Detailed fluid inclusion data should be compiled to determine the nature and temperature of the altering fluids to verify the types of fluid which altered TSC and in what proportion those fluids occurred. Fluid inclusion data should be compared to data from economic epithermal deposits, such as Steamboat Springs (White et al., 1992) to find any similarities or differences.

Stable Isotope Ratios

More oxygen isotope ratios should be measured to better define the boiling signature in Sulphur Creek canyon. Trace elements, along with stable isotope ratios, can define the depth of emplacement (Taylor, 2007) which may lead to a better understanding of the original environment. Fluid origin can be determined by establishing stable isotope ratios for O, H, S, and C.

Sulfur stable isotope ratios can be used as an indicator to define hypogene and supergene sulfates. High $\delta^{34}S$ are typically hypogene sulfates while low $\delta^{34}S$ indicate oxidized sulfides. Oxygen ratios can be used on sulfates to determine fluid origins, chemistry and temperature (Rye, 2005; Rye et al., 1992). Though this is the case, Lerouge et al. (2004) found no significant difference between alunite stable isotope ratios (H, O, and S isotopes) measured from economic and barren deposits.

Dating

Hypogene alunite can be $^{40}Ar/^{39}Ar$ dated to determine the timing of alteration emplacement.

Mineralogy

Detailed clay identification through clay speciation should be conducted on the hydrothermal clays to determine the type of clays and cation exchange in the clay structure.

Electron Microprobe

The large, brecciated veins at the base of the canyon may be the key to viable mineralization present in the system or why there is no viable mineralization in the system. Detailed microprobe analyses should be completed on vein samples, both brecciated and non-brecciated.

Samples containing smectite should be probed for fine grained Au. The Hishikari Au-Ag epithermal deposit, Japan, contains anomalous Au in low temperature clays (Faure et al., 2002). If Au is present in the smectites, the temperatures at which Au precipitates in TSC can be estimated.

High resolution microprobe maps should be made of the various types of silica alteration in the canyon (veining, silicification, and nodules). The maps can be used to correlate trace element mobility in the fluids (Rusk et al., 2008). Scanning electron microprobe-cathodoluminescence (SEM-CL) can be used to determine the timing of multiple quartz events in the canyon.

Mapping

The north fork of Sulphur Creek should be mapped and sampled to see if the epithermal alteration spreads beyond the rim of the caldera. Canyon structures should continue to be mapped based on orientation to other structures in the canyon, both active and inactive.

Sampling

Fluid samples should be collected from the north and south forks of Sulphur Creek and at the confluence with the Yellowstone River. If Au has been eroded in the system, it is possibly stream samples can lead to their discovery.

Fluids

The ammonia neutralized acid-sulfate fluids from the hot springs rising through TSC have not been assayed for Au concentrations. This should be done as the fluids could be remobilizing Au from deeper elevations in TSC.

CHAPTER SEVEN

CONCLUSIONS

Tuff of Sulphur Creek (480 ka) is a post-caldera collapse rhyolitic tuff that has been hydrothermally altered in the epithermal zone. Alteration in Sulphur Creek canyon is widespread, as seen in hand samples, geochemistry, and mineral assemblages. There are four mineral assemblages; two of the assemblages have minerals typical of both high- and low-sulfidation epithermal subtypes. Minerals supporting low-sulfidation include adularia (adjacent field area), illite, galena and sphalerite, no enargite, and no Bi-minerals. Minerals supporting high-sulfidation include hypogene alunite and kaolinite, and no adularia (in the south fork of Sulphur Creek). Stable isotope ratios suggest boiling in the canyon. Together, this information leads to a conclusion of overprinting in the canyon; paragenetically, high-sulfidation has overprinted low-sulfidation. The theory proposed to explain this phenomenon is boiling in the system caused high-sulfidation alteration and a hot spring deposit to form topographically above low-sulfidation alteration. As the regional water table lowered, acidic fluids began to generate high-sulfidation alteration over the low-sulfidation alteration.

There is no economic mineralization in altered TSC because this system did not produce viable mineralization the way many epithermal systems do. We need to know what factors were involved which prevented the deposition of Au in the altered TSC system. Is it because the solution was in a constantly changing state? It is possible that temperature, pressure, and/or fluid chemistry caused this system to be barren? With hot spring subtypes, erosion is often the cause for missing mineralization. However, since altered wall rock is present, as is the brecciated root zone, I find it extremely unlikely that erosion has lead to the lack of mineralization in altered TSC.

More work should be done to determine the differences between the altered Tuff of Sulphur Creek epithermal system and economically mineralized epithermal systems. Barren epithermal systems should be brought to the forefront of economic geology. Studying the differences between a mineralized system and a non-mineralized system will lead to a better understanding of epithermal systems and to the exploration for those systems. There are many papers that catalogue epithermal deposits (e.g., Simmons et al., 2005; Cooke and Simmons, 2000; White and Hedenquist, 1990) but Taylor (2007) really illustrates our need for this new knowledge. We live in a world with unprecedented mineralogical needs and we cannot fulfill those needs without a thorough understanding of that for which we are looking. The next big step in economic geology is understanding barren analogues to economic systems.

References

Andersen, A., 2010, Geochemistry of Inkpot Spring, Sulphur creek-Sevenmile Hole Area, Yellowstone Caldera, Wyoming, Washington State University thesis.

Barton, P.B., Jr., and Skinner, B.J., 1979, Sulfide mineral stabilities, *in* Barnes, H.L., ed., Geochemistry of hydrothermal ore deposits, 2^{nd} ed.: New York, Wiley-Interscience, p. 278-403.

Bargar, K.E., and Fournier, R.O., 1988, Effects of glacial ice on subsurface temperatures of hydrothermal systems in Yellowstone National Park, Wyoming: Fluid-inclusion evidence: Geology, v. 16, p. 1077-1080.

Berg, G., 1932, Vein filling during the opening of fissures: Economic Geology, v. 27, p. 87-94.

Bindeman, I.N., and Valley, J.W., 2001, Low-$\delta^{18}O$ rhyolites from Yellowstone: Magmatic evolution based on analyses of zircons and individual phenocrysts: Journal of Petrography, v. 48, p. 1491-151.

Bindeman, I.N., Watts, K.E., Schmitt, A.K., Morgan, L.A., and Shanks, P, W.C., 2007, Voluminous low $\delta^{18}O$ magmas in the late Miocene Heise volcanic field, Idaho: Implications for the fate of Yellowstone hotspot calderas: Geology, v. 35, p. 1019-1022.

Boroughs, S., Wolff, J., Bonnichsen, B., Godchaux, M., and Larson, P., 2005, Large volume, low-$\delta^{18}O$ rhyolites of the Snake River Plain, Idaho, USA: Geology, v. 33, p. 821-824.

Buchanan, L.J., 1981, Precious metal deposits associated with volcanic environments in the Southwest: Arizona Geological Society Digest 14, p. 237-262.

Criss R.E., and Taylor, H.P., 1983, An $^{18}O/^{16}O$ and D/H study of Tertiary hydrothermal systems in the southern half of the Idaho Batholith: Geological Society of America Bulletin, v. 94, p. 640-663.

Christiansen, R.L., 2001, The Quaternary and Pliocene Yellowstone volcanic field of Wyoming, U.S. Geological Survey Professional Paper 729-G, 145 p.

Christiansen, R.L., Foulger, G.R., and Evans, J.R., 2002, Upper-mantle origin of the Yellowstone hotspot, Geological Society of America Bulletin, v.114, p. 1245-1256.

Clayton, R.N., and Mayeda, T.K., 1963, The use of bromine pentafluoride in the extraction of oxygen from oxides and silicates for isotopic analysis: Geochimica et Cosmochimica Acta, v. 54, p.1353-1357.

Craig, H., 1963, The isotopic geochemistry of water and carbon in geothermal areas: *in* Nuclear Geology on Geothermal Areas, E. Tongiorgi, ed., Spoleto: Pisa, Consiglio Nazionale della Richerche, Laboratorio de Geologia Nucleare, 17-53.

Dansgaard, W., 1964, Stable isotopes in precipitation, Tellus, v. 16, p. 436-468.

Davies, A.G.S., Cooke, D.R., and Gemmell, B.J., 2008, Hydrothermal breccias and veins at the Kelian gold mine, Kalimantan, Indonesia: genesis of a large epithermal gold deposit: Economic Geology, v. 103, p. 717-757.

Drummand, S.E., and Ohmoto, H., 1985, Chemical evolution and mineral deposition in boiling hydrothermal system: Economic Geology, v. 80, p. 126-147.

Faure, G., and Mensing, T.M., 2005, *Isotopes: Principles and Applications*, 3rd ed., John Wiley & Sons, Hoboken, NJ, p. 716.

Faure, K., Matsuhisa, Y., Metsugi, H., Mizota, C., and Hayashi, S., 2002, The Hishikari Au-Ag epithermal deposit, Japan: Oxygen and Hydrogen isotope evidence in determining the source of paleohydrothermal fluids: Economic Geology, v. 97, p. 481-498.

Feely, T.C., Cosca, M.A., and Lindsay, C.R., 2002, Petrogenesis and implications of cryptic hybrid magmas from Washburn volcano, Yellowstone National Park, USA: Journal of Petrology, v. 111, p. 329-346.

Fournier, R.O., 1985, Silica minerals as indicators of conditions during gold deposition, *in* Tooker, E.W., ed., Geologic characteristics of the sediment- and volcanic-hosted types of gold depsoits-search for an occurrence model: U.S. Geological Survey Bulletin 1646, p. 15-26.

Fournier, R.O., 1989, Geochemistry and dynamics of the Yellowstone National Park hydrothermal system: Annual Reviews of Earth and Planetary Science, v.17, p. 13-53.

Fournier, R.O., and Rowe, J.J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-steam wells: American Journal of Science, v., 264, p. 685-697.

Gansecki, C.A., Mahood, G.A., and McWilliams, M.O., 1996, $^{40}Ar/^{39}Ar$ geochronology of rhyolites erupted following collapse of the Yellowstone caldera, Yellowstone Plateau volcanic field: Implications for crustal contamination: Earth and Planetary Science Letters, v. 42, p. 91-107.

Gottfried, D., Rowe, J.J., and Tilling, R.I., 1972, Distribution of gold in igneous rocks: U.S. Geological Survey Professional Paper 727, 42p.

Grønvold, F., and Westrum, E.F., Jr., 1976, Heat capacities of iron disulfides, thermodynamics of marcasite from 5 to 700 K, pyrite from 350 to 770 K, and the transformation of marcasite to pyrite: Journal of Chemical Thermodynamics, v. 8, p. 1039-1048.

Guha, J., Lu, H., Dubé, B., Robert, F., and Gagnon, M., 1991, Fluid characteristics of vein and altered wall rock in Archean mesothermal gold deposits: Economic Geology, v. 86, p. 667-684.

Gunnarsson, A., and Arnórsson, S., 2000, Amorphous silica solubility and the thermodynamic properties of H_4SiO^o in the range of 0^o to 350^o at P_{sat}: Geochimica et Cosmochimica Acta, v. 64, p. 2295-2307.

Haas, J.L., Jr., 1971, The effect of salinity on the maximum thermal gradient of a hydrothermal system at hydrostatic pressure: Economic Geology, v. 66, p. 940-946.

Heald, P., Foley, N.K., and Hayba, D.O., 1987, Comparative anatomy of volcanic-hosted epithermal deposits: acid-sulfate and adularia-sericite types: Economic Geology, v. 82, p. 1-26.

Heath, C.J., and Campbell, I.H., 2004, A new geochemical technique for gold exploration: Alkali element mobility associated with gold mineralization in the west Australian goldfields, Economic Geology, v. 99, p. 313-324.

Hedenquist , J.W., Arrubas, A.J., and Gonzales-Urien, E., 2000, Exploration for epithermal gold deposits: Reviews in Economic Geology, v. 13, p. 245-277.

Hemley, J.J., Hostetler, P.B., Gude, A.J., and Mountjoy, W.T., 1969, Some stability relations of alunite: Economic Geology, v. 64, p. 599-612.

Hildreth, W., Christiansen, R.L., and O'Neil, J.R., 1984, Oxygen isotopic study of the Yellowstone Plateau volcanic field: Journal of Geophysical Research, v. 89, p. 8339-8369.

Hildreth, W., Halliday, A.N., and Christiansen, R.L., 1991, Isotopic and chemical evidence concerning the genesis and contamination of basaltic and rhyolitic magma beneath the Yellowstone Plateau volcanic field: Journal of Petrology, v. 32, p. 63-138.

Jarvis, K.E., Gray, A.L., and Houk, R.S., 1992, Handbook of Inductively Coupled Plasma Mass Spectrometry, Chapman and Hall: New York.

Johnson, D.M., Hooper, P.R., and Conrey, R.M., 1999, XRF analysis of rocks and minerals for major and trace elements on a single low dilution Li-tetraborate fused bead, Advances in X-ray analysis, v. 41, p. 843-867.

Knaack, C., Cornelius, S., and Hooper, P, 1994, Trace element analyses of rocks and minerals by ICP-MS, Washington State University, Open-File Rep.

Koděra, P., Lexa, J., Rankin, A.H., and Fallick, A.E., 2005, Epithermal gold veins in a caldera setting: Banská Hodruša, Slovakia: Mineralium Deposita, v. 39, p. 921-943.
Larson, P.B., Phillips, A., John, D., Cosca, M., Pritchard, C., Andersen, A., Manion, J., 2009, A Preliminary study of older hot spring alteration in Sevenmile Hole, Grand Canyon of the Yellowstone River, Yellowstone Caldera, Wyoming: Journal of Volcanology and Geothermal Research, v.188, p. 225-236.

Landtwing, M.R., Dillenbeck, E.D., Leake, M.H., and Heinrich, C. A., 2002, Evolution of the breccia-hosted porphyry Cu-Mo_Au deposit at Agua Rica, Argentina: Progressive unroofing of a magmatic hydrothermal system: Economic Geology, v. 97, p. 1273-1292.

Larson. P.B., and Taylor, H.P., 1987, Solfataric Alteration in the San Juan Mountains, Colorado: Oxygen isotope variations in a boiling hydrothermal environment: Economic Geology, v. 82, p. 1019-1036.

Lerouge, C., Kunov, A., Fléhoc, C., Georgieva, S., Hikov, A., Lescuyer, J.L., Petrunov, R., and Velinova, N., 2004, Stable isotope study and origin of alunite from advanced argillic alteration systems in Bulgaria: Bulgarian Geological Society, Annual Scientific Conference "Geology 2004", Proceedings, 16-17.12.2004.

Lewis, A.J., Palmer, M.R., Sturchio, N.C., and Kemp, A.J., 1997, The rare earth element geochemistry of acid-sulphate and acid-sulphate-chloride geothermal systems from Yellowstone National Park, Wyoming, USA: Geochimica et Cosmochimica Acta, v.61, p. 695-706.

Li, G., Peacor, D.R., Essene, E.J., Brosnahan, D.R., and Beane, R.E., 1992, Walthierite, $Ba_{0.5}\square_{0.5}Al_3(SO_4)_2(OH)_6$, and huangite, $Ca_{0.5}\square_{0.5}Al_3(SO_4)_2(OH)_6$, two new minerals of the alunite group from the Coquimbo region, Chile: American Mineralogist, v. 77, p. 1275-1284.

Licciardi, J.M., and Pierce, K.L., 2008, Cosmogenic exposure-age chronologies of Pinedale and Bull Lake glaciations in greater Yellowstone and the Teton Range, USA: Quaternary Science Reviews, v. 27, p. 814-831.

Lindgren, W., 1936, Succession of minerals and temperatures of formation in ore deposits of magmatic affiliations: American Institute of Mining and Metallurgical Engineers Technical Publications 713, 23 p.

Murowchick, J.B. and Barnes, H.L., 1986, Marcasite precipitation from hydrothermal solutions: Geochimica et Cosmochimica Acta, v.50, p. 2615-2629.

Nagayama, T., 1993a, Precipitation sequence of veins at the Hishikari deposits, Kyushu, Japan, *in* Shikazano, N., Naito, K., and Izawa, E., eds., High Grade Epithermal Gold Mineralization, The Hishikari Deposit: Resource Geology Special Issue 14, p 13-17.

Neuendorf, K.K.E., Mehl, J.P., Jr., and Jackson, Julia, eds., 2005, Glossary of Geology, 5th ed., Alexandria, American Geological Institute, 779 p.

Obradovich, J.D., 1992, Geochronology of the late Cenozoic volcanism of Yellowstone National Park and adjoining area, Wyoming and Idaho: U.S. Geological Survey Open-file Report 92-408, 45 p.

Pierce, K.L., and Morgan, L.A., 1992, The track of the Yellowstone hot spot: Volcanism, faulting, and uplift, *in* Link, P.K., Kuntz, M.A., and Platt, L.B., eds., Regional Geology of eastern Idaho and western Wyoming: Geological Society of America Bulletin, v. 87, p. 703-710.

Ponce, D.A., and Glen, J.M.G., 2002, Relationship of epithermal gold deposits to large-scale fractures in northern Nevada: Economic Geology, v. 97, p. 3-9.

Pritchard, C., Unpublished dissertation, Yellowstone National Park, Wyoming, Washington State University.

Rusk, B.G., Lowers, H.A., and Reed, M.H., 2008, Trace elements in hydrothermal quartz: Relationships to cathodoluminescent textures and insights into vein formation: Geology, v. 36, p. 547-550.

Rye, R.O, 2005, A review of the stable-isotope geochemistry of sulfate minerals in selected igneous environments and related hydrothermal systems: Chemical Geology, v. 215, p. 5-36.

Rye, R.O., Bethke, P.M., and Wasserman, M.D., 1992, The stable isotope geochemistry of acid sulfate alteration: Economic Geology, v. 87, p. 225-262.

Sander, M.V., and Black, J.E., 1988, Crystallization and recrystallization of growth-zoned vein quartz crystals from epithermal systems—Implications for fluid inclusion studies: Economic Geology, v. 83, p. 1052-1060.

Saunders, J.A., 1990, Colloidal transport of gold and silica in epithermal precious-metal systems: Evidence from the Sleeper deposit, Nevada: Geology, v. 18, p. 757-760.

Schoonen, M.A.A. and Barnes, H.L., 1991, Mechanisms of pyrite and marcasite formation from solution: III. Hydrothermal processes, Geochimica et Cosmochimica Acta, v. 55, p. 3491-3504.

Sharp, Z.D., 1990, A laser-based microanalytical method for the in situ determination of oxygen isotope ratios in silicates and oxides: Geochimica et Cosmochimica Acta, v.54, p. 1353-1357.

Shaw, H.R., and Jackson, D.E., 1974, Linear island chains in the Pacific: Result of thermal plumes or gravitational anchors?: Journal of Geophysical Research, v. 78, p. 8634-8652.

Sillitoe, R.H., 1985, Ore-related breccias in volcanoplutonic arcs: Economic Geology, v. 80, p. 1467-1514.

Sillitoe, R.H.,1993, Epithermal models: genetic types, geometrical controls and shallow features, *in* Kirkham, R.V., Sinclair, W.D., Thorpe, R.I., and Duke, J.M., eds., Mineral Deposit Modeling: Geological Association of Canada, Special Paper 40, p. 403-417.

Simmons, S.F., White, N.C., and John, D.A., 2005, Geological Characteristics of Epithermal Precious and Base Metal Deposits: Economic Geology 100th Anniversary Volume, pp. 485-522.

Sturchio, N.C., Pierce, K.L., Murrell, M.T., and Sorey, M.L., 1994, Uranium-series ages of travertine and timing of the last glaciation in the northern Yellowstone area: Quaternary Research, v. 41, p. 265-277.

Takeuchi, A., and Larson, P.B., 2005, Oxygen isotope evidence for the late Cenozoic development of an orographic rain shadow in eastern Washington, USA: Geology, v.33, p.313-316.

Tarr, W.A., 1927, Alternation deposition of pyrite, marcasite, and possibly melnikovite, Journal of the Mineralogical Society of America, v. 12, p. 417-421.

Taylor, B.E., 2007, Epithermal gold deposits, *in* Goodfellow, W.D., ed., Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods: Geological Association of Canada, Mineral Deposits Division, Special Publication No.5, p. 113-139.

Taylor, H.P., 1968, The oxygen isotope geochemistry of igneous rocks: Contributions to Mineralogy and Petrology, v.19, p. 1-71.

Taylor, H.P., 1974, The application of oxygen and hydrogen isotope studies to problems of hydrothermal alteration and ore deposition: Economic Geology, v. 69, p. 843-883.

Taylor, H.P., and Sheppard, S.M.F., 1986, Igneous Rocks: I. Processes of isotopic fractionation and isotope systematics, Chapter 8, p. 227-271.

Tilling, R.I., Gottfried, D., and Rowe, J.J., 1973, Gold abundance in igneous rocks-bearing on gold mineralization: Economic Geology, 75th Anniversary volume, p. 392-423.

U.S. Geological Survey, *Mount Washburn quadrangle, Wyoming,* Provisional Edition 1986, 1:24,000, 7.5 Minute Series, Reston, Va: United States Department of the Interior, USGS, 1986.

Valley, J.W., Kitchen, N., Kohn, M.J., Niendorf, C.R., and Spicuzza, M.J., 1995, UWG-2, a garnet standard for oxygen isotope ratios: Strategies for high precision and accuracy with laser heating: Geochimica et Cosmochimica Acta, v.59, p. 5223-5231.

White, D.E., 1969, Thermal and mineral waters of the United States- Brief review of possible origins: International Geological Congress, 23rd, Prague, 1968, v. 19, p. 269-286.

White, D.E., Fournier, R.O., Muffler, L.J.P., Truesdell, A.H., 1975, Physical results of research drilling in thermal areas of Yellowstone National Park, Wyoming: U.S. Geological Survey Professional Paper 892, 70 p.

White, D.E., Heropoulos, C., and Fournier, R.O., 1992, Gold and other minor elements associated with the hot springs and geysers of Yellowstone National Park, Wyoming, supplemented with data from Steamboat Springs, Nevada: U.S. Geological Survey Bulletin 2001, 19 p.

Appendix I:
Sample Maps-
Distribution Maps
and
XRD Maps

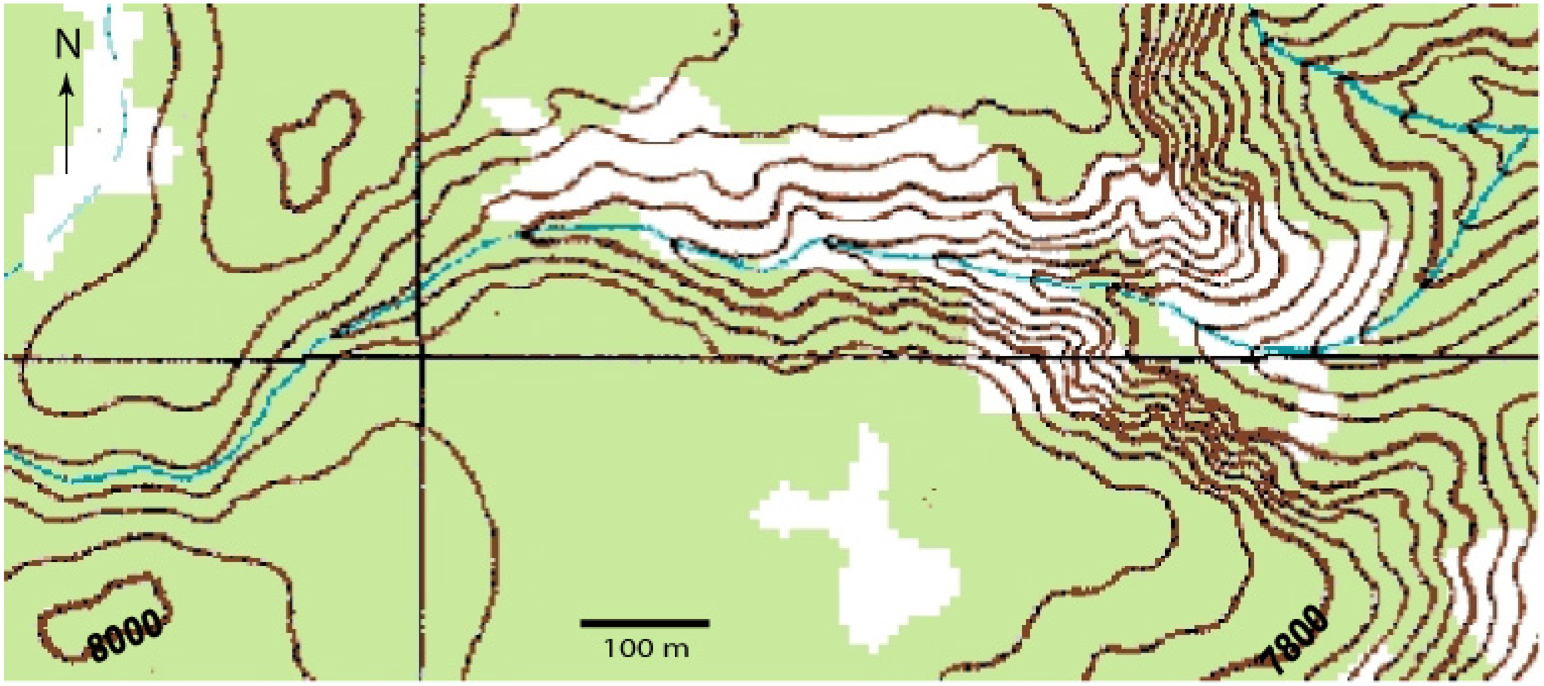


Figure I-1: Topographic base map of study area. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

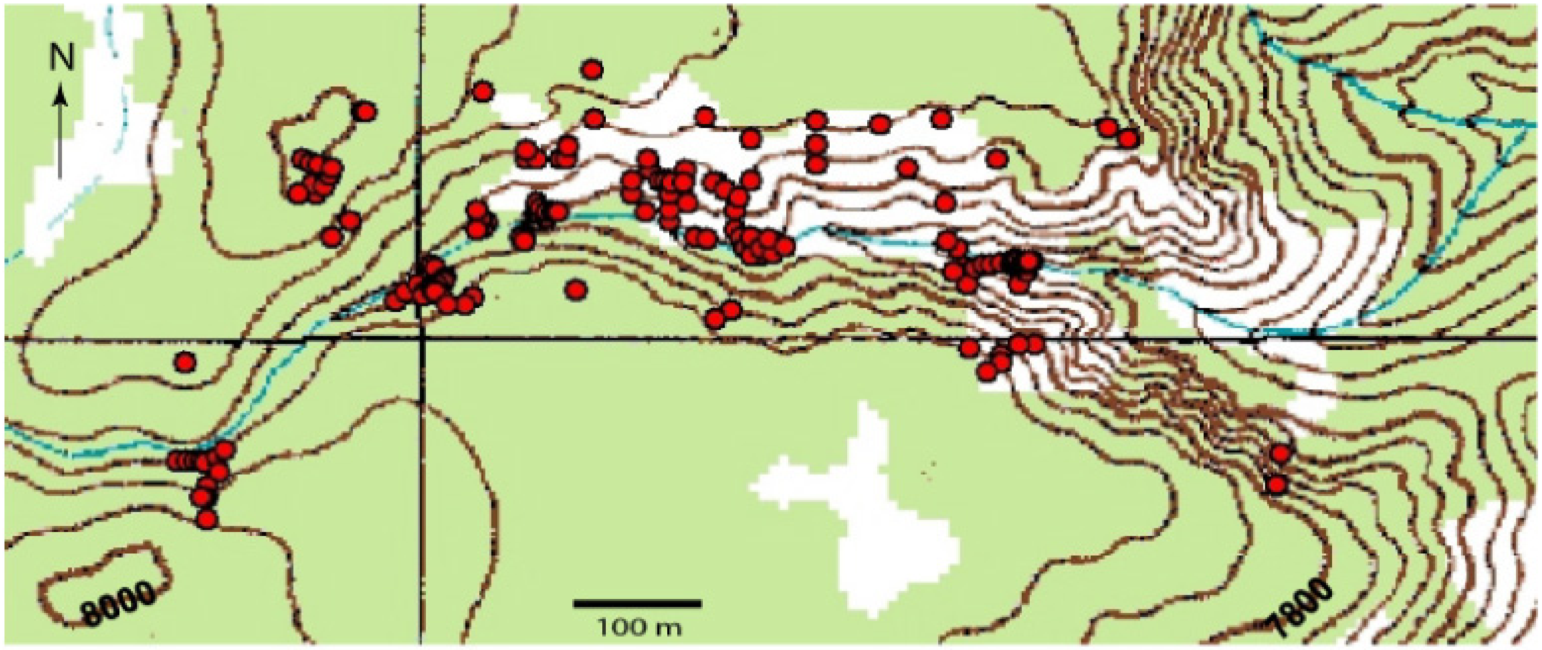


Figure I-2: Distribution map of all samples collected. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

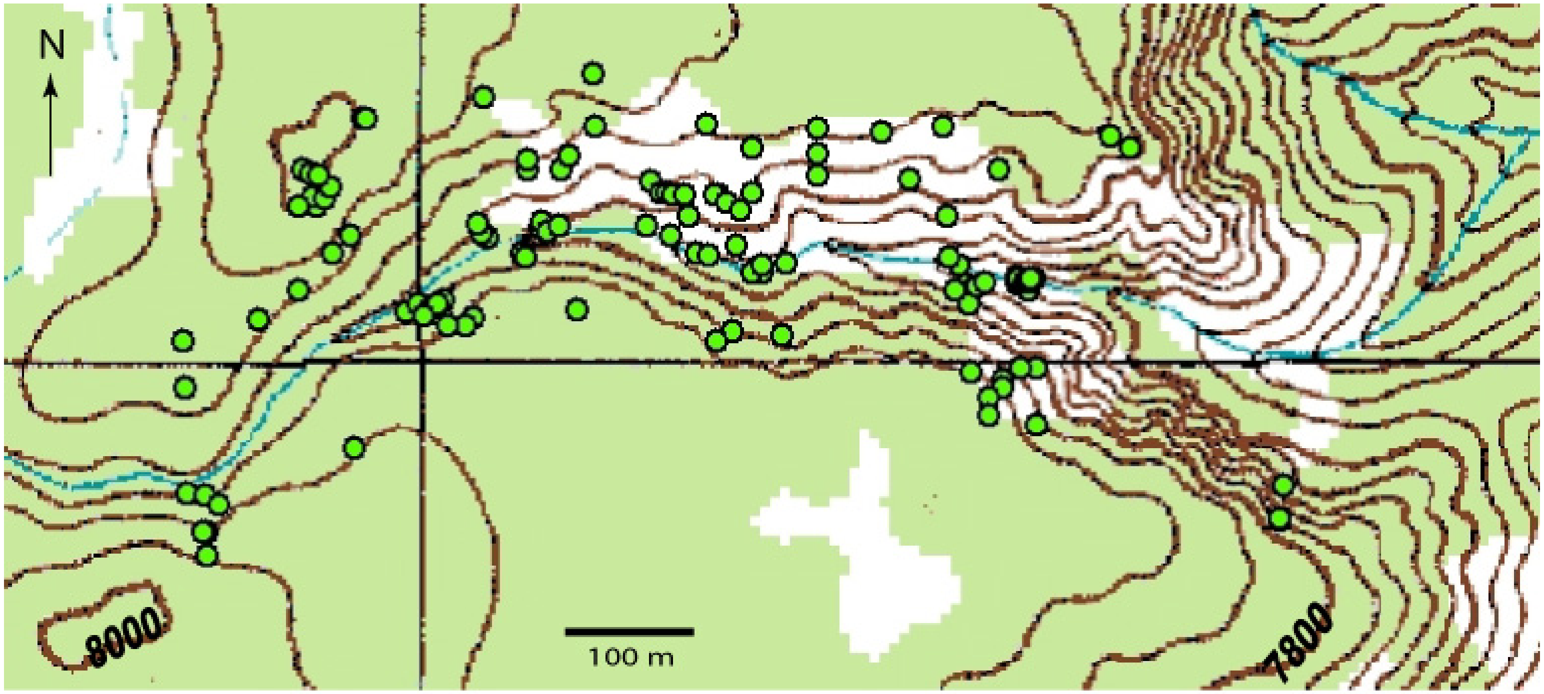


Figure I-3: Distribution map of silicified samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

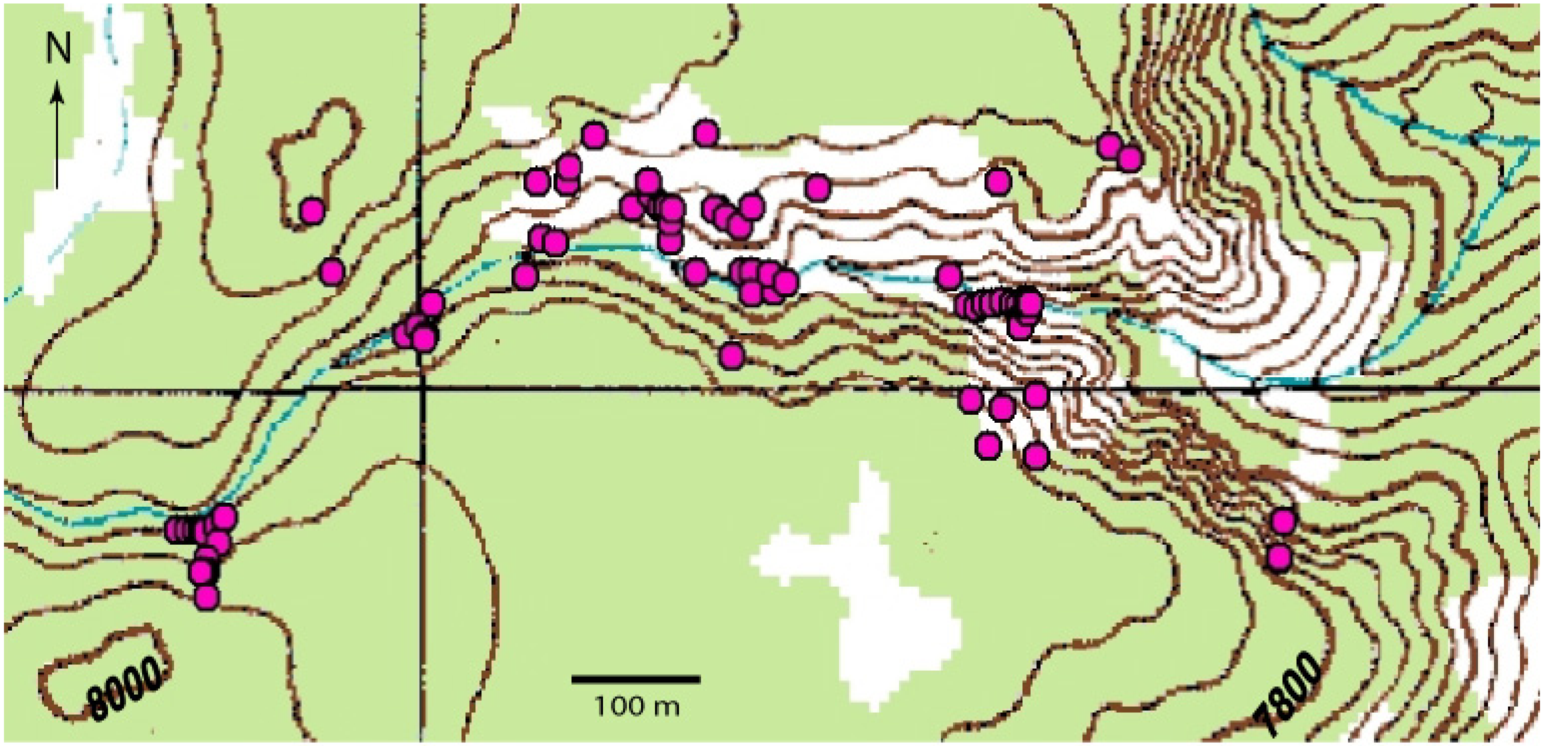


Figure I-4: Distribution map of argillized samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

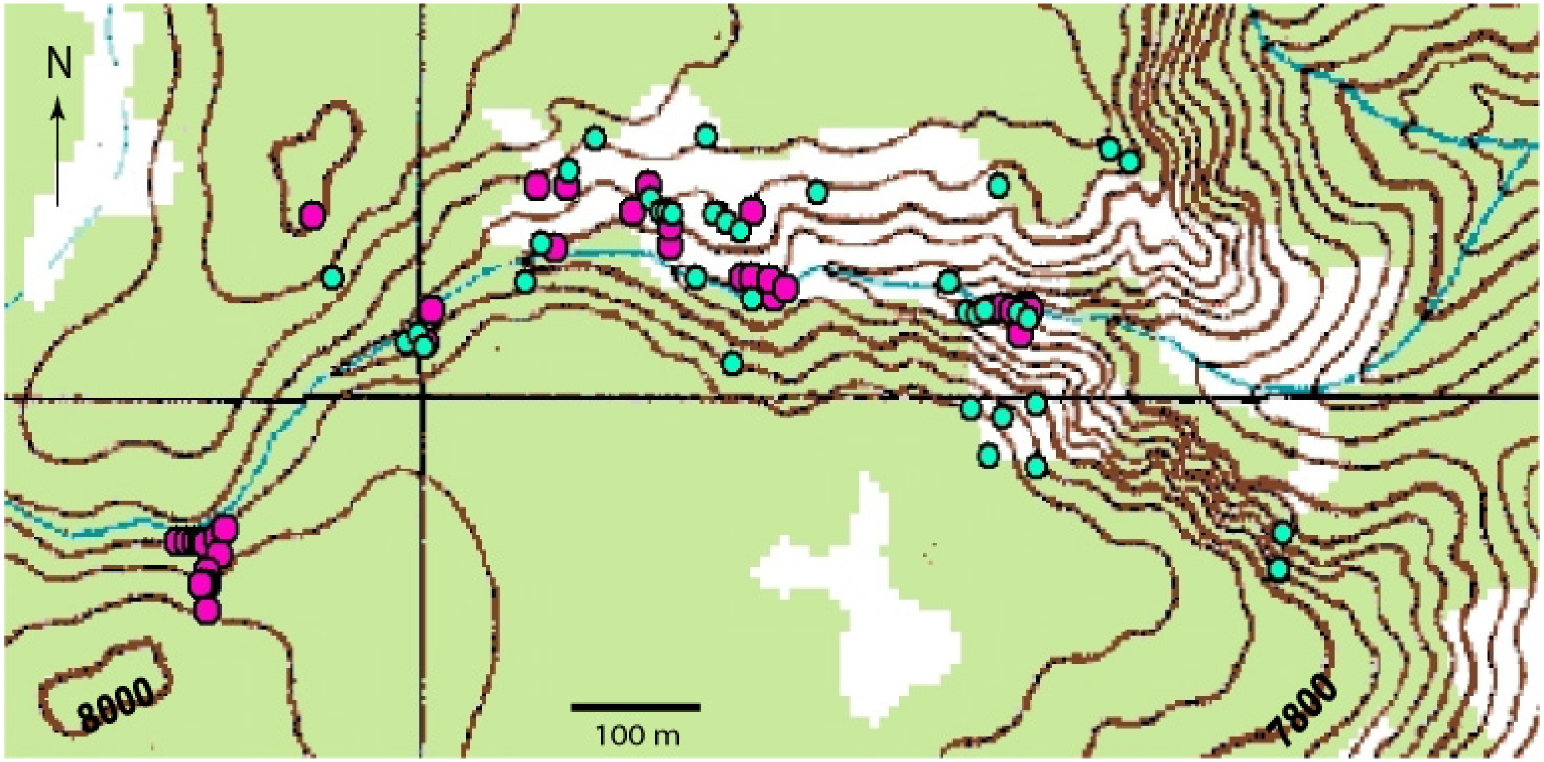


Figure I-5: Distribution map argillized samples. Pink circles represent samples with argillization as the main alteration; teal circles represent samples with argillization as a minor or overprinting alteration. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

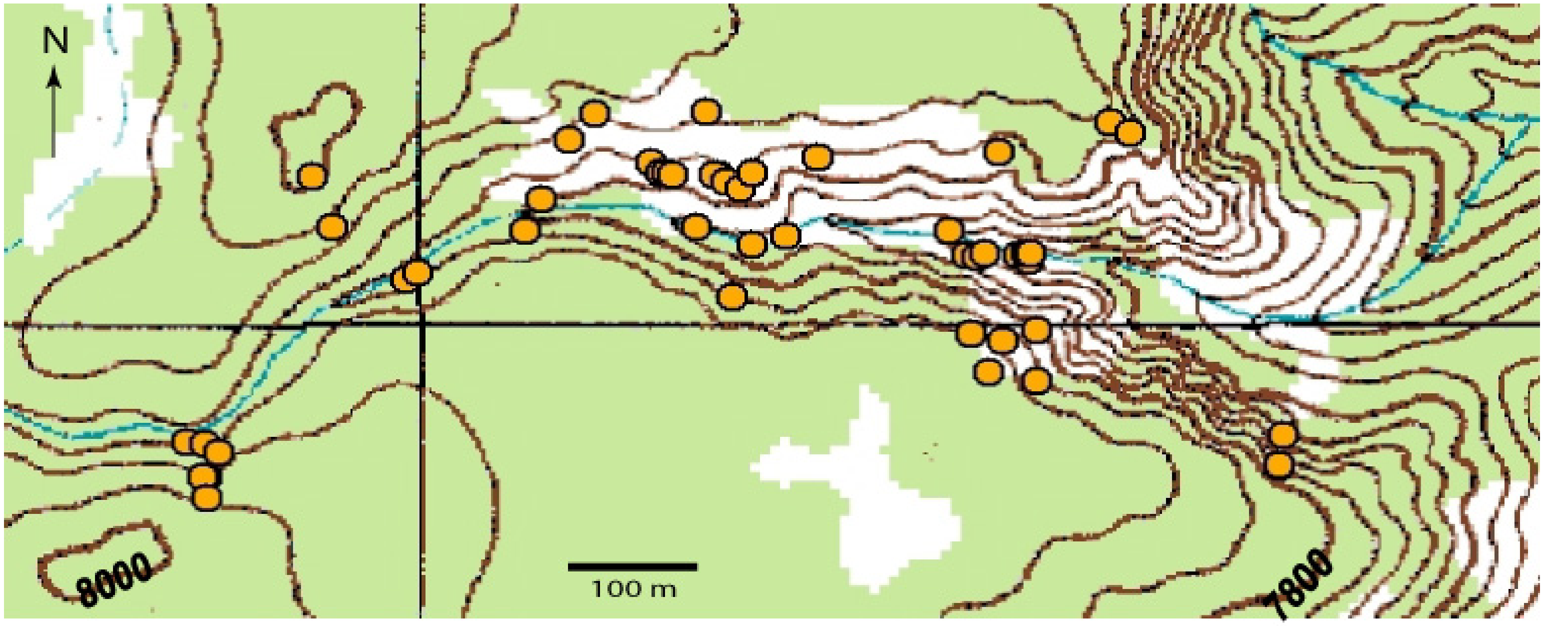


Figure I-6: Distribution map silicified and argillized samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

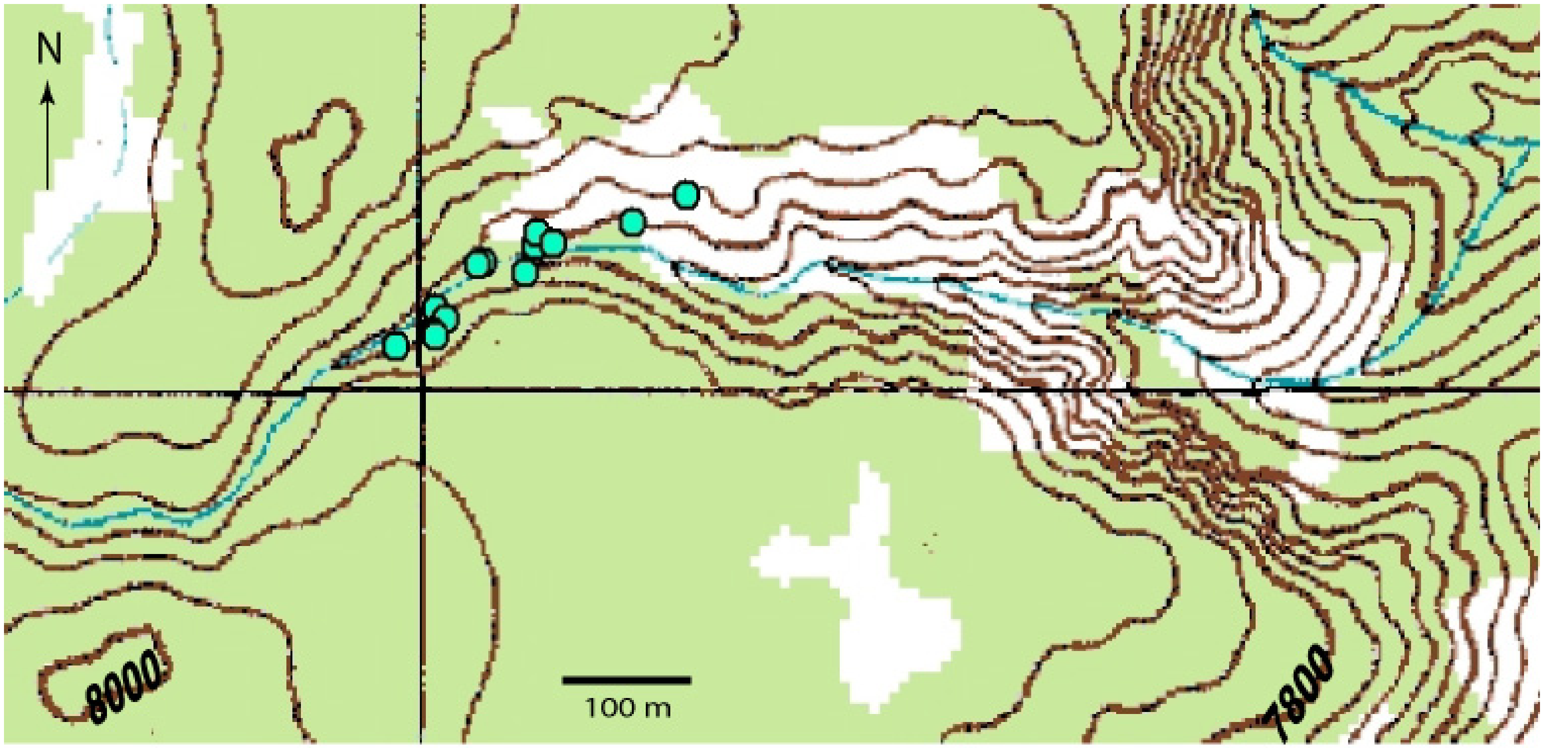


Figure I-7: Distribution map of leached samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

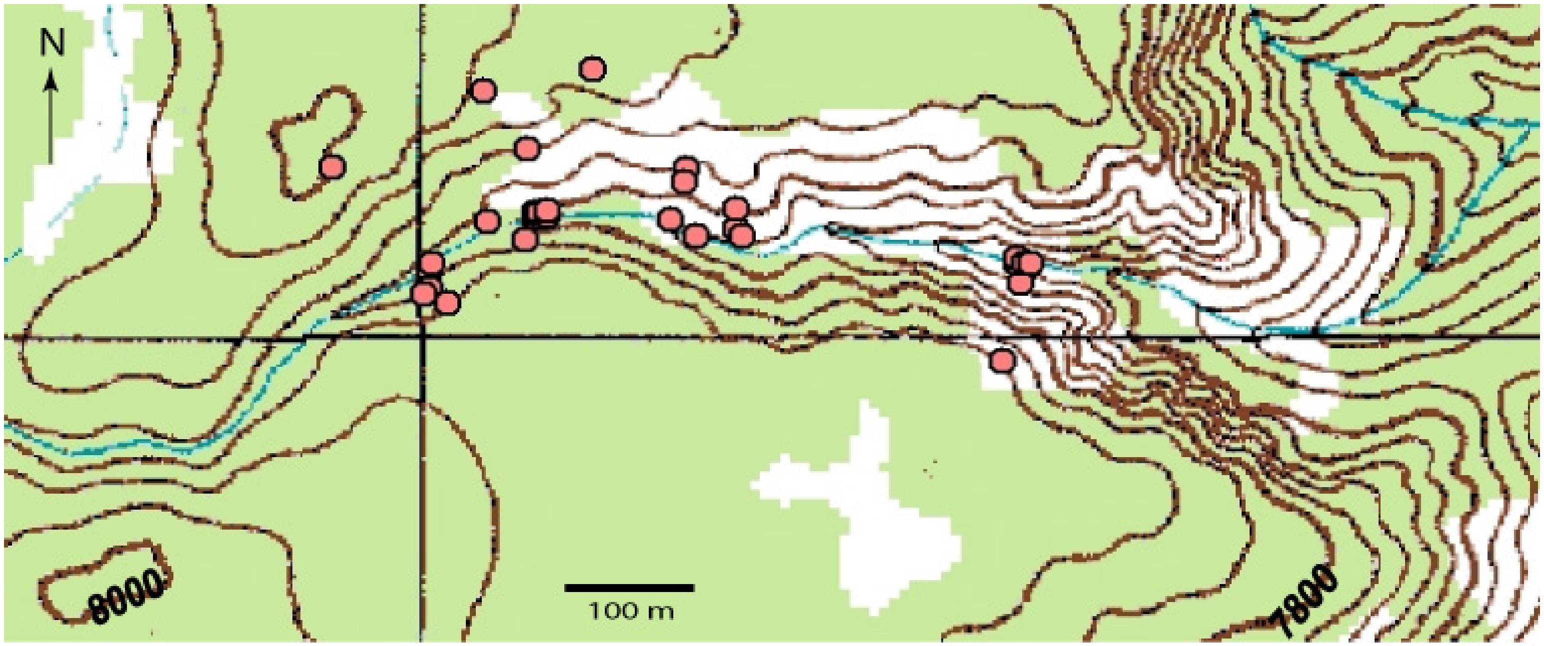


Figure I-8: Distribution map of silica veins. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

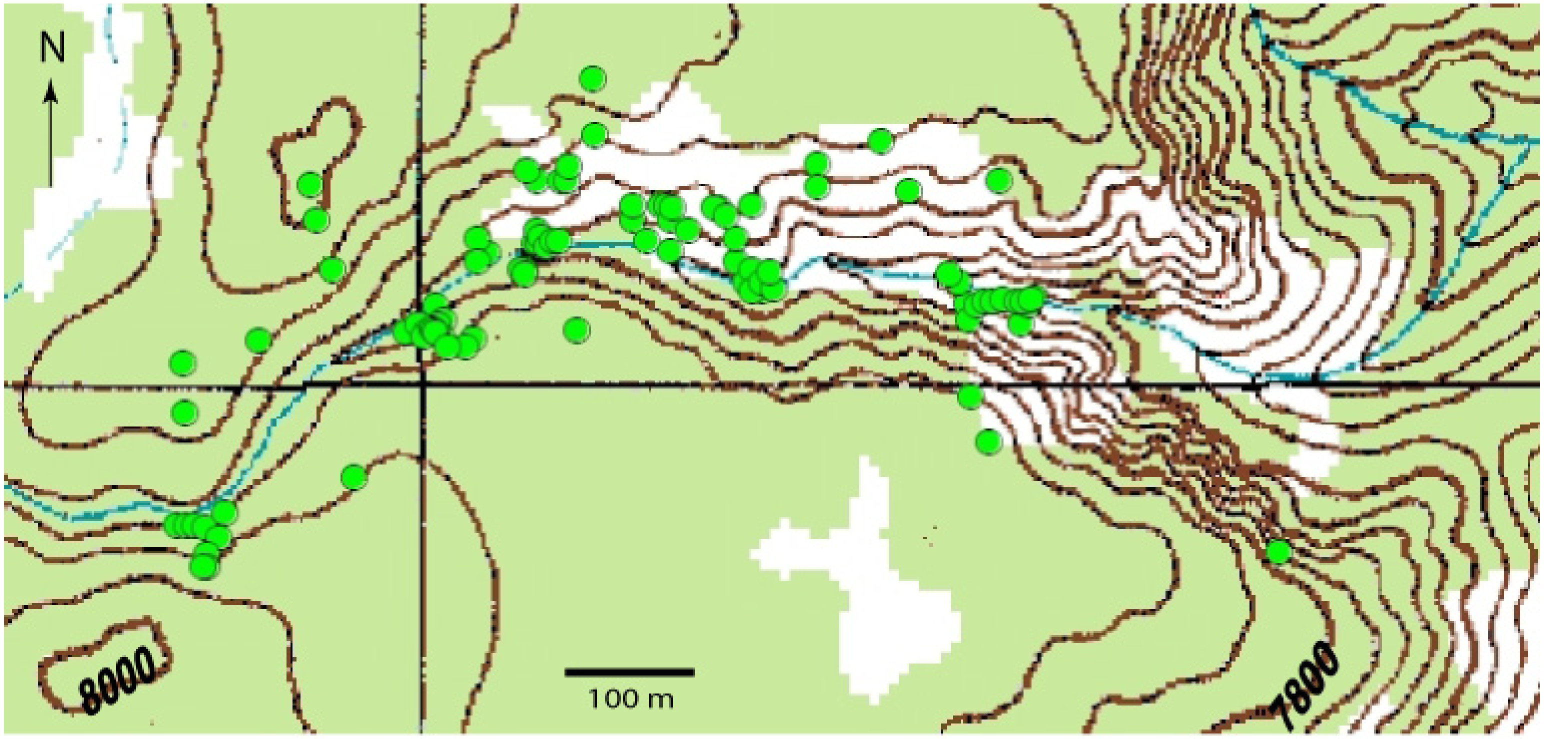


Figure I-9: Distribution map of silica veinlets. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

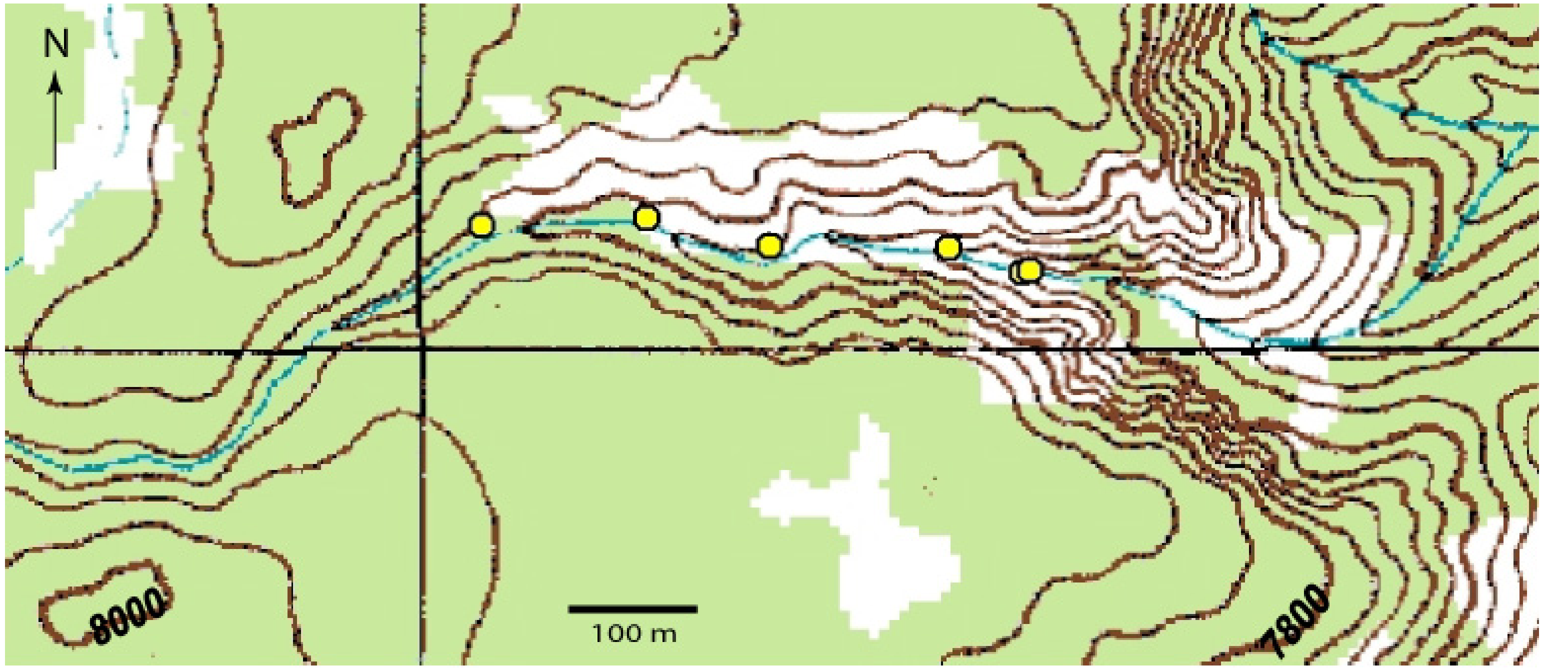


Figure I-10: Distribution map of sulfide veins. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

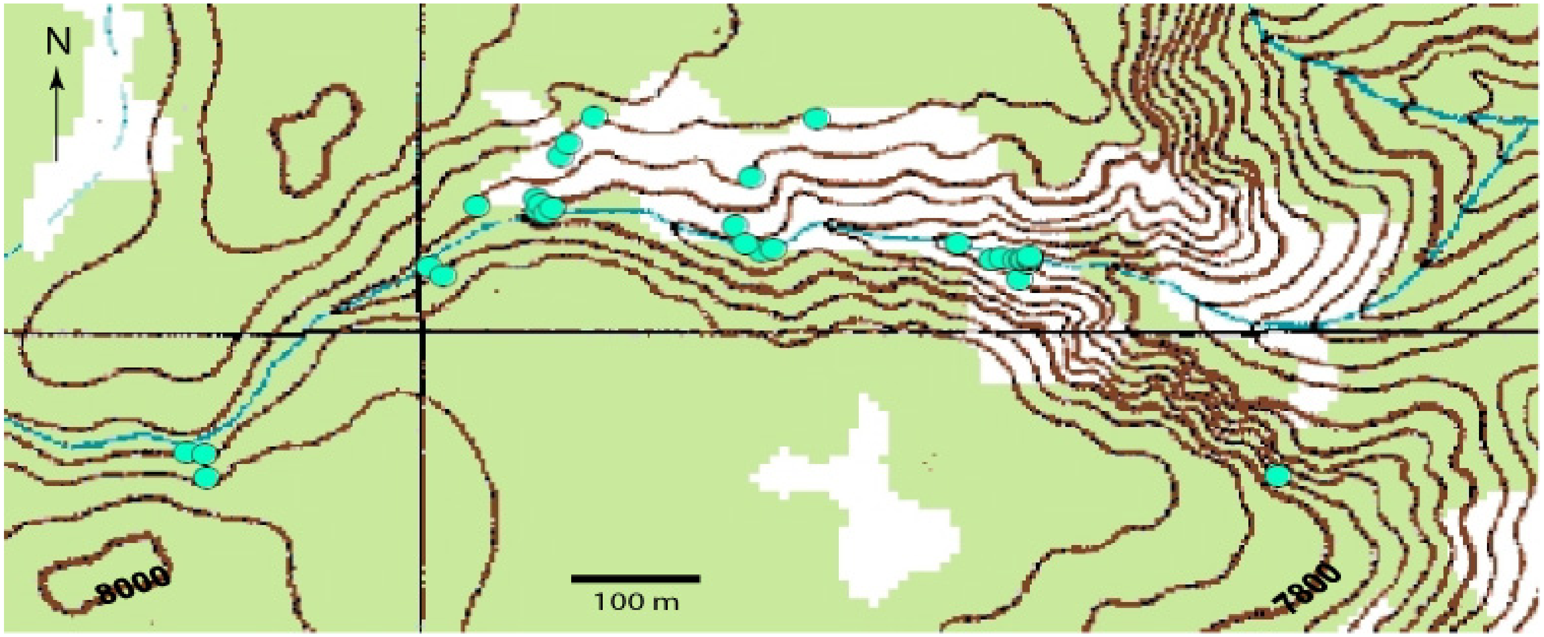


Figure I-11: Distribution map of sulfide veinlets. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

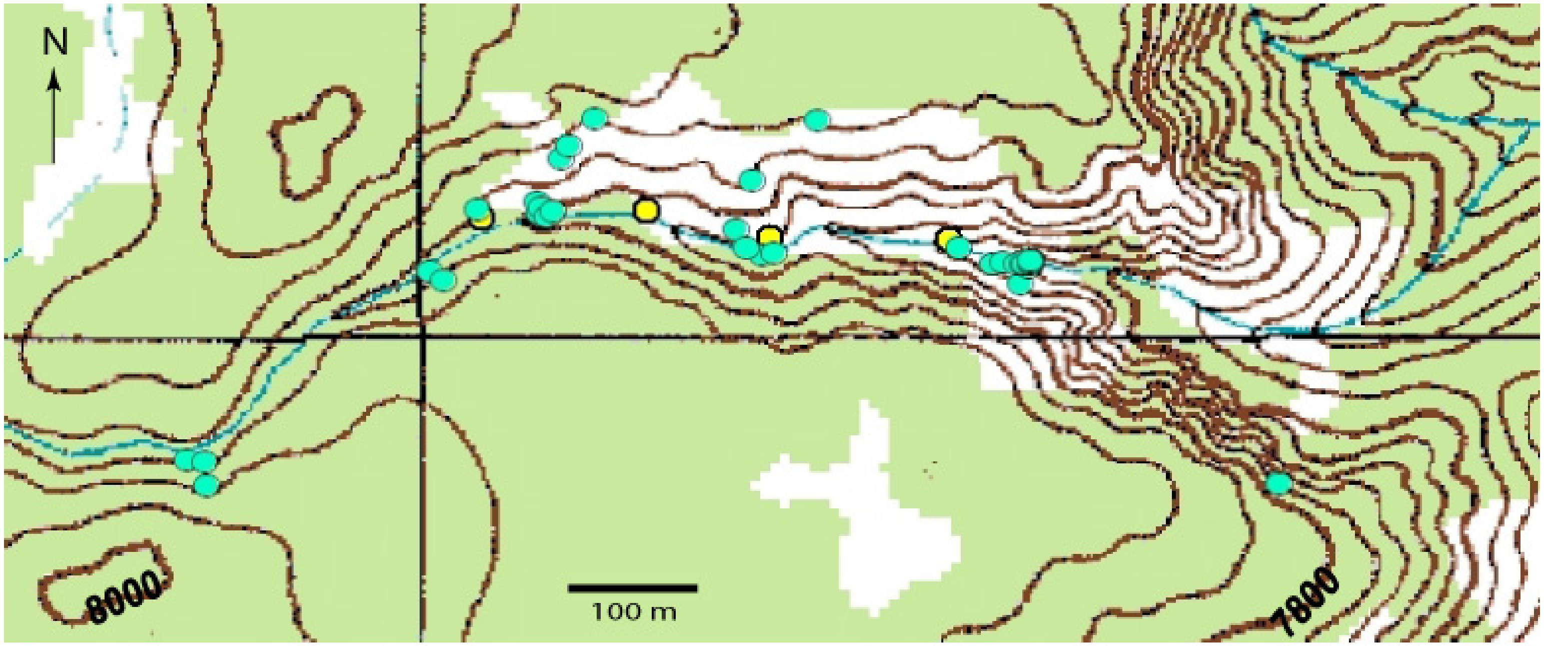


Figure I-12: Distribution map of sulfide veins (yellow) and sulfide veinlets (teal). Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

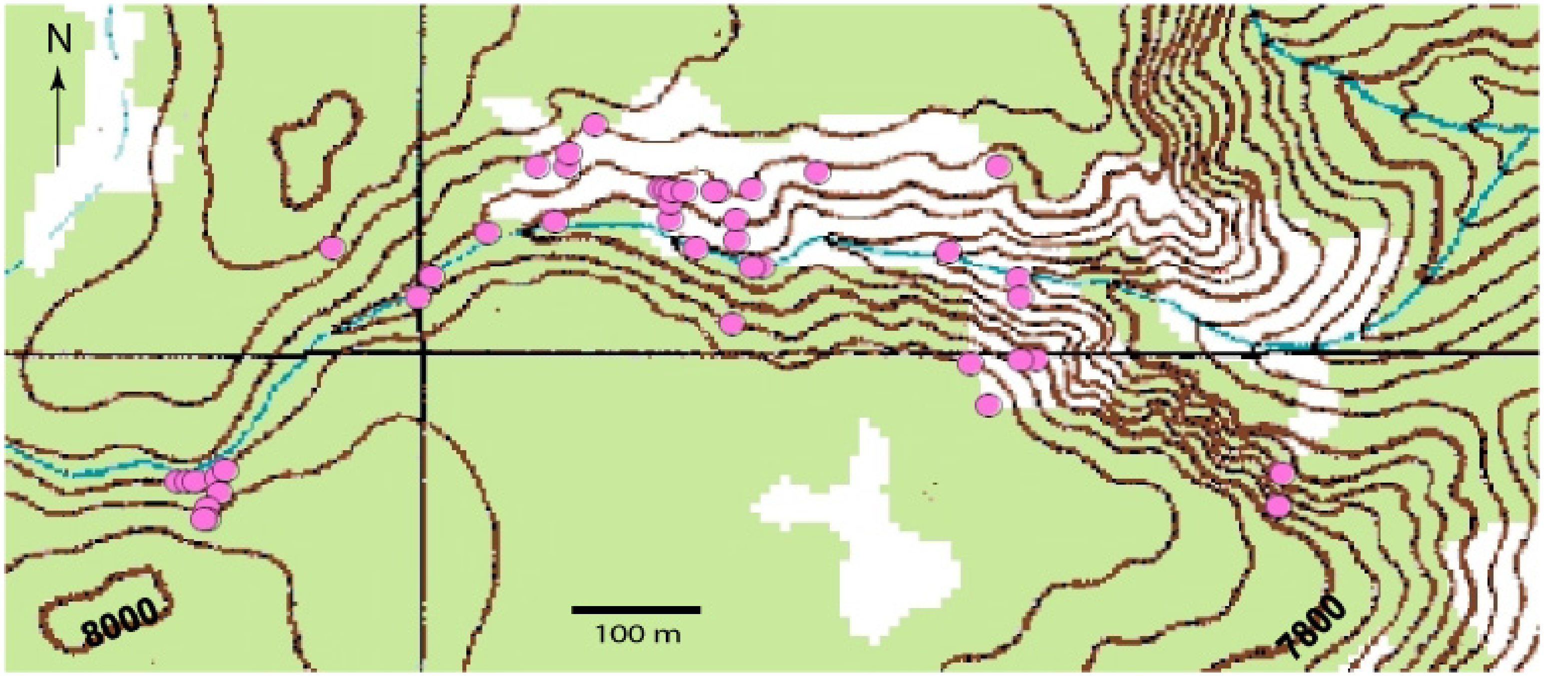


Figure I-13: Distribution map of clay veinlets. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

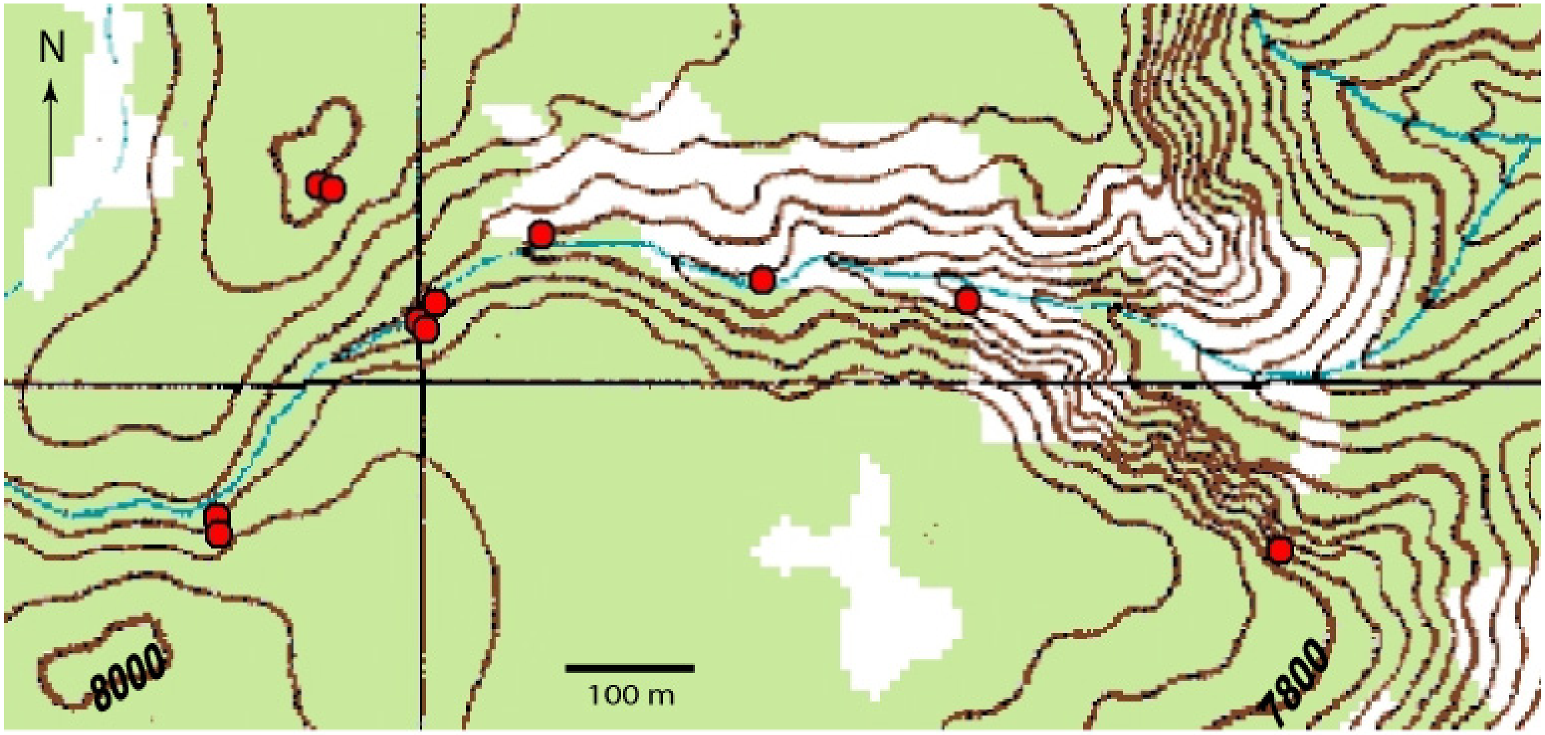


Figure I-14: Distribution map of empty veinlets. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

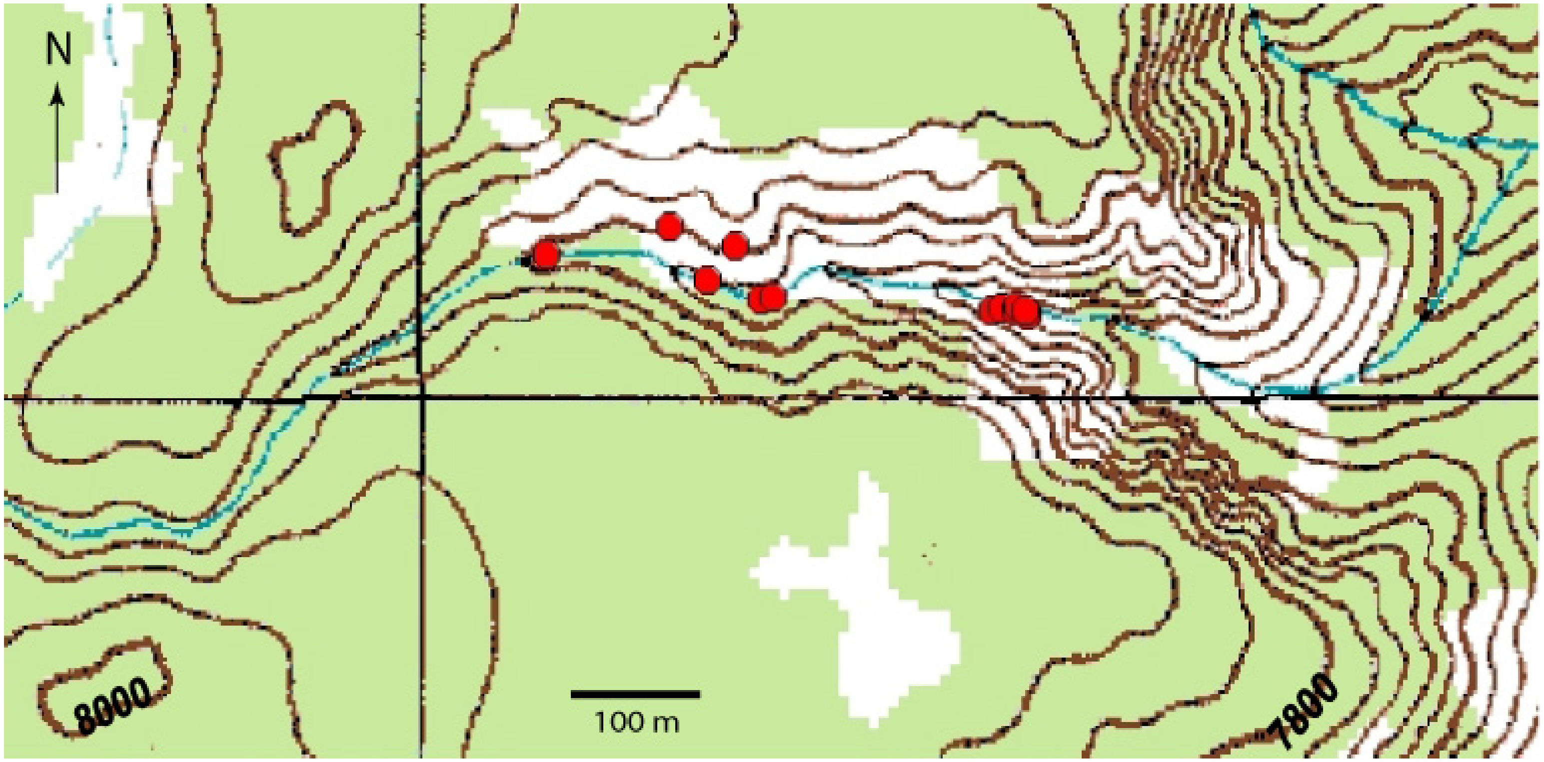


Figure I-15: Distribution map of brecciated veins. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.
Note: This map only shows samples collected from brecciated veins; there are many brecciated veins in the base of Sulphur Creek.

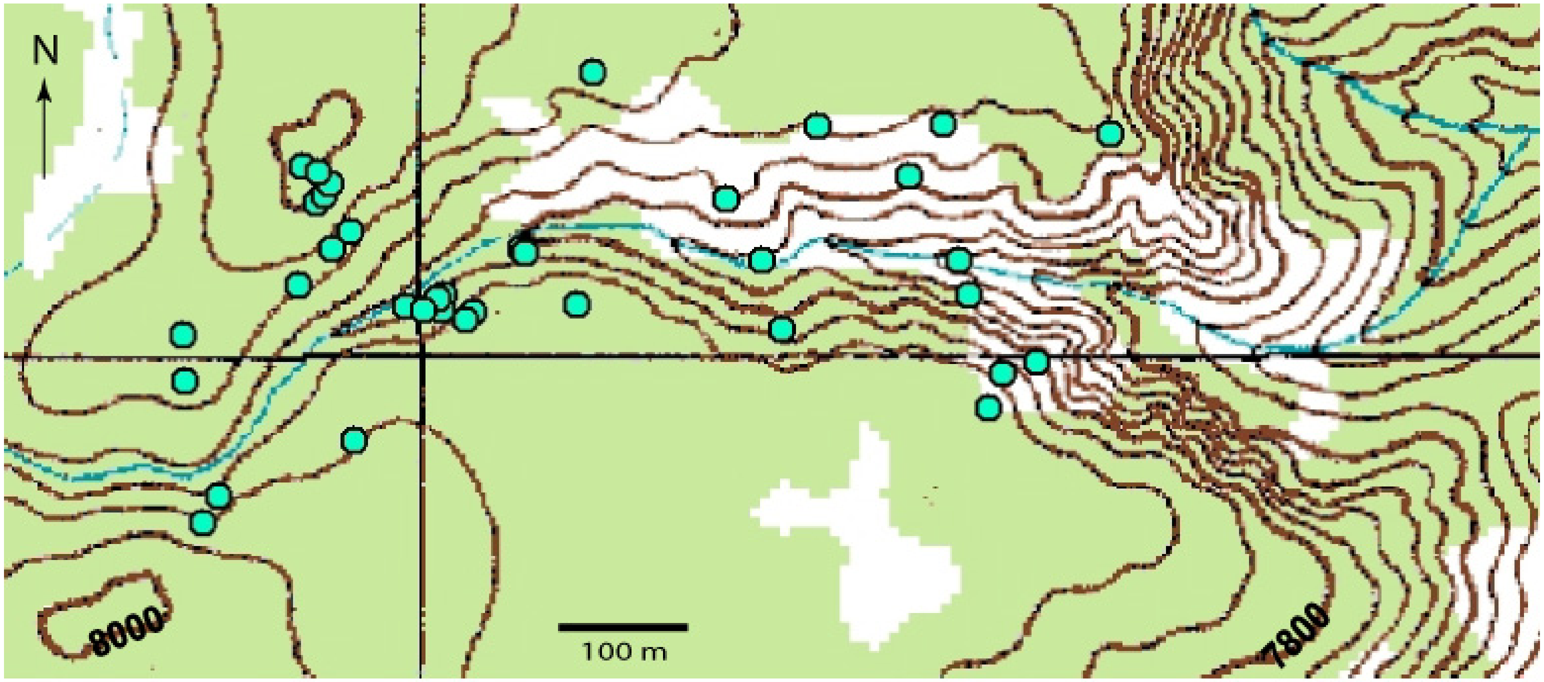


Figure I-16: Distribution map of vuggy silica. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

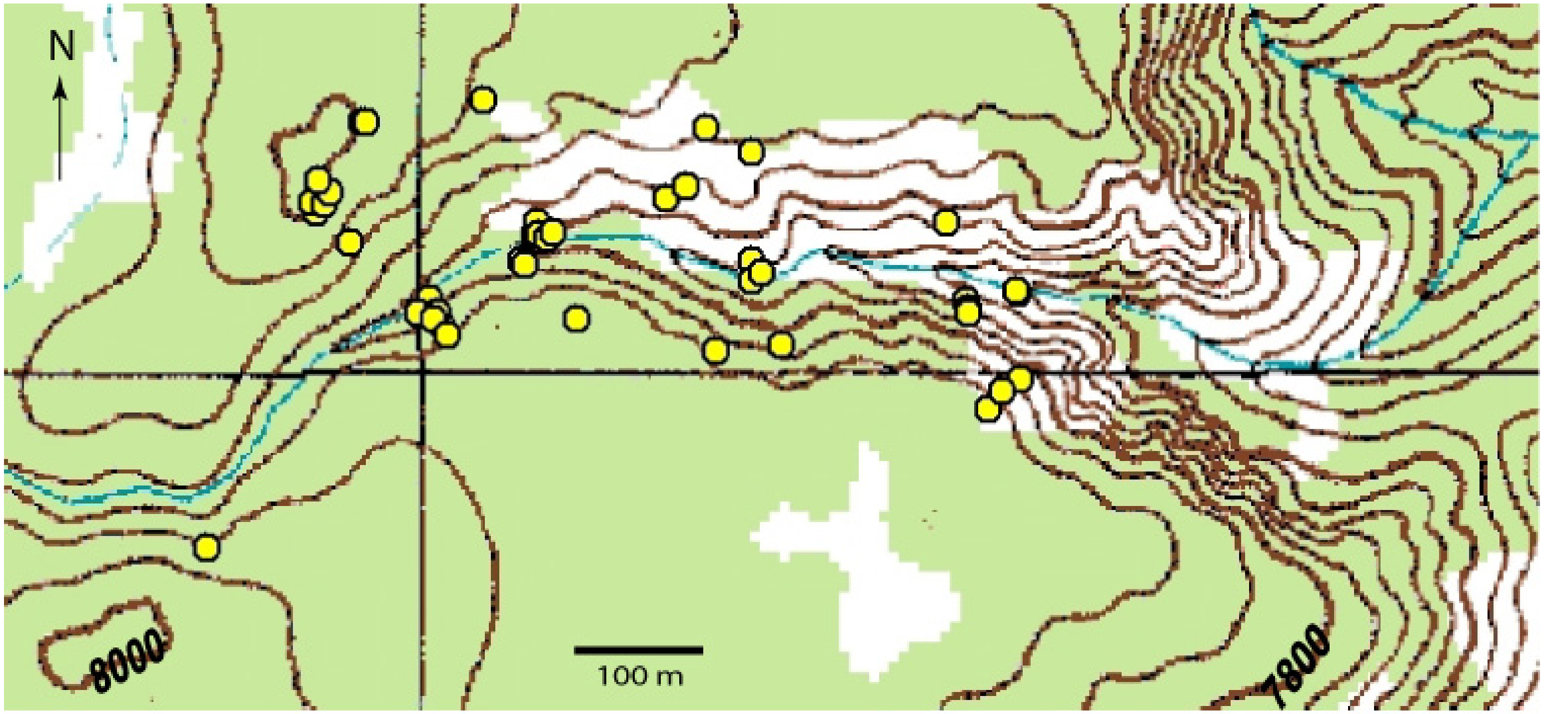


Figure I-17: Distribution map of drusy quartz. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

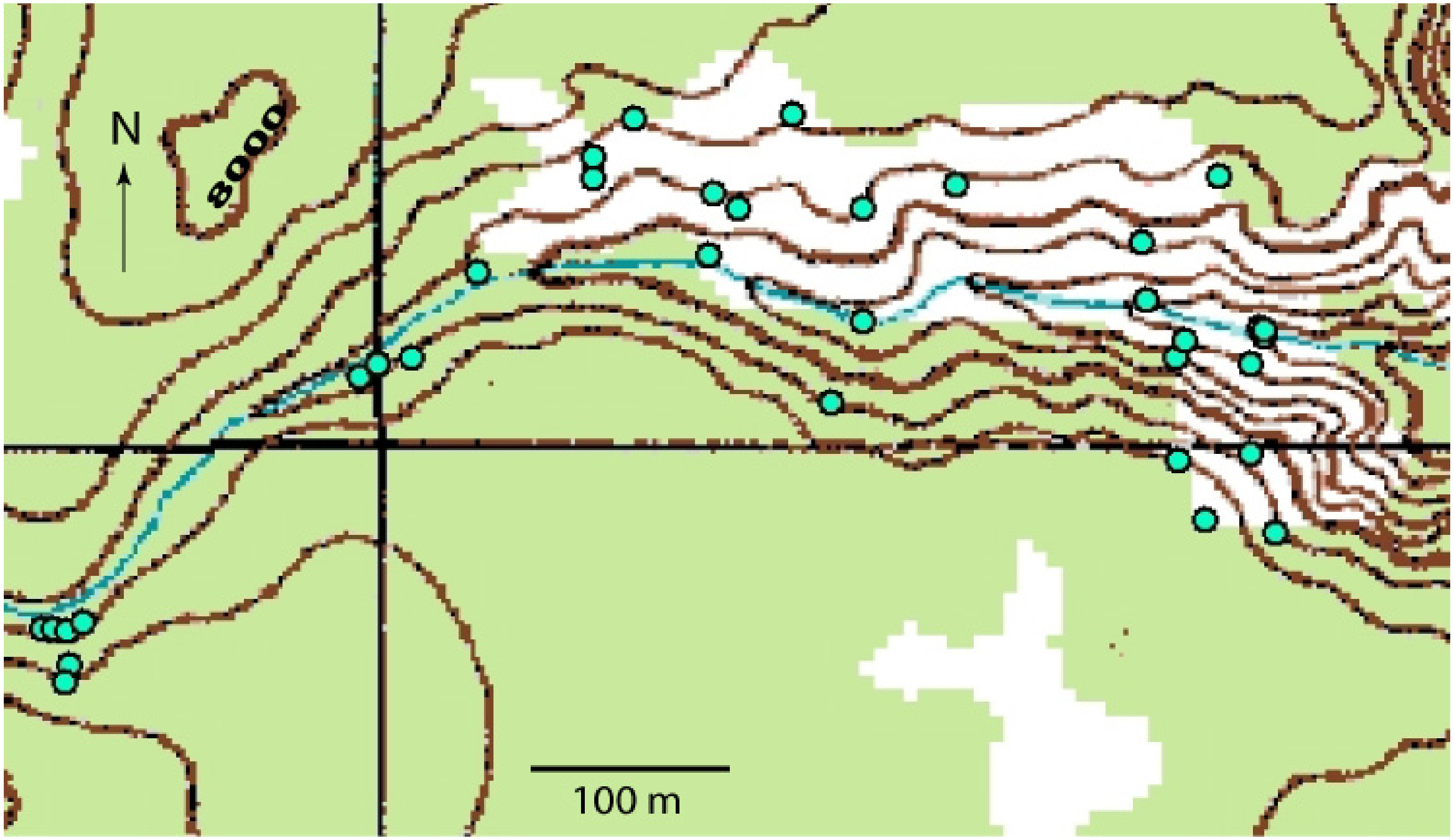


Figure I-18: Distribution map of argillized phenocrysts. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

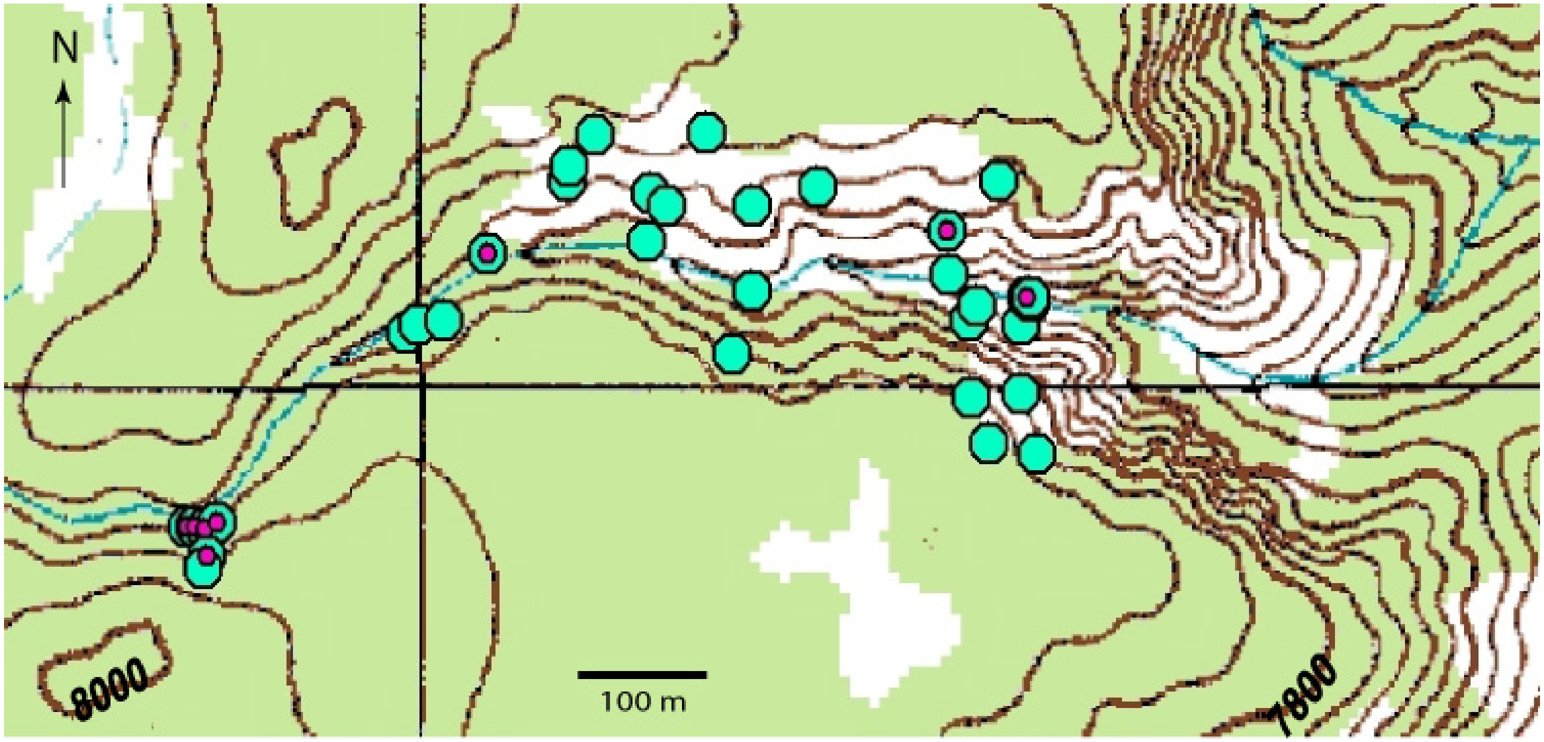


Figure I-19: Distribution map of argillized phenocrysts (teal) and fresh phenocrysts (pink). Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

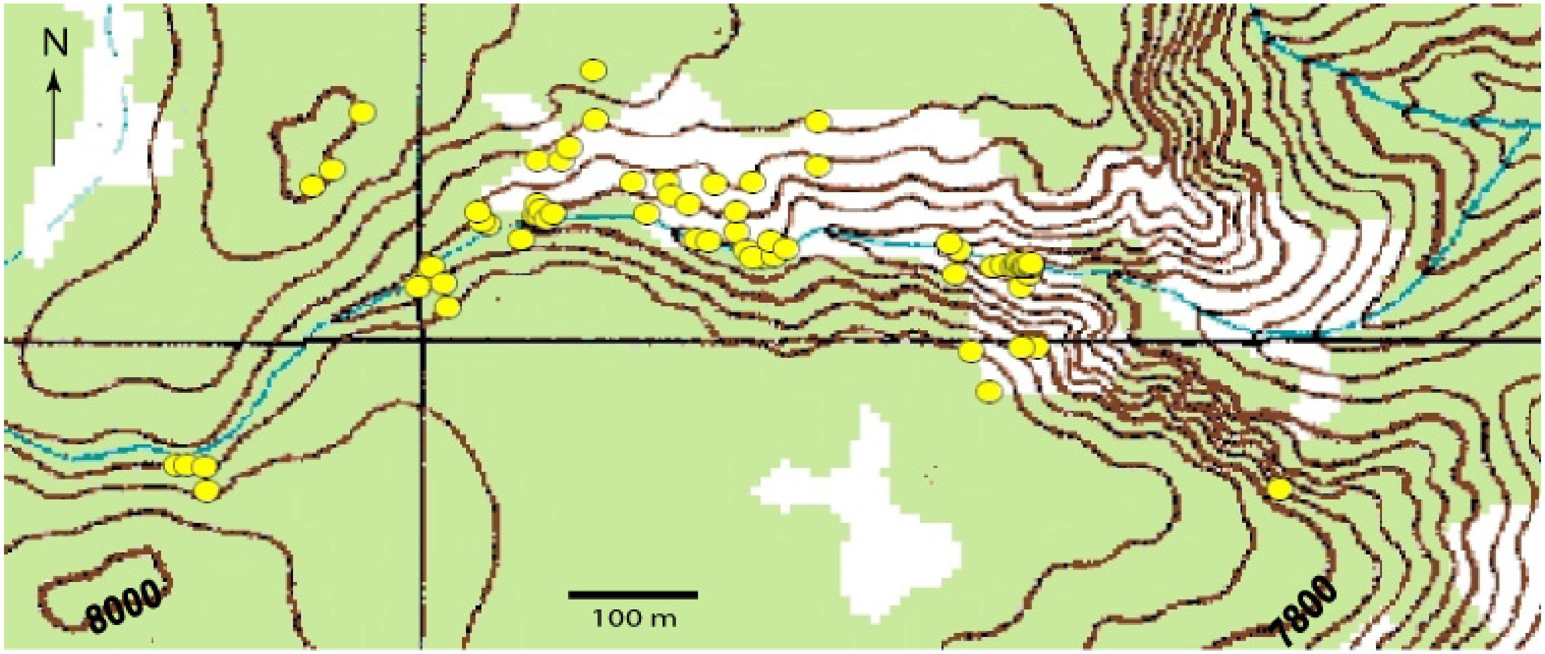


Figure I-20: Distribution map of sulfides. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

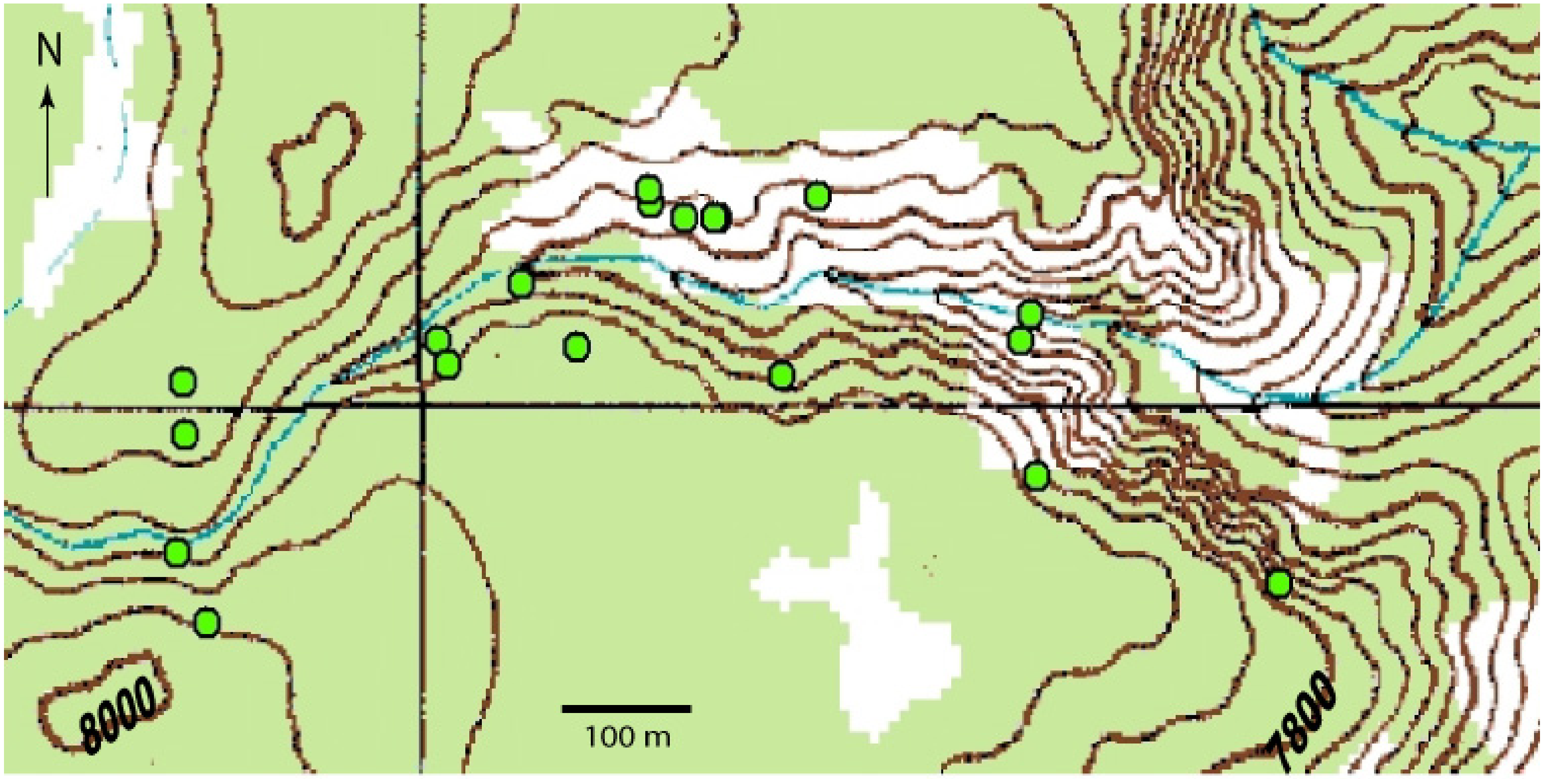


Figure I-21: Distribution map of oxidized samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

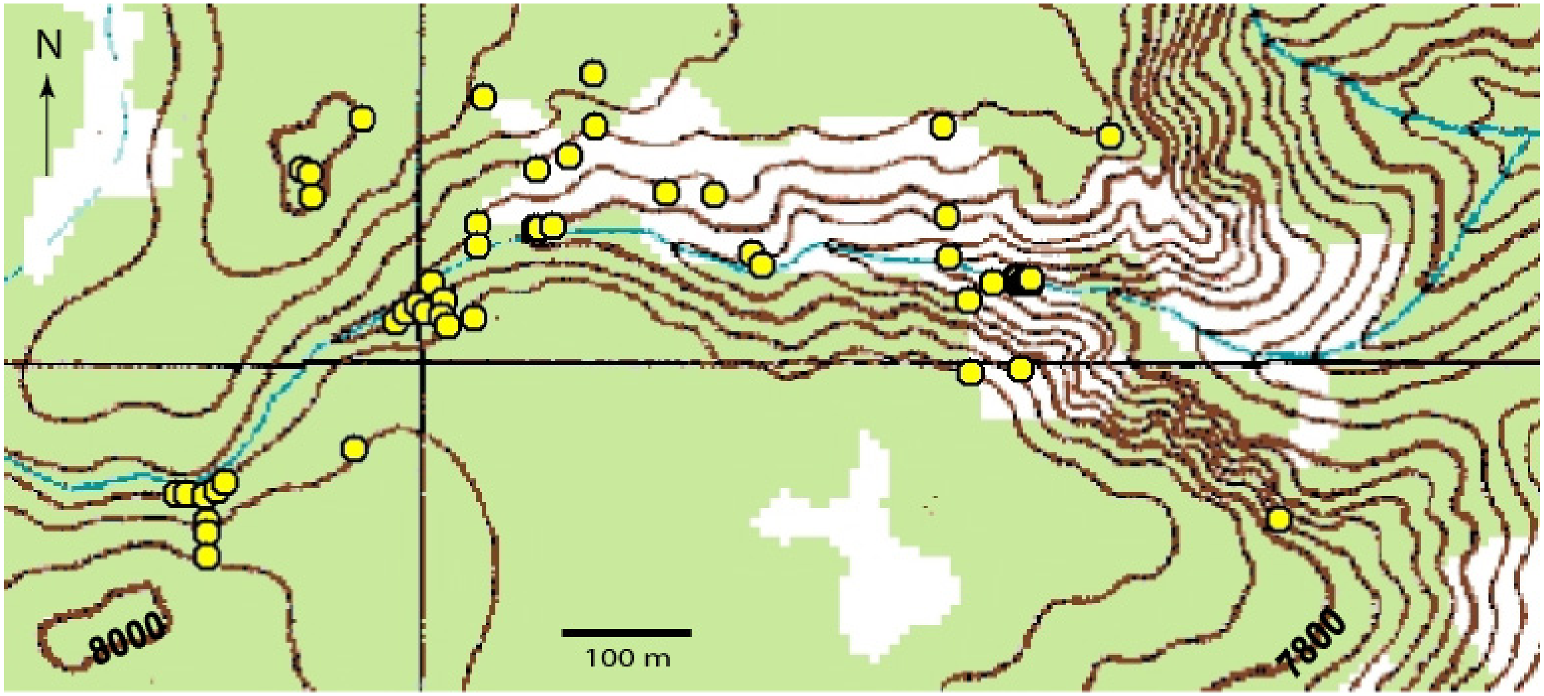


Figure I-22: Distribution map of all XRD samples. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

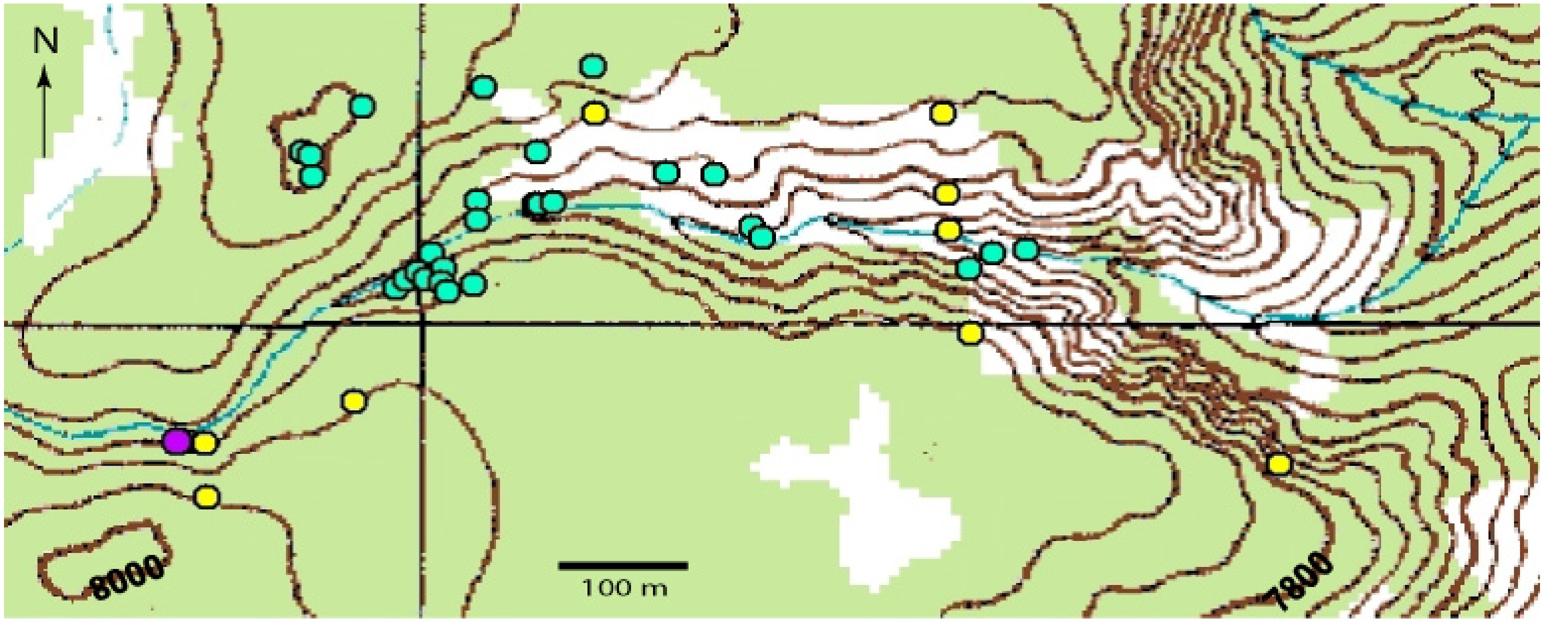


Figure I-23: Distribution map of all XRD samples containing quartz. Teal circles represent samples with major quartz peaks; yellow circles represent samples with minor quartz peaks; the purple circle represents two samples from the same location, one sample contains major quartz peaks and the other contains minor quartz peaks. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

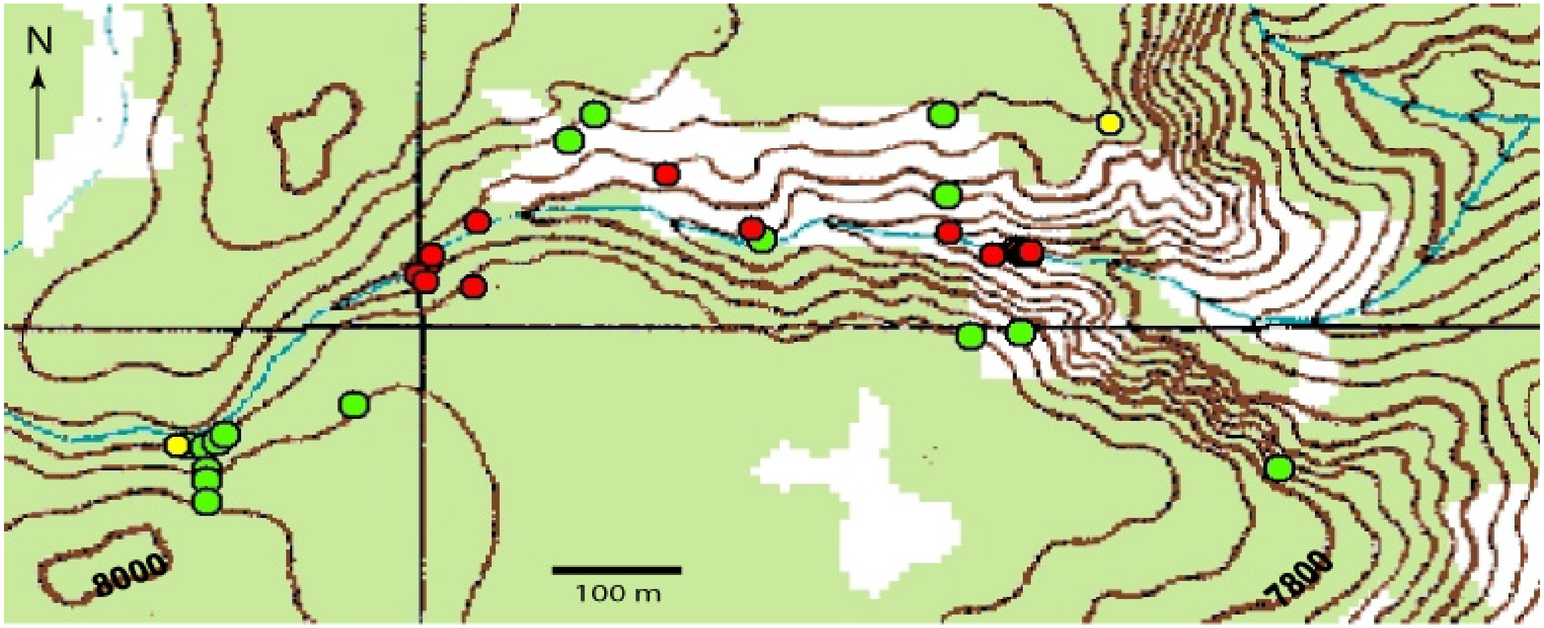


Figure I-24: Distribution map of all XRD samples containing opal. Green circles represent samples with major opal C-T peaks; red circles represent samples with minor opal peaks (various); yellow circles represent samples from the same location, one sample contains major opal C-T peaks and the other sample contains minor opal peaks (various). Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

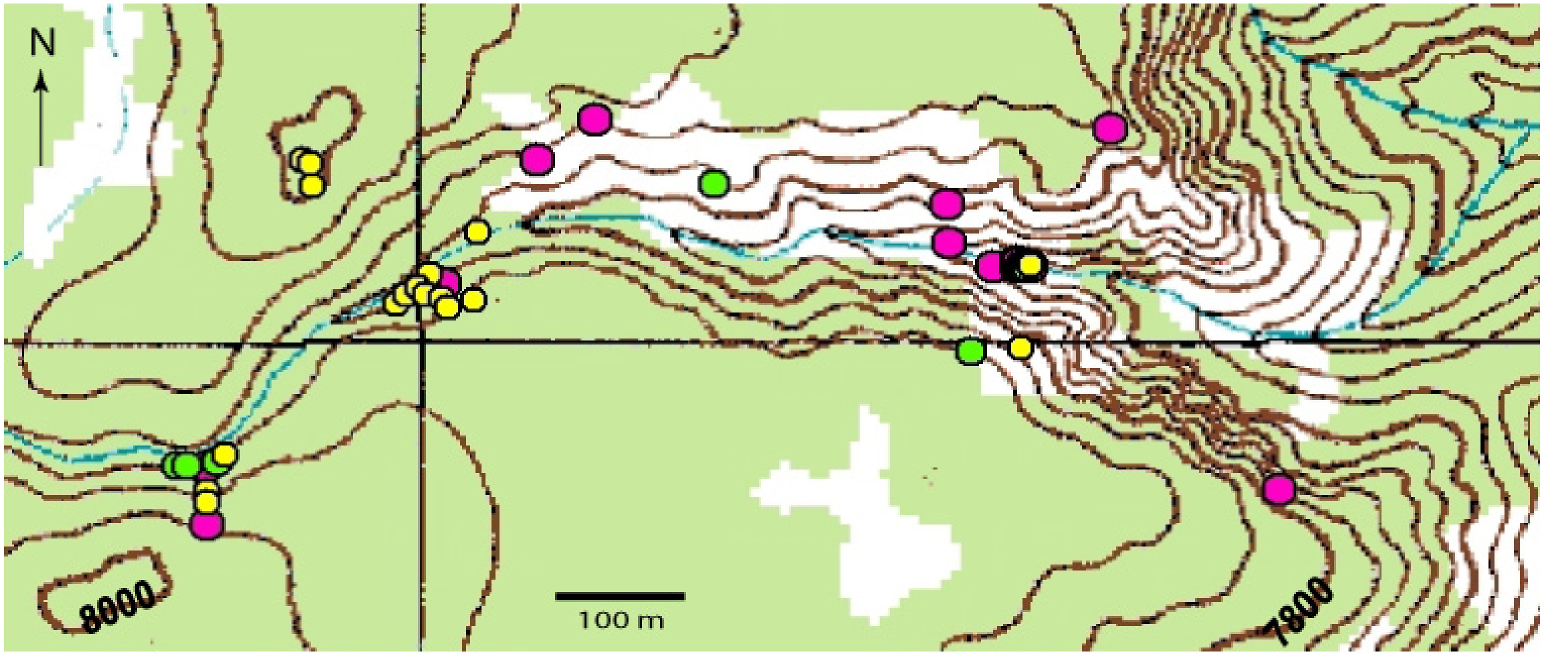


Figure I-25: Distribution map of all XRD samples containing kaolinite. Pink circles represent samples with major kaolinite peaks; yellow circles represent samples with minor kaolinite peaks; green circles represent samples with both kaolinite and dickite. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

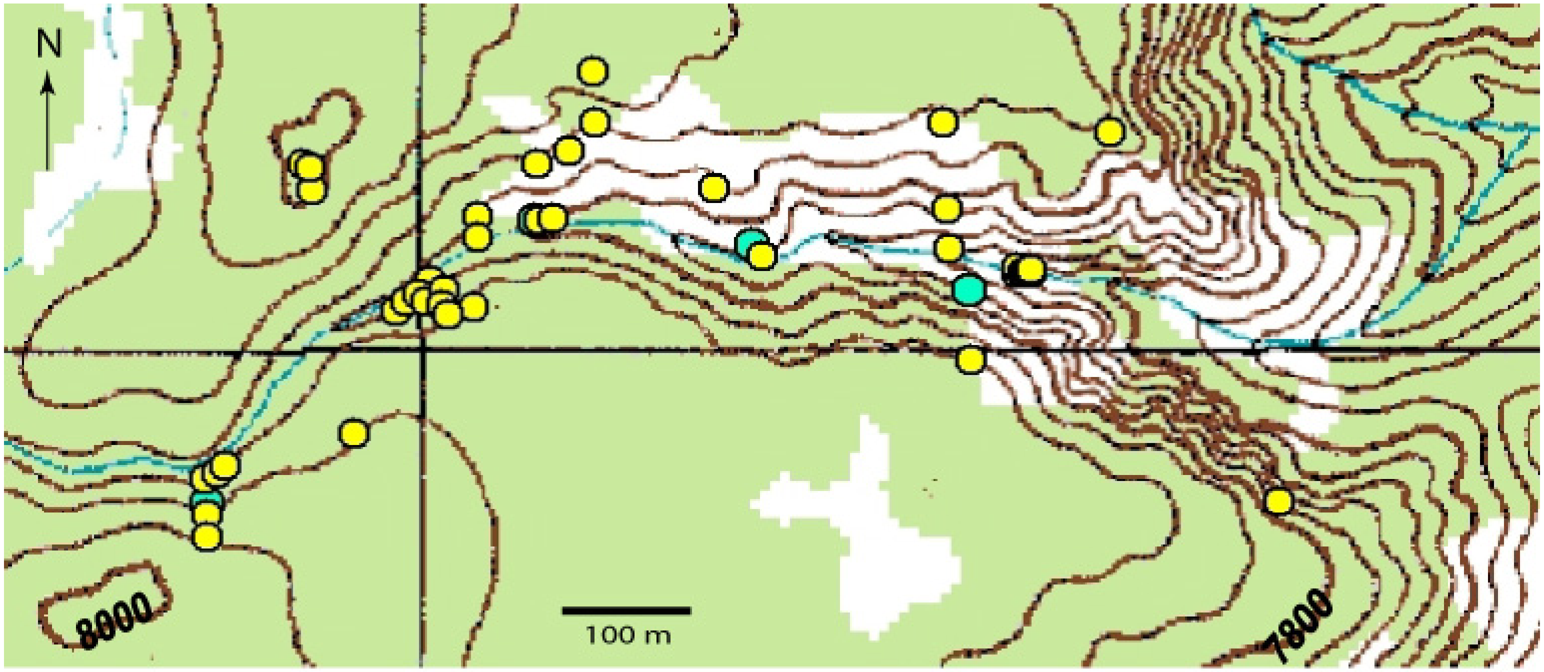


Figure I-26: Distribution map of all XRD samples containing illite. Teal circles represent samples with major illite peaks; yellow circles represent samples with minor illite peaks. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

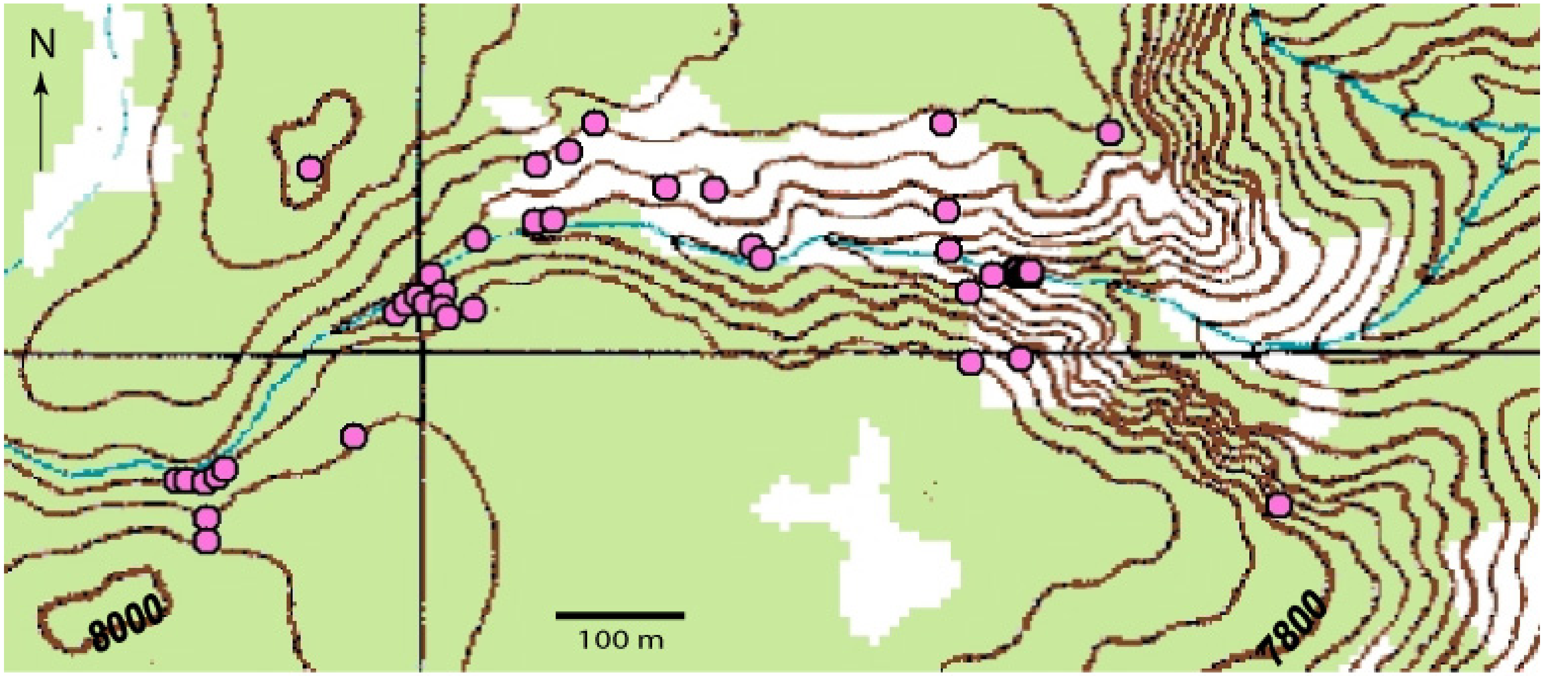


Figure I-27: Distribution map of all XRD samples containing sulfate. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

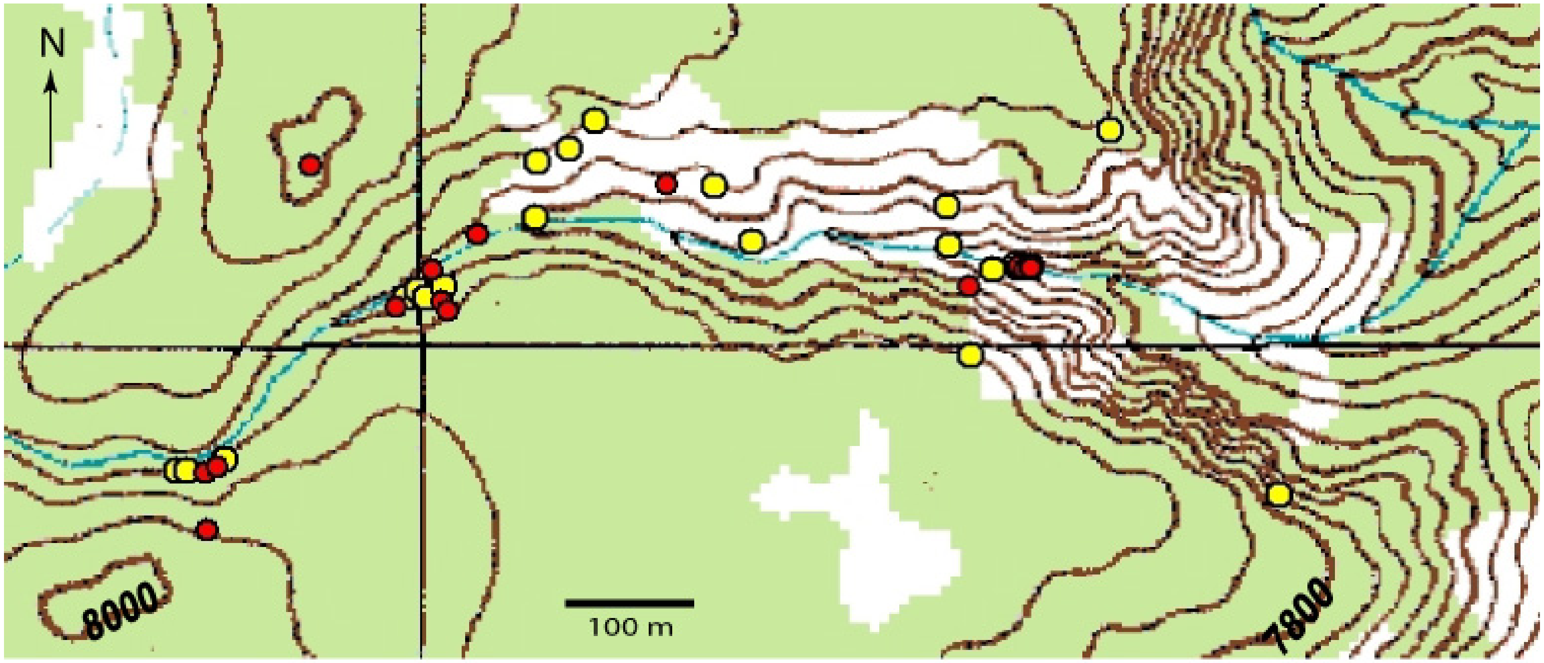


Figure I-28: Distribution map of all XRD samples containing alunite. Yellow circles represent samples with major alunite peaks; red circles represent samples with minor alunite peaks. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

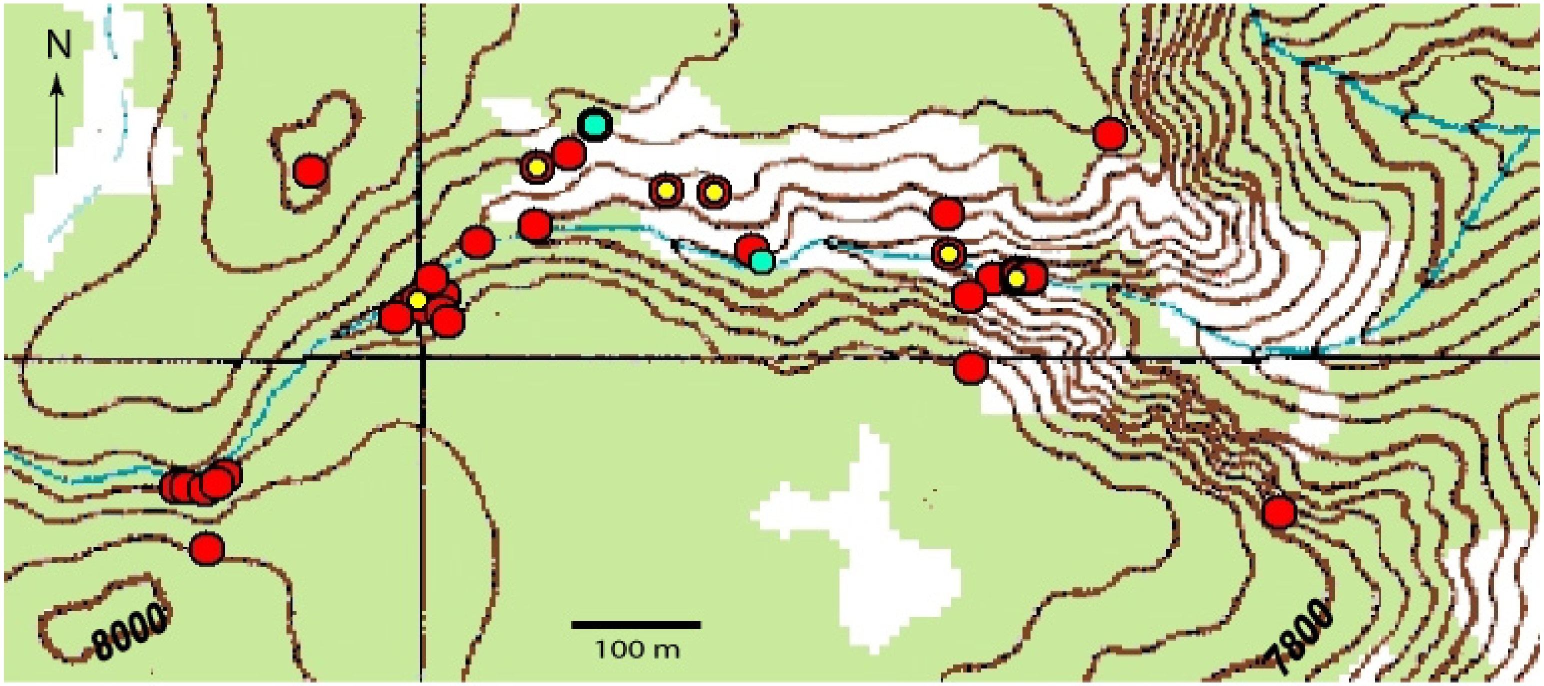


Figure I-29: Distribution map of all XRD samples containing alunite group minerals, excluding walthierite. Red circles represent samples with alunite; yellow circles represent samples with huangite; teal circles represent samples with rostite. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

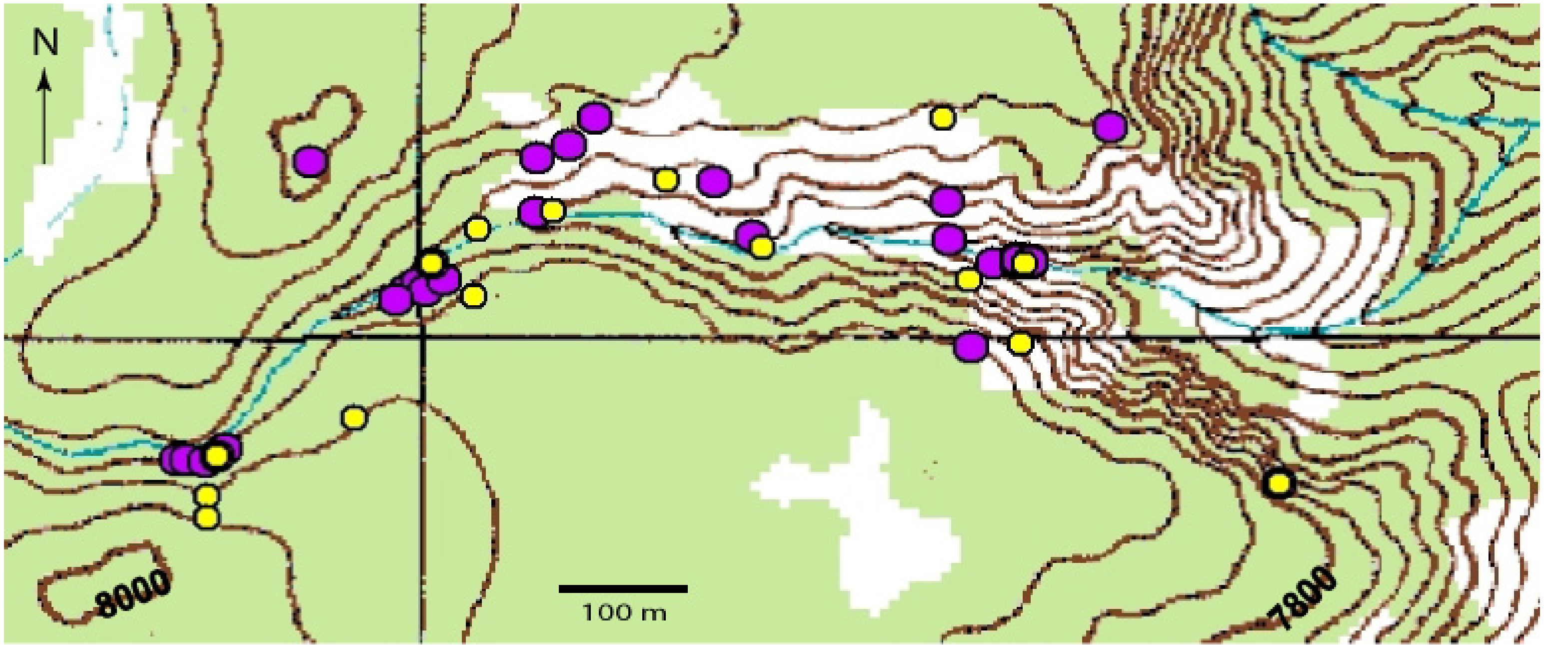


Figure I-30: Distribution map of all XRD samples containing Ba-sulfates. Purple circles represent samples with walthierite; yellow circles represent samples with barite. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

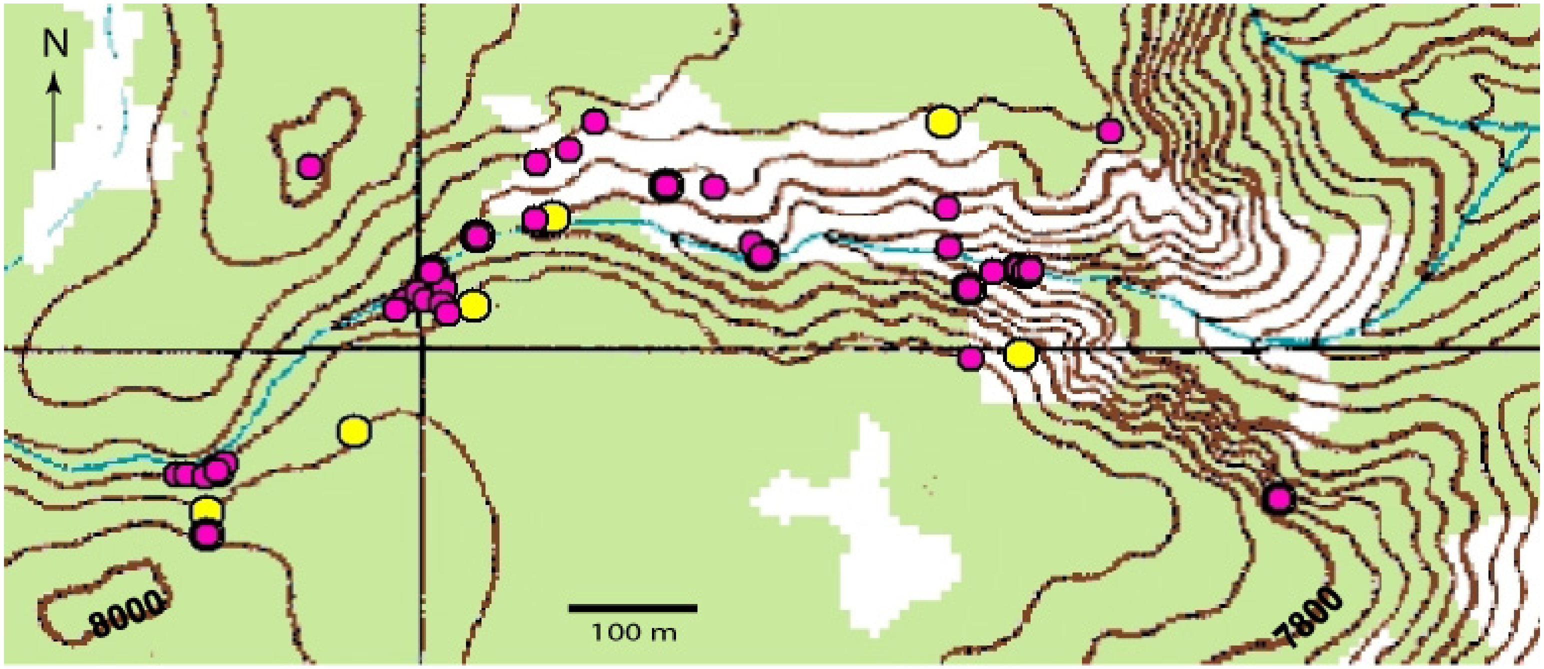


Figure I-31: Distribution map of all XRD samples containing sulfates. Pink circles represent samples with alunite group minerals- AGM- (including walthierite); yellow circles represent samples with barite. Samples with heavier black lines enclosing a pink circle contain both AGM's and barite. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

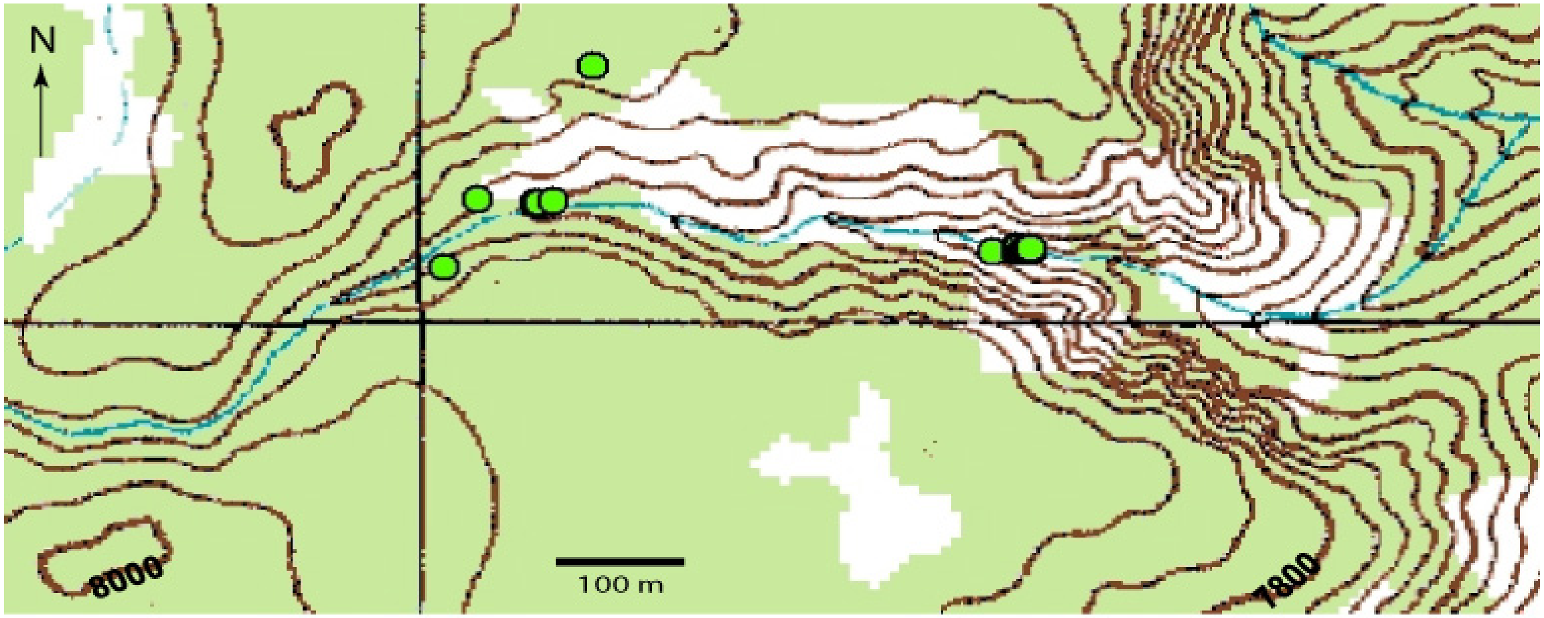


Figure I-32: Distribution map of all XRD samples containing sulfides. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

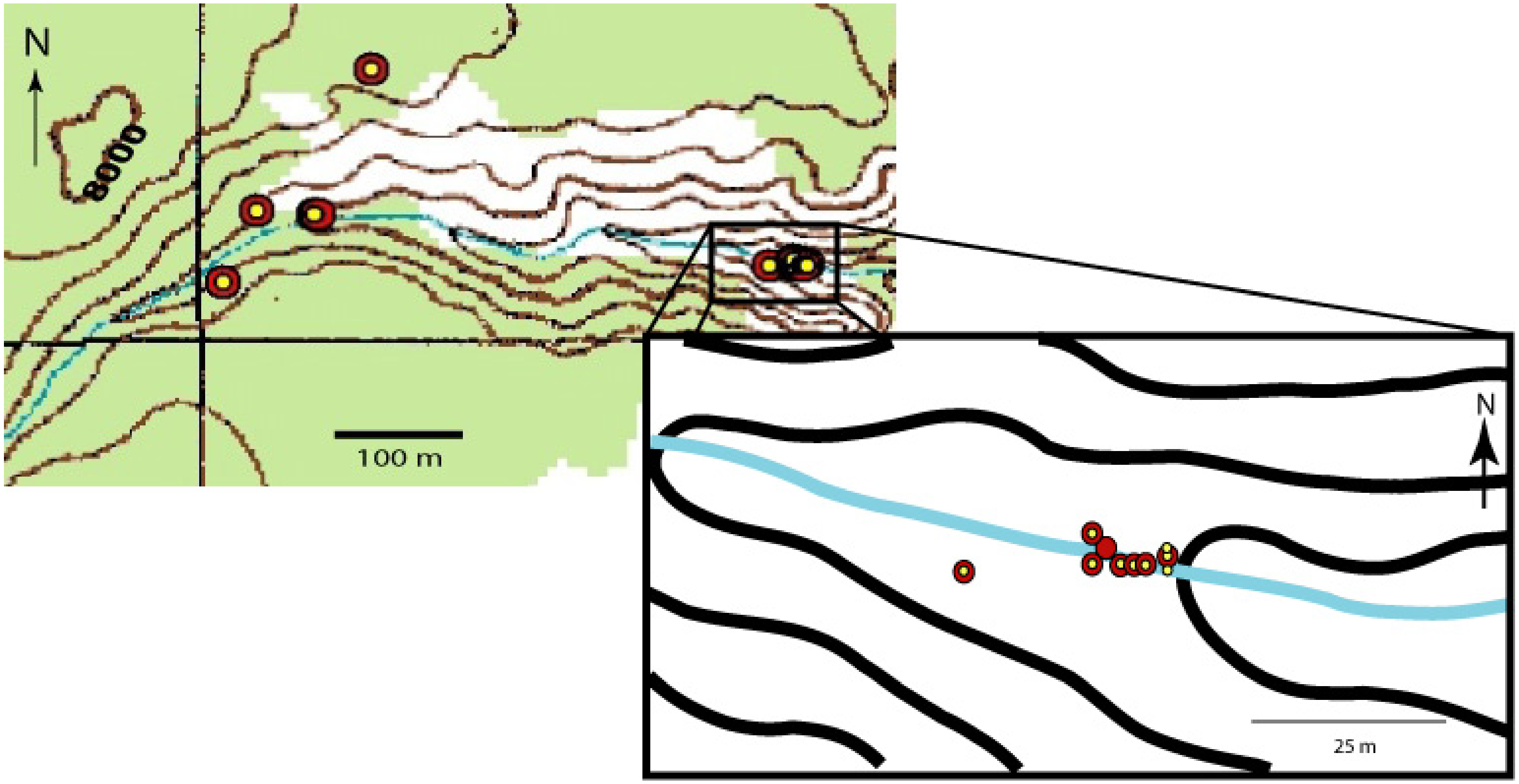


Figure I-33: Distribution map of all XRD samples containing pyrite and/or marcasite. Red circles represent samples with pyrite; yellow circles represent samples with marcasite. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

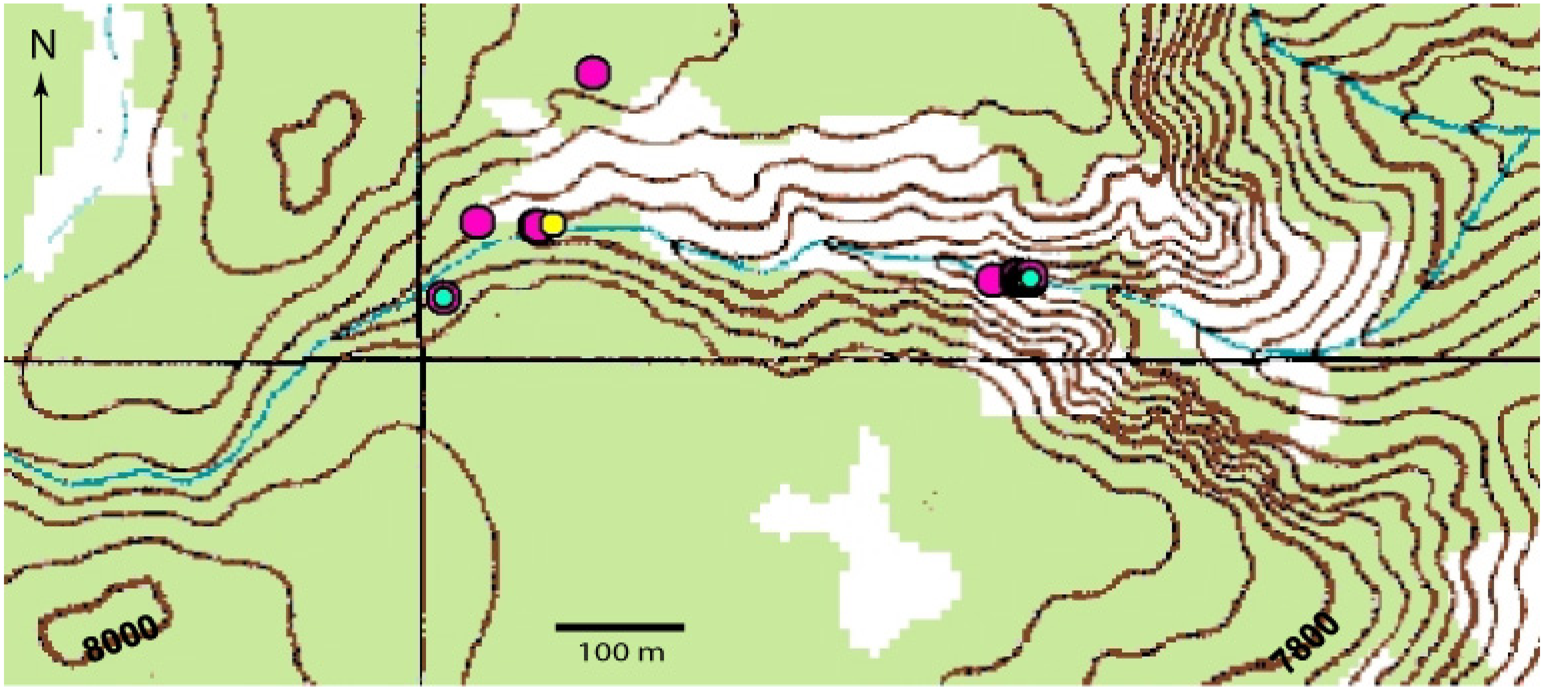


Figure I-34: Distribution map of all XRD samples containing sulfides. Pink circles represent samples with pyrite+ marcasite; teal circles represent samples with pyrite+ marcasite+ galena± sphalerite; the yellow circle represents one sample with minor cinnabar peaks. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

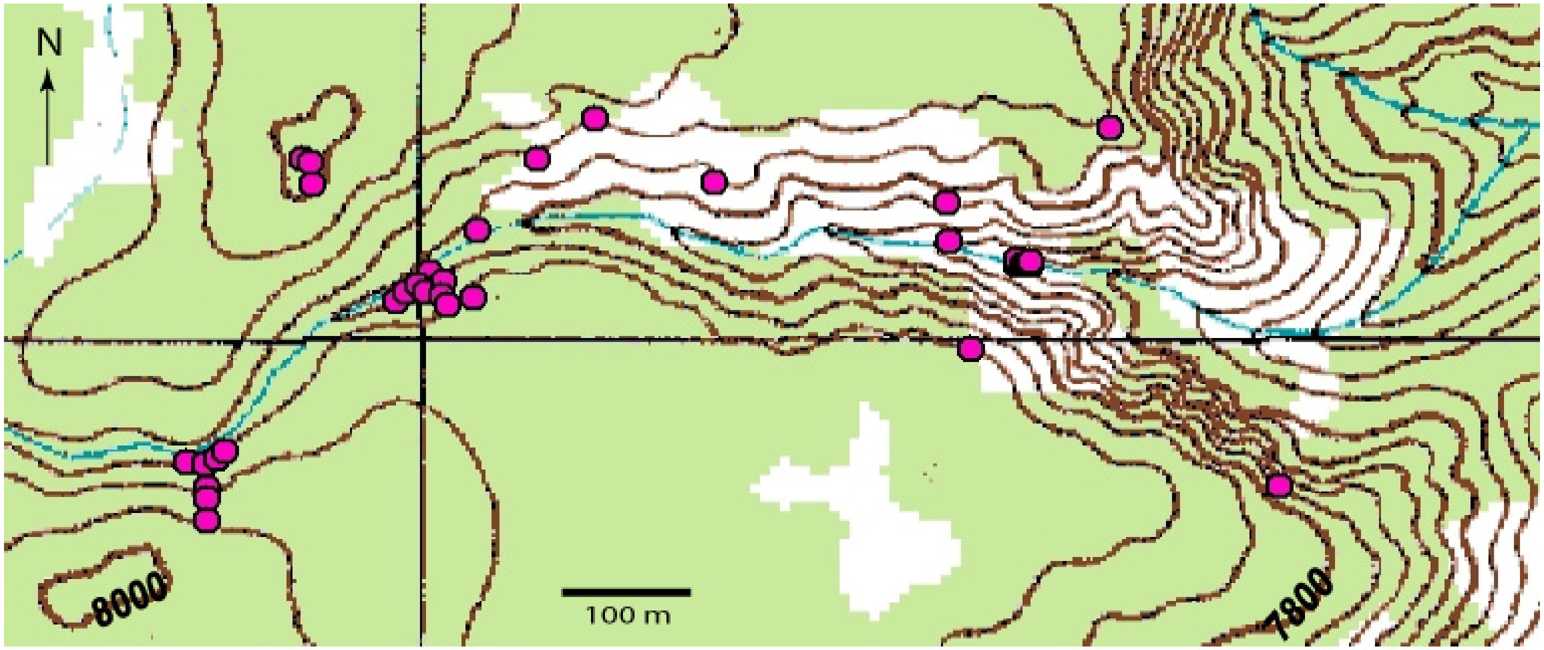


Figure I-35: Distribution map of all XRD samples representing Mineral Assemblage 1. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

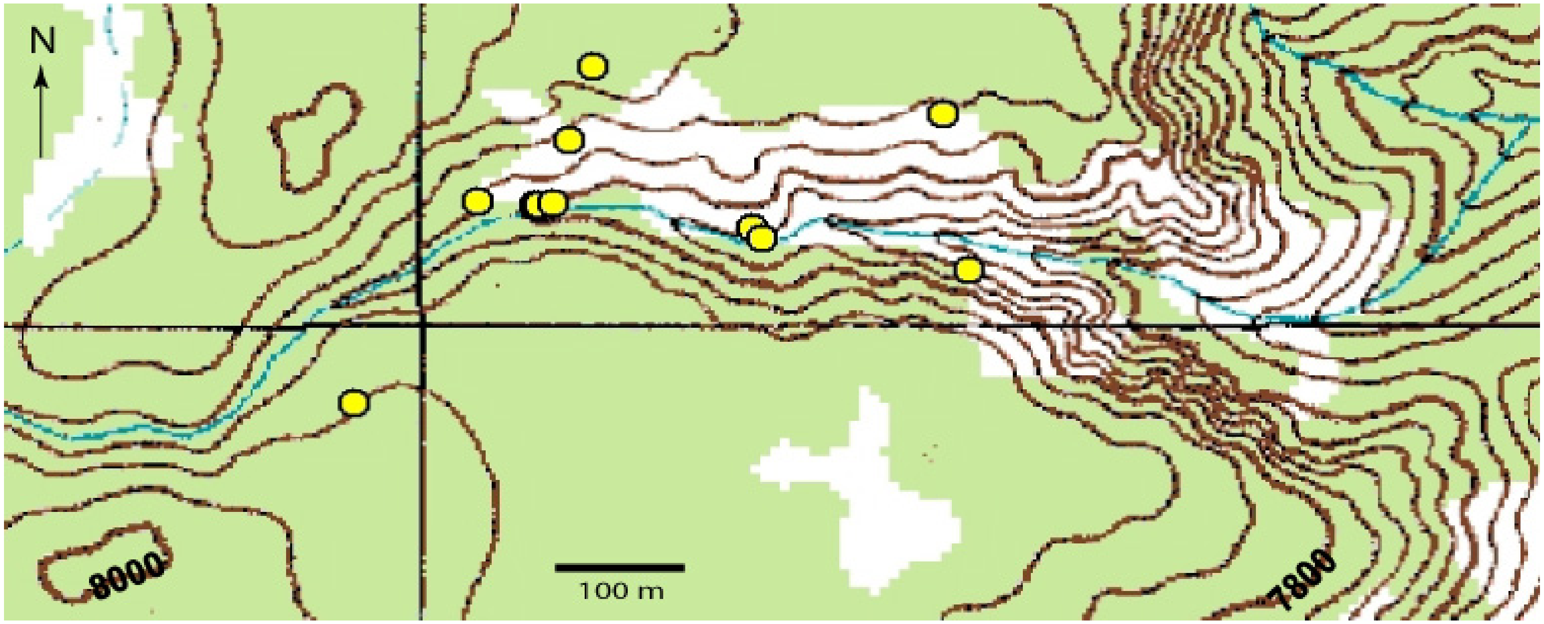


Figure I-36: Distribution map of all XRD samples representing Mineral Assemblage 2. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

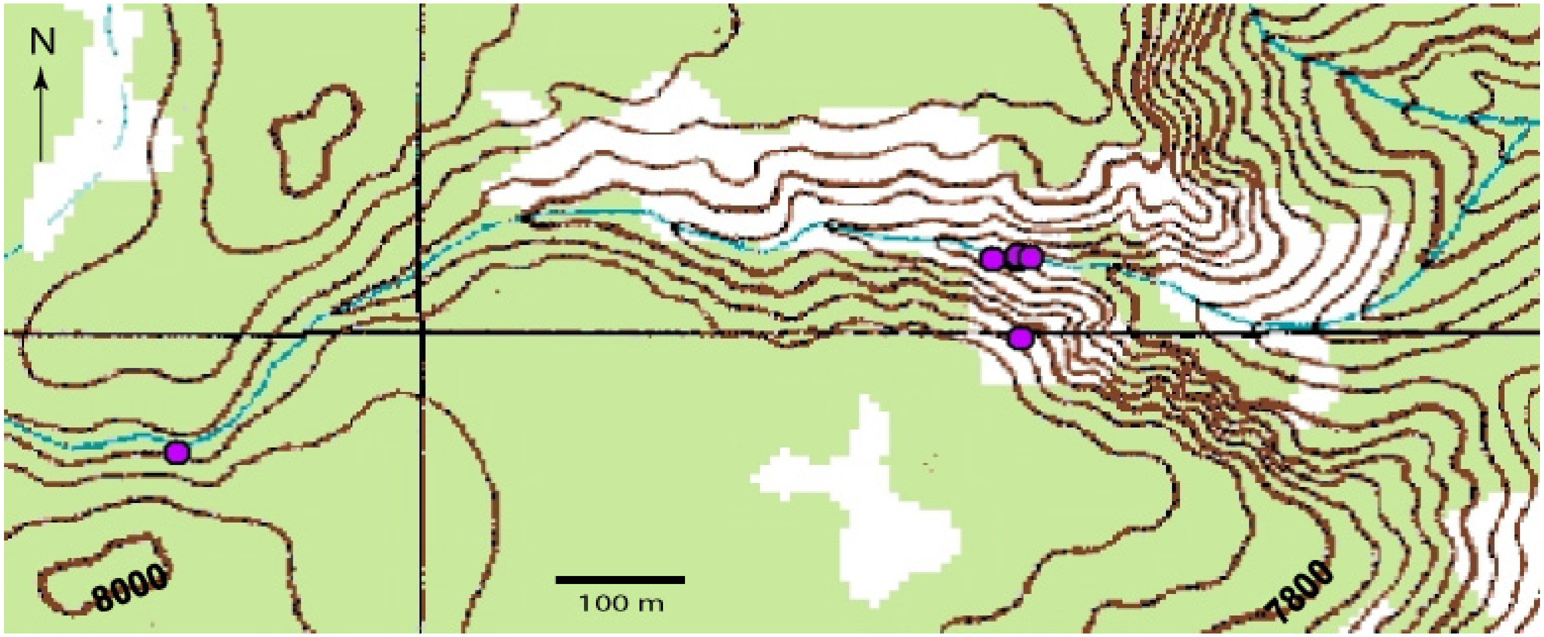


Figure I-37: Distribution map of all XRD samples representing Mineral Assemblage 3. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

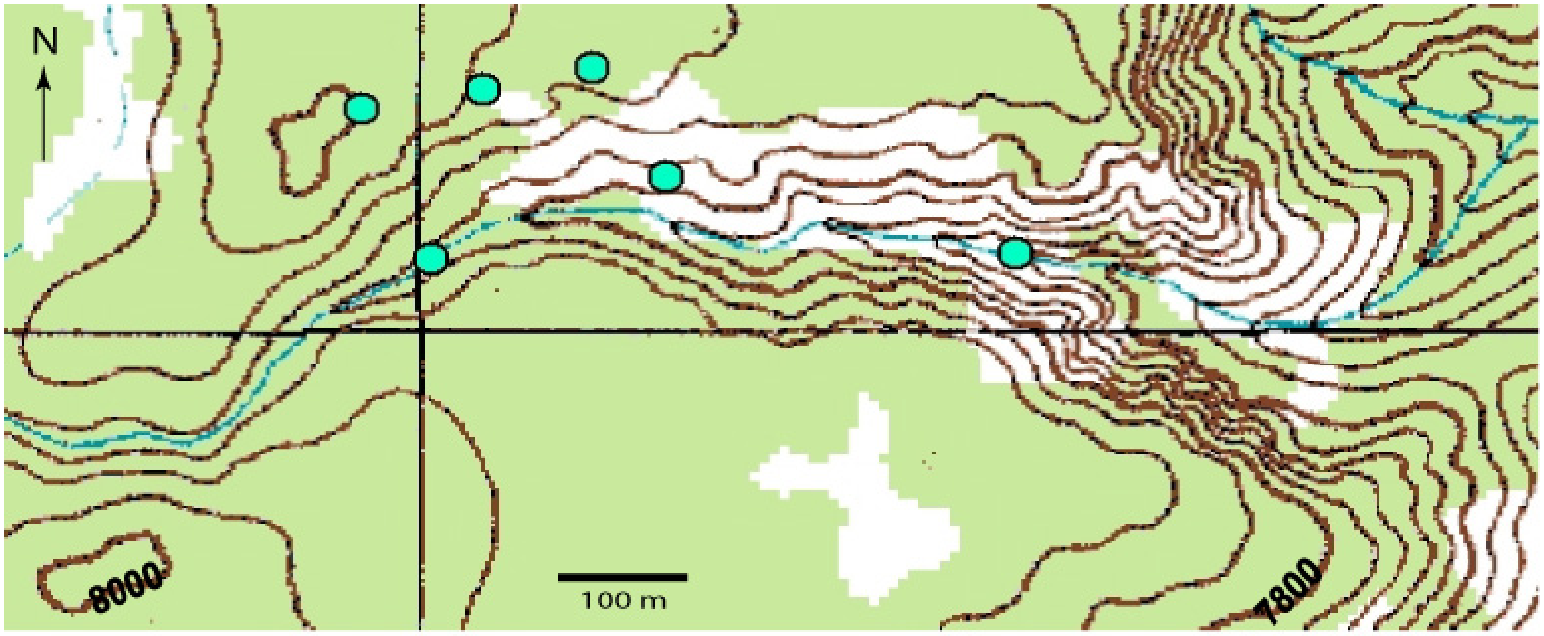


Figure I-38: Distribution map of all XRD samples representing Mineral Assemblage 4. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

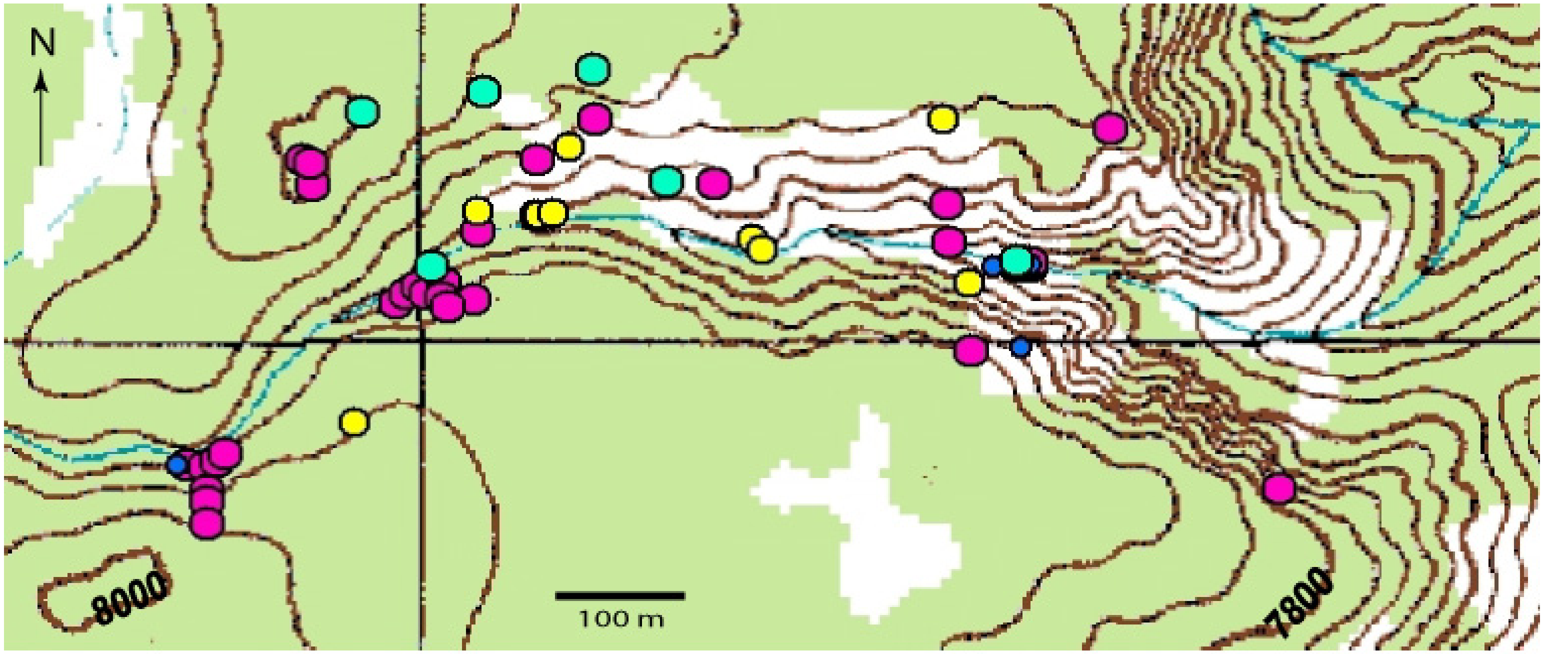


Figure I-39: Distribution map of XRD samples representing all four Mineral Assemblages. Pink circles represent samples in Mineral Assemblage 1; yellow circles represent samples in Mineral Assemblage 2; blue circles represent samples in Mineral Assemblage 3; teal circles represent samples in Mineral Assemblage 4. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Appendix II:
Active thermal areas,
Veins, and
Structures

Sample Label	Long(UTM)	Lat (UTM)	Location	Direction	Strike	Notes
Thermal 1	545080.4	4956096.1	Stream			
Thermal 2	545104.6	4956100.4	North wall-25 ft east T1			
Thermal 3	545118.9	4956101.8	North wall-10ft east T2	From 3 to 10	230	T3
Thermal 4	545136	4956100.4	Heading East			
Thermal 5	545143.1	4956107.5	North wall			
Thermal 6	545154.5	4956090.4	South wall			
Thermal 7	545168.8	4956097.6	Stream			
Thermal 8	545177.7	4956083.5	South wall			"Actively Steaming"
Thermal 9	545200.1	4956096.1	North wall	From 9 to 8	245	T9; Sulfur crystals; thermal area
Thermal 10	545129.2	4956093.2	South wall	From 10 to 3	140	T3
Thermal 11	545804	4956151	Stream-west of Confluence	From 11-12	156	T11
Thermal 12	545804.4	4956158.9	Stream-8.8ft east T-11			
Thermal 13	545806.8	4956163.1	Stream-16.6ft east T-11	Same trend as 11-12		
Thermal 14	545795.9	4956139.0	Stream-7ft west T-11	Same trend as 11-12		
Thermal 15	545766.1	4956097.1	Stream-30ft west T-11			
Thermal 16	545754.4	4956071.9	Stream-36ft west T-11; 6ft west T-15	From 16 to 11	215	T16
Thermal 17	545744.7	4956061.2	Stream-40ft west T-11	Same trend as 16 - 11		
Thermal 18	545699.1	4956022.4	Stream			
Thermal 19	545649.1	4956007.9	Stream			
Thermal 20	545619.1	4956007.9	Stream-30ft west T-19	From 19 to 20	85	T19
Thermal 21	545576.4	4956015.1	South wall			Tall green active spire
Thermal 22	545529.2	4956045.8	North wall			

Table II-1: Location of active thermal areas in the south fork of Sulphur Creek canyon.
Strike is in azimuth.

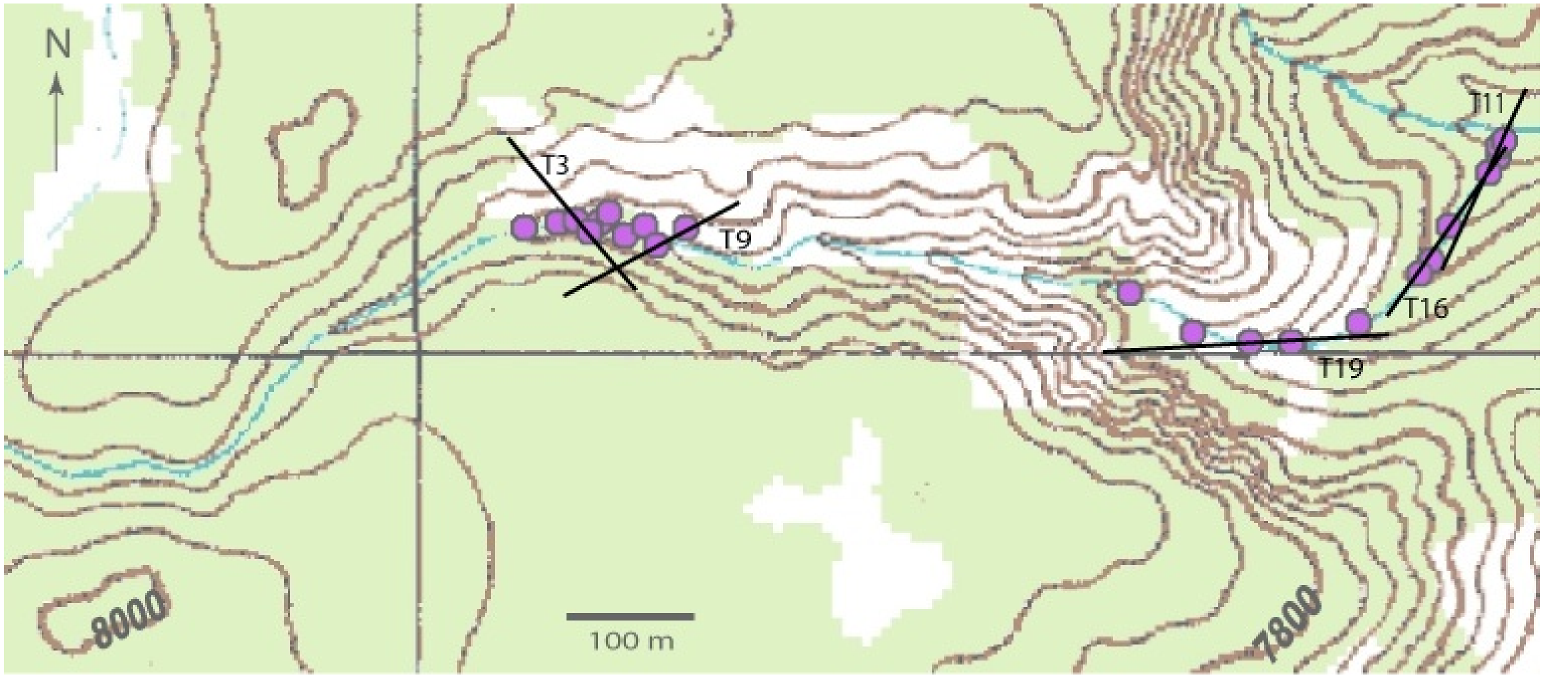


Figure II-1: Distribution map of active thermal areas in field area. Strikes are noted in Table II-1. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Sample Label	Long(UTM)	Lat (UTM)	Location	Strike	Dip	Notes
Vein 1	545118.9	4956101.8	North Wall	345	85E	V1a; Veining Zone
	"	"	"	326	86E	V1b
	"	"	"	291	79NE	V1c
Vein 2	545129.2	4956100.1	North Wall	342	72W	V2; Vertical Silica veins
Vein 3a	545699.1	4956022.4	Stream	105	--	V3a
Vein 3b	545691.3	4956016.6	Stream	110	--	V3b
Vein 4	545628.2	4956007.9	Between T20 and 21	--	--	
Vein 5	545593.2	4956014.7	West of T-21	115	--	V5; Large Sulfide Vein
Vein 6	545582.6	4956019.6	Stream	270	--	V6a; Large Dendritic Sulfide veins
	"	"	"	275	--	V6b
	"	"	"	35	--	V6c
Vein 7	545388.4	4956075.9	Stream	23	--	V7; Sulfide Vein

Table II-2: Location of veins in the south fork of Sulphur Creek canyon.
Strike is in azimuth.

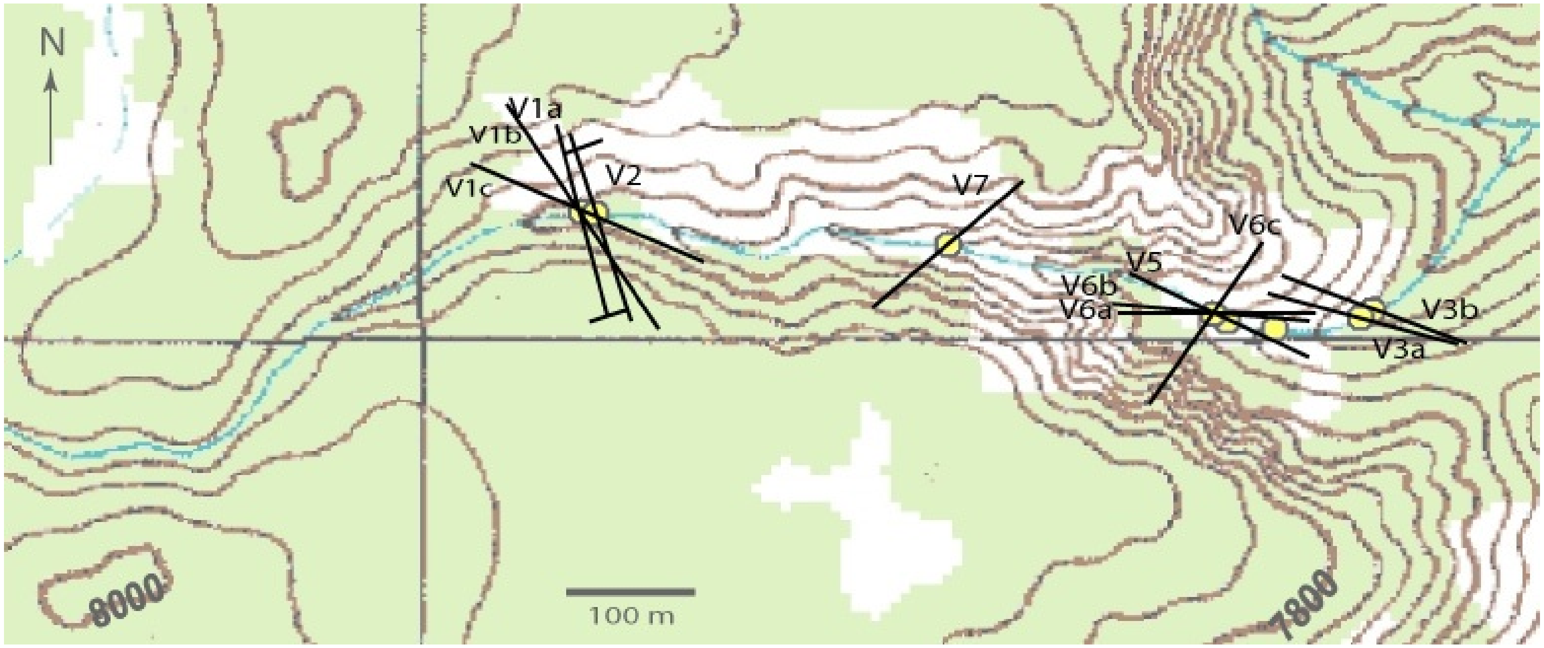


Figure II-2: Distribution map of some veining. Strikes and dips are noted in Table II-2. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Sample Label	Long(UTM)	Lat (UTM)	Location	Strike	Notes
Structure 1	545292.3	4956090.4	Stream	233	S1a; 4 fracture sets (some vein filling)
	"	"	"	355	S1b
	"	"	"	292	S1c
	"	"	"	305	S1d
Structure 2	545712.7	4956029.3	Btw T17 and 18	120	S2a; Veining in Stream bed
	"	"	Stream	110	S2b
	"	"	"	175	S2c
Structure 3	545676.7	4956010.8	Btw T18 and 19	145	S3a; Sulfide Veins
	"	"	Stream	45	S3b; Intersects 145NS
Structure 4	545582.6	4956019.6	Stream	275	S4a; Brx veins in Stream
	"	"	"	35	S4b
Structure 5	545388.4	4956075.9	Stream to South wall	260	S5; Propogating structure (V7)
Structure 6	545576.4	4956015.1	Stream to South wall	70	S6; Lineation to 3rd spire; begins at T21
Structure 7	545529.2	4956045.8	Stream to South wall	205	S7; begins at T22

Table II-3: Location of stuctures in the south fork of Sulphur Creek canyon.
Strike is in azimuth.

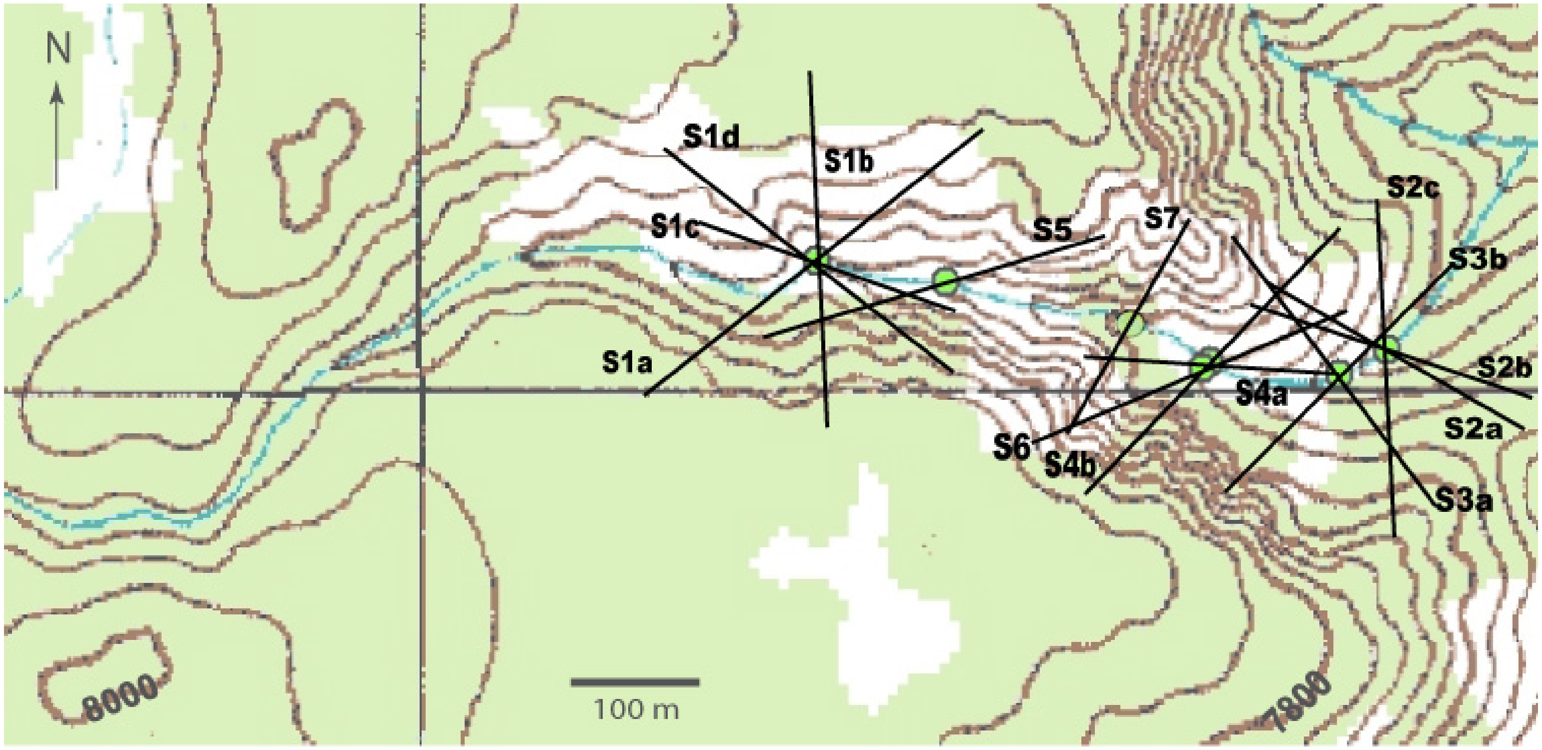


Figure II-3: Distribution map of some structures. Strikes are noted in Table II-3. Inset from USGS 1:24,000 topographic map of Mount Washburn Quadrangle (1986). Crosshairs intersect at 545000 and 4956000 (UTM). Contour interval 40 feet.

Appendix III:
Results

Sample	Outcrop	Thin Section	XRF/ICP	XRD	SI	Picture
YS-08-JM23	Outcrop 1	X	X	X		X
YS-08-JM24	Outcrop 1	X		X		X
YS-08-JM27	Outcrop 1	X		X		X
YS-08-JM28	Outcrop 1	X		X		X
YS-08-JM31	Outcrop 1	X		X		X
YS-08-JM32	Outcrop 1			X		X
YS-08-JM35	Outcrop 1	X		X		X
YS-08-JM59	Outcrop 2	X		X	X	X
YS-08-JM61	Outcrop 2			X		
YS-08-JM62	Outcrop 2	X	X	X		X
YS-08-JM36	Outcrop 3		X	X		X
YS-08-JM37	Outcrop 3			X		X
YS-08-JM38	Outcrop 3	X	X	X	X	X
YS-08-JM39	Outcrop 3			X	X	X
YS-08-JM42	Outcrop 3	X	X	X	X	X
YS-08-JM43	Outcrop 3		X	X		X
YS-08-JM44	Outcrop 3	X	Assay	X		X
YS-08-JM45	Outcrop 3			X		X
YS-08-JM130	Outcrop 3	X	X	X		X
YS-08-JM78	Outcrop 4A	X	Assay		X	X
YS-08-JM81	Outcrop 4A			X		X
YS-08-JM82	Outcrop 4A		X	X		X
YS-08-JM70	Outcrop 4B	X	X	X		X
YS-08-JM72	Outcrop 4B	X				X
YS-08-JM74	Outcrop 4B	X	X	X		X
YS-08-JM83	Outcrop 4B		X	X	X	X
YS-08-JM85	Outcrop 4B	X	X	X	X	X
YS-08-JM86	Outcrop 4B			X		X
YS-08-JM89	Outcrop 4B		X	X		X
YS-08-JM136	Outcrop 4B	X		X		X
YS-08-JM137	Outcrop 4B	X	X	X		X
YS-08-JM17	Outcrop 4C	X	X	X		X
YS-08-JM22	Outcrop 4C	X	X	X		X
YS-08-JM112	Outcrop 4C	X				X
YS-08-JM113	Outcrop 4C				X	X
YS-08-JM115	Outcrop 4C		X	X		X
YS-08-JM117	Outcrop 4C		X	X		X
YS-08-JM140	Outcrop 4C	X				X
YS-08-JM142	Outcrop 4C	X				X
YS-08-JM155#2	Outcrop 4C	X	Assay	X		X
YS-08-JM155#3	Outcrop 4C	X		X		X
YS-08-JM156	Outcrop 4C		X	X		X
YS-08-JM77	Outcrop 5				X	X
YS-08-JM97	Outcrop 6	X	X	X		X
YS-08-JM98	Outcrop 6	X			X	X
YS-08-JM107	Outcrop 6	X	X	X		X
YS-08-JM04	Outcrop 7		X	X		X
YS-08-JM08	Outcrop 7		X	X		X
YS-08-JM09	Outcrop 7	X			X	X
YS-08-JM11	Outcrop 7	X				X
YS-08-JM12	Outcrop 7				X	X
YS-08-JM13	Outcrop 7	X	X	X	X	X
YS-08-JM20	Stream	X	Assay		X	X
YS-08-JM21	Stream	X	Assay			X
YS-08-JM116	Stream	X				X
YS-08-JM118	Stream	X	X			X
YS-08-JM120A	Stream				X	X
YS-08-JM149	Stream	X	Assay	X		X
YS-08-JM150	Stream			X	X	X
YS-08-JM151	Stream			X		
YS-08-JM152	Stream	X	X	X		X
YS-08-JM153	Stream			X	X	X
YS-08-JM154	Stream			X		
YS-08-JM155#1	Stream			X		
YS-08-JM121	South Ridge	X	X	X		X
YS-08-JM124	South Ridge				X	X
YS-08-JM128	South Ridge			X	X	X
YS-07-JM02	South Ridge	X	X	X		X
YS-07-JM05	South Ridge	X	X	X	X	X
YS-08-JM123	South Ridge	X				X
YS-08-JM125	South Ridge				X	X
YS-08-JM131	South Ridge			X		
YS-08-JM132	South Ridge			X		X
YS-08-JM133	North Ridge	X	X	X	X	X
YS-08-JM144	NR/OC4C		X	X		X
YS-08-JM145	NR/OC4C	X				X
YS-08-JM135	North Ridge			X		
YS-08-JM146	North Ridge		X	X		X

Table III-1a: Samples used for analyses (arranged by outcrop).

Sample	Outcrop	Thin Section	XRF/ICP	XRD	SI	Picture
YS-07-JM02	South Ridge	X	X	X		X
YS-07-JM05	South Ridge	X	X	X	X	X
YS-08-JM04	Outcrop 7		X	X		X
YS-08-JM08	Outcrop 7		X	X		X
YS-08-JM09	Outcrop 7	X			X	X
YS-08-JM11	Outcrop 7	X				X
YS-08-JM12	Outcrop 7				X	X
YS-08-JM13	Outcrop 7	X	X	X	X	X
YS-08-JM17	Outcrop 4C	X	X	X		X
YS-08-JM20	Stream	X	Assay		X	X
YS-08-JM21	Stream	X	Assay			X
YS-08-JM22	Outcrop 4C	X	X	X		X
YS-08-JM23	Outcrop 1	X	X	X		X
YS-08-JM24	Outcrop 1	X		X		X
YS-08-JM27	Outcrop 1	X		X		X
YS-08-JM28	Outcrop 1	X		X		X
YS-08-JM31	Outcrop 1	X		X		X
YS-08-JM32	Outcrop 1			X		X
YS-08-JM35	Outcrop 1	X		X		X
YS-08-JM36	Outcrop 3		X	X		X
YS-08-JM37	Outcrop 3			X		X
YS-08-JM38	Outcrop 3	X	X	X	X	X
YS-08-JM39	Outcrop 3			X	X	X
YS-08-JM42	Outcrop 3	X	X	X	X	X
YS-08-JM43	Outcrop 3		X	X		X
YS-08-JM44	Outcrop 3	X	Assay	X		X
YS-08-JM45	Outcrop 3			X		X
YS-08-JM59	Outcrop 2	X		X	X	X
YS-08-JM61	Outcrop 2			X		
YS-08-JM62	Outcrop 2	X	X	X		X
YS-08-JM70	Outcrop 4B	X	X	X		X
YS-08-JM72	Outcrop 4B	X				X
YS-08-JM74	Outcrop 4B	X	X	X		X
YS-08-JM77	Outcrop 5				X	X
YS-08-JM78	Outcrop 4A	X	Assay		X	X
YS-08-JM81	Outcrop 4A			X		X
YS-08-JM82	Outcrop 4A		X	X		X
YS-08-JM83	Outcrop 4B		X	X	X	X
YS-08-JM85	Outcrop 4B	X	X	X	X	X
YS-08-JM86	Outcrop 4B			X		X
YS-08-JM89	Outcrop 4B		X	X		X
YS-08-JM97	Outcrop 6	X	X	X		X
YS-08-JM98	Outcrop 6	X			X	X
YS-08-JM107	Outcrop 6	X	X	X		X
YS-08-JM112	Outcrop 4C	X				X
YS-08-JM113	Outcrop 4C				X	X
YS-08-JM115	Outcrop 4C		X	X		X
YS-08-JM116	Stream	X				X
YS-08-JM117	Outcrop 4C		X	X		X
YS-08-JM118	Stream	X	X			X
YS-08-JM120A	Stream				X	X
YS-08-JM121	South Ridge	X	X	X		X
YS-08-JM123	South Ridge	X				X
YS-08-JM124	South Ridge				X	X
YS-08-JM125	South Ridge				X	X
YS-08-JM128	South Ridge			X	X	X
YS-08-JM130	Outcrop 3	X	X	X		X
YS-08-JM131	South Ridge			X		
YS-08-JM132	South Ridge			X		X
YS-08-JM133	North Ridge	X	X	X	X	X
YS-08-JM135	North Ridge			X		
YS-08-JM136	Outcrop 4B	X		X		X
YS-08-JM137	Outcrop 4B	X	X	X		X
YS-08-JM140	Outcrop 4C	X				X
YS-08-JM142	Outcrop 4C	X				X
YS-08-JM144	NR/OC4C		X	X		X
YS-08-JM145	NR/OC4C	X				X
YS-08-JM146	North Ridge		X	X		X
YS-08-JM149	Stream	X	Assay	X		X
YS-08-JM150	Stream			X	X	X
YS-08-JM151	Stream			X		
YS-08-JM152	Stream	X	X	X		X
YS-08-JM153	Stream			X	X	X
YS-08-JM154	Stream			X		
YS-08-JM155#1	Stream			X		
YS-08-JM155#2	Outcrop 4C	X	Assay	X		X
YS-08-JM155#3	Outcrop 4C	X		X		X
YS-08-JM156	Outcrop 4C		X	X		X

Table III-1b: Samples used for analyses (arranged by sample number).

Sample	SiO2 (%)	Al2O3 (%)	FeO (%)	MgO (%)	CaO (%)	Na2O (%)	K2O (%)	TiO2 (%)	P2O5 (%)	MnO (%)	SO3 (%) >/=	Cl (%) >/=
YS-08-JM23	79.87	14.24	0.45	0.03	0.10	0.66	4.28	0.288	0.076	0.002	5.36	0.01
YS-08-JM36	97.76	1.51	0.14	0.00	0.07	0.02	0.13	0.331	0.036	0.002	0.04	0.01
YS-08-JM38	91.92	3.44	2.03	0.01	0.04	0.05	2.41	0.080	0.010	0.002	0.03	0.01
YS-08-JM38*	97.74	1.51	0.14	0.00	0.07	0.03	0.13	0.335	0.037	0.002	0.06	0.01
YS-08-JM42	80.42	14.69	0.36	0.00	0.04	0.30	3.89	0.258	0.042	0.002	5.88	0.01
YS-08-JM43	77.17	15.33	0.36	0.00	0.02	0.06	6.62	0.383	0.046	0.001	5.15	0.01
YS-08-JM130	98.10	1.32	0.09	0.00	0.06	0.03	0.07	0.304	0.013	0.002	0.05	0.01
YS-08-JM62	98.99	0.45	0.03	0.03	0.02	0.13	0.11	0.227	0.011	0.002	0.00	0.01
YS-08-JM133	99.59	0.18	0.04	0.00	0.01	0.03	0.06	0.102	0.005	0.002	0.07	0.01
YS-08-JM82	98.52	0.66	0.26	0.00	0.02	0.00	0.20	0.315	0.024	0.001	0.04	0.01
YS-08-JM70	89.49	8.28	0.79	0.00	0.02	0.04	1.16	0.203	0.017	0.001	2.65	0.01
YS-08-JM74	78.03	16.64	0.08	0.00	0.02	0.36	4.44	0.339	0.098	0.001	5.82	0.01
YS-08-JM83	92.57	3.40	1.59	0.00	0.10	0.17	1.82	0.277	0.056	0.002	1.07	0.01
YS-08-JM85	93.12	3.50	1.20	0.00	0.05	0.13	1.88	0.116	0.011	0.002	0.49	0.01
YS-08-JM89	98.37	0.88	0.26	0.00	0.04	0.00	0.06	0.370	0.022	0.001	0.12	0.01
YS-08-JM137	71.67	21.59	0.84	0.00	0.01	0.32	5.15	0.385	0.036	0.001	5.73	0.01
YS-08-JM97	82.45	11.65	0.19	0.00	0.06	0.56	4.77	0.298	0.024	0.001	2.97	0.01
YS-08-JM107	72.63	22.98	0.19	0.00	0.04	0.08	3.60	0.458	0.034	0.001	5.18	0.01
YS-08-JM22	79.84	15.33	0.33	0.00	0.06	0.58	3.55	0.283	0.025	0.001	4.61	0.01
YS-08-JM115	63.65	26.18	2.10	0.00	0.02	0.24	7.24	0.474	0.084	0.001	6.15	0.01
YS-08-JM117	93.38	3.76	0.04	0.00	0.09	0.88	1.55	0.290	0.021	0.001	0.12	0.01
YS-08-JM144	98.07	0.71	0.08	0.02	0.04	0.19	0.20	0.645	0.040	0.002	0.06	0.01
YS-08-JM146	79.35	12.26	0.45	0.01	0.22	2.44	4.81	0.422	0.022	0.007	0.08	0.02
YS-08-JM156	78.82	12.38	0.42	0.00	0.26	2.74	5.08	0.277	0.028	0.001	0.08	0.01
YS-08-JM04	89.17	7.84	0.04	0.00	0.01	0.12	2.23	0.530	0.059	0.001	4.88	0.01
YS-08-JM08	80.75	12.38	1.12	0.02	0.18	1.64	3.60	0.286	0.027	0.001	0.06	0.01
YS-08-JM13	70.66	21.19	0.72	0.00	0.09	0.86	6.07	0.384	0.032	0.001	5.82	0.01
YS-08-JM17	78.79	12.56	0.36	0.02	0.26	2.48	5.26	0.239	0.021	0.001	0.05	0.01
YS-08-JM121	92.08	6.67	0.07	0.01	0.03	0.16	0.51	0.429	0.046	0.001	2.45	0.02
YS-07-JM02	80.76	12.69	0.57	0.00	0.11	1.32	4.17	0.348	0.023	0.003	3.20	0.01
YS-07-JM05	98.27	0.76	0.29	0.00	0.01	0.10	0.10	0.455	0.021	0.001	0.00	0.01

Table III-2: XRF major and minor element analyses, normalized to oxides. Concentrations in weight percent.

* Repeat bead

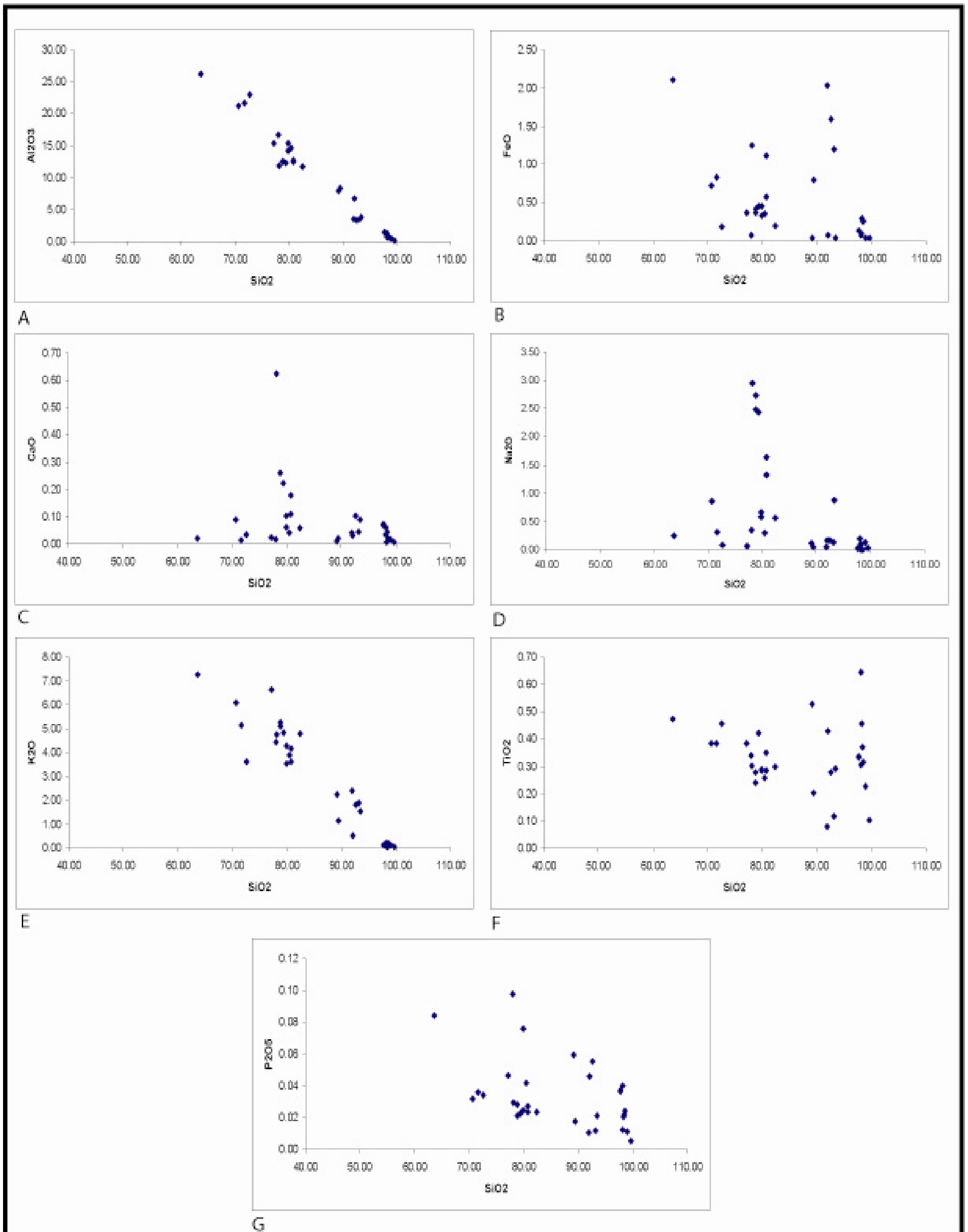


Figure III-1: Major and minor elements plotted against SiO_2. Units in weight percent.

Sample	La (ppm)	Ce (ppm)	Nd (ppm)	Ba (ppm)	Th (ppm)	Nb (ppm)	Y (ppm)	U (ppm)	Pb (ppm)	Rb (ppm)	Cs (ppm)	Sr (ppm)	Sc (ppm)	Zr (ppm)	Ni (ppm)	Cr (ppm)	V (ppm)	Ga (ppm)	Cu (ppm)	Zn (ppm)
YS-08-JM23	60.30	95.60	35.60	701.90	19.70	36.20	40.60	5.90	34.00	56.20	9.60	111.90	5.30	267.80	4.10	7.80	6.20	28.30	1.00	10.80
YS-08-JM36	32.70	50.60	17.00	243.30	26.70	54.70	17.10	8.00	22.40	6.70	4.40	68.40	4.10	380.20	1.60	7.20	6.30	13.50	0.00	0.00
YS-08-JM38	12.70	26.50	14.40	248.10	3.40	5.80	8.90	4.90	5.30	105.40	6.00	22.70	2.10	68.60	3.10	11.40	8.30	7.90	3.40	6.90
YS-08-JM38*	32.20	52.50	15.70	253.10	27.10	55.20	16.90	9.20	23.30	6.90	4.60	69.00	4.30	385.50	1.40	7.80	7.10	13.00	0.70	1.30
YS-08-JM42	23.80	45.80	17.00	1446.60	23.20	31.50	19.50	9.50	24.00	81.30	6.50	37.40	4.70	237.20	6.20	12.70	8.60	13.80	0.90	1.30
YS-08-JM43	34.40	43.30	17.50	1213.50	24.70	65.70	28.00	8.90	41.10	105.60	0.00	44.00	5.10	429.30	2.10	15.90	32.70	71.10	2.30	0.00
YS-08-JM130	10.30	23.30	10.20	552.00	22.90	51.80	16.60	8.10	5.30	5.40	5.20	21.50	3.60	330.00	0.20	5.80	4.70	2.70	0.00	0.00
YS-08-JM62	4.70	0.00	1.20	72.70	5.40	39.60	6.80	1.50	0.90	7.50	3.60	16.20	1.20	228.50	1.40	7.20	5.30	9.10	0.00	1.10
YS-08-JM133	4.80	4.90	3.00	107.90	2.90	19.40	2.50	0.00	1.70	4.00	2.70	11.20	0.60	120.10	1.10	15.40	5.80	4.30	0.40	0.00
YS-08-JM82	34.80	60.60	23.30	277.50	23.10	59.30	37.50	6.40	11.80	11.50	4.20	22.30	5.70	312.70	0.70	6.30	10.20	5.10	1.50	7.00
YS-08-JM70	16.10	28.80	8.30	1120.30	13.50	29.70	11.90	3.00	28.70	5.10	0.00	30.80	3.90	222.00	2.20	5.10	4.40	13.30	4.60	2.00
YS-08-JM74	96.60	151.30	49.10	608.20	28.10	43.10	15.80	5.40	24.90	13.60	2.70	188.20	6.50	319.40	1.60	6.80	7.40	19.70	2.50	2.10
YS-08-JM83	45.60	91.80	35.50	427.30	23.70	39.20	39.40	4.90	24.50	54.50	3.60	65.70	5.20	286.90	0.40	13.00	3.10	10.30	4.80	5.10
YS-08-JM85	33.20	57.70	19.70	259.20	11.90	17.40	11.90	4.50	15.40	90.00	5.70	18.30	3.30	149.80	0.00	11.60	3.50	6.20	5.00	1.60
YS-08-JM89	32.80	53.50	15.70	2751.00	25.40	58.60	42.40	6.80	25.30	2.90	2.40	41.30	3.70	393.60	2.30	5.90	3.70	0.50	4.90	0.00
YS-08-JM137	28.90	45.70	15.40	557.80	19.70	38.60	15.20	4.50	23.20	26.20	2.30	50.60	8.40	334.70	1.20	7.70	9.80	16.20	0.70	2.80
YS-08-JM97	44.10	79.70	28.00	916.70	25.60	44.50	17.10	4.60	25.00	130.70	2.60	30.90	3.10	308.40	6.10	2.60	5.40	12.90	1.20	0.40
YS-08-JM107	46.30	70.90	21.90	763.00	28.20	45.60	37.20	6.20	35.40	9.10	0.00	44.70	7.10	413.60	0.70	7.60	9.70	15.20	0.00	3.70
YS-08-JM22	26.80	52.80	20.50	675.20	17.50	40.50	25.20	7.60	29.40	38.80	0.00	34.70	7.50	287.80	1.80	5.60	9.80	18.90	0.10	1.80
YS-08-JM115	75.80	117.10	36.40	528.10	21.60	53.20	27.60	6.10	36.50	14.10	0.00	98.60	5.40	416.70	2.30	20.90	18.30	36.90	0.00	0.30
YS-08-JM117	50.90	104.10	45.80	821.20	31.10	49.60	42.10	7.00	34.20	48.30	1.10	24.50	3.20	334.30	0.00	1.90	2.50	5.00	0.00	0.00
YS-08-JM144	74.60	137.30	59.00	1484.40	35.80	67.00	54.50	11.70	39.40	5.30	2.30	67.60	4.00	598.60	0.70	8.20	5.40	3.10	0.30	0.50
YS-08-JM146	45.10	82.80	32.90	1118.70	32.20	53.60	37.20	6.50	28.20	161.20	3.70	35.80	3.20	462.70	2.50	5.90	9.10	26.10	0.60	8.30
YS-08-JM156	75.10	153.80	64.50	837.50	25.00	46.50	49.00	5.00	27.80	171.40	2.70	33.90	3.40	315.90	2.60	2.10	3.40	20.40	1.60	8.90
YS-08-JM04	60.70	106.90	35.30	1341.60	26.90	63.50	31.30	7.20	42.10	10.00	0.00	53.10	5.60	520.40	0.00	12.80	10.10	26.30	0.00	0.10
YS-08-JM08	58.30	114.50	42.70	663.80	21.60	42.40	45.70	4.50	34.80	119.40	7.00	32.40	5.70	288.30	6.30	11.20	11.20	16.80	3.10	9.50
YS-08-JM13	43.30	86.30	38.90	774.60	27.30	44.40	30.60	6.10	26.00	58.10	0.00	51.00	11.60	348.00	5.30	21.90	11.80	14.40	3.70	4.30
YS-08-JM17	60.50	119.70	50.20	801.00	26.30	45.30	24.50	5.70	25.60	175.10	2.30	32.80	3.20	285.80	4.10	4.90	6.40	18.30	0.00	9.00
YS-08-JM121	34.50	58.60	20.80	2203.30	20.00	106.90	42.30	11.70	26.20	17.70	10.30	104.60	10.40	829.80	21.30	42.20	22.70	47.40	2.50	2.00
YS-07-JM02	46.50	83.80	35.20	782.90	24.40	44.60	35.40	5.70	24.60	108.10	3.50	31.30	5.20	361.20	0.70	3.60	5.70	17.50	3.70	11.10
YS-07-JM05	25.10	45.00	17.90	1235.70	13.00	55.10	33.00	5.30	29.50	7.90	1.10	20.90	4.10	465.40	15.30	3.80	0.00	0.00	3.70	0.80

Table III-3: XRF trace element analyses

*Repeat bead

Sample	La (ppm)	Ce (ppm)	Pr (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Gd (ppm)	Tb (ppm)	Dy (ppm)	Ho (ppm)	Er (ppm)	Tm (ppm)	Yb (ppm)	Lu (ppm)	Ba (ppm)	Th (ppm)	Nb (ppm)	Y (ppm)	Hf (ppm)	Ta (ppm)	U (ppm)	Pb (ppm)	Rb (ppm)	Cs (ppm)	Sr (ppm)	Sc (ppm)	Zr (ppm)
YS-08-JM23	59.59	96.16	10.02	35.42	7.46	1.16	6.62	1.19	7.57	1.48	3.94	0.55	3.26	0.49	701	19.25	36.21	37.60	7.59	2.45	4.32	31.78	56.4	9.55	109	4.9	272
YS-08-JM23*	60.11	97.09	10.15	35.80	7.52	1.16	6.61	1.21	7.65	1.51	3.88	0.55	3.29	0.48	712	19.21	36.50	37.71	7.74	2.47	4.40	31.59	55.9	9.57	110	4.6	273
YS-08-JM36	60.11	97.09	10.15	35.80	7.52	1.16	6.61	1.21	7.65	1.51	3.88	0.55	3.29	0.48	712	19.21	36.50	37.71	7.74	2.47	4.40	31.59	55.9	9.57	110	4.6	273
YS-08-JM38	33.51	51.40	4.93	16.03	2.92	0.33	2.12	0.37	2.64	0.60	2.06	0.36	2.52	0.43	242	26.37	55.96	15.24	11.73	4.07	7.74	22.69	7.5	6.45	68	3.9	403
YS-08-JM38*	12.80	30.13	3.73	13.99	2.93	0.53	2.30	0.39	2.20	0.39	0.99	0.14	0.85	0.12	244	3.43	6.11	8.94	1.87	0.43	3.89	6.17	106.6	5.40	24	2.0	70
YS-08-JM42	34.51	50.79	5.00	16.03	3.47	0.57	4.15	0.98	7.36	1.59	4.53	0.68	4.31	0.65	2805	25.03	59.71	38.86	12.39	4.32	6.65	24.17	3.6	2.18	43	3.9	423
YS-08-JM43	27.96	53.18	5.55	18.24	3.63	0.43	3.07	0.56	3.69	0.78	2.35	0.38	2.41	0.39	1596	24.10	34.00	19.62	7.28	2.40	9.46	24.76	86.6	5.72	39	4.7	249
YS-08-JM130	33.15	49.79	5.26	18.51	4.05	0.68	3.90	0.74	4.99	1.13	3.51	0.57	3.79	0.62	1302	25.80	68.77	28.24	14.87	5.17	7.56	41.22	110.3	1.68	46	5.6	461
YS-08-JM62	11.55	21.68	2.53	9.15	2.08	0.21	1.96	0.41	2.90	0.64	2.03	0.33	2.30	0.38	567	22.22	54.00	15.06	10.24	3.78	4.82	4.54	5.6	6.41	22	3.3	352
YS-08-JM133	1.51	3.38	0.42	1.57	0.44	0.04	0.49	0.11	0.90	0.22	0.76	0.14	1.00	0.17	75	4.68	41.07	5.87	7.54	2.83	1.48	1.62	8.6	4.96	17	1.2	243
YS-08-JM82	3.81	6.89	0.64	1.79	0.22	0.02	0.23	0.05	0.38	0.10	0.35	0.06	0.44	0.08	111	3.45	20.53	2.65	4.04	1.93	0.78	1.58	5.4	2.09	13	0.3	124
YS-08-JM70	36.35	66.14	7.10	24.88	4.92	0.56	4.51	0.88	6.01	1.28	3.66	0.56	3.49	0.51	276	22.21	61.66	32.84	10.32	4.41	5.49	11.24	12.3	4.62	22	5.8	335
YS-08-JM74	18.10	30.89	3.09	9.95	1.92	0.35	1.75	0.32	2.14	0.46	1.44	0.24	1.62	0.25	1130	13.08	30.74	10.80	6.53	2.05	3.20	27.25	4.9	2.71	30	3.6	230
YS-08-JM83	94.28	150.04	15.66	48.79	8.52	1.37	6.04	0.84	4.07	0.69	1.83	0.30	2.02	0.33	610	26.54	42.84	14.07	9.19	2.99	5.16	23.86	14.3	0.88	182	6.9	312
YS-08-JM85	49.89	94.59	10.53	37.04	7.69	0.98	6.86	1.17	7.29	1.44	3.97	0.59	3.74	0.58	435	22.97	40.41	36.69	8.59	2.85	5.25	23.00	58.3	5.17	67	4.7	304
YS-08-JM89	34.08	59.29	5.97	19.49	3.42	0.50	2.60	0.41	2.31	0.49	1.39	0.23	1.55	0.26	268	11.81	18.54	11.19	4.55	1.37	2.66	14.91	94.1	5.93	19	3.0	158
YS-08-JM137	34.45	50.54	4.94	15.99	3.38	0.57	4.05	0.98	7.37	1.59	4.57	0.69	4.28	0.65	2799	24.43	59.86	38.56	12.35	4.31	6.50	24.21	3.5	2.21	42	4.3	421
YS-08-JM97	25.34	41.34	3.99	13.26	2.70	0.27	2.22	0.40	2.61	0.55	1.67	0.27	1.84	0.30	559	18.83	35.81	12.53	8.41	2.46	4.11	20.33	24.7	1.80	46	6.9	304
YS-08-JM107	45.07	82.29	8.82	29.80	5.57	1.09	4.32	0.74	4.37	0.83	2.23	0.34	2.28	0.36	937	25.53	45.84	16.46	9.40	3.18	5.80	24.40	133.9	3.64	31	3.5	319
YS-08-JM22	41.46	70.60	7.03	21.77	3.73	0.58	3.73	0.78	5.92	1.31	3.93	0.61	3.83	0.59	765	26.63	45.77	32.28	10.92	3.09	5.53	35.82	8.9	1.33	41	6.0	404
YS-08-JM115	27.14	50.03	5.81	21.18	4.53	0.58	3.99	0.69	4.35	0.90	2.54	0.40	2.68	0.42	674	17.47	40.39	23.50	8.39	2.87	6.65	25.57	38.7	1.03	35	7.7	288
YS-08-JM117	70.55	110.52	11.05	34.79	5.15	0.58	3.55	0.63	4.47	1.02	3.00	0.47	3.04	0.49	578	20.20	48.70	23.83	10.77	3.46	5.67	32.17	13.5	0.65	100	4.9	382
YS-08-JM144	50.00	109.68	12.80	48.00	10.28	1.17	8.79	1.36	7.77	1.53	4.23	0.64	4.11	0.67	844	31.25	50.55	38.85	10.44	3.54	6.75	33.54	51.2	1.09	25	2.7	353
YS-08-JM146	61.05	116.13	13.13	47.78	9.95	0.59	8.60	1.53	9.53	1.97	5.46	0.84	5.32	0.84	1244	34.41	66.41	48.31	16.93	4.57	11.40	34.60	5.6	0.56	64	3.4	626
YS-08-JM156	48.91	90.14	10.08	36.31	7.57	1.11	6.59	1.14	7.09	1.46	4.07	0.63	4.01	0.62	1141	32.93	54.46	35.97	13.09	3.77	6.44	27.97	164.1	4.61	37	3.7	479
YS-08-JM04	77.07	155.82	17.86	64.76	13.12	1.56	11.03	1.80	10.38	1.94	5.06	0.73	4.56	0.68	840	25.59	47.45	47.39	9.60	3.27	5.52	27.97	175.6	2.08	34	4.1	327
YS-08-JM08	61.73	108.19	11.02	35.95	5.85	0.66	4.14	0.78	5.33	1.18	3.56	0.56	3.67	0.60	1327	27.40	64.77	28.90	14.76	4.46	7.07	41.58	10.4	0.84	53	5.6	539
YS-08-JM13	58.20	118.12	12.41	44.88	9.23	1.44	8.20	1.39	8.51	1.68	4.61	0.68	4.30	0.66	666	21.20	42.63	43.03	8.74	2.96	5.54	36.25	121.0	2.92	33	5.3	297
YS-08-JM17	43.51	87.72	10.38	38.34	8.11	1.04	6.58	1.11	6.61	1.28	3.59	0.54	3.40	0.52	749	27.09	44.95	29.90	9.81	3.09	5.74	25.07	57.4	1.41	50	11.9	352
YS-08-JM121	63.20	125.32	14.70	52.47	10.27	1.33	7.44	1.13	6.11	1.08	2.82	0.42	2.63	0.41	810	26.66	44.94	23.49	9.12	3.22	5.93	27.13	177.4	2.42	33	3.2	294
YS-07-JM02	45.40	89.51	10.14	36.64	7.61	1.14	7.03	1.12	6.83	1.40	3.85	0.57	3.75	0.59	793	24.75	45.22	33.97	10.14	3.08	4.89	23.43	107.3	2.34	32	6.0	364
YS-07-JM05	26.93	50.30	5.50	18.90	3.54	0.30	3.26	0.67	4.91	1.12	3.36	0.53	3.55	0.59	1229	12.50	56.48	29.43	13.35	4.02	5.62	27.95	8.2	0.81	21	3.5	496

Table III-4: ICP-MS trace element analyses.

* Repeat bead

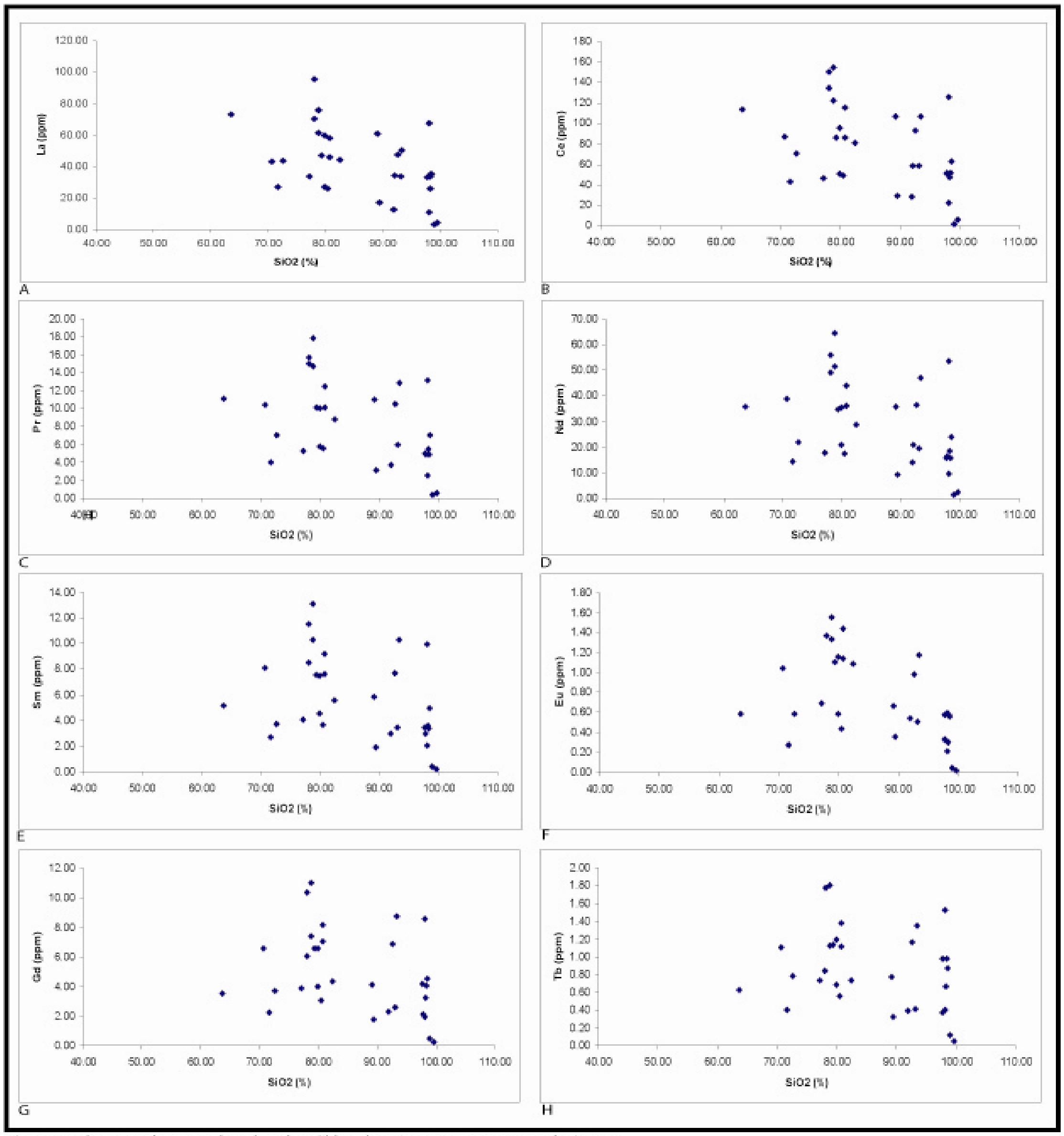


Figure III-2: Trace elements plotted against SiO_2. Plots A-H represent rare earth elements.

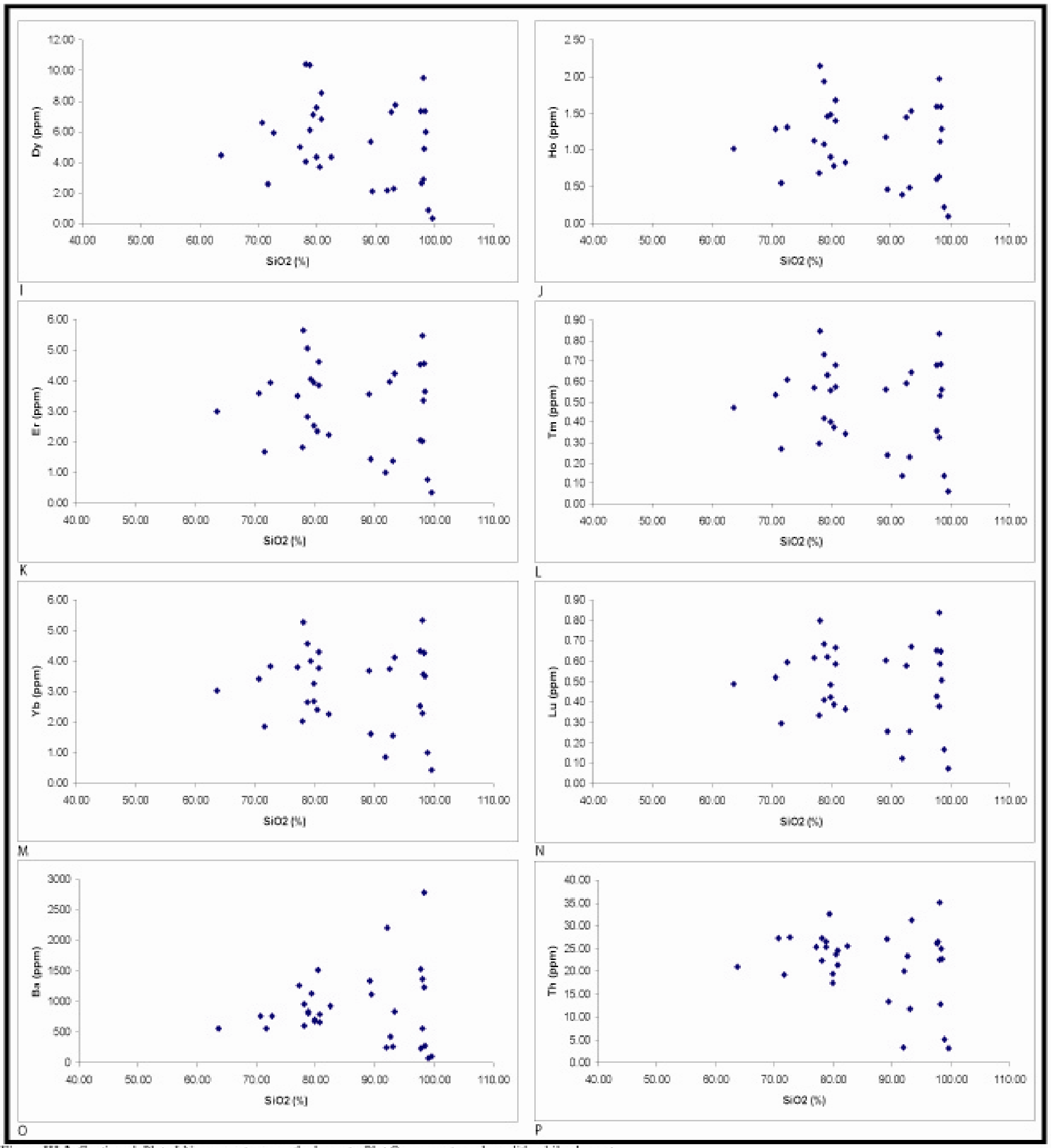


Figure III-2: Continued. Plots I-N represent rare earth elements. Plot O represents a large lithophile element.

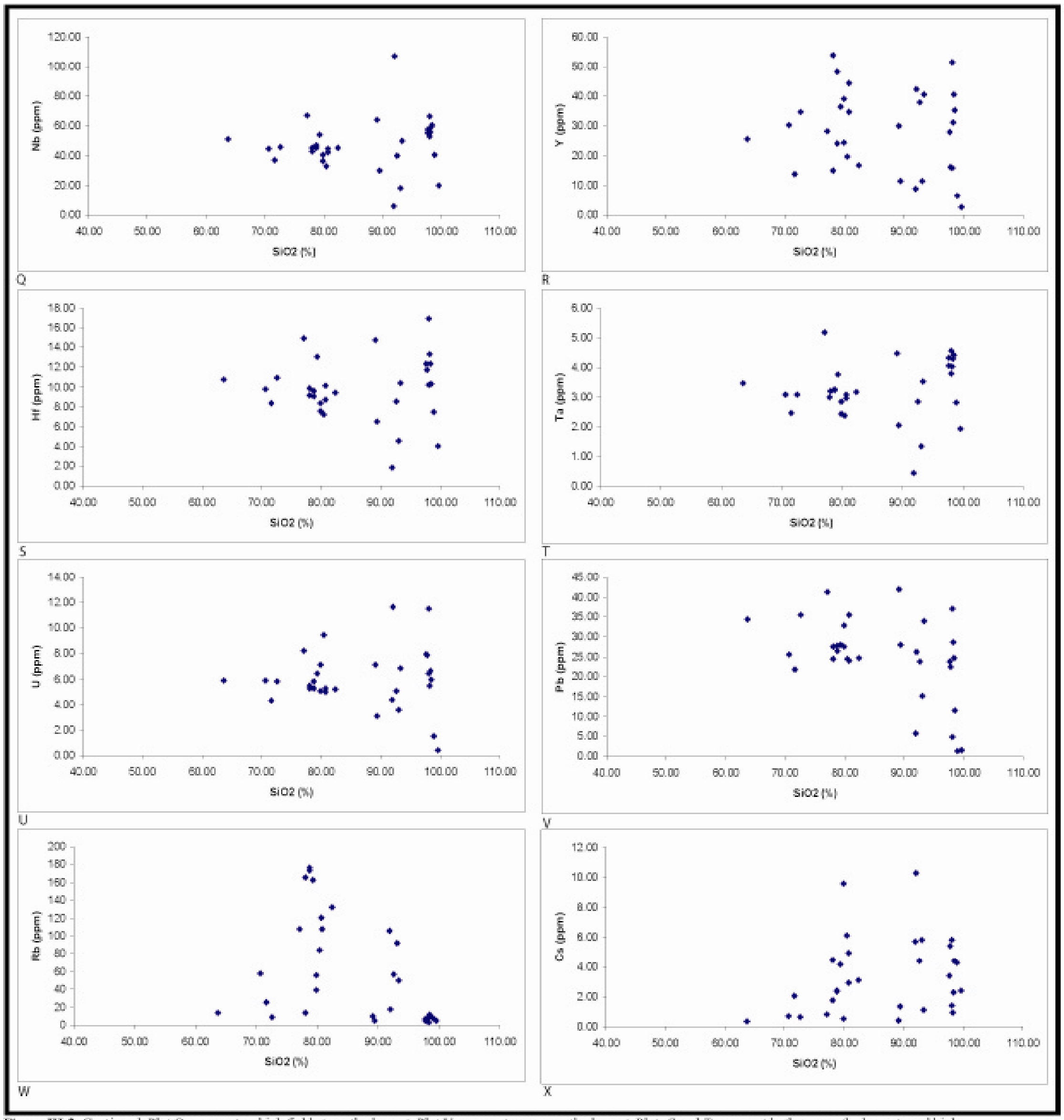


Figure III-2: Continued. Plot Q represents a high field strength element. Plot V represents a rare earth element. Plots S and T represent both rare earth elements and high field strength elements. Plots W and X represent large lithophile elements.

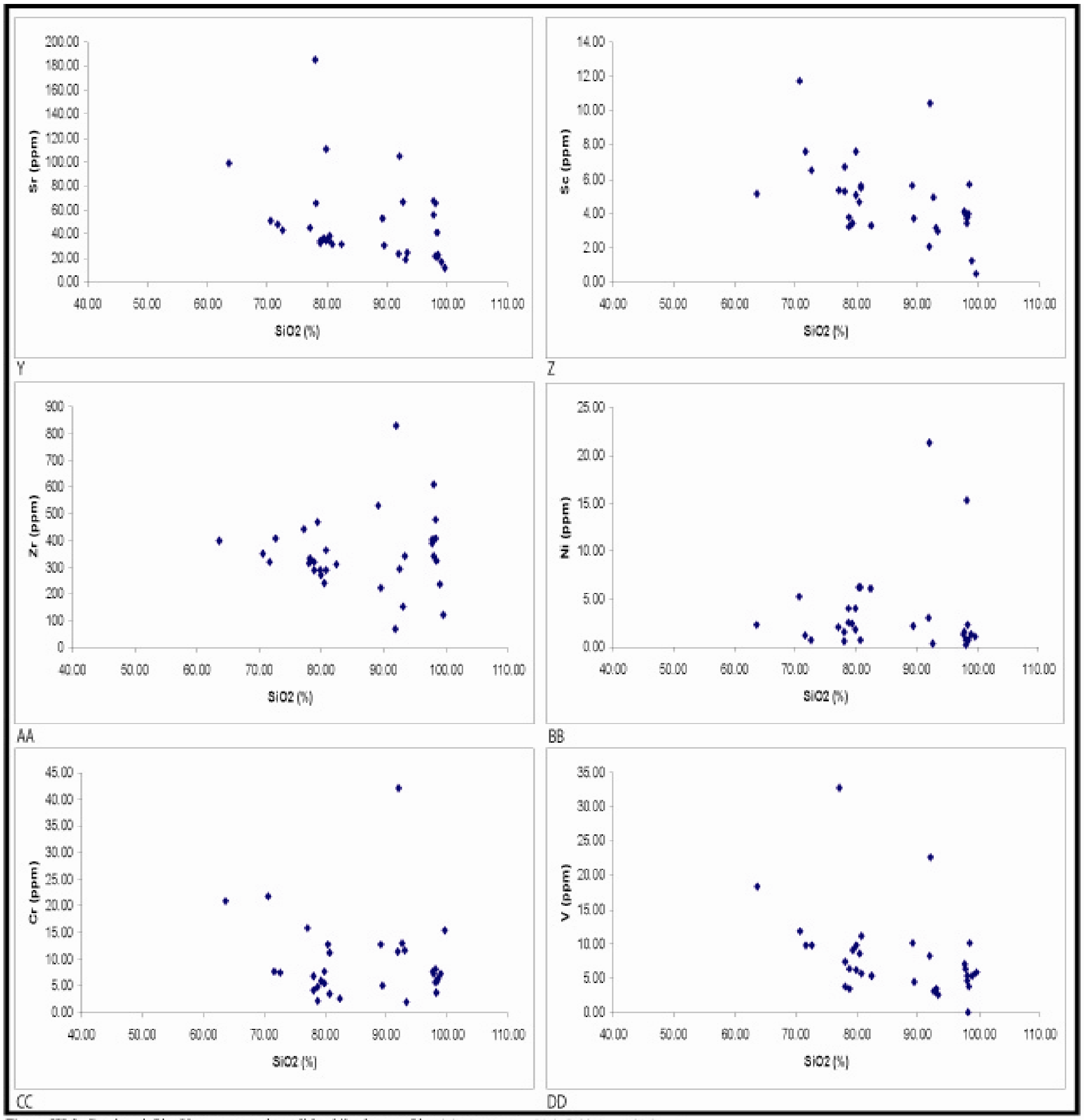


Figure III-2: Continued. Plot Y represents a large lithophile element. Plot AA represents a high field strength element.

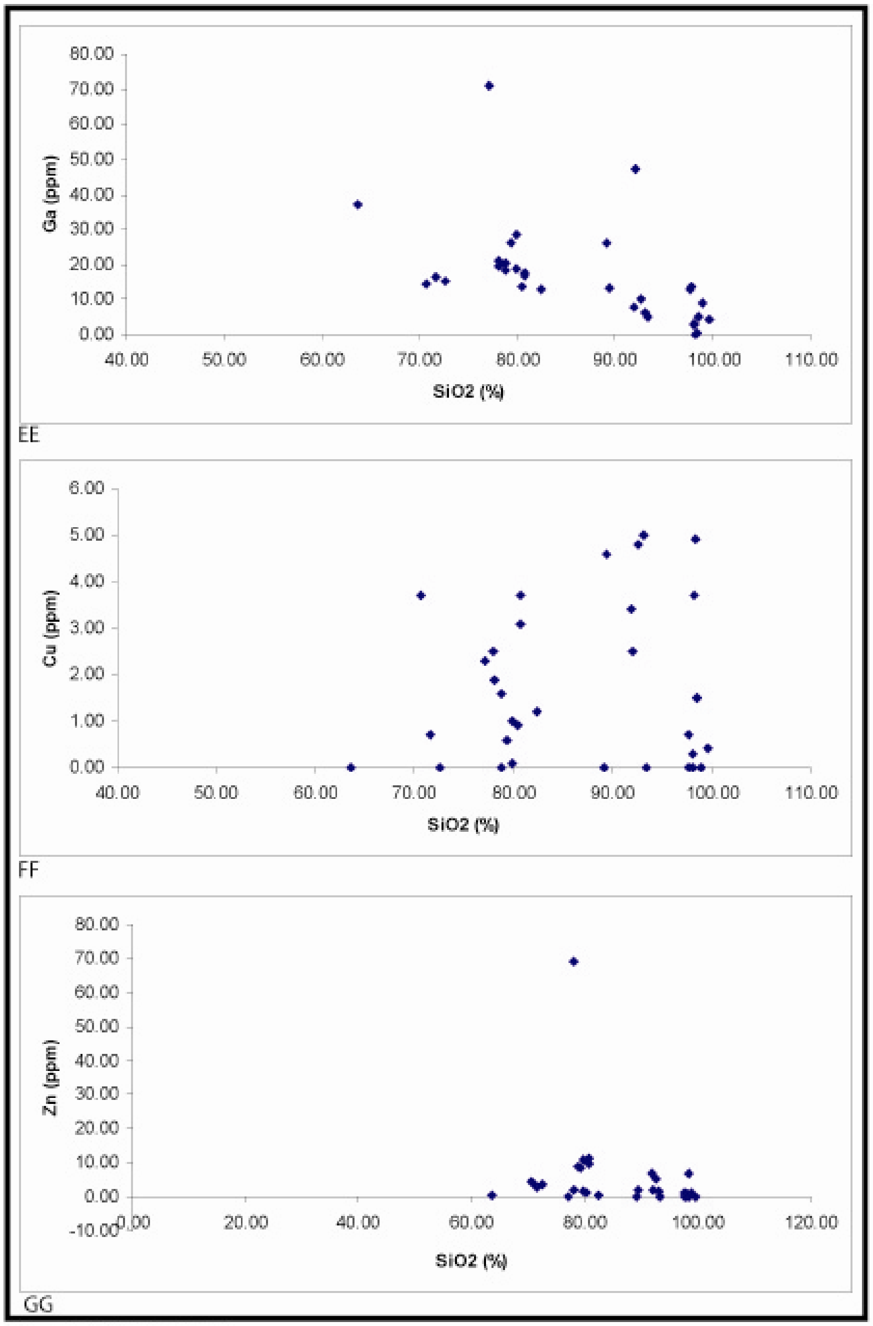


Figure III-2: Continued.

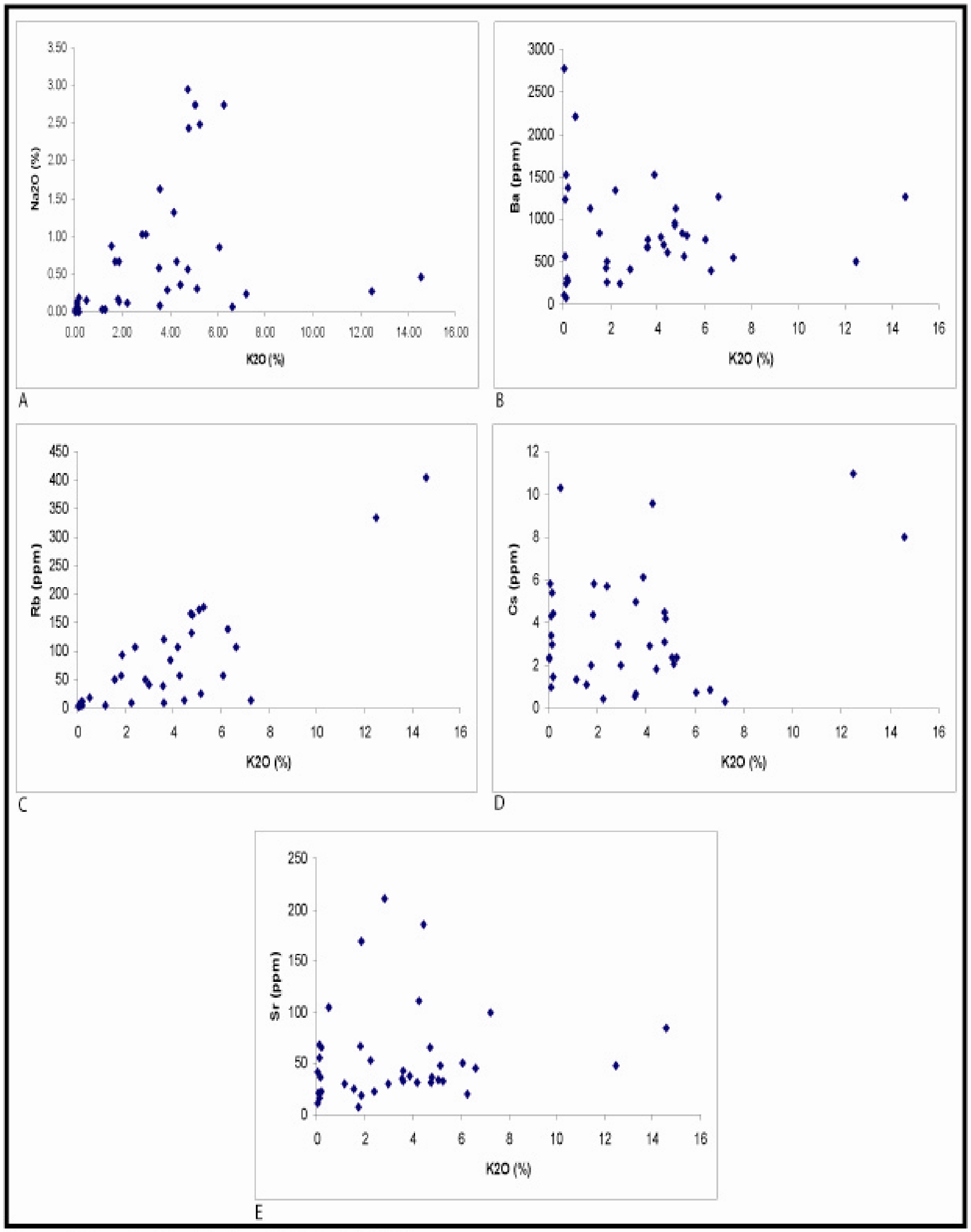


Figure III-3: Large ion lithophile elements plotted against K_2O.

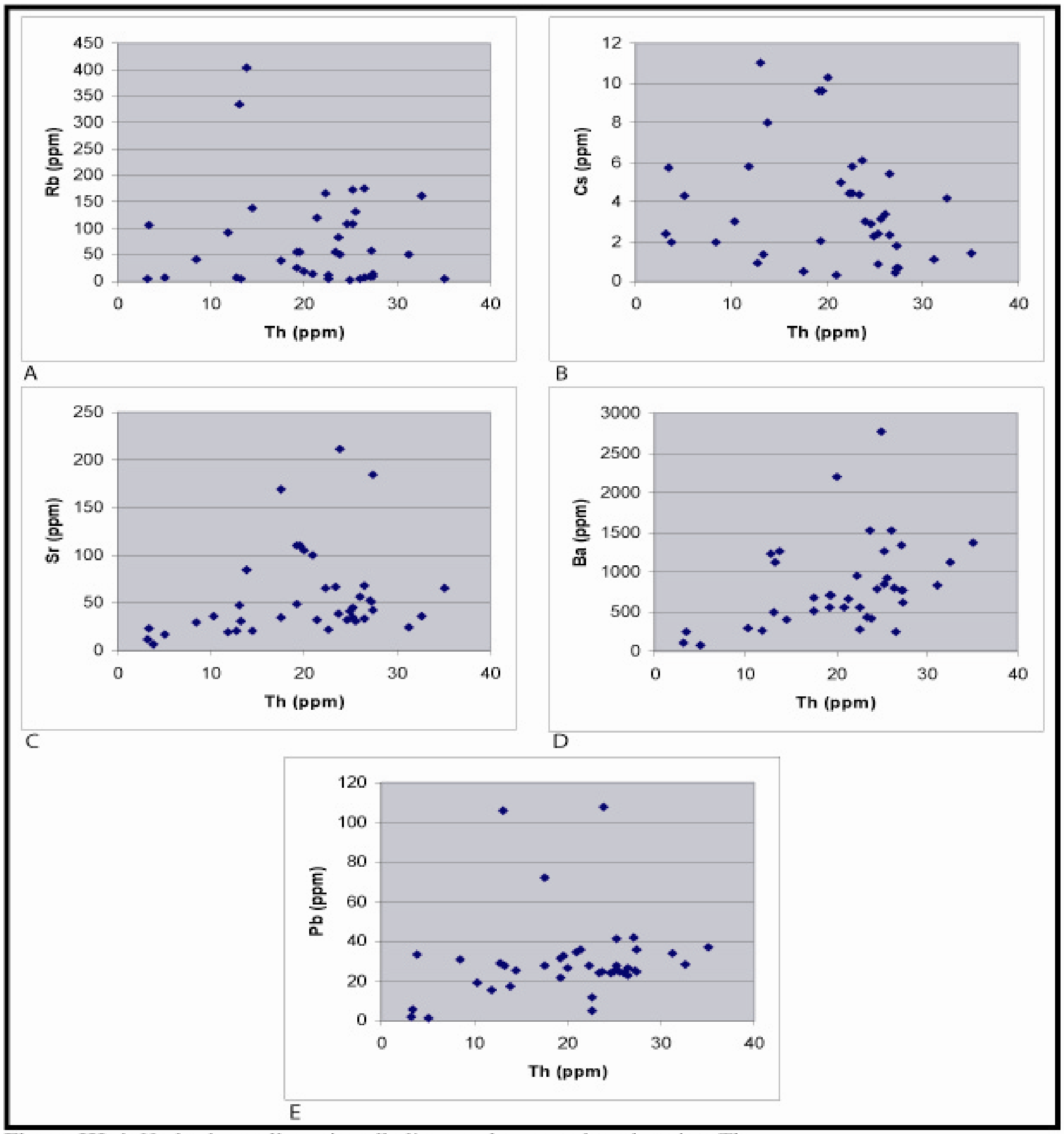


Figure III-4: Hydrothermally active alkali trace elements plotted against Th.

Element	Detection Limit (ppm)	TD ICP	INAA
Ag	0.3	X	X
Al	0.01%		X
As	0.5	X	
Au	2 ppb	X	
Ba	50	X	
Be	1		X
Bi	2		X
Br	0.5	X	
Ca	0.01%		X
Cd	0.3		X
Ce	3	X	
Co	1	X	
Cr	2	X	
Cs	1	X	
Cu	1		X
Eu	0.2	X	
Fe	0.01%	X	
Hf	1	X	
Hg	1	X	
Ir	5 ppb	X	
K	0.01%		X
La	0.5	X	
Lu	0.05	X	
Mg	0.01%		X
Mn	1		X
Mo	1		X
Na	0.01%	X	
Nd	5	X	
Ni	1	X	X
P	0.001%		X
Pb	3		X
Rb	15	X	
S*	0.01%		X
Sb	0.1	X	
Sc	0.1	X	
Se	3	X	
Sm	0.1	X	
Sn	0.01%	X	
Sr	1		X
Ta	0.5	X	
Tb	0.5	X	
Th	0.2	X	
Ti	0.01%		X
U	0.5	X	
V	2		X
W	1	X	
Y	1		X
Yb	0.2	X	
Zn	1	X	X

Table III-5: ActLabs major and trace element detection limits and geoanalytical tests used to identify each element.
TD-ICP: Total digestion Inductively coupled plasma
INAA: Instrumental Neutron Activation Analysis
* S measures sulfide sulfur, not native sulfur.

Sample	Al (%)	Fe (%)	Mg (%)	Ca (%)	Na (%)	K (%)	Ti (%)	P (%)
YS-JM-44	5.69	3.96	0.05	0.02	0.1	5.18	0.18	0.009
YS-JM-78	4.39	1.31	0.05	0.02	0.17	6.05	0.18	0.006
YS-JM-155 #2	4.13	14.5	0.02	0.11	1.02	2.61	0.12	0.006
YS-JM-149	3.74	8.26	0.01	0.06	0.38	1.24	0.13	0.007
YS-JM-21	3.73	6.23	0.03	0.07	0.38	1.18	0.11	0.062
YS-JM-118	3.54	8.39	0.04	0.06	0.25	0.77	0.1	0.055
YS-JM-20	5.42	1.92	< 0.01	0.03	0.02	0.07	0.13	0.008
YS-JM-152	1.79	26.1	0.02	0.03	0.25	0.72	0.04	0.002

Table III-6: Assay major and minor element analyses.

Concentrations in weight percent and are not normalized to oxides.

Sample	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Yb (ppm)	Lu (ppm)	Ba (ppm)	Th (ppm)	Y (ppm)	Hf (ppm)	Ta (ppm)	U (ppm)	Pb (ppm)	Rb (ppm)	Cs (ppm)	Sr (ppm)	Sc (ppm)
YS-JM-44	39.3	63	25	4.6	1.4	< 0.5	2.5	0.37	500	13.1	31	5	1.7	5.6	106	334	11	48	5.3
YS-JM-78	52	80	28	6.4	1.3	< 0.5	4.5	0.69	1260	13.8	47	6	2.4	6	17	405	8	84	7.1
YS-JM-155 #2	42.7	58	23	3.4	0.6	< 0.5	1.9	0.26	400	14.5	14	4	1.8	6.4	25	139	< 1	20	2.7
YS-JM-149	32	32	6	1.8	< 0.2	< 0.5	2	0.45	< 50	8.4	26	4	< 0.5	68.9	31	41	2	30	3.6
YS-JM-21	223	248	57	11.4	1.5	< 0.5	3.9	0.51	410	23.9	52	4	3.4	6.1	108	51	3	211	4.8
YS-JM-118	204	223	55	11	1.5	1	3.5	0.54	510	17.5	57	3	< 0.5	4.2	72	< 15	< 1	169	4.4
YS-JM-20	28.8	39	6	2.1	< 0.2	< 0.5	2.4	0.37	300	10.3	21	6	2.3	4	19	< 15	3	36	3.7
YS-JM-152	9.1	16	< 5	1	< 0.2	< 0.5	0.8	0.14	< 50	3.8	9	1	< 0.5	< 0.5	33	< 15	2	7	1.7

Table III-7: Assay trace element analyses.

Sample	Ni (ppm)	Cr (ppm)	V (ppm)	Cu (ppm)	Zn (ppm)	Be (ppm)	Cd (ppm)	Mo (ppm)	S (%)	Bi (ppm)	Au (ppb)	Ag (ppm)	As (ppm)	Br (ppm)	Co (ppm)	Hg (ppm)	Ir (ppb)	Mn (ppm)	Sb (ppm)	Se (ppm)	W (ppm)	Sn (ppm)
YS-JM-44	25	12	29	11	115	< 1	2.7	15	5.91	< 2	969	0.3	103	< 0.5	16	4	< 5	48	74.8	13	8	< 0.01
YS-JM-78	5	9	12	8	14	1	< 0.3	8	0.99	< 2	257	1.3	104	< 0.5	3	< 1	< 5	27	13	5	< 1	< 0.01
YS-JM-155 #2	82	< 2	9	13	44	3	1.8	45	19	< 2	56	0.5	429	< 0.5	26	7	< 5	79	89.3	< 3	< 1	< 0.01
YS-JM-149	24	< 2	42	6	36	3	0.6	28	10.8	< 2	17	< 0.3	2540	< 0.5	11	< 1	< 5	32	34.2	< 3	< 1	< 0.01
YS-JM-21	28	< 2	11	16	76	4	0.4	36	7.69	< 2	2	0.7	319	< 0.5	11	4	< 5	47	4.8	< 3	< 1	< 0.01
YS-JM-118	59	6	13	31	109	3	0.8	72	11.4	< 2	< 2	0.7	650	< 0.5	15	2	< 5	27	7.8	< 3	< 1	< 0.01
YS-JM-20	3	< 2	6	6	7	1	< 0.3	5	2.08	< 2	< 2	0.4	225	< 0.5	2	< 1	< 5	19	35.8	< 3	17	< 0.01
YS-JM-152	182	13	10	14	106	1	3	30	> 20.0	< 2	< 2	< 0.3	568	< 0.5	62	19	< 5	79	24.6	< 3	< 1	< 0.01

Table III-7: Continued.

Batch	Date Run	Run Order	Sample	Type	Weight (mg)	Hole #	Raw Delta‰
--	6/10/2009	--	UWG-2	garnet	--	--	5.42
			JM-38	qtz			-0.5
--	6/26/2009	--	UWG-2	garnet	--	--	5.53
			UWG-2	garnet			4.95
			JM-133	qtz			5.22
			UWG-2	garnet			4.22
			JM-77	qtz			-1.38
			JM-136	qtz			5.14
			UWG-2	garnet			4.78
A-140	9/4/2009	3	UWG-2	garnet	2	3	4.18
		4	UWG-2	garnet	2	4	5.09
		5	JM-38	qtz	3	5	-1.16
		6	JM-39	qtz	1.9	6	-0.82
		7	JM-42	qtz	2	7	-2.53
		8	JM-128	qtz	2	8	4.7
		9	UWG-2	garnet	1.8	9	4.85
		10	JM-59	qtz	2.8	10	0.147
		11	JM-133	qtz	2	11	4.65
		12	JM-78	qtz	1.9	12	-0.5
		13	UWG-2	garnet	1.7	13	4.22
		14	JM-77	qtz	2.5	14	-2.01
		15	JM-128	qtz	2.3	15	4.9
		16	JM-77	qtz	1.8	17	-2.73
		17	UWG-2	garnet	1.8	18	4.54
B-135	9/10/2009	3	UWG-2	garnet	1.7	3	4.83
		4	JM-83	qtz	2.2	7	-2.321
		5	JM-85	qtz	2.3	9	-2.763
		6	JM-98	qtz	2	10	-1.693
		7	JM-113	qtz	2	11	-0.384
		8	UWG-2	garnet	2.3	4	4.576
		9	JM-09	qtz	1.9	12	-0.489
		10	JM-12	qtz	3	14	-1.105
		11	JM-13m	qtz	2.8	15	0.671
		12	JM-13v	qtz	2.9	16	-1.871
		13	UWG-2	garnet	1.9	5	4.22
		14	JM-120A	qtz	2.3	17	2.397
		15	JM-20	qtz	1.9	18	-1.535
		16	JM-83R	qtz	2.6	8	-2.289
		17	JM-09R	qtz	1.8	13	-1.292
		18	UWG-2	garnet	2	6	3.937
A-141	9/15/2009	2	UWG-2	garnet	2.4	2	5.664
		3	UWG-2	garnet	1.9	3	5.535
		4	JM-136	qtz	2	7	6.203
		5	JM-120A	qtz	1.9	8	3.578
		6	JM-13m	qtz	3.4	9	-3.52
		7	JM-05-07	qtz	2.3	10	3.393
		8	UWG-2	garnet	1.7	4	5.154
		9	JM-124	qtz	1.8	11	-2.988
		10	JM-150	qtz	2	12	-0.805
		11	JM-153	qtz	1.9	13	-0.429
		12	UWG-2	garnet	2	5	5.143
		13	JM-125	qtz	2	18	2.549
		14	JM-05-07R	qtz	2.2	15	4.134
		15	JM-153 R	qtz	1.8	17	-0.59
		16	UWG-2	garnet	2.4	6	5.462

Table III-8: Raw data for stable isotope analyses.
'--' denotes author did not perform analyses; qtz: quartz

Sample	Outcrop	Type of sample	Color	Second Sample	Batch number	Run order	Weight (mg)	$\delta^{18}O$ (‰)
YS-08-JM59	Outcrop 2	Matrix	White		A-140	10	2.8	1.22
YS-08-JM38	Outcrop 3	Vein	White	X	--/A-140	--/5	--/3	-0.05
YS-08-JM39	Outcrop 3	Vein	White		A-140	6	1.9	0.25
YS-08-JM42	Outcrop 3	Vein	White		A-140	7	2	-1.46
YS-08-JM78	Outcrop 4A	Matrix	Gray		A-140	12	1.9	0.57
YS-08-JM83	Outcrop 4B	Matrix	Dark/Light Gray	X	B-135	4/16	2.2/2.6	-0.95
YS-08-JM85	Outcrop 4B	Vein	White		B-135	5	2.3	-1.41
YS-08-JM136	Outcrop 4B	Vein (opal)	White	X	--/A-141	--/4	--/2	6.44
YS-08-JM113	Outcrop 4C	Drusy Quartz	white		B-135	7	2	0.97
YS-08-JM77*	Outcrop 5	Drusy Quartz	Clear		--	--	--	-0.35
YS-08-JM77*	Outcrop 5	Vein	White	X	A-140	14/16	2.5/1.8	1.3
YS-08-JM98	Outcrop 6	Matrix	Dark Gray		B-135	6	2	-0.33
YS-08-JM09**	Outcrop 7	Vein	White	X	B-135	9/17	1.9/1.8	0.47
YS-08-JM12	Outcrop 7	Vein	White		B-135	10	3	0.25
YS-08-JM13m	Outcrop 7	Matrix	Gray		B-141	6	3.4	-3.01
YS-08-JM13v	Outcrop 7	Vein (opal)	Cream		B-135	12	2.9	2.03
YS-08-JM13v	Outcrop 7	Vein	White		B-135	11	2.8	-0.51
YS-08-JM20	Stream	Vein	White		B-135	15	1.9	-0.18
YS-08-JM120A	Stream	Opal Nodule	Clear	X	B-135/A-141	14/5	2.3/1.9	3.92
YS-08-JM150	Stream	Vein	Clear		A-141	10	2	-0.3
YS-08-JM153	Stream	Vein	Clear	X	A-141	11/15	1.9/1.8	0
YS-08-JM124	South Ridge	Float	White		A-141	9	1.8	-2.48
YS-08-JM128	SR	Matrix	White	X	A-140	8/15	2/2.3	5.87
YS-07-JM05	South Ridge	Drusy Quartz	White	X	A-141	7/14	2.3/2.2	4.27
YS-08-JM125	SR Float	Matrix	White		A-141	13	2	3.06
YS-08-JM133	NR	Matrix	White	X	--/A-140	--/11	--/2	5.99

Table III-9: Overview of normalized stable isotope ratios analyses.

Vein, unless otherwise stated, includes quartz veins and veinlets; matrix=silicified altered groundmass; drusy quartz lines vugs in wall rock.

'--' denotes author did not perform analyses.

*Vein with drusy quartz **Quartz from breccia healing.

Appendix IV:
Sample Description

Sample	Date Collected	Outcrop	Relative Location	Long (UTM)	Lat (UTM)
YS-07-JM01	8/8/2007	SR	Top	545631.5	4955881.1
YS-07-JM02	8/8/2007	SR	Top	545632	4955883
YS-07-JM03	8/8/2007	SR	Top	545635.3	4955907
YS-07-JM04	8/8/2007	SR	Top	545453	4955995
YS-07-JM05	8/8/2007	SR	Top	545442	4955995
YS-07-JM06	8/8/2007	SR	Top	545428	4955987
YS-07-JM07	8/8/2007	SR	Top	545428	4955980
YS-08-JM02	7/29/2008	OC7	Middle	545402	4956058
YS-08-JM03	7/29/2008	OC7	Middle	545402	4956052
YS-08-JM04	7/29/2008	OC7	Middle	545404	4956047
YS-08-JM05	7/29/2008	OC7	Middle	545404	4956043
YS-08-JM06	7/29/2008	OC7	Middle	545409	4956056
YS-08-JM07	7/29/2008	OC7	Middle	545415	4956059
YS-08-JM08	7/29/2008	OC7	Base	545422	4956059
YS-08-JM09	7/29/2008	OC7	Base	545429	4956061
YS-08-JM10	7/29/2008	OC7	Base	545436	4956059.5
YS-08-JM11	7/29/2008	OC7	Base	545441	4956057.5
YS-08-JM12	7/29/2008	OC7	Middle	545442.5	4956051
YS-08-JM13	7/29/2008	OC7	Middle	545442	4956043
YS-08-JM14	7/29/2008	OC7	Base	545448	4956057
YS-08-JM15	7/29/2008	OC4C	Base	545452	4956062
YS-08-JM16	7/29/2008	OC7	Base	545448	4956053
YS-08-JM17	7/29/2008	OC4C	Base	545446	4956063
YS-08-JM18	7/29/2008	OC7	Base	545395.5	4956072
YS-08-JM19	8/1/2008	Stream	Stream	545203.4	4956082.1
YS-08-JM20	8/1/2008	Stream	Stream	545212.4	4956079.6
YS-08-JM21	8/1/2008	Stream	Stream	545252.2	4956067
YS-08-JM22	8/1/2008	OC4C	Base	545389	4956078
YS-08-JM23	8/2/2008	OC1	Base: Mid	544822	4955902
YS-08-JM24	8/2/2008	OC1	Base: Mid	544829	4955901
YS-08-JM25	8/2/2008	OC1	Base: Mid	544835	4955901
YS-08-JM26	8/2/2008	OC1	Base: Mid	544839	4955901
YS-08-JM27	8/2/2008	OC1	Base: Mid	544842	4955900
YS-08-JM28	8/2/2008	OC1	Base: Mid	544850	4955904
YS-08-JM29	8/2/2008	OC1	Middle	544852	4955892
YS-08-JM31	8/2/2008	OC1	Middle	544843	4955881
YS-08-JM32	8/2/2008	OC1	Middle	544843.5	4955872
YS-08-JM33	8/2/2008	OC1	Top	544841	4955872
YS-08-JM34	8/2/2008	OC1	Middle	544839	4955872
YS-08-JM35	8/2/2008	OC1	Middle	544857	4955911
YS-08-JM36	8/2/2008	OC3	Middle	544983	4956031
YS-08-JM37	8/2/2008	OC3	Middle	544990	4956037
YS-08-JM38	8/2/2008	OC3	Base	545007	4956053
YS-08-JM39	8/2/2008	Stream/OC3	Stream	545009	4956059
YS-08-JM40	8/2/2008	OC3	Base	545011	4956057
YS-08-JM41	8/2/2008	OC3	Middle	545019	4956048.5
YS-08-JM42	8/2/2008	OC3	Base	544999.2	4956043.6
YS-08-JM43	8/2/2008	OC3	Middle	545005	4956037
YS-08-JM44	8/2/2008	OC3	Middle	545017	4956047
YS-08-JM45	8/2/2008	OC3	Top	545016	4956034.5
YS-08-JM46	8/2/2008	OC3	Middle	545007	4956039
YS-08-JM47	8/2/2008	OC3	Middle	545013	4956043
YS-08-JM48	8/2/2008	OC3	Middle	545003	4956035
YS-08-JM49	8/2/2008	OC3	Middle	545009	4956041
YS-08-JM50	8/2/2008	OC3	Middle	545010	4956039
YS-08-JM51	8/2/2008	OC3	Middle	545012	4956037
YS-08-JM52	8/3/2008	NR	Top	544828	4955981
YS-08-JM53	8/3/2008	Float NR	Float	544826	4956016
YS-08-JM54	8/3/2008	Float NR	Float	544882	4956032
YS-08-JM55	8/3/2008	Float NR	Float	544911	4956054
YS-08-JM56	8/3/2008	NR	Top	544935	4956082

Table IV-1: Sample locations.
SR: south ridge; OC: outcrop; NR: north ridge.

Sample	Date Collected	Outcrop	Relative Location	Longitude	Latitude
YS-08-JM57	8/3/2008	NR	Top	544948	4956095
YS-08-JM58	8/3/2008	OC2	Top: Bottom	544924	4956117
YS-08-JM59	8/3/2008	OC2	Top: Mid	544921	4956124
YS-08-JM60	8/3/2008	OC2	Top: Mid	544911	4956117
YS-08-JM61	8/3/2008	OC2	Top	544913	4956144
YS-08-JM62	8/3/2008	OC2	Top	544919	4956142
YS-08-JM65	8/3/2008	OC2	Top: Bottom	544930	4956123
YS-08-JM66	8/3/2008	OC2	Top: Bottom	544934	4956131
YS-08-JM67	8/3/2008	OC2	Top	544926	4956140
YS-08-JM68	8/3/2008	OC2	Top: Bottom	544935	4956137
YS-08-JM69	8/3/2008	OC4B	Middle	545079	4956144
YS-08-JM70	8/3/2008	OC4B	Middle	545086	4956144
YS-08-JM71	8/3/2008	OC4B	Middle	545104	4956143.5
YS-08-JM72	8/3/2008	OC4B	Middle	545108	4956144
YS-08-JM73	8/3/2008	OC4B	Middle	545079	4956152
YS-08-JM74	8/3/2008	OC4B	Middle	545109	4956155
YS-08-JM75	8/3/2008	OC5	Middle	545077	4956081
YS-08-JM76	8/3/2008	OC5	Middle	545074	4956081
YS-08-JM77	8/3/2008	OC5	Middle	545078	4956078
YS-08-JM78	8/3/2008	OC4A	Base	545050	4956093
YS-08-JM79	8/3/2008	OC4A	Base	545047	4956089
YS-08-JM80	8/3/2008	OC4A	Middle	545046	4956096
YS-08-JM81	8/3/2008	OC4A	Middle	545043	4956103
YS-08-JM82	8/3/2008	OC4A	Base	545043	4956087
YS-08-JM83	8/5/2008	OC4B	Base	545085	4956100
YS-08-JM84	8/5/2008	OC4B	Base	545087	4956110
YS-08-JM85	8/5/2008	OC4B	Base	545088	4956100
YS-08-JM86	8/5/2008	OC4B	Base	545089	4956104.5
YS-08-JM87	8/5/2008	Stream/OC4B	Base	545093	4956097
YS-08-JM88	8/5/2008	OC4B	Base	545093	4956102
YS-08-JM89	8/5/2008	OC4B	Base	545098	4956102
YS-08-JM90	8/5/2008	OC4B	Base	545100	4956102
YS-08-JM91	8/5/2008	OC4B	Base	545103	4956102
YS-08-JM92	8/5/2008	OC6	Middle	545157	4956116
YS-08-JM93	8/5/2008	OC6	Middle	545156.5	4956127
YS-08-JM94	8/5/2008	OC6	Middle	545169	4956135
YS-08-JM95	8/5/2008	OC6	Middle	545168	4956144
YS-08-JM96	8/5/2008	OC6	Middle	545177	4956127
YS-08-JM97	8/5/2008	OC6	Middle	545182	4956127
YS-08-JM98	8/5/2008	OC6	Base	545167	4956102
YS-08-JM99	8/5/2008	OC6	Base	545184	4956095
YS-08-JM100	8/5/2008	OC6	Middle	545184	4956103
YS-08-JM101	8/5/2008	OC6	Base/Middle	545184	4956116
YS-08-JM102	8/5/2008	OC6	Middle	545186	4956125
YS-08-JM103	8/5/2008	OC6	Middle	545196	4956136
YS-08-JM104	8/5/2008	OC6	Middle	545197	4956109
YS-08-JM105	8/5/2008	OC6	Middle	545195	4956125
YS-08-JM106	8/5/2008	OC6	Middle	545219	4956125
YS-08-JM107	8/5/2008	OC6	Middle	545216	4956125
YS-08-JM108	8/5/2008	OC6	Middle	545226	4956119
YS-08-JM109	8/5/2008	OC4C	Base	545233	4956088
YS-08-JM110	8/5/2008	OC4C	Base	545233	4956103
YS-08-JM111	8/5/2008	OC4C	Middle	545235	4956113
YS-08-JM112	8/5/2008	OC4C	Middle	545245	4956127
YS-08-JM113	8/5/2008	OC4C	Base	545237	4956081
YS-08-JM114	8/5/2008	OC4C	Base	545240	4956072
YS-08-JM115	8/5/2008	OC4C	Base	545244	4956080.5
YS-08-JM116	8/5/2008	Stream	Stream	545244.8	4956067.4
YS-08-JM117	8/5/2008	OC4C	Base	545251	4956072
YS-08-JM118	8/5/2008	Stream	Stream	545261.2	4956069
YS-08-JM119	8/5/2008	OC4C	Base	545257	4956080
YS-08-JM120A	8/5/2008	Stream	Stream	545269.4	4956073.5

Table IV-1: Continued.

Sample	Date Collected	Outcrop	Relative Location	Longitude	Latitude
YS-08-JM120B	8/5/2008	SR	Top	545418	4955973
YS-08-JM121	8/6/2008	SR	Top	545405	4955992
YS-08-JM122	8/6/2008	SR Float	Top	545454	4955953
YS-08-JM123	8/6/2008	SR Float	Top	545419	4955959.5
YS-08-JM124	8/6/2008	SR	Top	545229	4956022.5
YS-08-JM125	8/6/2008	SR Float	Top	545266	4956020
YS-08-JM126	8/6/2008	SR	Top	545218	4956015
YS-08-JM127	8/6/2008	SR	Top	545116	4956039
YS-08-JM128	8/6/2008	SR	Top	545039.4	4956032.5
YS-08-JM129	8/6/2008	SR	Top	545033	4956027
YS-08-JM130	8/6/2008	SR/OC3	Top	545021	4956028
YS-08-JM131	8/6/2008	SR Float	Top	544951	4955935
YS-08-JM132	8/6/2008	SR	Top	544844	4955855
YS-08-JM133	8/6/2008	NR	Top	544956.6	4956181.8
YS-08-JM134	8/6/2008	NR	Top	544961.2	4956181.7
YS-08-JM135	8/6/2008	NR	Top	545046.5	4956198.1
YS-08-JM136	8/6/2008	OC4B	Top	545127	4956216
YS-08-JM137	8/6/2008	OC4B	Top	545129	4956176
YS-08-JM138	8/8/2008	NR/ OC4C	Top	545210	4956178
YS-08-JM139	8/8/2008	OC4C	Top	545244	4956161
YS-08-JM140	8/8/2008	OC4C	Top	545291.7	4956174.9
YS-08-JM141	8/8/2008	OC4C	Top	545291.8	4956156.4
YS-08-JM142	8/8/2008	OC4C	Top/Middle	545291.9	4956139.8
YS-08-JM143	8/8/2008	NR/ OC4C	Top	545339.2	4956171.5
YS-08-JM144	8/8/2008	NR/ OC4C	Top	545385.3	4956175.5
YS-08-JM145	8/8/2008	NR/ OC4C	Top	545426	4956144.5
YS-08-JM146	8/8/2008	NR	Top	545508.3	4956169
YS-08-JM147	8/8/2008	NR	Top	545521.9	4956159.6
YS-08-JM148	8/8/2008	OC4C	Middle	545360	4956137
YS-08-JM149	8/8/2008	Stream	Stream	545439.4	4956060.4
YS-08-JM150	8/8/2008	Stream	Stream	545439.2	4956064
YS-08-JM151	8/8/2008	Stream	Stream	545441.4	4956061.6
YS-08-JM152	8/8/2008	Stream	Stream	545443	4956060
YS-08-JM153	8/8/2008	Stream	Stream	545444.5	4956060
YS-08-JM154	8/8/2008	Stream	Stream	545446.1	4956060
YS-08-JM155#1	8/8/2008	Stream	Stream	545449	4956059
YS-08-JM155#2	8/8/2008	Stream/OC4C	Base	545449	4956061
YS-08-JM155#3	8/8/2008	OC4C	Base	545449	4956062
YS-08-JM156	8/8/2008	OC4C	Base	545387	4956109
YS-08-JM157	8/8/2008	Stream	Stream	545392.8	4956053.4

Table IV-1: Continued.

Sample	Hand Sample Descriptions
YS-07-JM01	Sil d.gry; Arg ovrprt; clay and empty vlts; opal, al, kaol; sphere; oxidized
YS-07-JM02	Sil d.gry; Arg ovrprt; silica, sulfide, and clay vlts; al, kaol, opal, qtz, sulfides-oxidized; cb; sphere
YS-07-JM03	Sil d.gry; Arg ovrprt; clay vlts; opal, al, kaol; sphere
YS-07-JM04	Sil d.gry; Arg ovrprt; clay vlts; vs; opal, kaol, al; well preserved cb; sulfides in vugs
YS-07-JM05	Sil gry-d.gry; clay vlts; drusy qtz; opal, qtz, sulfides; well preserved cb; phenos-alt
YS-07-JM06	Sil wht; Arg ovrprt; minor vs; drusy qtz; kaol, al, opal
YS-07-JM07	Sil d.gry; milky wht opal vn; al, bar
YS-08-JM02	Sil wht; v.minor Arg ovrprt; silica and empty vlts; al, bar, minor clays; cb infilled-silica
YS-08-JM03	Sil wht; drusy qtz; al, bar, minor clays; cb infilled-silica
YS-08-JM04	Sil wht-buff; wht silica vlt; vs; drusy qtz; illite, minor al, bar; well preserved cb replaced-silica; phenos-alt
YS-08-JM05	Sil wht; drusy qtz; al, bar, minor clays; cb infilled-silica
YS-08-JM06	Sil; Arg wht ovrprt; silica vlts perp. to comp; al, bar, minor clays; cb infilled-silica; phenos-alt
YS-08-JM07	Sil l.gry; minor Arg ovrprt; silica vlts; minor clays, al; cb infilled-silica
YS-08-JM08	Crackle-Mosaic brx vn; Arg wr healed by l.-d.gry silica and sulfides; kaol, al, qtz; clast supported
YS-08-JM09	Milled-Mosaic brx vn; Arg wr healed by silica and sulfides; silica and sulfides vlts; clasts: 2.5cm to mm
YS-08-JM10	Milled brx; Arg gry wr healed by silica and sulfides; clasts: 2.5cm to mm (ext. fine grained to large angular clasts)
YS-08-JM11	Sil gry; Arg ovrprt; clay vlts perp to comp; silica vlts; drusy qtz; kaol, al; cb replaced-silica
YS-08-JM12	Wht silica vn; Arg wht wr; kaol, al
YS-08-JM13	Arg gry; silica vn; clay, silica, sulfide vlts; bar, al, kaol, sulfides; well preserved cb replaced-silica; phenos-alt; oxidized
YS-08-JM14	Mosaic-Milled brx; Arg wht wr healed by silica and sulfide; silica and sulfide vlts; clast supported
YS-08-JM15	Sil l.gry; silica vlts; cb replaced-silica
YS-08-JM16	Sil wht-l.gry; Arg ovrprt; bar, al; cb replaced-silica (sulfides)
YS-08-JM17	Arg d.gry; leached; qtz, al, opal, sanidine (XRD), minor dis sulfides; phenos-fresh to alt
YS-08-JM18	Sil l.gry; silica and sulfide vlts; vs; sulfides dis in wr
YS-08-JM19	Sil gry-d.gry; Arg ovrprt; silica vn; clay vlts; kaol, al; massive sulfides in wr
YS-08-JM20	Mosaic-Milled brx vn; Sil wr healed by silica and sulfide; al, minor kaol; brx includes pieces of opal/chal
YS-08-JM21	Milled brx; Sil wr healed perp to fluid flow by silica and sulfide; sulfide/silica and clay vlts; sulfides dis in vn
YS-08-JM22	Sil l.gry; major Arg ovrprt; sulfide vn with al selvage-minor brx; clay and silica vlts; qtz, kaol; cb; phenos-alt
YS-08-JM23	Arg tan-buff; clay/silica vlts; wr brx (no vn)-healed by silica; minor wht clay, sulfides; oxidized
YS-08-JM24	Arg gry; sl. Sil; clay and silica/sulfide vlts; cb; phenos-fresh to alt
YS-08-JM25	Arg tan; clay vlts perp to cb; micro silica vlts; phenos-fresh to alt
YS-08-JM26	Arg wht; leached
YS-08-JM27	Arg wht-l.gry; sl. silicified; silica vlts; sulfide vlts-micro; rounded phenos- fresh to alt
YS-08-JM28	Arg gry (bleached); clay and empty vlts; round to euhedral phenos- fresh to alt
YS-08-JM29	Arg wht-l.gry; opaline veneer; empty, clay and silica vlts; vs
YS-08-JM31	Arg gry (bleached); clay vlts para to comp; silica vlts-clay selvage; sulfide vlts; sm sphere; phenos- fresh to alt
YS-08-JM32	Arg wht (bleached); opal veneer; silica vlts-clay selvage; drusy qtz; sm and large sphere
YS-08-JM33	Arg l.gry; sl Sil; clay and silica vlts; vs; large sphere; phenos-alt
YS-08-JM34	Arg gry (bleached); possible vlts
YS-08-JM35	Arg wht; clay and silica vlts; leached; cb
YS-08-JM36	Leached gry
YS-08-JM37	Sil buff; Arg ovrprt; silica vlts; vs;mphenos-alt
YS-08-JM38	Wht silica vn-colloform; sulfide vlts-micro; drusy qtz; sulfides in brx mtx/selvage
YS-08-JM39	Gry silica vn; Arg wr in brx-selvage; clay vlts; possible sulfides
YS-08-JM40	Leached l. gry-wht; silica and empty vlts; sm sphere
YS-08-JM41	Leached, non-welded pumice frags; some brx healed by silica
YS-08-JM42	Sil l.gry-buff; Arg ovrprt; empty, silica, clay vlts; drusy qtz; sulfides; phenos-alt
YS-08-JM43	Arg wht; silica and empty vlts; leached; no internal structure
YS-08-JM44	Sil gry porphrhy; sulfide/silica vlts-micro; vs; GOLD, sulfides; phenos-alt
YS-08-JM45	Sil wht; silica vlts; vs; drusy qtz
YS-08-JM46	Sil gry; silica vn-minor brx; al; cb
YS-08-JM47	Sil gry; silica vlts; vs; drusy qtz; al; cb; oxidized
YS-08-JM48	Sil gry; Arg ovrprt; silica vns-brx; silica vlts; vs; bar, al; no internal structure
YS-08-JM49	Leached wht; silica vlts; brx healed by silica
YS-08-JM50	Leached buff pumice; silica vlts; drusy to crustiform silica; colloform silica; minor brx healed by silica
YS-08-JM51	Leached wht; silica vlts; mosaic-crackle brx healed by silica
YS-08-JM52	Sil gry; silica vlts; vs; clays, al; oxidized
YS-08-JM53	Sil buff; silica vlts; vs; sphere; heavily oxidized
YS-08-JM54	Sil l.gry-wht; opaline; silica vlts
YS-08-JM55	Sil wht; vs; opaline
YS-08-JM56	Sil l.gry; Arg ovrprt; clay and silica vlts-sinuous and random; vs; al, kaol

Table IV-2: Overview of hand sample descriptions.

Sil: silicified; Arg: Argillized; ovrprt: overprint; d: dark; l.: light; gry: gray; wht: white; org: orange; vlts: veinlets; vn: vein; brx: breccia; vs: vuggy silica; qtz: quartz; al: alunite; kaol: kaolinite; bar: barite; chal: chalcedony; marc: marcasite; pyt: pyrite;
clays: can include kaolinite, illite, and sulfates; sphere: sphereulites; cb: compression banding; phenos: phenocrysts; alt: altered;
v.: very; perp: perpendicular; para: parallel; comp: compression; wr: wall rock; ext.: extremely; dis: disseminated; micro: microscopic
sl.: slightly; sm: small; mtx: matrix; frags: fragments; (XRD): feldspar could only be identified by XRD, not in hand sample.
* Two samples collected.

Sample	Hand Sample Descriptions
YS-08-JM57	Sil l.gry; vs; drusy qtz; al
YS-08-JM58	Sil; silica vlts; vs; drusy qtz; wht-tan clays
YS-08-JM59	Sil and minor Arg; drusy qtz; wht-tan clays, sulfides
YS-08-JM60	Sil l.gry; no internal structure; most alt in outcrop
YS-08-JM61	Sil; vs; wht-tan clays; sm sphere
YS-08-JM62	Sil l.gry; opal veneer; silica vlts-micro; wht-tan sphere-internally leached
YS-08-JM65	Sil; vs; drusy qtz; wht-tan clays
YS-08-JM66	Sil; vs; drusy qtz; wht-tan clays
YS-08-JM67	Sil; empty vlts; vs; drusy qtz; wht-tan clays
YS-08-JM68	Silica vn; empty vlts; possible sulfides
YS-08-JM69	Sil wht; faint cb
YS-08-JM70	Arg gry (brx); silica vlts-clay selvage; al, kaol, sulfides
YS-08-JM71	Sil wht; silica and sulfide vlts
YS-08-JM72	Arg wht-tan; clay and silica vlts; cb; possible sphere; phenos-alt
YS-08-JM73	Sil wht; qtz vn; minor silica vlts
YS-08-JM74	Sil; Arg tan-l.gry ovrprt; clay vlts; sulfide and silica vlts-micro; opal, al, sulfides; phenos-alt
YS-08-JM75	Leached wht; silica vlts
YS-08-JM76	Sil l.gry; silica vlts; vs; drusy qtz; sulfur, sulfides, white clays; oxidized
YS-08-JM77	Sil buff; heavy Arg ovrprt; gry silica vn; silica vlts; vs; drusy qtz
YS-08-JM78	Sil gry; silica vn; clay and silica vlts; sulfides, al; euhedral phenos-fresh to alt
YS-08-JM79	Leached wht pumice
YS-08-JM80	Sil gry; marc vn; wr-dis sulfides
YS-08-JM81	Sil; brx wr; silica and sulfide vlts; sphere
YS-08-JM82	Leached wht; minor brx; silica vlts
YS-08-JM83	Leached yellow; silica vn (dis sulfides)-brx and sulfide selvage; silcia vlts; drusy qtz
YS-08-JM84	Leached wht-l.org; silica and sulfides vlts; drusy qtz; al, dis sulfides
YS-08-JM85	Sil wht-l.org; silica vn; drusy qtz; sulfides/silica vlts
YS-08-JM86	Sil wht; minor Arg ovrprt; silica, empty, and minor sulfide vlts
YS-08-JM87	Milled-Mosaic brx; Sil wht wr healed by marc-minor pyt/silica; wr-previous silica vlts; crackle brx-silica/sulfide vlts; silica vn-sulfide selvage; drusy qtz
YS-08-JM88	Wht silica vn; smooth, porcelain
YS-08-JM89	Leached wht; minor brx; silica vlts-sulfide selvage; sulfide vlts; drusy qtz; al, bar
YS-08-JM90	Arg gry; clay vlts; kaol, al; cb
YS-08-JM91	Sil wht; silica vlts; opaline veneer
YS-08-JM92	Leached wht; silica vlts; vugs infilled-silica
YS-08-JM93	Arg wht-tan; silica vlts-perp to cb; minor sulfides
YS-08-JM94	Sil gry; Arg ovrprt; cb replaced-silica; phenos-alt; oxidzied
YS-08-JM95	Arg wht; cb replaced-silica; oxidized
YS-08-JM96	Sil gry; Arg wht-tan ovrprt; silica and clay vlts; bar, al, clays
YS-08-JM97	Sil gry; Arg wht ovrprt; silica vlts-para to cb; clay vlts; drusy qtz; sulfides; phenos-alt
YS-08-JM98	Sil gry; sulfide vn; silica vlts; cb; phenos-alt
YS-08-JM99	Sil wht; d.gry silica vns-brx; silica vlts
YS-08-JM100	Arg wht; clay vlts-"spider-web veinlets"
YS-08-JM101	Crackle brx; Arg wht and gry wr healed by silica vlts; clay vlts; minor sulfides
YS-08-JM102	Sil gry; minor Arg wht-tan ovrprt; silica and clay vlts; cb
YS-08-JM103	Leached wht; silica vns; drusy qtz
YS-08-JM104	Sil wht; silica vlts; minor sulfides
YS-08-JM105	Sil wht; gry silica vein-clay vlts; al; oxidized
YS-08-JM106	Sil gry; Arg wht-tan ovrprt; clay and silica vlts; al; oxidized
YS-08-JM107	Sil; Arg wht-tan ovrprt; silica and clay vlts; al, sulfides; oxidized
YS-08-JM108	Sil (sl) wht-tan; major Arg ovrprt; silica vlts; vs
YS-08-JM109	Sil d.gry; l.gry silica vn-clay vlt (like 113); spider-like silica/sulfide vlts; al, kaol; well preserved cb
YS-08-JM110	Silica vn-brx; some brx lined by sulfides; silica vlts-cut brx; clay vlts
YS-08-JM111	Sil gry; minor Arg ovrprt; al, kaol, opal; cb
YS-08-JM112	Arg buff; sl. sil; clay vlts-connect arg phenos: kaol and al; silica and sulfide vlts
YS-08-JM113	Silica vn-colloform; ~7.5cm wide; minor brx on selvage- Arg wr; opal veneer; minor amytheist and rose qtz
YS-08-JM114	Arg wht; <mm silica and sulfide vlts
YS-08-JM115	Arg buff; silica vlts; drusy qtz; kaol, al, qtz, opal
YS-08-JM116	Sil gry; Arg ovrprt; clay vlts perp to cb-connect arg phenos; silica vlts; drusy qtz; al, kaol, sulfides
YS-08-JM117	Sil wht; silica and empty vlts; vs; drusy qtz; al, bar; cb
YS-08-JM118	Milled brx vn-2.5cm; Arg wr healed by silica/sulfide and sulfide/silica; silica and sulfide vlts-micro; brx~ 5cm-mm
YS-08-JM119	Arg gry; sulfide vn; silica vlts; kaol, al, opal
YS-08-JM120A	Silica nodule-opal; Sil and minor Arg wr; sulfides, bar

Table IV-2: Continued.

Sample	Hand Sample Descriptions
YS-08-JM120B	Sil l.gry; drusy qtz; opal, al, bar; sphere
YS-08-JM121	Sil wht-tan; minor Arg ovrprt; clay and silica vlts; al, bar, sulfides; sphere; phenos-alt
YS-08-JM122	Sil l.gry; Arg buff ovrprt; kaol; phenos-alt; oxidized
YS-08-JM123	Sil wht-l.gry; Arg ovrprt; silica and clay vlts; vs; kaol, sulfides; phenos-alt
YS-08-JM124	Sil l.gry rhy; v.minor Arg ovrprt; clay vlts; al, opal; well preserved cb; phenos-alt
YS-08-JM125	Ext Sil wht; heavy vs; drusy qtz; opaline; internally obliterated; oxidized
YS-08-JM126	Sil wht; drusy qtz; opaline
YS-08-JM127	Sil wht-l.pink; silica vlts; vs; drusy qtz; cb replaced-silica; oxidized
YS-08-JM128	Sil wht; vs; silica vlts; no internal structure; opaline
YS-08-JM129	Sil wht-l.gry; silica vlts; vs
YS-08-JM130	Sil wht; gry silica vns; silica vlts; drusy qtz; sulfides; oxidized
YS-08-JM131*	Sil wht and silica nodule; silica vlts; vs; sulfur
YS-08-JM132*	Sil wht-l.gry and Arg wht; oxidized
YS-08-JM133	Sil wht-l.pink; drusy qtz; sulfides, rose qtz
YS-08-JM134	Sil wht; drusy qtz; cb
YS-08-JM135	Sil wht-l.gry; silica vns; drusy qtz; opaline
YS-08-JM136	Sil wht; silica vn; silica vlts; vs; sulfides; opaline
YS-08-JM137	Sil; Arg wht-l.gry ovrprt; silica vlts; clay vlts-connect arg phenos; sulfide vlts-micro
YS-08-JM138	Sil gry-d.gry; v. minor Arg ovrprt; al, bar; vugs-drusy qtz; sphere; phenos-alt
YS-08-JM139	Sil gry; drusy qtz; cb; sphere
YS-08-JM140	Sil wht-gry; sulfide vlts; vs; sphere
YS-08-JM141	Sil gry; wht silica vlts
YS-08-JM142	Sil wht-l.gry; minor Arg ovrprt; clay and silica vlts; sulfides; cb; phenos-alt; oxidized
YS-08-JM143	Sil wht; silica vlts; cb
YS-08-JM144	Sil wht; vs
YS-08-JM145	Sil l.gry; Arg ovrprt; silica and clay vlts; kaol, al; cb replaced-silica; sphere; phenos-alt
YS-08-JM146	Sil gry; heavy Arg ovrprt; vs-sulfur; al, kaol, bar, qtz; cb; sphere
YS-08-JM147	Sil gry; v. minor Arg ovrprt; large sphere
YS-08-JM148	Sil wht-gry; silica vlts; vs
YS-08-JM149	Milled-Mosaic brx vn; Sil wr healed by sulfide-minor silica; silica vn; wr-drusy qtz, sulfide/silica vlts; al
YS-08-JM150	Silica nodule; Sil wr; al, sulfides
YS-08-JM151	Milled-Mosaic(minor crackle) brx vn; Sil wr healed by silica-sulfide selvage; brx:cm-mm; minor sulfides
YS-08-JM152	Sulfide vn; minor brx; silica and sulfide vlts; al
YS-08-JM153	Sil wht; silica vn-sulfide selvage; sulfide vlts
YS-08-JM154	Crackle-Mosaic brx vn; Arg wr healed by sulfide/silica; selvage wr-Sil; brx:2.5cm-mm; brx-colloform silica
YS-08-JM155#1	L.gry silica vn-sulfides; Sil wr-lighter gry, brx; Arg-some wr; sulfide vlts; phenos-alt; "flame structures" and rip-up clasts
YS-08-JM155#2	Sil buff; ~1cm sulfide vn; Sil wr brx healed by silica and sulfide vlts; oxidized
YS-08-JM155#3	Sil gry; sulfide vlts; sulfides, al, wht clays; phenos-alt
YS-08-JM156	Sil gry; drusy qtz; kaol, al, opal, qtz, albite (XRD); cb; phenos-fresh to alt
YS-08-JM157	Sil l.gry; sulfides, minor kaol

Table IV-2: Continued.

YS-07-JM01

Brief Description:

Silicified d.gry tuff with arg overprint

Location:

N 4955881.1
W 545631.5
South Ridge: Top of section

Field Notes:

- Cliff Wall

Description:

- Silicified; slightly argillized
- Clay veinlets
- "Empty" veinlets
- Mineralogy: opal, alunite, kaolinite
- Sphereulites
- Oxidized

YS-07-JM02

Brief Description:
Silicified d. gry tuff with arg overprint

Location:
N 4955883
W 545632
South Ridge: Top of section

Field Notes:

- Under Cliff Wall

Description:

- Silicified; slightly argillized
- Sphereulites
- Mineralogy: alunite/walthierite, kaolinite, opal
- Abundant qtz eyes
- Microveinlets- clay (not abundant; rare)

Thin Section**:**

- Oxidized sulfides in silica mtx
- Silicified and arg
- Silica veinlets
- Sulfide veinlets
- Clay veinlets
- Primary igneous txt observed where silica/arg has not completely replaced mtx

XRD**:**
Major Minerals:

- Opal c-t, alunite/walth, kaol, albite

Minor Minerals:

- Qtz, illite, barite

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-07-JM02

YS-07-JM03

Brief Description:

Silicified d. gry tuff with arg overprint

Location:

N 4955907
W 545635.3
South Ridge: Top of section

Field Notes:

- No Notes; to the West of JM02-07

Description:

- Silicified; slightly argillized
- Sphereulites
- Mineralogy: alunite, kaolinite, opal
- Microveinlets- clay

YS-07-JM04

Brief Description:

Silicified d. gry tuff with arg overprint

Location:

N 4955995
W 545453
South Ridge: Top of section

Field Notes:

- No Notes; to the West of JM03-07

Description:

- Silicified; slightly argillized
- Well preserved comp banding
- Mineralogy: alunite, kaolinite, opal
  - pyt in leached vugs
- Microveinlets- clay

YS-07-JM05

Brief Description:

Silicified gry-d. gry tuff; well preserved comp banding; drusy qtz

Location:

N 4955995
W 545442
South Ridge: Top of section

Field Notes:

- 4ft to the right (West) of 07-JM04

Description:

- Silicified Tuff
- Flow preserved in squashed pumice which has been dissolved and the interior has been replaced with drusy qtz
- Phenos appear to be argillized then silicified noted by a bright white pheno covered in a sugary texture; hard
- Martix appears to be glassy
- Looks to be breccia but I don't think that it is based on the fact that the pumice shows a clear alignment while the phenos are randomly oriented about the pumice; never do the pumice and feldspar? share a space as opposed to the qtz phenos (noting that they are part of the pumice)
- Colloform silica replacement of pumice with drusy center

Thin Section:

- Micrograph: Clay veinlets- leading to/from arg phenos
- Micrograph: Sulfates with disseminated sulfides
- Micrograph: Colloform silica veinlet with sulfides
- Scattered disseminated sulfides
- Relict primary txt

XRD:

Major Minerals:

- Opal c-t, barite

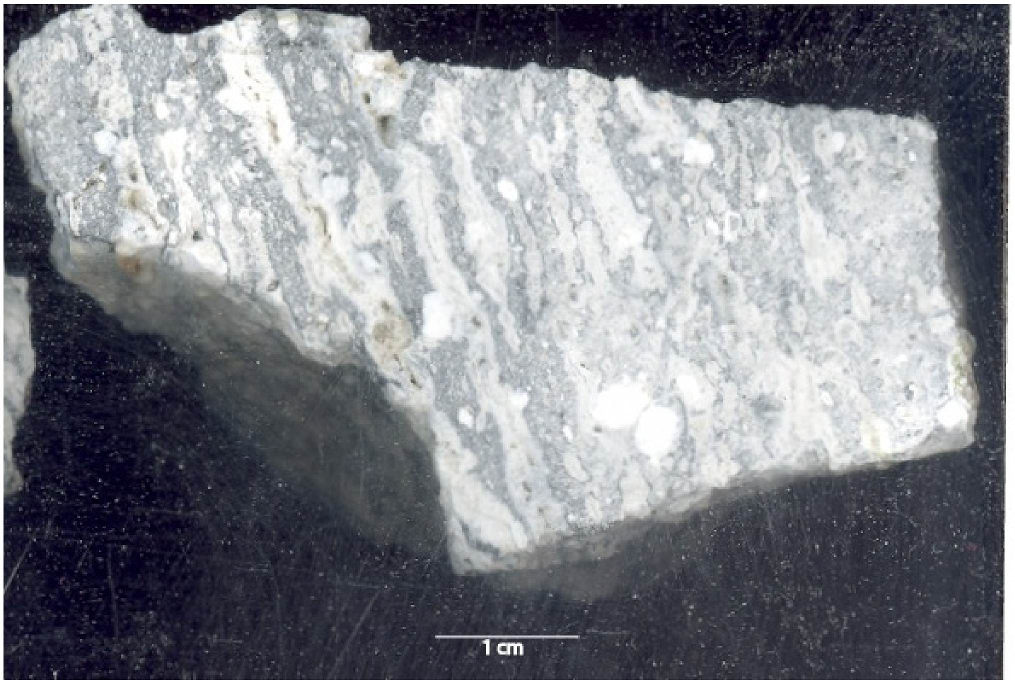
Minor Minerals:

- Diaspore, kaolinte

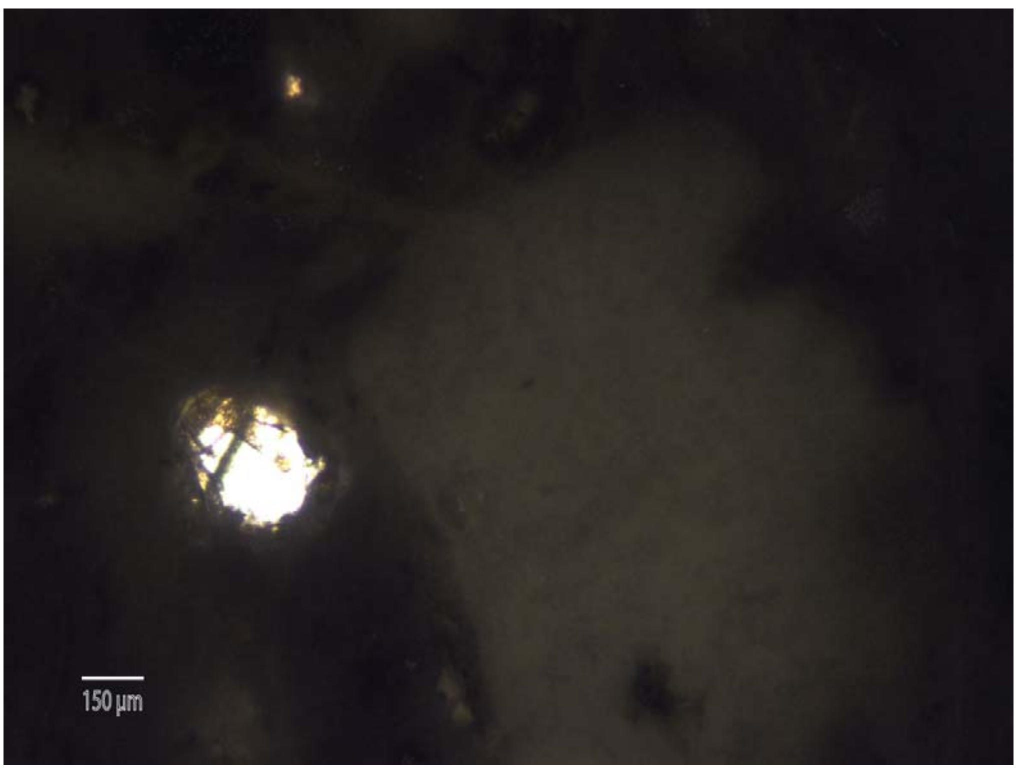
Mineral Assemblage 3

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

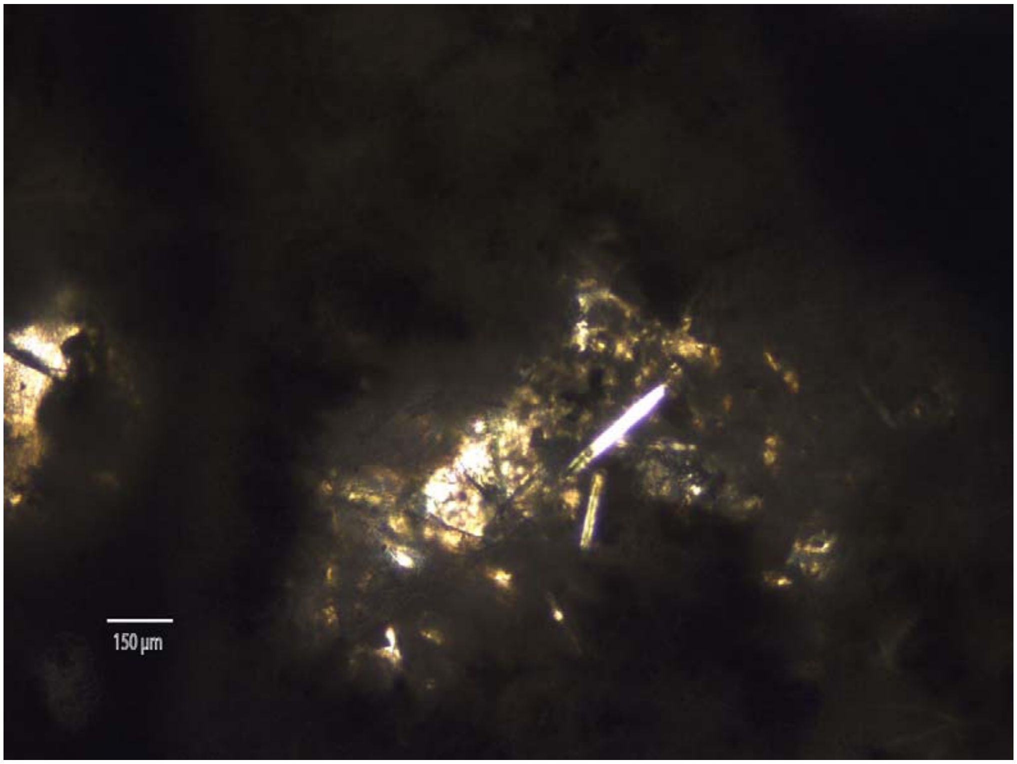
Stable Isotope: 4.27 ‰



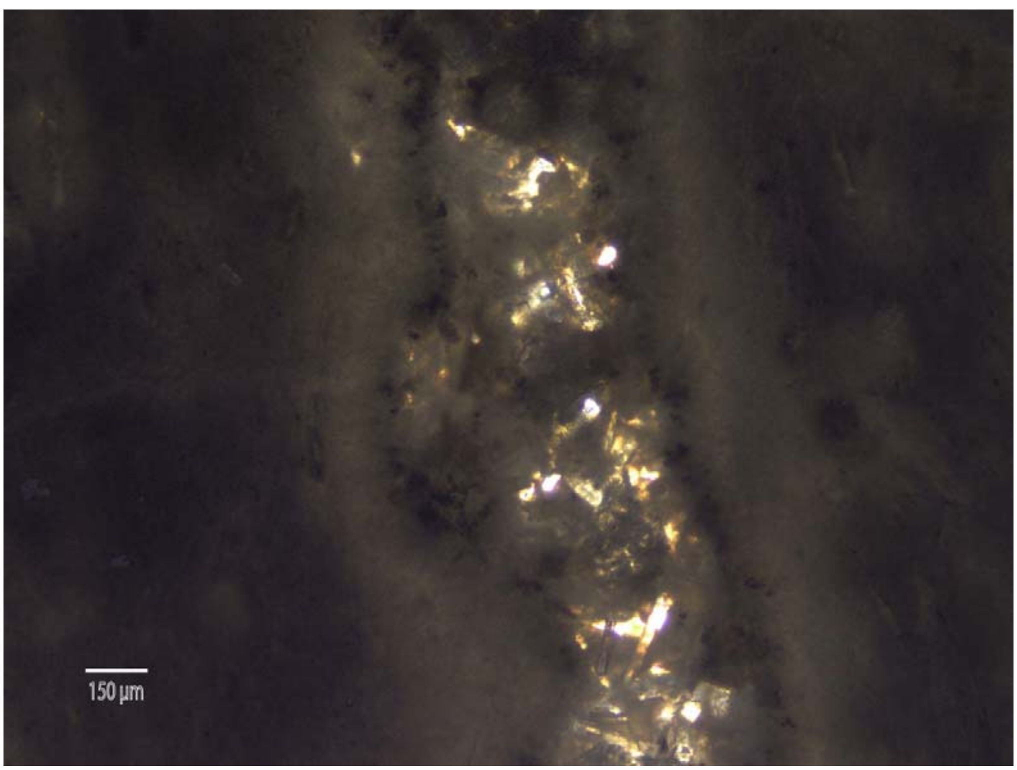
Scan: YS-07-JM05



YS-07-JM05: Clay veinlets- leading to/from arg phenos



YS-07-JM05: Sulfates with disseminated sulfides



YS-07-JM05: Colloform silica veinlet with sulfides.

YS-07-JM06

Brief Description:

Silicified wht tuff with arg overprinting

Location:

N 4955987

W 545428

South Ridge: Top of section

Field Notes:

- Allie's collected from top of spire
- Below 07-JM07

Description:

- Argillized; slightly silcified
- Minor acid leaching
- Druzy qtz
- Minerals: kaolinite, alunite, opal

YS-07-JM07

Brief Description:

Silicified d. gry tuff

Location:

N 4955980

W 545428

South Ridge: Top of section

Field Notes:

- No Notes
- Above 07-JM06

Description:

- Silicified
- Mineralogy: Alunite or Barite, opal, implied Kaolinite
- Milky white silica vein: ~1.5cm

YS-08-JM02

Brief Description:
Silicified wht tuff with minor arg overprint

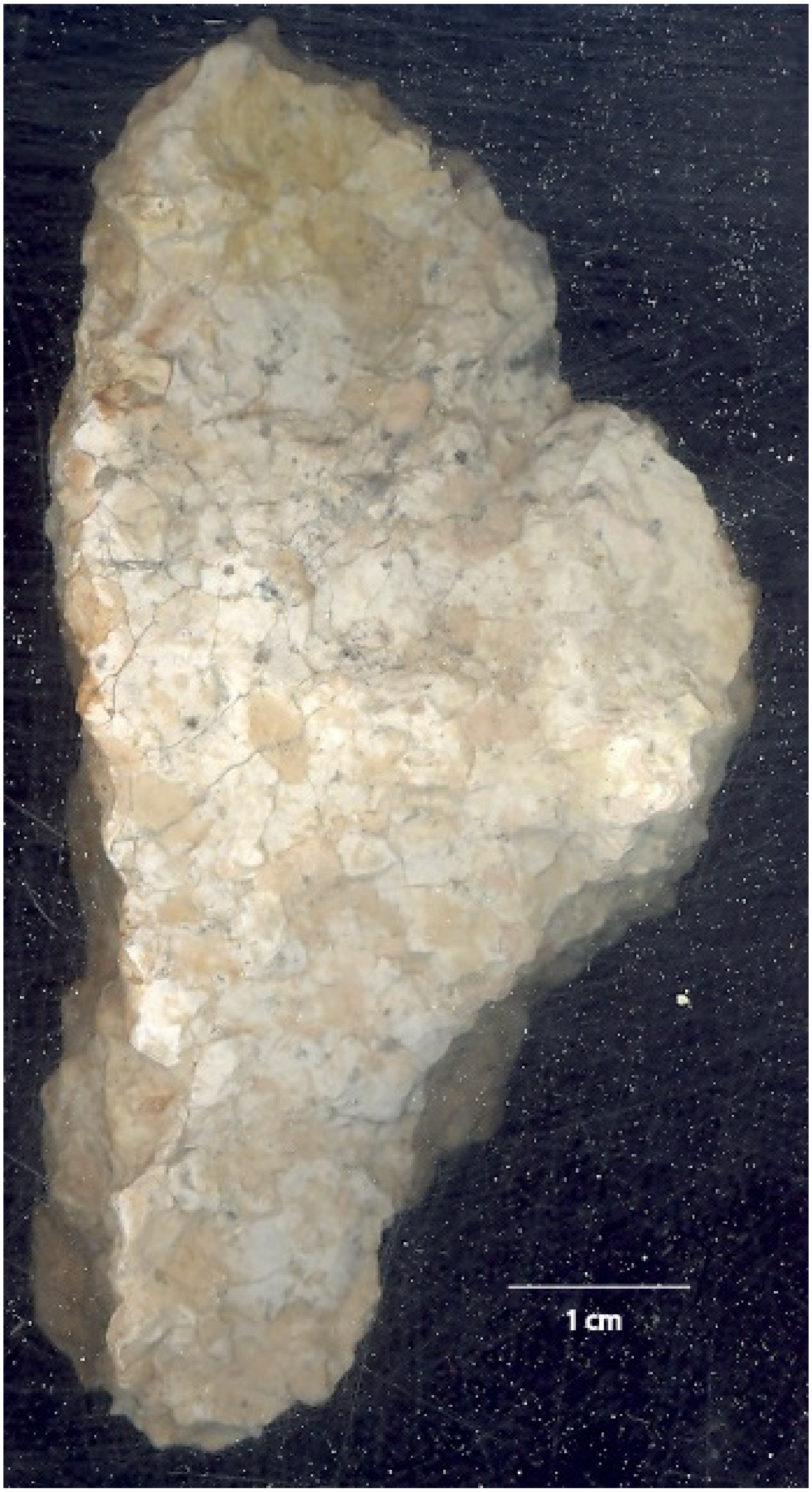
Location:
N 4956058
W 545402
Outcrop 7: Middle

Field Notes:

- Sample from under tree
- small samples

Description:

- Silicified; arg overprint very minor
- Silica veinlets (some micro)
- "Empty" veinlets
- Compression banding infilled w. silica
- Mineralogy: Alunite and/or barite, minor clays



Scan: YS-08-JM02

YS-08-JM03

Brief Description:
Silicified wht tuff

Location:
N 4956052
W 545402
Outcrop 7: Middle

Field Notes:

- 25ft upslope from JM02

Description:

- Silicified
- No veinlets
- Compression banding infilled w. silica
- Mineralogy: alunite and/or barite, minor clays
- Drusy qtz

YS-08-JM04

Brief Description:

Silicified wht tuff; minor brx; qtz veinlet; arg phenos

Location:

N 4956047
W 545404
Outcrop 7: Middle

Field Notes:

- 11ft up section and left (further in section: i.e.- East) from JM03

Description:

- Silicified wht to buff
- Acid leached
- Flow preserved- silica replacement
- Micro silica veinlets leading from larger silica veinlet to another
- Phenos are almost lost in matrix b/c of alteration
  - phenos are white and angular
- Drusy qtz in fluid dissolved vuggy area
- V. minor expansion brecciation healed by silica (angular bx)
- Not sure if they are sphereulites or not. It may be bx due to fluid dissolving and rearranging; the pieces are angular so probably NOT sphereulites! Plus, from middle of section and almost all sphereulites are from the top of the section. The rock has been hit pretty hard so, I'm not sure though (but pretty sure)

XRD**:**

Major Minerals:

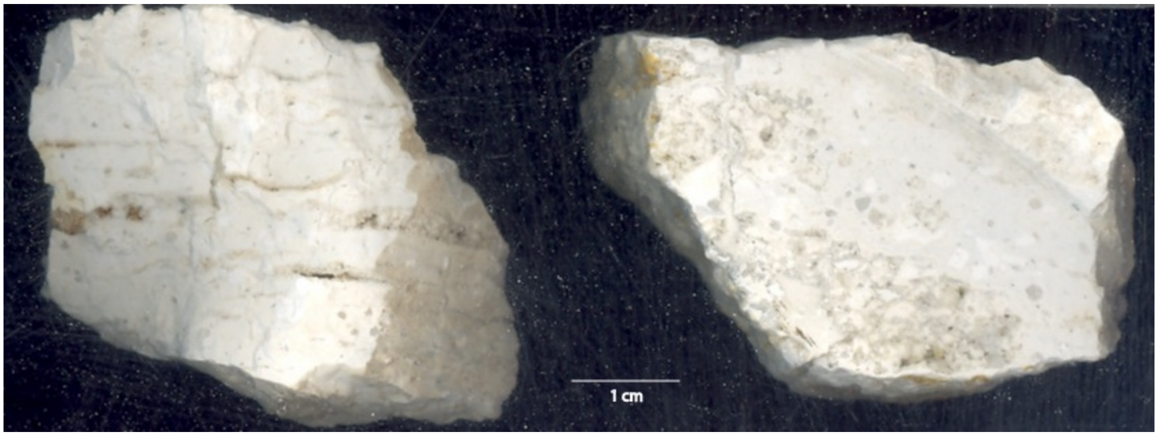
- Qtz, illite

Minor Minerals:

- Alunite, barite

Mineral Assemblage 2

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM04

YS-08-JM05

Brief Description:

Silicified wht tuff

Location:

N 4956043
W 545404
Outcrop 7: Middle

Field Notes:

- ~19ft up section from JM04; directly above JM04
- Topmost part of section

Description:

- Silicified wht tuff
- Compression banding infilled w. silica
- No veinlets
- Drusy qtz
- Arg phenos: alunite and/or barite, probably qtz/opal and illite

YS-08-JM06

Brief Description:
Arg wht tuff

Location:
N 4956056
W 545409
Outcrop 7: Middle

Field Notes:
- 25ft to left (East) of JM02

Description:
- Possibly slightly silicified (with an Arg overprint)
- Compression banding infilled w. silica
- Silica veinlets (hairline) perp. to flow
- Proto phenos: qtz eyes
- Arg phenos: alunite and/or barite, probably qtz/opal and illite

YS-08-JM07

Brief Description:
Silicified l.gry tuff with minor arg overprint

Location:
N 4956059
W545415
Outcrop 7: Middle

Field Notes:

- 25ft to left (East) towards convergence
- Approx 20 ft below JM06 (on slope)

Description:

- Silicified with minor Arg overprint
- Compression banding infilled w. silica
- Silica veinlets (hairline) perp. to flow
- Arg phenos: alunite and/or barite, probably qtz/opal and illite?

YS-08-JM08

Brief Description:

Breccia w. subrounded arg clasts of wall rock (qtz eyes) healed by silica/sulfides

Location:

N 4956059
W 545422
Outcrop 7: Base

Field Notes:

- 25ft east
- Approximately 5-10ft below JM07 in section
- Silicified outcrop; hard to break
- Large weathered out phenocrysts

Description:

- Crackle and Mosaic breccia w. arg clasts of wall rock healed by l.-d.gry silica/sulfides clustered in silica
- Kaolinite, alunite, qtz
- Clast supported with gray matrix
- Breccia is btw mm and .5cm
- Thought they were healed by silica only—but that is not the case; there are definitely sulfides in the sample
- Wall rock – breccia—white to buff
- 80% SiO2 – So, I don't think the wall rock was silicified prior to this hydrothermal event
- Brx moved (crackle) but not dissolved
- Veinlets in the breccia/matrix
- There are no visible phenos which seems strange to me. Most every other sample has abundant phenos. But here there maybe a qtz eye every now and then, but other than that, nothing.
- Low sulfates according to XRF
- So, XRF oxides look like unaltered tuff—the only thing that has elevated levels are the lithophile elements—(especially Cr and V)

XRD:
Major Minerals:

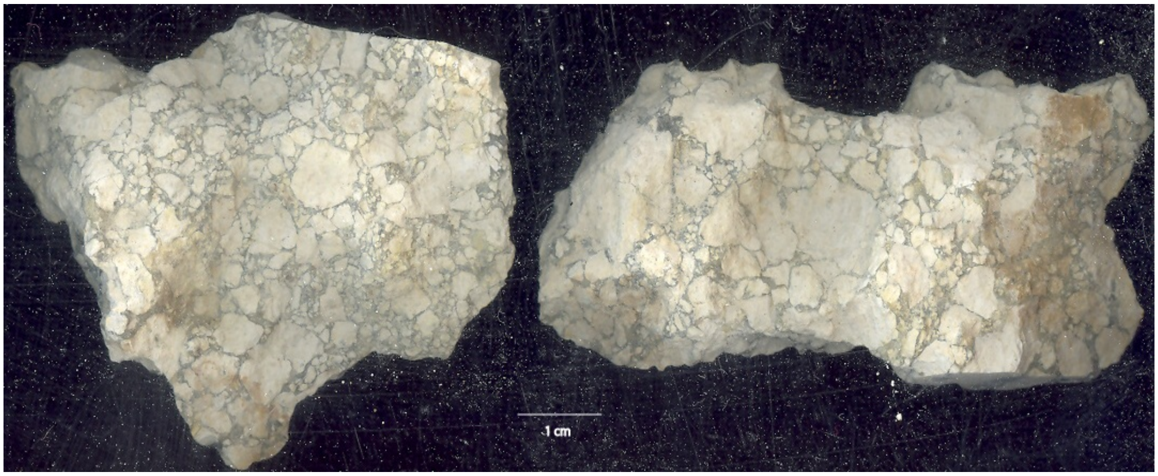
- Qtz, Kaolinite, Alunite/ Walth, albite

Minor Minerals:

- Opal ct, pyt, marc

Mineral Assemblage 3

XRF/ ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM08

YS-08-JM09

Brief Description:

Milled to Mosaic breccia w. arg clasts of wall rock healed by silica/sulfides

Location:

N 4956061
W 545429
Outcrop 7: Base

Field Notes:

- 25ft towards convergence (east)
- Directly below (~1ft JM08)
- Large arg phenos
- Directly above creek bed

Description:

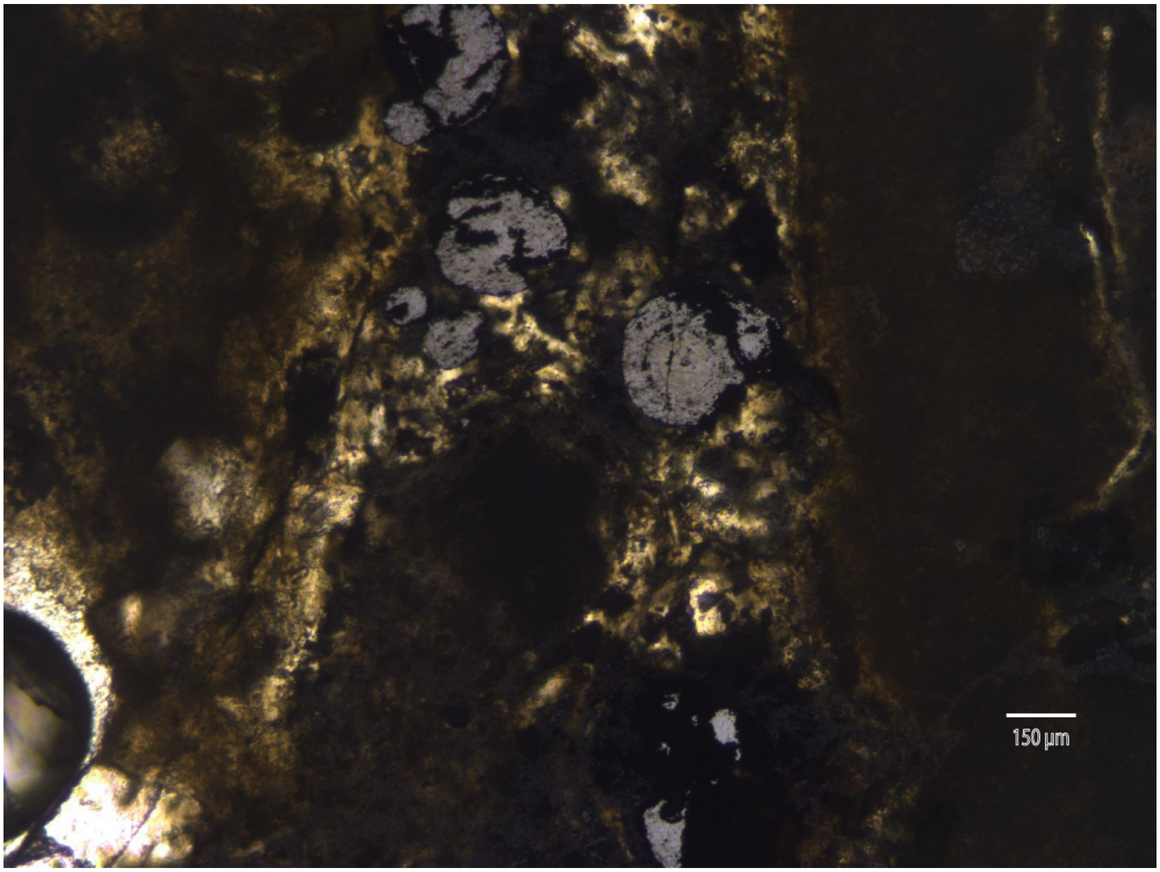
- Milled to Mosaic breccia w. arg clasts of wall rock healed by silica (probably qtz)
- Sulfides in clusters and selvage of silica vein
- Brx between 2.5cm to mm; larger clasts but matrix supported
- White clay (kaolinite)

Thin Section:

- Micrograph: Botryoidal sulfide grains; fractured
- Silica veinlets with sulfides
- Brx healed by massive silica
    - wall rock- flooded by silica (no primary igneous txt)
    - brx is ripped apart
- Disseminated pyt through silica mtx
- Sulfides veinlets

Stable Isotope**:** 0.47‰

Scan: YS-08-JM09



YS-08-JM09: Botryoidal sulfide grains.

YS-08-JM10

Brief Description:

Arg gry tuff

Location:

N 4956059.5
W 545436
Outcrop 7: Base

Field Notes:

- Right before first creek drop
- Below and btw ridge and spires
- Opal present in float, not in samples yet
- Above river

Description:

- Looks like JM18 and JM07 except JM10 has brx
- Argillized gray tuff
- Milled breccia w large angular clasts (1in to mm)
    - (ext fine grained to angular clasts)
- Healed by silica
- Sulfides clustered in silica
- White clay (kaolinite?)
- Visible compression banding

YS-08-JM11

Brief Description:

Silicified gry tuff with arg overprint

Location:

N 4956057.5
W 545441
Outcrop 7: Base

Field Notes:

- Approx. 10ft-15ft above first drop
- Sugary nature—alunite?
- Prevalent kaolinite in float (sticks to tongue)

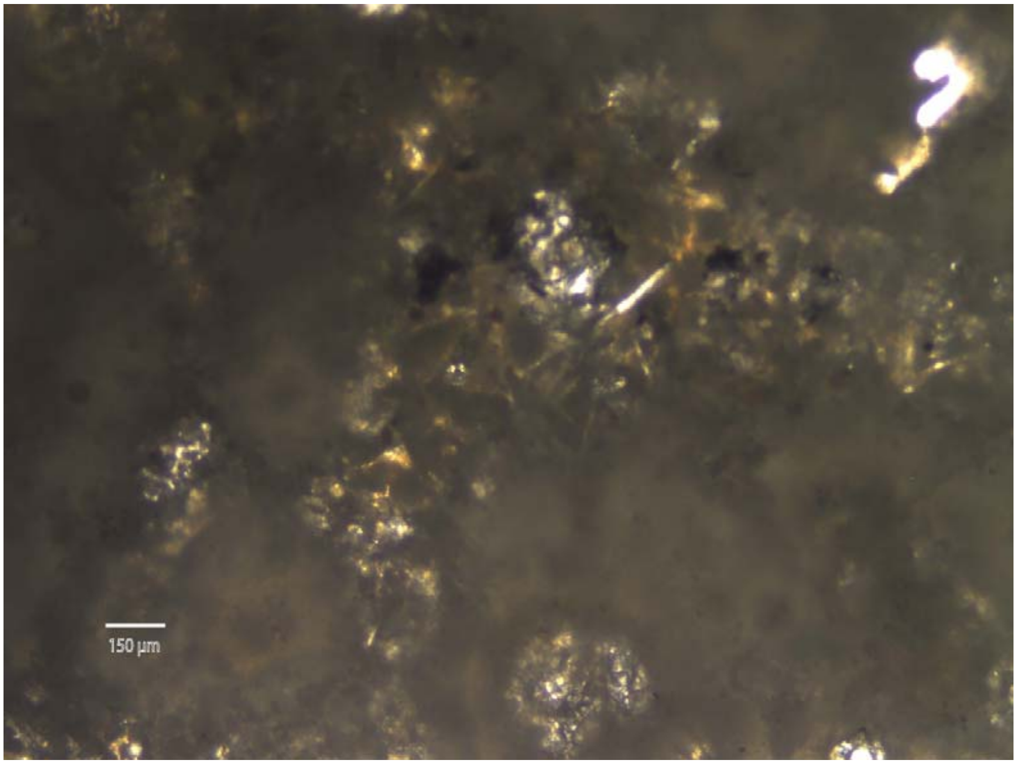
Description:

- Silicified gry tuff with arg overprint
- Elongated vugs w silica replacement
- Clay veinlets perp to flow
- Drusy qtz
- Arg phenos: kaol, alunite
- Qtz eyes
- White clay (kaolinite) masses in light gray matrix
- Primary igneous txt vaguely preserved

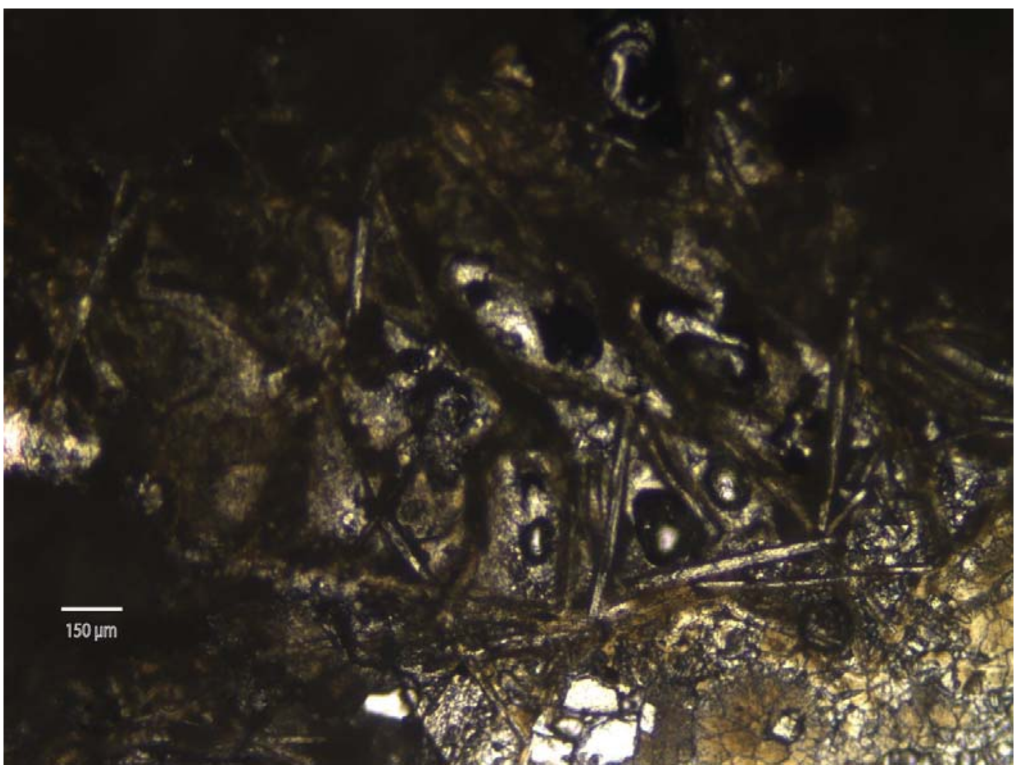
Thin Section:

- Micrographs (2): Blade sulfates in argillized matrix
- Silica veinlets
- Silicified wall rock- veinlets cut compression

Scan: YS-08-JM11



YS-08-JM11: Bladed sulfates in argillized matrix. Note minor sulfides in matrix.



YS-08-JM11: Bladed sulfates.

YS-08-JM12

Brief Description:

Wht opal vein

Location:

N 4956051
W 545442.5
Outcrop 7: Middle

Field Notes:

- Approx. 10’ East (up stream) from JM11
- 7-10ft up section from JM11

Description:

- Wht opal vein
- Wall rock arg
- Kaolinite, alunite

Stable Isotope: 0.25‰

YS-08-JM13

Brief Description:
Silicified light to d.gry tuff with Arg overprint; arg phenos

Location:
N 4956043
W 545442
Outcrop 7: Middle

Field Notes:

- ~25ft upslope from JM12
- East; above and btw JM11 and JM12
- 30-35ft above JM11t below JM07 in section
- Smaller phenos
- Oxidized
- Qtz veins
    - Few cm to 1in

Description:

- Arg gry tuff
- Well preserved compression banding
- Clay and silica veinlets
- Arg phenos: barite, alunite, kaolinite
- Wht euhedral clays
- Pumice shards have been mostly dissolved and then had a slight silica replacement as well as clay filling in the vugs
- V. minor rip-up brx along silica vein

Thin Section:

- Ext fine-grained sulfides
    - Disseminated throughout silica mtx with minor larger –once round- sulfides
- Sulfide veinlets
- Micro silica veinlets
- All veinlets crosscut each other

Stable Isotope:

- Matrix: -3.01‰
- Vein1: -0.51‰
- Vein2: 2.03‰

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM13

YS-08-JM14

Brief Description:

Mosaic-milled brx healed by silica and sulfide veinlets

Location:

N 4956057
W 545448
Outcrop 7: Base

Field Notes:

- Directly above creek
- Approx 25ft east of JM11

Description:

- Mosaic- milled brx healed by silica and sulfide
- Wall rock: Arg wht tuff
- Clasts supported
- Minor sulfides clustered in silica mtx
- Wht clay (kaolinite) in gry mtx
- Sulfide veinlets with minor internal brx
- Arg phenos: kaolinite, alunite, barite?
- Possible qtz

YS-08-JM15

Brief Description:

Silicified l.gry tuff

Location:

N 4956062
W 545452
Outcrop 4C: Base

Field Notes:

- Across Stream (north wall)
- Approx 2ft east of JM14
- 1-2 ft above stream
- North wall!!

Description:

- Silicified l.gry tuff
- Minor clay/sulfates
- Compression banding with silica replacement
- Silica veinlets

YS-08-JM16

Brief Description:

Silicified wht-l.gry tuff with arg overprint

Location:

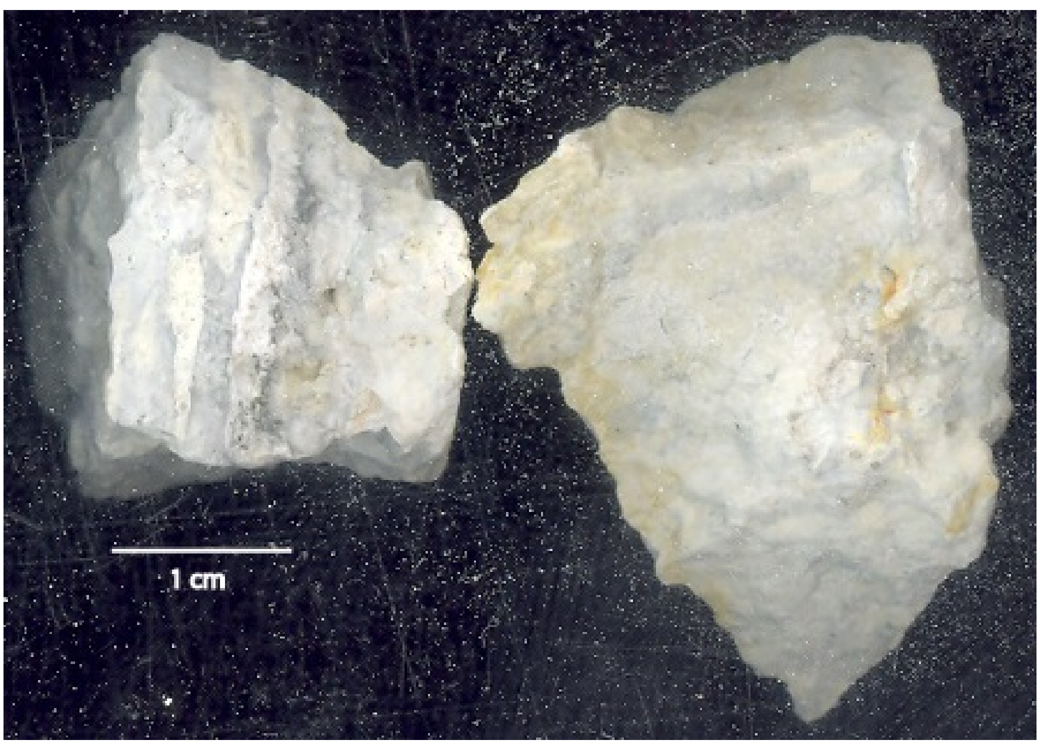
N 4956053
W 545448
Outcrop 7: Base

Field Notes:

- On South wall
- Approx 10-15ft (13ft) above creek bed and approx above JM14
- Good outcrop before bend?
- Thin crusty layer on outcrop: Sinter

Description:

- Silicified wht-l.gry tuff with arg overprint
- Minor sulfides clustered in silica
- Silica replaced flow banding
- Arg phenos: barite, alunite, probably kaol, and qtz
- Proto phenos: qtz eyes



YS-08-JM17

Brief Description:

Argillized d.gry tuff; arg phenos

Location:

N 4956063
W 545446
Outcrop 4C: Base

Field Notes:

- North wall
- ~2-3ft above creek
- ~10ft up stream from JM15

Description:

- Arg d. gry tuff
- Qtz, alunite, opal c-t
- Acid leached
- Minor white clay
    - possible kaolinite
- Euhedral phenos
- Highly argillized
- Internal structure almost obliterated
    - Some pumice shards visible—clay replacement
- No veins

Thin Section:

- Primary txt
- Minor dissolved sulfides
    - perp. to compression banding

XRD:

Major Minerals:

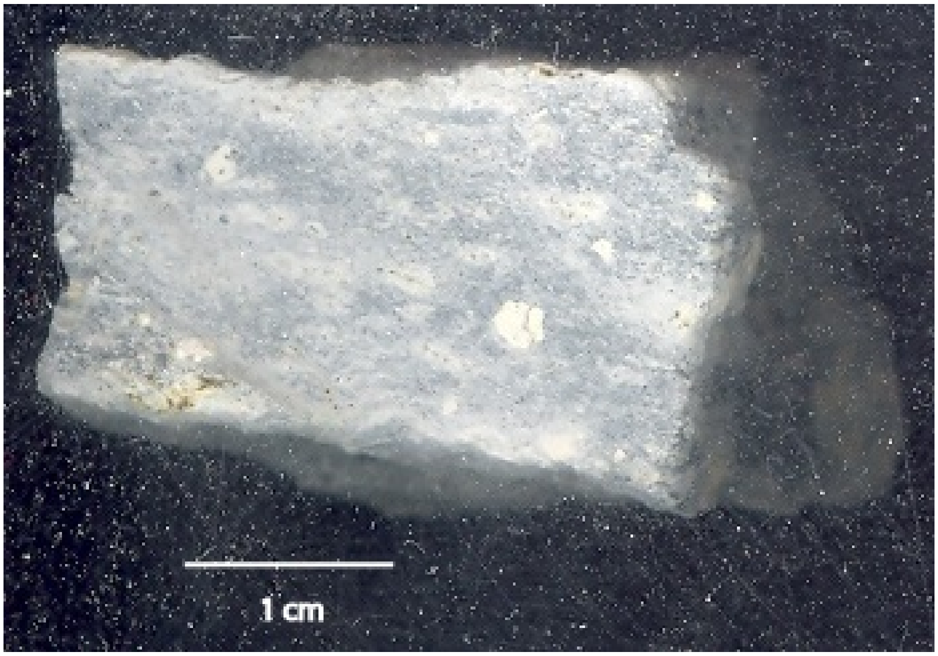
- Qtz, kaolinite, al/walth, sanidine

Minor Minerals:

- Dickite, illite, opal ct

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM17

YS-08-JM18

Brief Description:

Silicified, l.gry tuff

Location:

N 4956072
W 545395.5
Outcrop 7: Base

Field Notes:

- Upstream from others (to the West)
- South wall
- Directly above stream bed, under tree

Description:

- Silicified, l.gry tuff
- Hairline silica veinlets
- Sulfide veinlets
- Sulfides clustered in silica replacement
- Slightly acid leached
- White, euhedral clay (kaolinite?)

YS-08-JM19

Brief Description:

Silicified gry-d.gry tuff with arg overprint

Location:

N 4956082.1
W 545203.4
Stream: Base

Field Notes:

- ~15 m long vein in stream bean
- Opal, brecciated, sulfides
  - dotty, fine to disseminated pyt
- 1-5 cm wide
- Porcelainic opal
- N20W
- Colloform
- Pyt looks encrusting

Description:

- Silicified gry-d.gry tuff with arg overprint
- Silica vein
- Massive pyt in silica
- Clay veinlets
- Kaolinite/alunite
- Wht clay phenos

YS-08-JM20

Brief Description:

Brecciated mosaic-milled silica/sulfide vein w. previously silicified wall rock

Location:

N 4956079.6
W 545212.4
Stream: Base

Field Notes:

- From ~5m East
- Vein
- PYT!

Description:

- Brecciated mosaic-milled silica/sulfide
- Previously silicified wall rock
- Minor arg phenos (kaolinite)
- Alunite
- Brx includes clasts of mosaic opal/chalcedony

Thin Section:

- Sulfides distributed throughout silica mtx
- Relict primary txt

Stable Isotope: -0.18‰

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)

Scan: YS-08-JM20

YS-08-JM21

Brief Description:

Milled brx; perp to flow healed by silica/sulfide

Location:

N 4956067
W 545252.2
Stream: Base

Field Notes:

- Sample from stream, east of JM20
- Silicified
- Pyt healed fractures

Description:

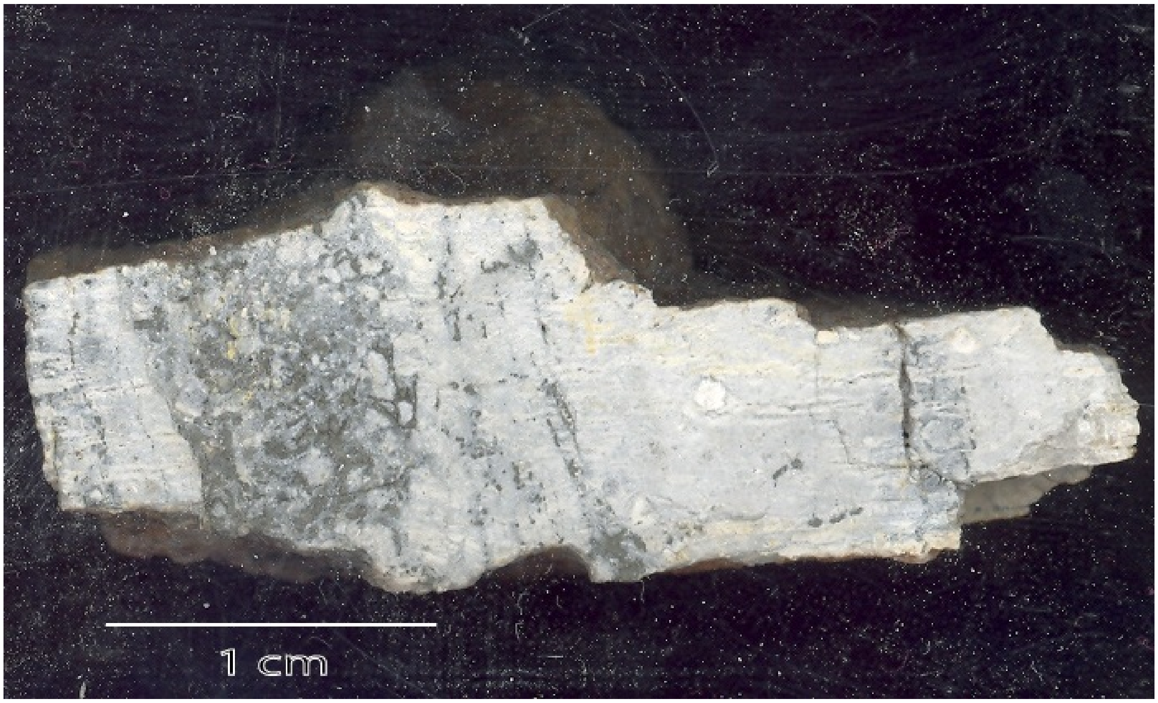
- Milled brx- perp to flow healed by silica/sulfide
- Silcified wall rock
- Sulfides throughout silica mtx
- Sulfide/silica veinlets
- Clay veinlets
- Qtz eyes

Thin Section:

- Botryoidal, colloform marcasite
- Botryoidal sulfides
- Micro silica veinlets
- Primary txt preserved
- Silicified
- Pyt
- Both continuous and discontinuous sulfide veinlets
    - Cross-cut texture
    - Some mirco veinlets
- Sulfides infill silica filled vugs

Au + 49 Element Assay: See Tables III- 6 and 7 (Appendix III)

Scan: YS-08-JM21



Scan: YS-08-JM21

YS-08-JM22

Brief Description:

L.gry tuff; sulfide/silica vein w minor breccia

Location:

N 4956078
W 545389
Outcrop 4C: Base

Field Notes:

- Vein in North wall
- No sulfides visible
  - Microscopic!
- Vein ~5cm wide

Description:

- Silicified white to l.gry tuff with major arg overprint
- Sulfide vein w breccia
  - alunite in selvage of vein
- Compression banding
- Walth, qtz, kaolinite
- Wht clay phenos- kaolinite
- Clay veinlets
- Remnant pumice- leached
- Argillization halo around pumice
- Micro veining too small to tell mineralogy but moves from leached pheno to mtx
- Matrix gray but is visibly bleached
- Silica and sulfide vein with brecciation; some brx has been leached
- Brx milled; rounded clasts
- Some wall rock has been dissolved- qtz eyes in the vein matrix
- Argillized phenos

Thin Section:

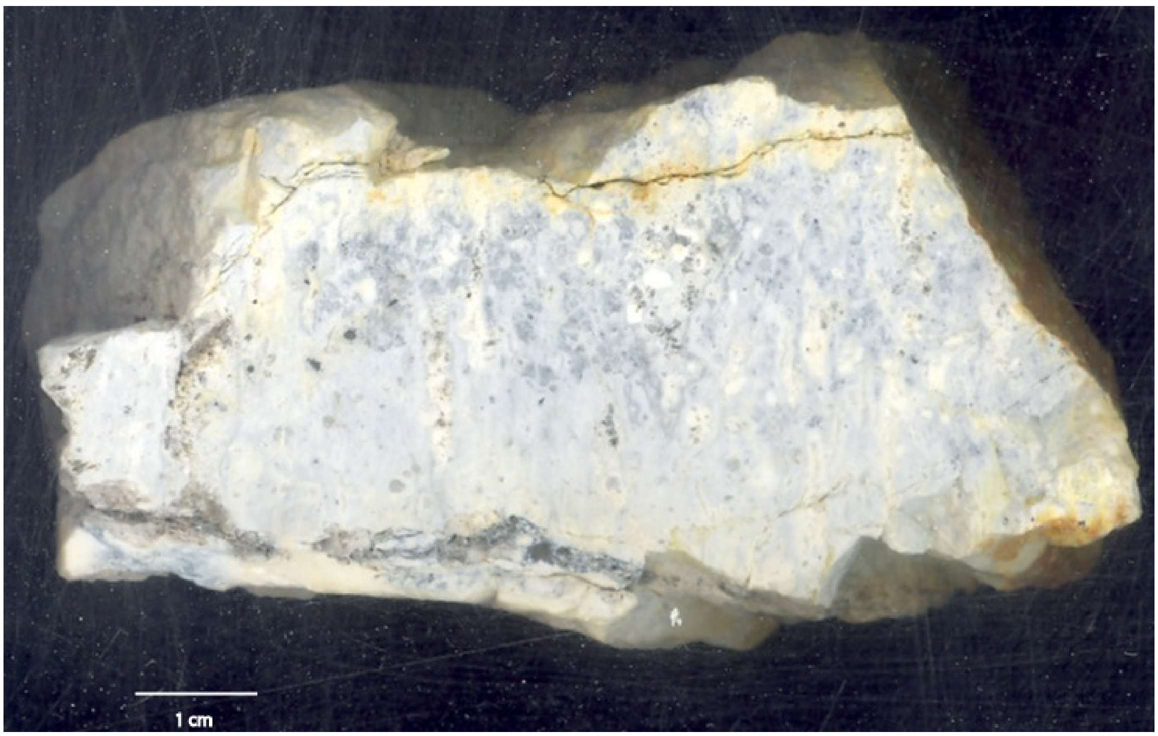
- Clay veinlets (some micro)- leading to/from arg phenos
- Silica veinlets (some micro)
- Sulfides- cluster in mtx
- Extremely fine grained pyt
  - Some larger grains
- Silicified mtx
- High concentration of veinlets
  - Silica and some clay

XRD:
Major Minerals:
- Kaolinite, alunite, walth

Minor Minerals:
- Illite, mont, huangite, albite, opal ct, qtz

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM22

YS-08-JM23

Brief Description:

Argillized brx tuff

Location:

N 4955902
W 544822
Outcrop 1: Base

Field Notes:

- Also first outcrop of western edge
- Gray qtz; qtz eyes, slightly vuggy; no sulfides
- Outcrop is covered by moss; lichens hiding possible veins

Description:

Uncut:

- Moss covered
- Relationships difficult to decipher b/c of moss and oxidation
- Dark gray matrix
- Solid, white clay veinlets
- Qtz eyes

Cut Surface:

- Brecciated
  - Pieces ~0.3-0.8"
- Healed by silica
- Some clasts rounded, others angular
- Microfractures cross cut breccia
  - mostly stem from healing but some cut healed section
  - unable to tell what they are; Fe stained
- Minor white clay replacement- amorphous
- Clay veinlets
- Qtz eyes
- Possibly 2 periods of fragmentation because some fragments rounded and some angular

Thin Section:

- High concentration of veinlets and microveinlets (silica/clay)
- V.minor sulfide
  - Always close to clay veins but never in or on vein

XRF/ ICP-MS: See Tables III-2, 3, 4 (Appendix III)

XRD:
Run 1:
Major Minerals:

- Qtz, Al/walth, Kaol

Minor Minerals:

- Opal C-T, dickite

Run 2:
Major Minerals:

- Opal C-T, Al/walth, kaol

Minor Minerals:

- Qtz, dickite

Mineral Assemblage 3

Scan: YS-08-JM23

YS-08-JM24

Brief Description:

Argilized gry tuff

Location:

N 4955901

W 544829

Outcrop 1: Base

Field Notes:

- Outcrop is ~ 20-25 ft east of JM23
- No qtz eyes

Description:

- Light to dark gray argillized tuff
- White phenocrysts
  - some euhedral (rectangular), semi-rounded (often circular), and rounded (argillized)
  - range in sizes (less than 1/20" to 3/20")
  - some look like clay but are often hard
  - feldspar lithics cut compression banding
    - mostly angular but sometimes subrounded
- Qtz eyes range in size but are <0.04cm
- Minor fracture-vuggy (~2.5cm minor vugs) (~5cm major vugs-width of sample)
  - perpendicular to compression
- Veinlets: clay (immobile Al + silica) suggesting fluids reacting with wall rock
  - cut compression
- Adjacent to JM23, yet shows no sign of brx

Thin Section:

- Micrograph (3): Argillized pheno with clay veinlets cross cutting or altering pheno
- Silicified wall rock
- Silica/sulfide veinlets (some micro)
- Minor sulfides aligned in wall rock fabric
- Clay veinlets: lead to/from arg phenos

XRD:

Major Minerals:

- Walth/al, kaolinite, opal ct, illite

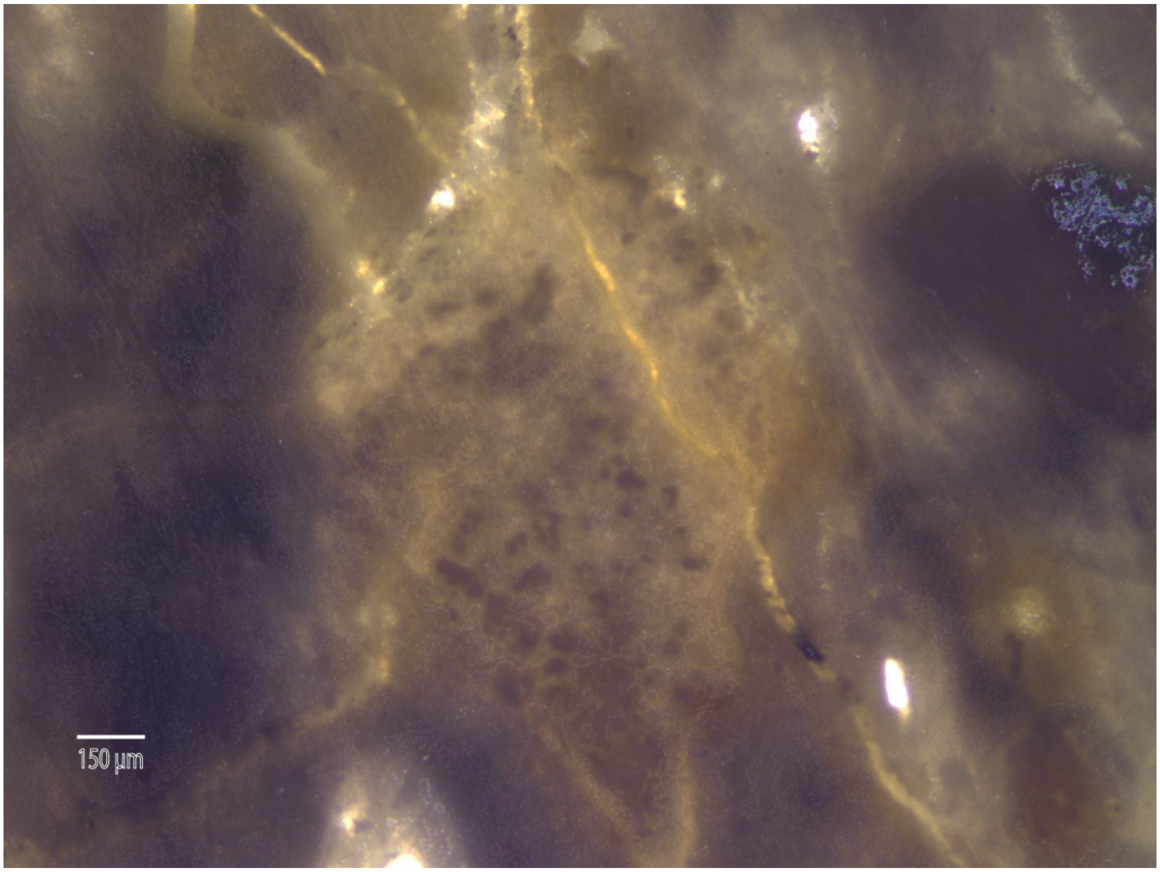
Minor Minerals:

- Qtz, dickite, mont, illite

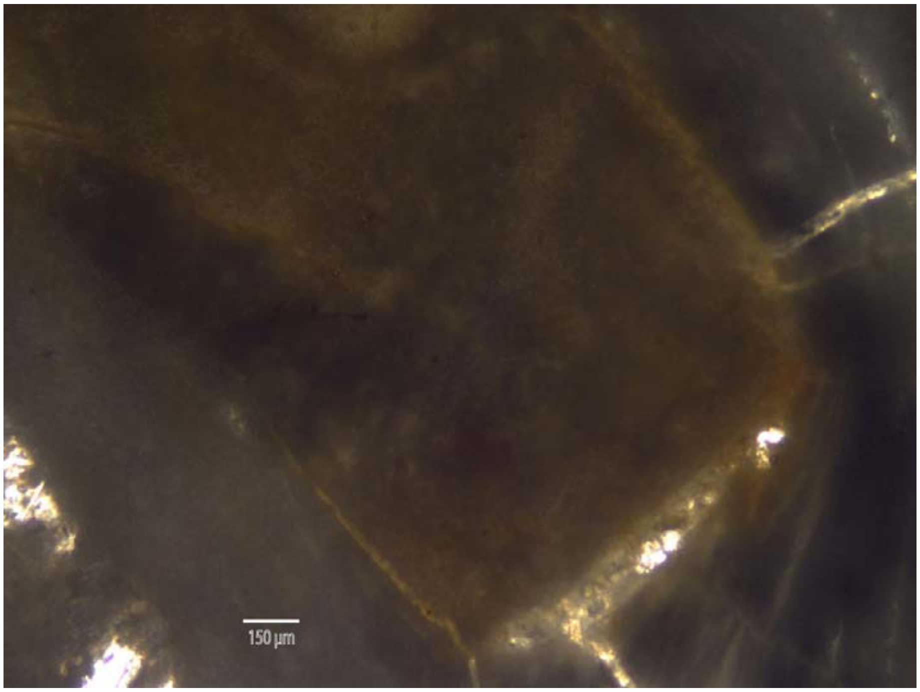
Mineral Assemblage 1

*****In the whole rock sample, illite is not a major component but in the "clays" sample, illite is a major mineral along with kaolinite

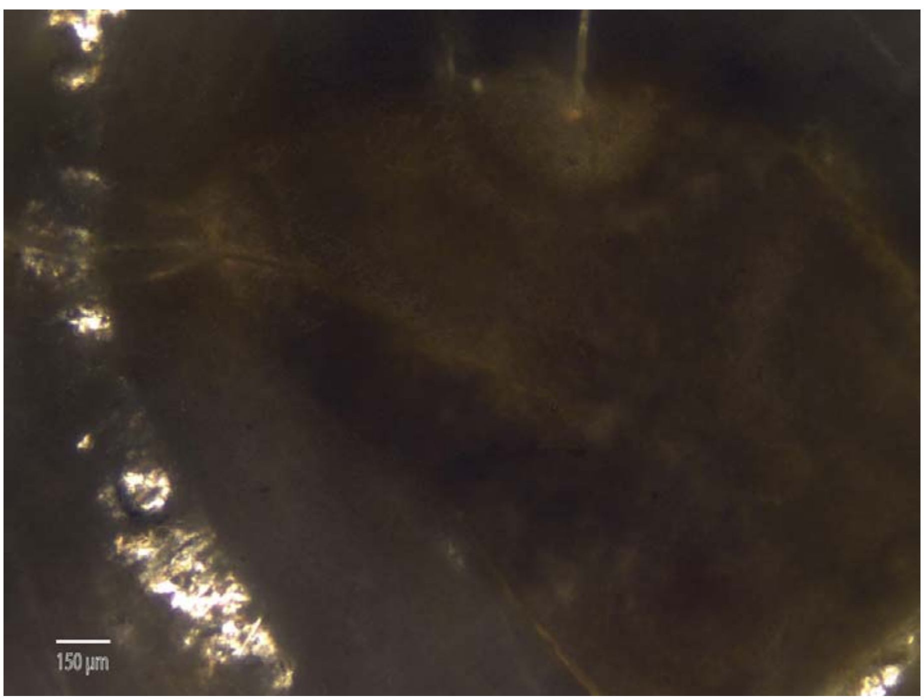
Scan: YS-08-JM24



YS-08-JM24: Argillized phenocryst with clay veinlets altering phenocryst and cross-cutting phenocryst. Note disseminated sulfides inside of the phenocryst as well as in the clay veinlet cross-cutting phenocryst. Sulfides are also located in the selvage of the altering veinlets as well as in the matrix. One sulfide veinlet with a clay selvage is visible in the middle of the picture on the left-hand side.



YS-08-JM24: Argillized phenocryst with minor disseminated clays. Silica veinlets wet the grain rim and one clay veinlet cross-cuts the grain.



YS-08-JM24: Same phenocryst as above. Upper left-hand corner of the phenocryst contains a sulfide veinlet with clay selvage and clay veinlets, all cross-cutting the argillized phenocryst.

YS-08-JM25

Brief Description:

Tan Argilized tuff

Location:

N 4955901
W 544835
Outcrop 1: Base

Field Notes:

- Continuing laterally: approx 20ft
- Edge of slope/tree line
- No silicification
- Veinlets

Description:

- Arg tan tuff
- Dominated by clay veinlets
  - veinlets perp to flow banding
- Micro silica veinlets
- Proto phenos: Qtz eyes, Ca- albite
- Alteration minerals: small euhedral clay (kaolinite), al/walth, qtz/opal c-t

YS-08-JM26

Brief Description:

Wht Arg tuff

Location:

N 4955901
W 544839
Outcrop 1: Base

Field Notes:

- Qtz eyes
- White clay
- Silicified
- 15ft laterally over (East?) from JM25
- Small outcrop, east of main outcrop
- Slightly vuggy

Description:

- Arg white tuff
- Heavy acid leaching of phenos
- White clay: koalinite (sticks to tongue)
- No veinlets

YS-08-JM27

Brief Description:

Wht- l.gry Argilized, slightly silicified, tuff

Location:

N 4955900
W 544842
Outcrop 1: Base

Field Notes:

- Approx 10 ft east of JM26
- Sample from bottom of rock mass
- Silicified
- Small phenocrysts

Description:

- Light to dark gray argillized tuff, slightly sil
- Moss covered
- Central bleaching
    - Protolith still visible, just bleached white
- Minor leaching of phenos (exterior)
- Large sphereulites
    - In devitrified section: brx
- Rounded feldspars- altered
    - Brown, light pink, and white
- Qtz eyes ~ 4mm
- Elongated vugs
    - <0.12cm
- V. minor silica veinlets

Thin Section:

- Silica microveinlets
    - Perp to compression
- Micro sulfide veinlets with silica selvage

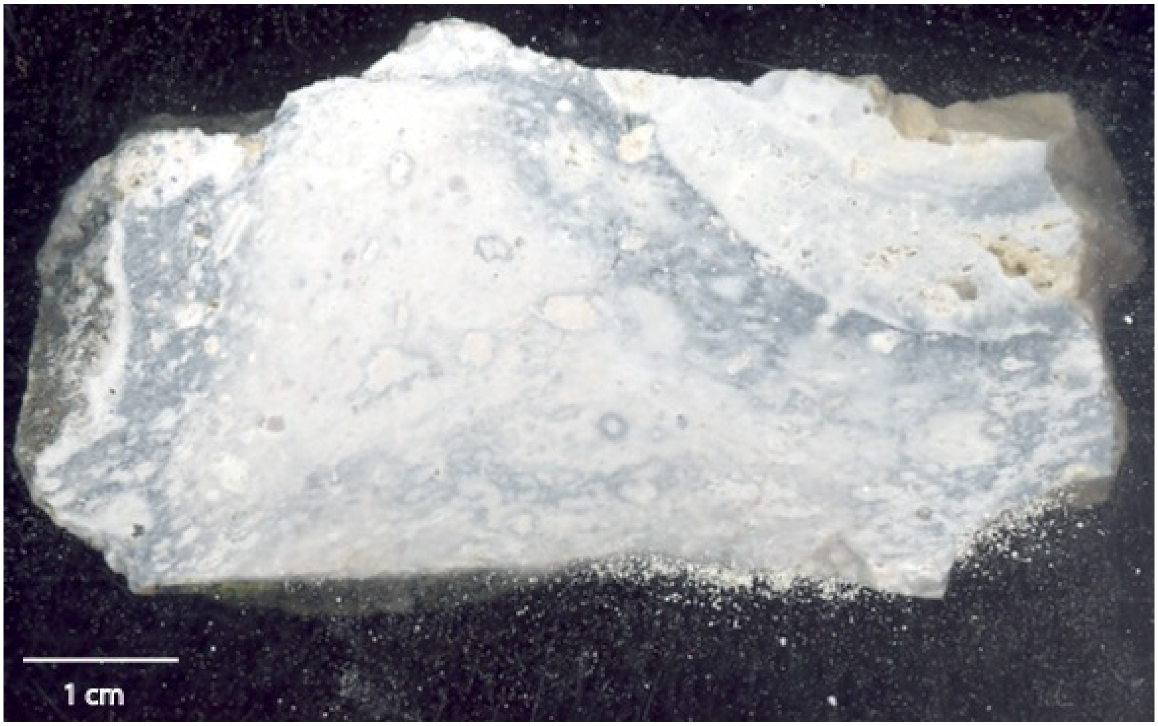
XRD:
Major Minerals:

- Opal c-t, kaolinite

Minor Minerals:

- Illite, beidellite, alunite/walth, dickite, mont, qtz

Mineral Assemblage 1



Scan: YS-08-JM27

YS-08-JM28

Brief Description:
Gray, bleached, arg tuff

Location:
N 4955904
W 544850
Outcrop 1: Base

Field Notes:

- Approx 30ft East of JM27
- East edge of outcrop/cliff

Description:

- Dark gray but slightly bleached
- Argillized
- No compression foliation
- Rounded to subrounded phenos- pinkish brown (clay/alunite?)
  - (~0.10cm)
- "Empty" veinlets
- Clay veinlets
  - perp. to sub-perp to compression
  - connecting arg phenos
- Elongated euhedral feldspar (~5mm)
- Non-lineated qtz eyes
- Alteration phenos: white clays (kaolinite, dickite?), barite, tridymite
  - rounded clays

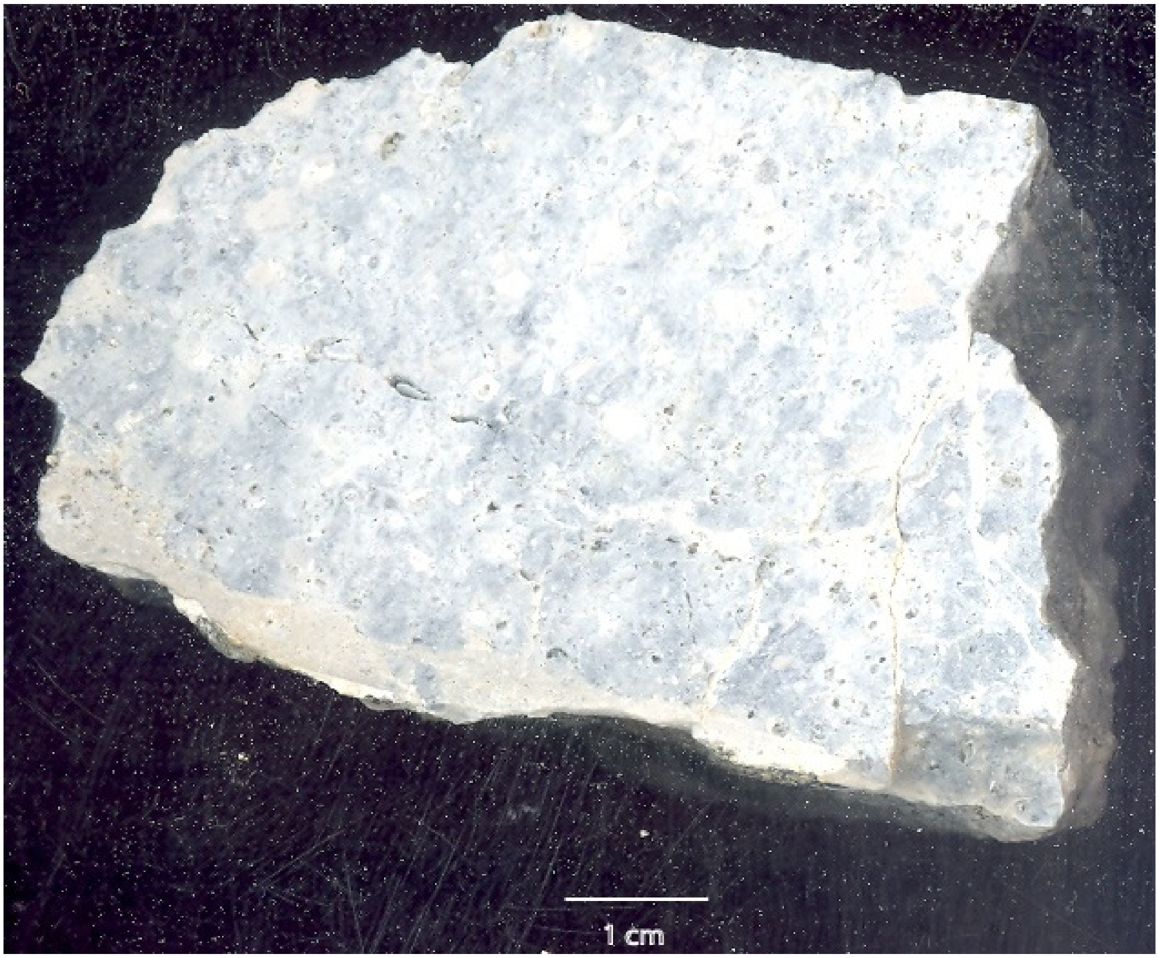
XRD:
Major Minerals:

- Kaolinite, barite, opal ct

Minor Minerals:

- Illite, al/walth, dickite, pyrophyllite

Mineral Assemblage 1



Scan: YS-08-JM28

YS-08-JM29

Brief Description:

Wht-l.gry Arg tuff

Location:

N 4955892
W544852
Outcrop 1: Middle

Field Notes:

- Approx 25 ft upslope from JM28
- Under Tree
- Veinlets
- Qtz eyes, clay

Description:

- Bleached white to light gry Arg tuff
- Acid leached
- “Empty”veinlets
    - original: possibly clay because leading from leached pheno to leached pheno
- Large and tiny clay phenos in a gry mtx
- Clay veinlets
    - Parallel to flow
- Silica veinlets with clay selvage
- Alteration minerals: kaolinite, opal, probably alunite
- Opal veneer covering sample

YS-08-JM31

Brief Description:

Bleached gry argillized tuff; minor clay/silica veinlets

Location:

N 4955881
W 544843
Outcrop 1: Middle

Field Notes:

- Approx 40-50ft up section from of JM27
- Near top of slope under trees
- Possible qtz veinlets
- Argillized
- Slightly vuggy

Description:

- Bleached gry arg tuff
- Devitrified small sphereulites
  - not lineated but confined to one side of the sample
  - not all spheres are connected but some are
- Clay veinlets
  - parallel to flow
- Silica veinlets with clay selvage
- Picture in field book under XRD descriptions
- Vuggy silica
- Absorbs water quickly
- Arg phenos
- Qtz eyes and albite

Thin Section:

- Sulfides
  - in sil/arg mtx and encrusting arg phenos
- Sulfide veinlets and mircoveinlets
- Clay and silica veinlets
  - silica veinlets- clay and sulfide selvage and sulfide infill

XRD:
Major Minerals:

- Opal c-t, Illite

Minor Minerals:

- Montmorillanite, albite, kaolinite, diaspore

Mineral Assemblage 1

Scan: YS-08-JM31

YS-08-JM32

Brief Description:

Wht bleached argillized tuff

Location:

N 4955872
W 544843.5
Outcrop 1: Middle

Field Notes:

- Approx 10 ft West of JM31
- Porcelain Opal
- Silica infilled vugs
- Clay

Description:

- Tuff has been completely bleached
- Native sulfur in vugs
- Large, elongated vugs: ~2.5cm or smaller
  - possible drusy qtz in vugs
- Large and small sphereulites
- Smaller sphereulites not restricted but all over samples
- Sparse (extremely) clay/silica veinlets
  - silica veinlets with clay selvage
- Opal veneer covering sample
- Minor gry matrix inside of bleaching
- Clays and silica

XRD:

Major Minerals:

- Opal c-t, barite

Minor Minerals:

- Montmorillanite, illite, kaol

Mineral Assemblage 1

Scan: YS-08-JM32

YS-08-JM33

Brief Description:

Arg l.gry tuff; slightly silicified

Location:

N 4955872
W 544841
Outcrop 1: Top

Field Notes:

- Approx 10ft West of JM32
- On Western edge of tree line/slope
- ~30ft from top
- Under tree
- Clay

Description:

- Arg l.gry tuff; slightly silicifed
- Acid leached
- Very minor clay and silica veinlets
- Arg phenos: probably illite
- Large sphereulites

YS-08-JM34

Brief Description:
Arg, bleached gry tuff

Location:
N 4955872
W 544839
Outcrop 1: Middle

Field Notes:
- Approx 10ft to the West and slightly up slope from JM27
- Silicified
- Good flow banding
- Very weathered
- Opal present
- No real structures to note, no vugs

Description:
- Arg, bleached gry tuff
- Possible veinlets but sample too small to tell (not cut)
  - possible clay veinlets
- Gray matrix with white clay: Kaolinite or illite

YS-08-JM35

Brief Description:
Wht leached argillized tuff

Location:
N 4955911
W 544857
Outcrop 1: Middle

Field Notes:
- Small outcrop to east of OC1
- Not solidified, veinlets, no flow/compression
- Sample collected ~40ft east of Outcrop 1, ~30 ft above stream

Description:
- Bleached, white, featureless argillized tuff
- Lineated clay veinlets
    - looks like skin cells with membrane or ant tunnels
    - both parallel and perpendicular to flow
- Not silicified
- Phenos dissolved internally by thermal fluids; removed, left shell
    - looks weathered but is an internal feature
    - acid leached
- Clay is buff to beige
- Qtz eyes
- Most altered sample from outcrop

Thin Section:
- Clay and silica veinlets
- Well preserved igneous txt

XRD:
Major Minerals:
- Opal c-t, alunite/walthierite

Minor Minerals:
- Illite, diaspore, kaolinite, albite, edingtonite

Mineral Assemblage 1

Scan: YS-08-JM35

YS-08-JM36

Brief Description:
Leached gray tuff

Location:
N 4956031
W 544983
Outcrop 3: Middle

Field Notes:
- Outcrop 2, going downstream, south side (Outcrop 3 overall)
- Under trees at top of rib, center of outcrop
- Biochemical weathering due to moss
- No sulfides, but silicified

Description:
- Leached gray tuff
- Visible compression banding

XRD:
Major Minerals:
- Qtz

Minor Minerals:
- Kaolinite, montmorillinite, illite, al/walth

Mineral Assemblage 1

XRF/ ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM36

YS-08-JM37

Brief Description:
Silicified buff tuff with arg overprint; silica veinlets

Location:
N 4956037
W 544990
Outcrop 3: Middle

Field Notes:
- Downstream edge of Outcrop 3
- Approximately 30ft up from river
- Nice large qtz eyes (~1 cm)
- No visible veins

Description:
- Silicified Buff tuff, Arg overprint
- Silica veinlets
- Argillized phenos
- Large qtz eyes
- Vuggy Silica

Thin Secion:
- Micro silica veinlets
- Silicified with arg overprint

XRD:
Major Minerals:
- Qtz, alunite/walth, albite

Minor Minerals:
- Kaolinite, illite

Mineral Assemblage 1

Scan: YS-08-JM37

YS-08-JM38

Brief Description:
Silica vein: Vuggy and Colloform

Location:
N 4956053
W 545007
Outcrop 3: Base

Field Notes:
- Second part of Outcrop 2 (outcrop 3)
- Approximately 5-10 ft above river, under tree
- Thick vein with small (<1cm) veinlets above and below
- Vein and host rock are vuggy

Description:
- Silica vein with massive/disseminated fine-grained pyt
- Vug filling with drusy qtz
- Colloform 2.7cm vein; possible sulfide housed in colloform (too fine grained for XRD to detect)
- Most sulfides are in brx mtx in the selvage and not part of the vein (flooded matrix)

Thin Section:
- Micrograph (4): Collofrom silica vein with sulfides
- Micrograph: Clustered sulfides in silica vein
- Micrograph: Sulfide veinlet cross-cutting colloform silica vein
- Sulfide microveinlets crosscut silica vein
- Sulfides linearly scattered throughout silica colloforms
- Sulfides/silica heal brx at edge of sample

XRD:
Major Minerals:
- Qtz, al/walth, albite

Minor Minerals:
- Opal ct, kaolinite, mont, illite

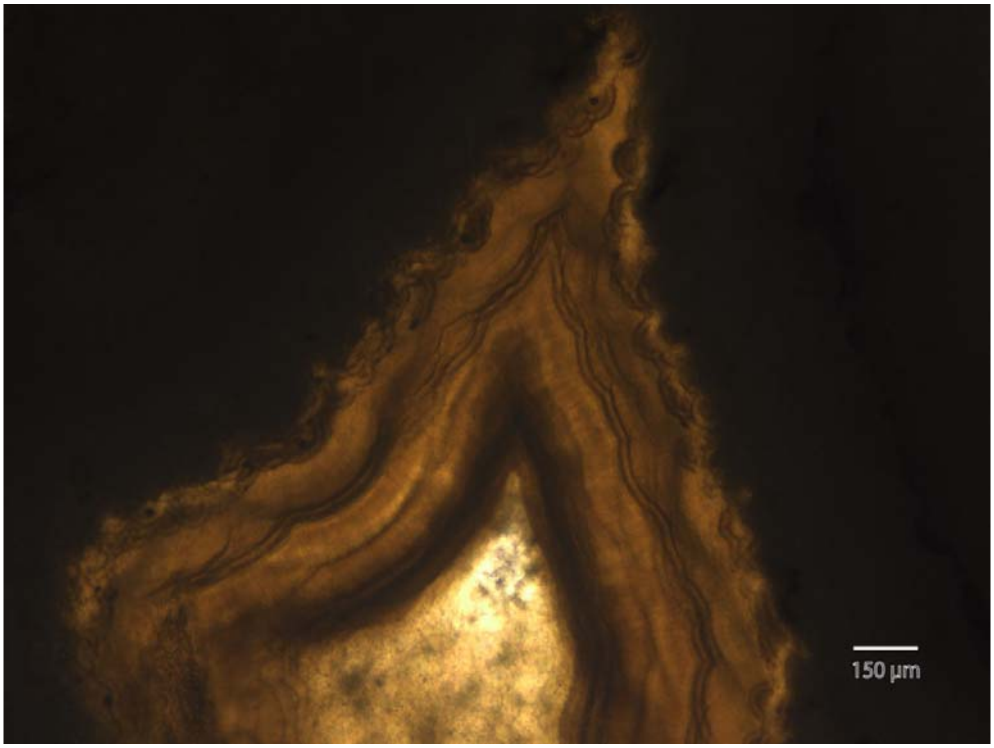
Mineral Assemblage 1

Stable Isotope: -0.05‰

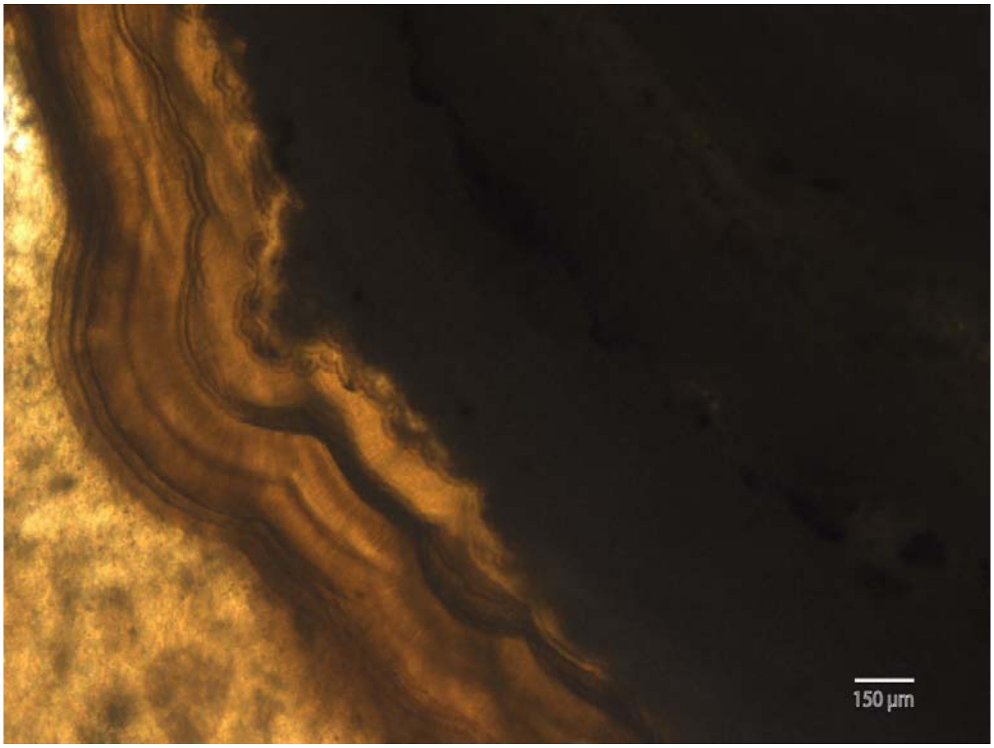
XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)
- JM38 had a repeat bead and the repeat came out differently than the original, I can explain: because JM38 is a vein with some brecciation, I imagine the vein is housed in the "repeat" bead (which is elevated in SiO_2 @ 97.7 and MnO and

P_2O_5) and the original bead has the vein and wall rock breccia in it. That explains elevated FeO in the bead—high pyt in the Silica matrix with the bx.

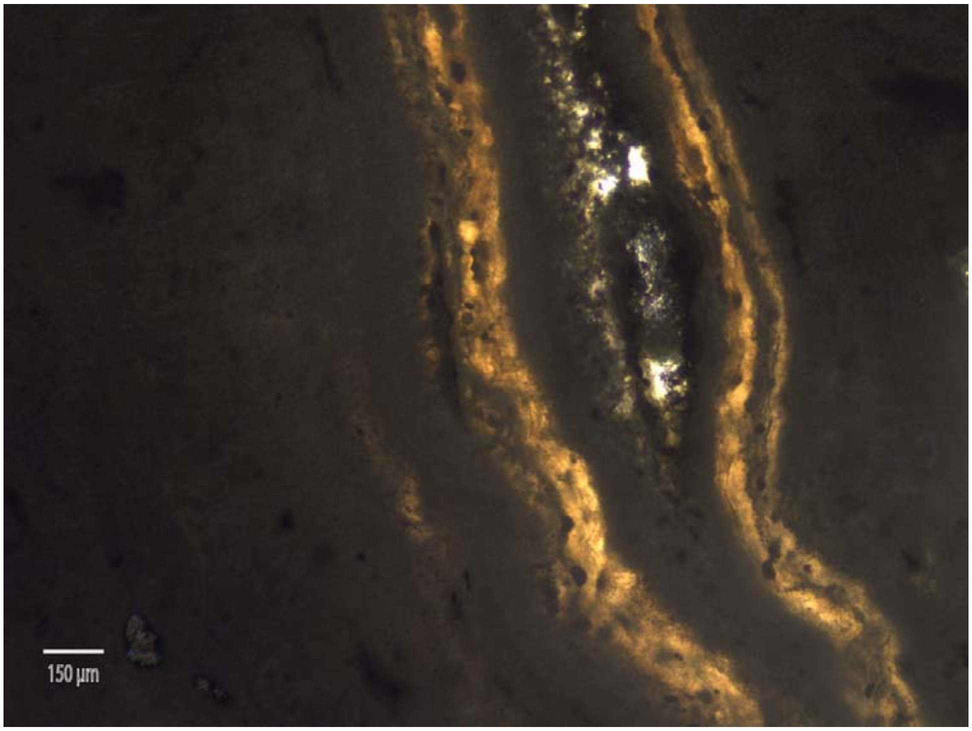
Scan: YS-08-JM38



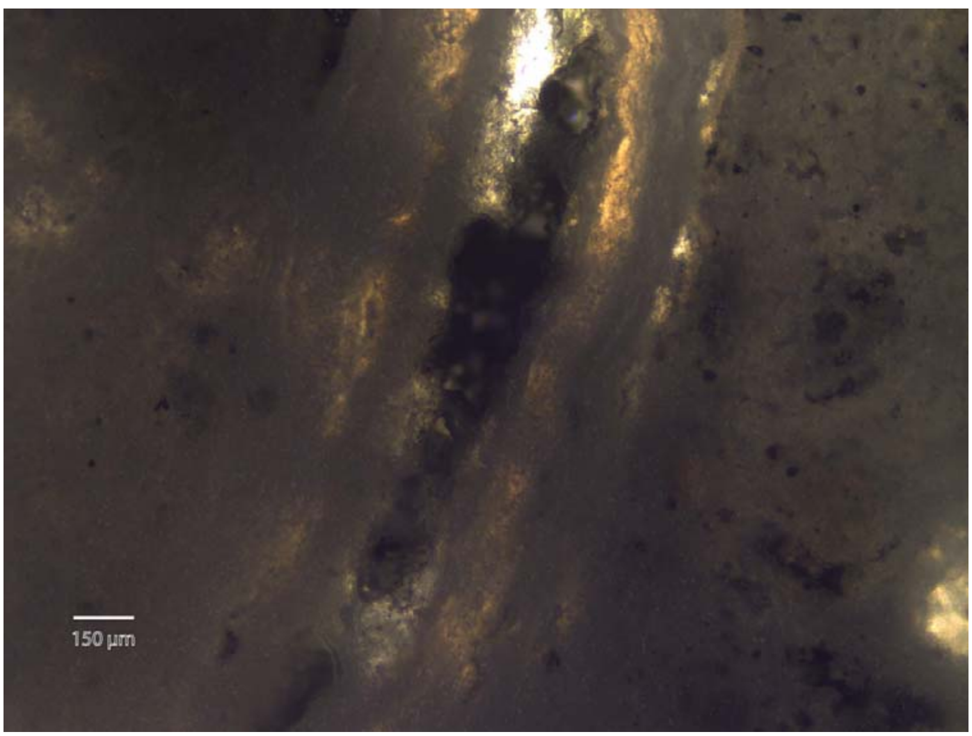
YS-08-JM38: Colloform silica veinlet



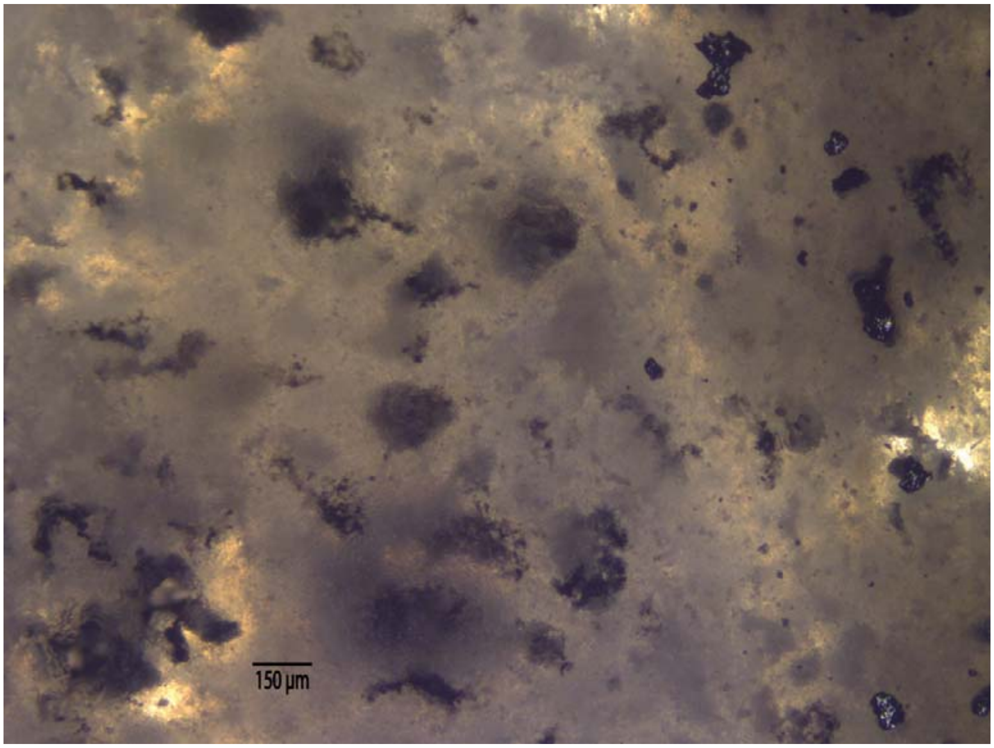
YS-08-JM38: Same veinlet as above. Note aligned sulfides in the darker section of the picture.



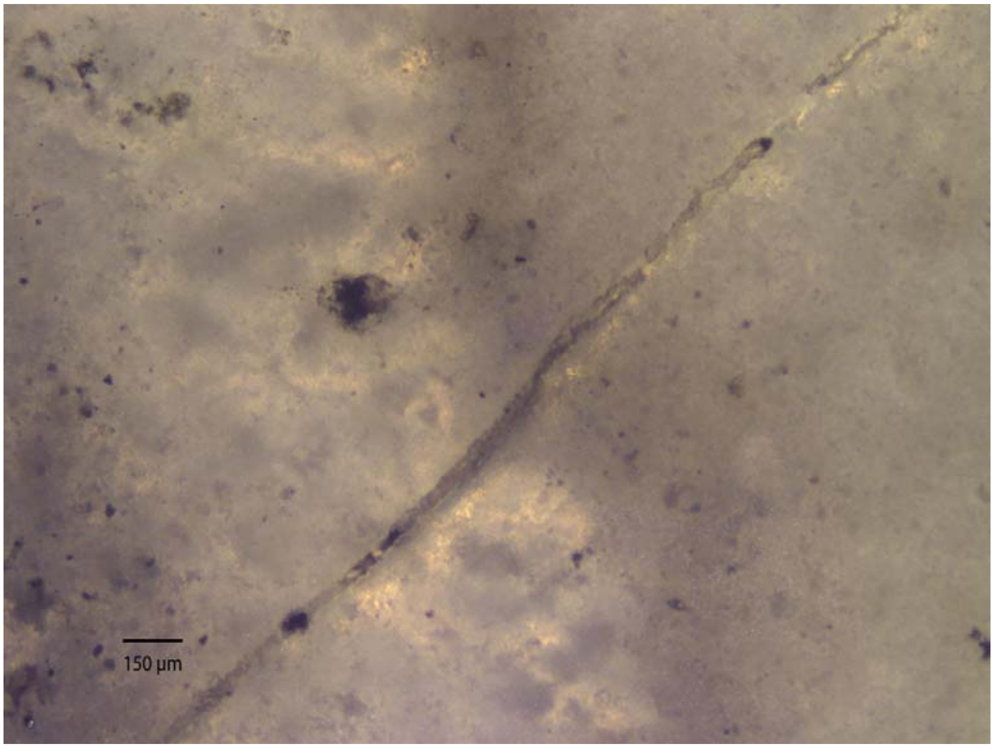
YS-08-JM38: Colloform silica veinlet with aligned sulfides and sulfides disseminated throughout larger silica vein.



YS-08-JM38: Colloform silica veinlet with a high concentration of sulfides in the center of the vein. Note sulfides scattered throughout larger silica vein.



YS-08-JM38: Although sulfides are scattered throughout the vein, they are still clustered.



YS-08-JM38: Sulfide veinlet cross-cutting colloform vein. Note sulfides scattered throughout silica vein.

YS-08-JM39

Brief Description:

Silica vein with brx wall rock (arg) on selvage

Location:

N 4956059
W 545009
Outcrop 3: Base/Stream

Field Notes:

- Vein
- Base of Stream

Description:

- Silica vein with brx wall rock (arg) on selvage
- Solid gray silica mass in center
- Possible sulfides
- Clay veinlets in silica vein
- Wht clay clasts

XRD:
Major Minerals:

- Qtz

Minor Minerals:

- Opal c-t, al/walth, barite

Mineral Assemblage 4

Stable Isotope: 0.25‰

Scan: YS-08-JM39

YS-08-JM40

Brief Description:

Leached, l.gry to white tuff

Location:

N 4956057
W 545011
Outcrop 3: Base

Field Notes:

- No Notes

Description:

- Leached, l.gry to white tuff
- Silica veinlets
- “Empty” veinlets
- Small sphereulites
- Qtz eyes

YS-08-JM41

Brief Description:

Leached, large non-welded pumice fragments brx in places and healed by silica

Location:

N 4956048.5
W 545019
Outcrop 3: Middle

Field Notes:

- 1st outcrop on downstream end (to East) up the wall

Description:

- Leached
- Large non-welded pumice fragments brx in places and healed by silica
- Qtz eyes
- Euhedral clay phenos

YS-08-JM42

Brief Description:
Silicified l.gry to buff tuff, Arg overprint

Location:
N 4956043.6
W 544999.2
Outcrop 3: Base

Field Notes:
- No Notes

Description:
- Gry to buff silicified tuff with arg overprint
  - silicified zone separated by non-silicified zone by a single qtz vein
- Silica veinlets
  - randomly oriented
- Clay is buff to beige
- Qtz eyes
- "Empty" veinlets
- Clay veinlets
- Drusy qtz

Thin Section:
- Micrograph (5): Argillized phenocrysts
- Micrograph: Expansion breccia
- Micro silica veinlets
  - perp to comp
- Clay microveinlets
- Colloform silica veinlets separating arg from silicified section
- Sulfides associated with silica infill
- Sulfides in wall rock

XRD:
Major Minerals:
- Qtz, huangite, walth/al

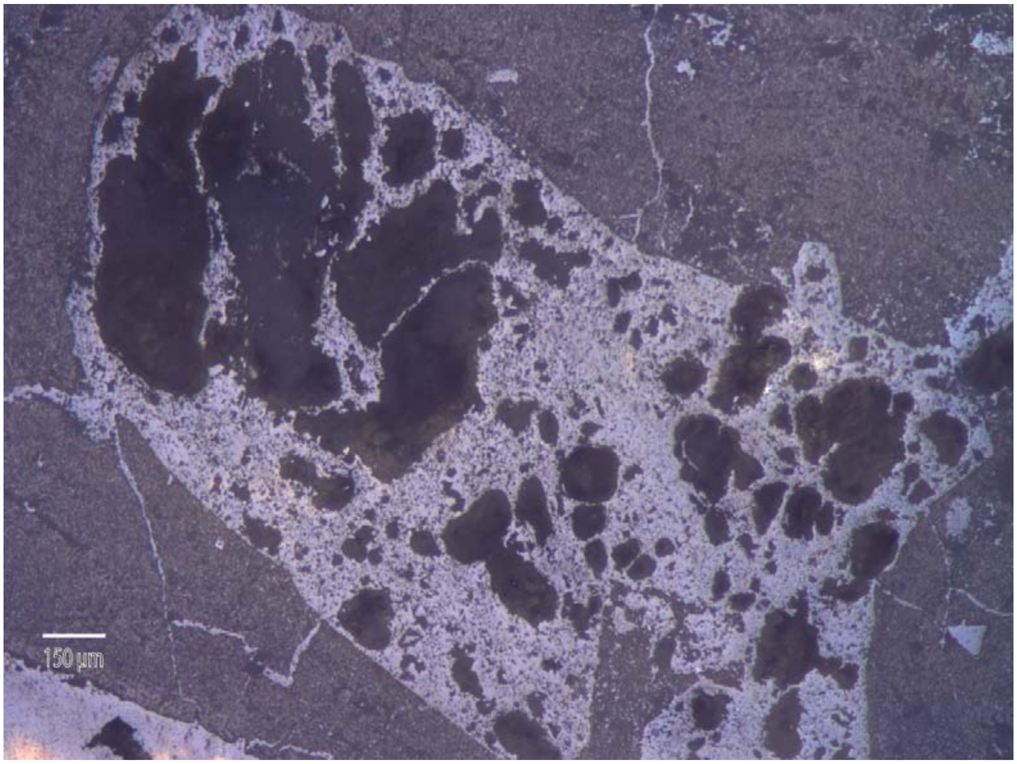
Minor Minerals:
- Opal ct, kaolinite, illite

Mineral Assemblage 1

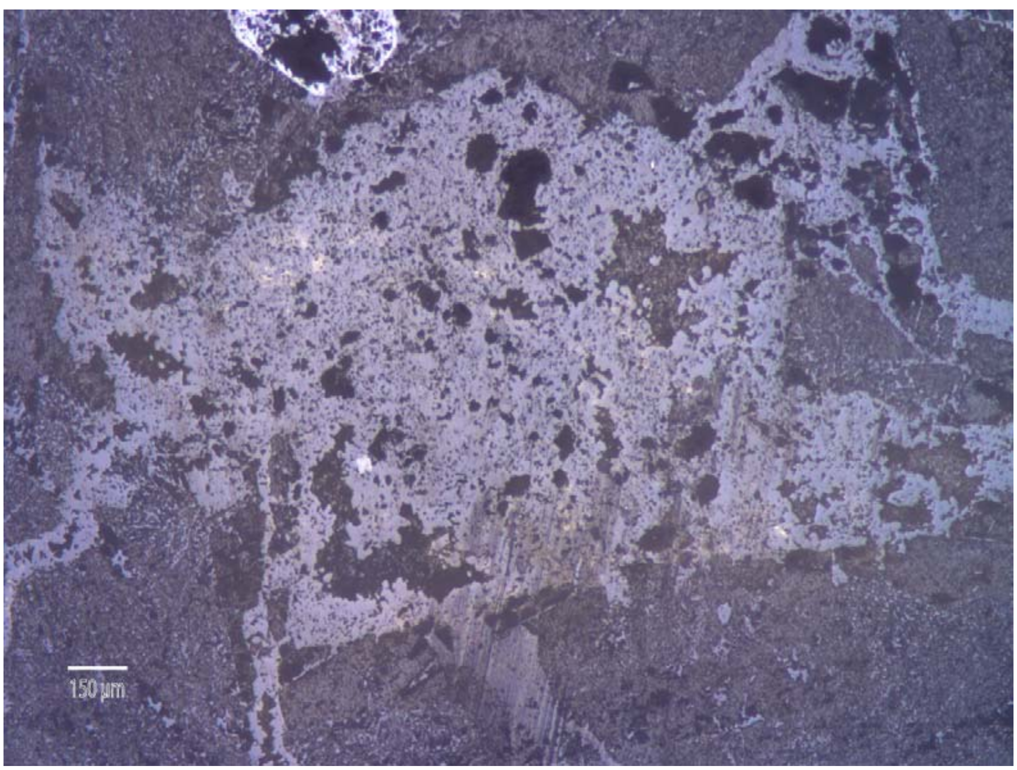
Stable Isotope: -1.46

XRF/ ICP-MS: See Table III-2, 3, 4 (Appendix III)

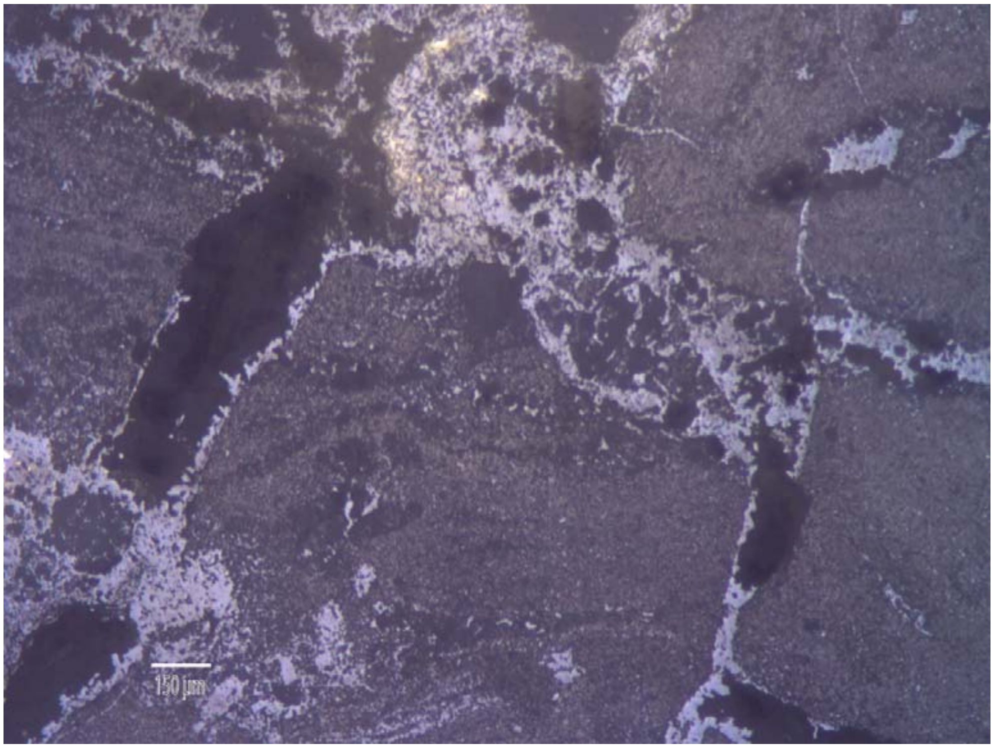
Scan: YS-08-JM42



YS-08-JM42: Argillized phenocryst with altering clay veinlets.

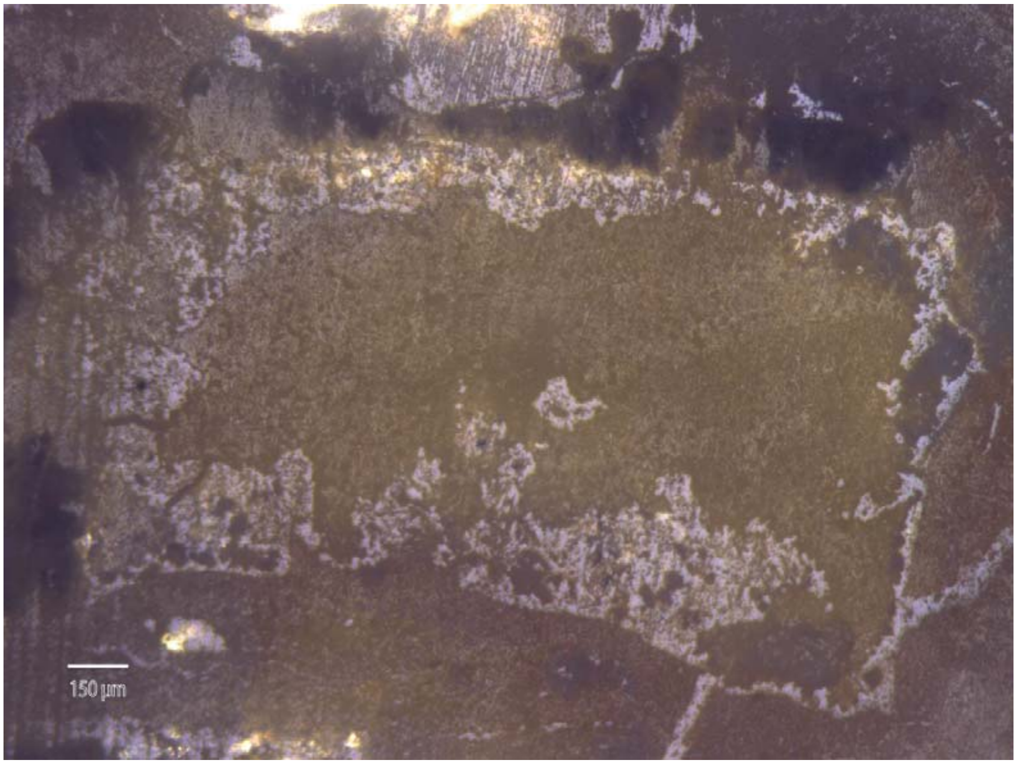


YS-08-JM42: Argillized phenocryst with altering clay veinlets.

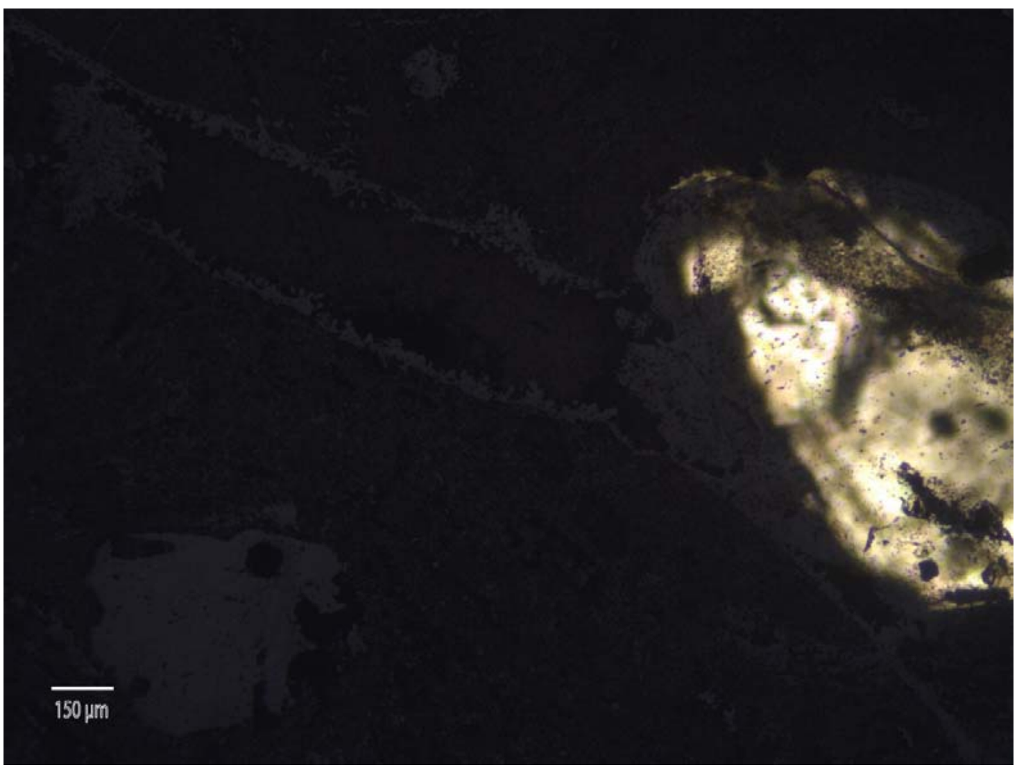


YS-08-JM42: Expansion breccia healed by silica and clay veinlets. Note primary igneous texture in brecciated wall rock.

YS-08-JM42: Argillized phenocrysts with altering clay veinlets.



YS-08-JM42: Argillized phenocryst with clays “wetting” the edge of the grain.



YS-08-JM42: Quartz eye with clays “wetting” the edge of the grain.

YS-08-JM43

Brief Description:
 Argillized wht tuff

Location:
 N 4956037
 W 545005
 Outcrop 3: Middle

Field Notes:
- West of tree

Description:
- Wht argillized tuff
- "Empty" veinlets
  - possibly silica
  - random orientation
- Silica veinlets
  - random orientation
- Acid leached
- Some qtz eyes remain, but few and lack orientation
- Clays: kaolinite, illite, mont
- No internal structure

Thin Section:
- Thin Section did not come out. Too leached.

XRD:
Major Minerals:
 Qtz, al/walth
Minor Minerals:
 Opal c-t, kaolinite, illite, mont, albite, pyropholite, diaspore
Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM43

YS-08-JM44

Brief Description:

Silicified gray porphyritic tuff with sulfides and argillized phenos

Location:

N 4956047
W 545017
Outcrop 3: Middle

Field Notes:

- ~10ft upstream (west) from JM41

Description:

- Sil gray porphyry
- Sulfides
- White clays
- Acid leached
- Possible silica vein

Thin Section:

- Sulfide/Silica microveinlets
- Little primary txt remains
- Massive silica with random and numerous pockets of sulfides
- Sulfides are aligned perpendicular to primary fabric

XRD:
Major Minerals:

- Qtz, kaolinite, al/walth, pyt

Minor Minerals:

- Illite, mont, marcasite, galena, sphalerite, albite, zunyite
- Other possibilities: Ni pyt, Realgar (AsS), Cinnabar (HgS) Stibnite (Sb_2S_3) and Berlinite ($AlPO_4$)

Mineral Assemblage 1

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)

Scan: YS-08-JM44

YS-08-JM45

Brief Description:

Silicified white tuff; silica veinlets

Location:

N 4956034.5
W 545016
Outcrop 3: Top

Field Notes:

- From Very Top

Description:

- Silicified white tuff
- Silica veinlets
  - randomly oriented
- Acid leached
- Drusy quartz
  - vuggy on qtz vein

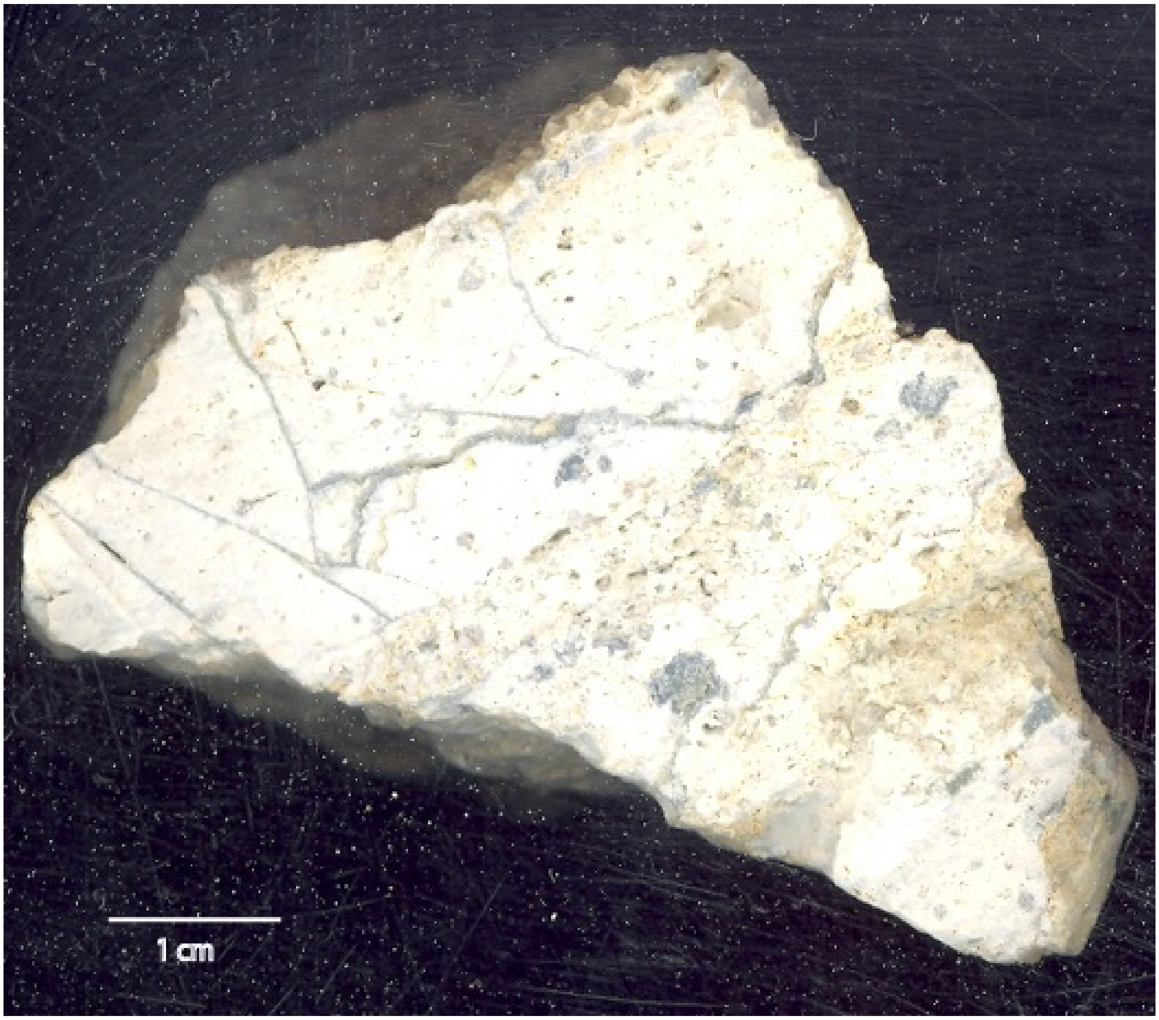
XRD:
Major Minerals:

- Qtz

Minor Minerals:

- Illite, kaolinite, alunite

Mineral Assemblage 1



Scan: YS-08-JM45

YS-08-JM46

Brief Description:
Silicified gray tuff

Location:
N 4956039
W 545007
Outcrop 3: Top

Field Notes:

- Under tree on left

Description:

- Silicified gray to white tuff
- Compression lineation
- Alunite
- Silica vein with minor brx
- Qtz eyes

YS-08-JM47

Brief Description:
Silicified gray tuff

Location:
N 4956043
W 545013
Outcrop 3: Top

Field Notes:
- Middle under tree

Description:
- Silicified gray tuff
- Compression banding
- Vuggy silica
- Drusy qtz
- Alunite
- Acid leached
- Fe stain
- White clay - kaolinite?
- Opalized

Scan: YS-08-JM47

YS-08-JM48

Brief Description:

Silicified/Arg gry tuff (internally structureless)

Location:

N 4956035
W 545003
Outcrop 3: Top

Field Notes:

- Farthest extent upstream (West) of outcrop

Description:

- Silicified and Arg gry tuff (internally structureless)
- Silica veins with brx
- Barite, alunite
- Silica veinets
- Acid leached
- Qtz eyes
- White to brown clay

YS-08-JM49

Brief Description:

Leached, weak hi silica wht tuff

Location:

N 4956041
W 545009
Outcrop 3: Top

Field Notes:

- No Notes

Description:

- Leached, weak hi silica wht tuff
- Silica veinlets
- Silica healed brx
  - veinlets w/ major vein (silica) and brx
- Wht clay clasts

YS-08-JM50

Brief Description:

Leached, weak hi silica buff tuff (pumice)

Location:

N 4956039
W 545010
Outcrop 3: Top

Field Notes:

- Original waypt was the same as JM49

Description:

- Leached, weak hi silica buff tuff (pumice)
  - white to brown
- Minor brx
- Colloform- vuggy to crustiform silica
  - silica flooded near vugs
- Silica veinlets

YS-08-JM51

Brief Description:

Leached, white tuff; Mosaic and crackle breccia healed by silica

Location:

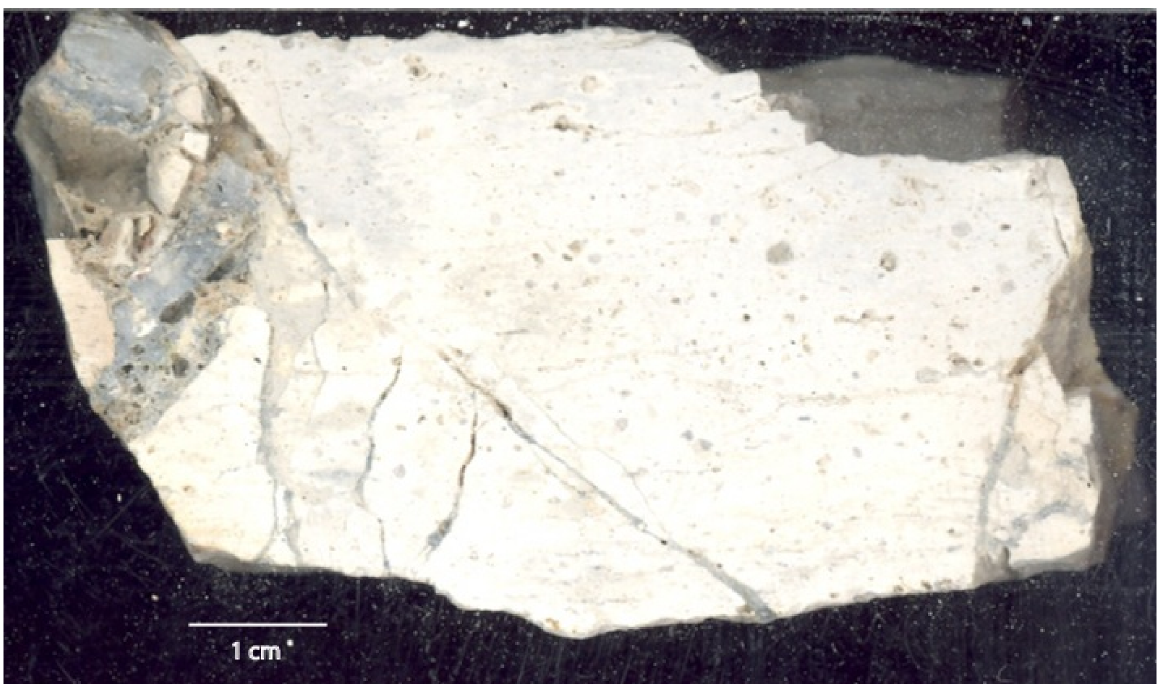
N 4956037
W 545012
Outcrop 3: Top

Field Notes:

- Original waypoint same as JM49 and JM50

Description:

- Leached, hi silica wht tuff
- Mosaic to crackle brx healed by silica (collapse brx)
- Silica veinlets
- Minor wht clay



YS-08-JM52

Brief Description:
Silicified, gray tuff with clay and alunite

Location:
N 4955981
W 544828
North Ridge: Top

Field Notes:
- Outcrop mostly hidden by trees, small
- On North wall
- 10ft down from top on east wall of ravine to altered clearing
- Veinlets, heavily oxidized, sugary texture
- Silicified, no visible qtz eyes

Description:
- Silicified tuff
- Clay and alunite
- Acid leached
- Fe stained throughout
- Tiny phenos throughout gry matrix
- Field description suggests veinlets
  - probably silica due to silicification of outcrop

YS-08-JM53

Brief Description:

Sil buff tuff

Location:

N 4956016
W 544826
North Ridge: Top (float)

Field Notes:

- Above JM52, top of ridge
- Large boulder, float
- Silicified, heavily oxidized, minor qtz eyes, vein(let)s

Description:

- Silicified buff tuff
- Sample broken off from OC2
- Acid leached
- Sphereulites
- Heavily oxidized
- According to field observations: veinlets
  - probably silica due to silicification

YS-08-JM54

Brief Description:
Opalized, l.gry-wht tuff

Location:
N 4956032
W 544882
North Ridge: Top (Float)

Field Notes:
- Downstream along top of ridge
- Small piece under tree, float
- Lots of silica, silica replacement following shape of vugs

Description:
- Silicified, l.gry- wht tuff
- Silica veinlets

YS-08-JM55

Brief Description:

Opalized wht tuff

Location:

N 4956054
W 544911
North Ridge: Top (Float)

Field Notes:

- Moving along same wall, downstream (east)
- Nearly at top, small piece, float
- Compression banding through vein
- Silicified- pure silica (white)
- Some opal present

Description:

- Silicified wht tuff
- Acid leached

YS-08-JM56

Brief Description:

Silicified l.gry tuff with arg overprint

Location:

N 4956082
W 544935
North Ridge: Top

Field Notes:

- Moving downstream (east), North wall, down from ridge, in place, under tree
- Silicified, silica veinlets
- ~25% qtz eyes ranging in size
- Minor clay

Description:

- Silicified l,gry tuff with arg overprint
- Clay and silica veinlets
  - sinuous and random
- Alunite, kaolinite
- Acid leached
- Qtz eyes

YS-08-JM57

Brief Description:

Sil l.gry tuff

Location:

N 4956095
W 544948
North Ridge: Top

Field Notes:

- Moving downstream (East), middle of rib??
- Possible float but trend of lateral rocks suggests in place
- Qtz eyes, clay

Description:

- Sil l.gry tuff
    - Non arg version of JM56
- Drusy qtz
- Alunite, opal
- Acid leached

YS-08-JM58

Brief Description:
Silicified tuff

Location:
N 4956117
W 544924
Outcrop 2: Base (Ridge sample)

Field Notes:
- North Wall: silicified outcrop on Ridge
- Downstream from JM57
- Boulders below are breaking off this outcrop
- Sample from bottom of outcrop
- Vuggy, lots of clay, qtz eyes
- Vein-y, boytridial shaped qtz

Description:
- Silicified tuff
- Wht to tan clays: Illite or kaolinite
- Drusy qtz
- Silica veinlets
- Acid leached
- Qtz eyes

YS-08-JM59

Brief Description:
Silicified white to tan tuff

Location:
N 4956124
W 544921
Outcrop 2: Middle (Ridge sample)

Field Notes:
- 10ft directly above JM58
- Sugary texture
- Silicified

Description:
- Silicified tuff
- Wht to tan clays
- Acid Leached
- Drusy qtz
- Compression banding preserved
- Silica replacement
- No veinlets
- Sphereulites

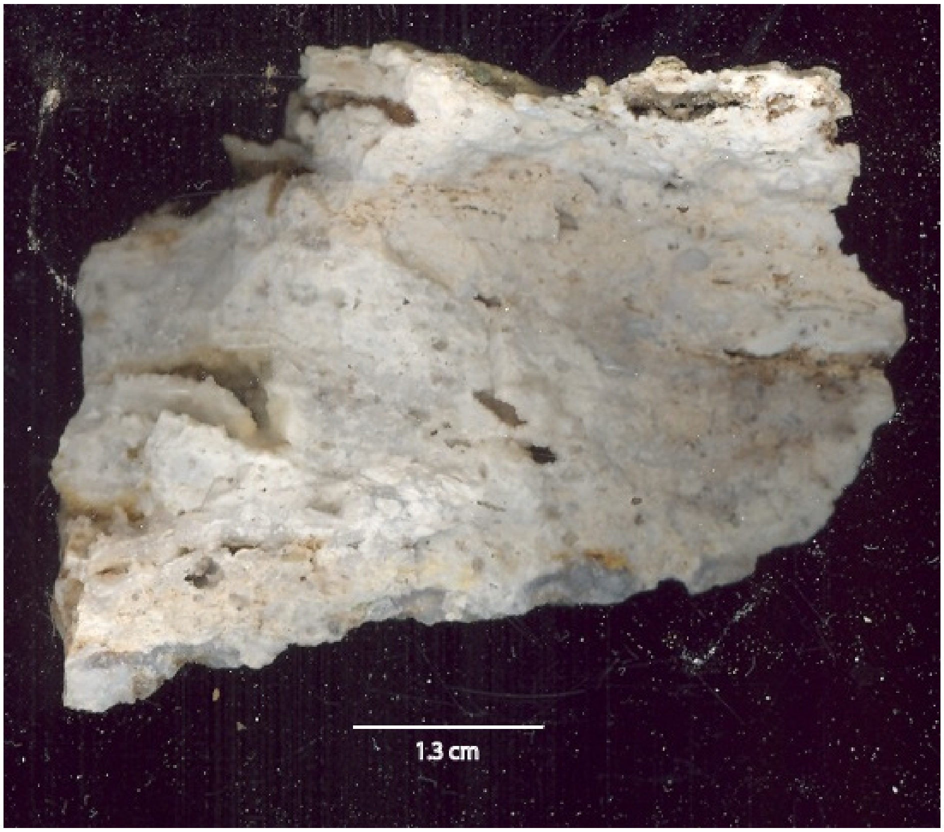
Thin Section:
- Micrograph (5): Colloform silica veinlets with micro-drusy quartz.
- Large round sulfides
- Micro brx
- Eu-subhedral sulfides scattered throughout silica/arg mtx of rhy

XRD:
Major Minerals:
- Qtz

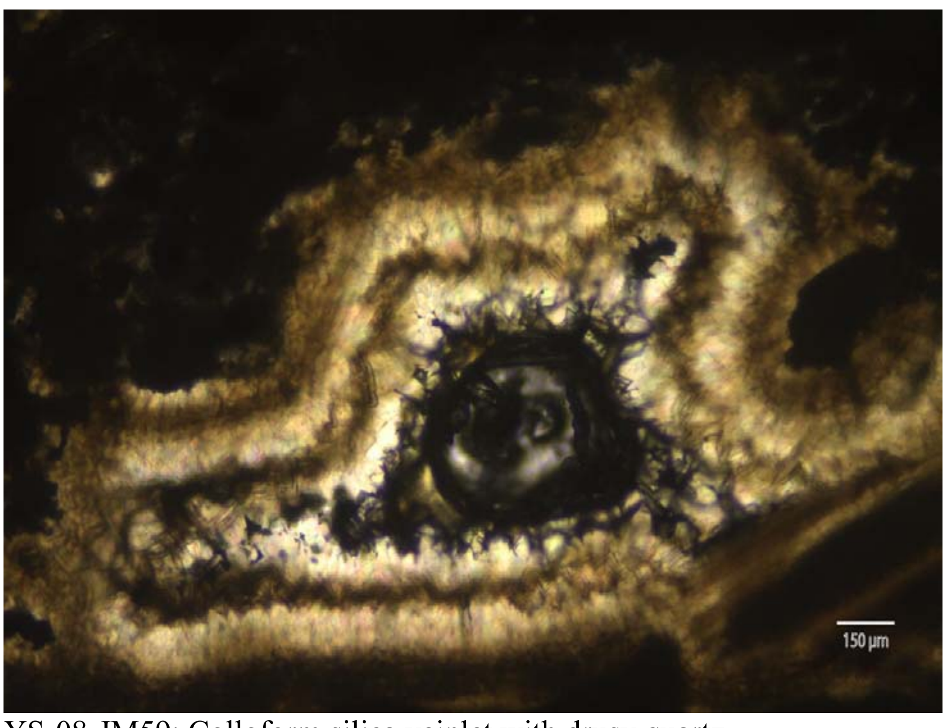
Minor Minerals:
- Illite, Kaolinite

Mineral Assemblage 1

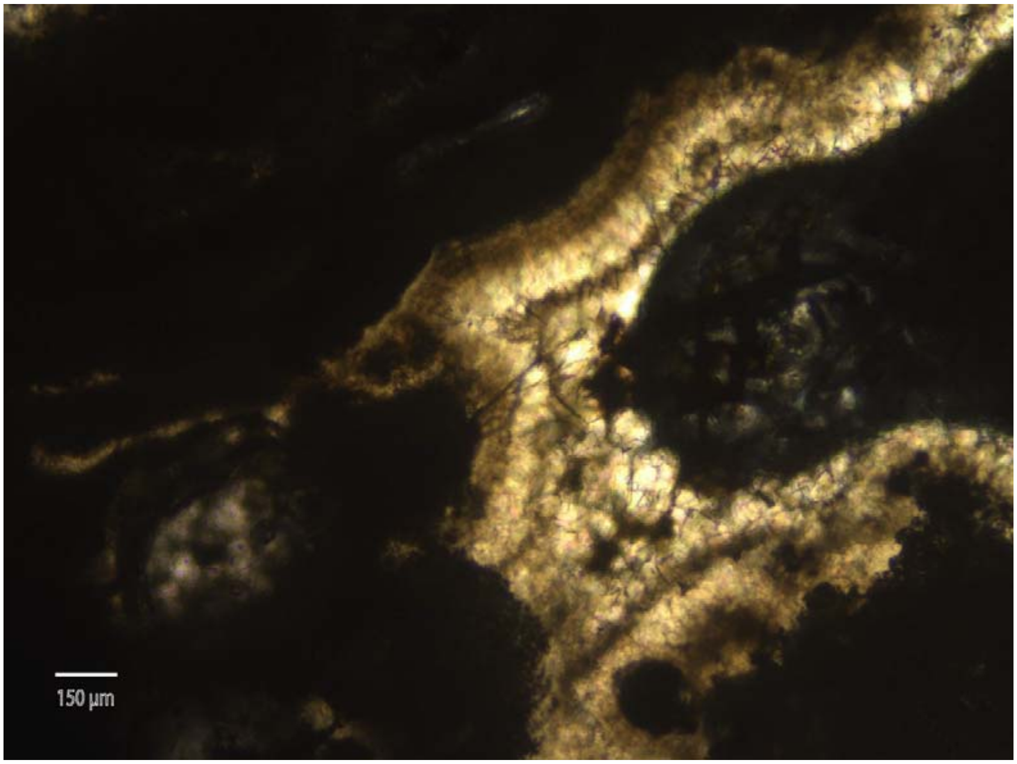
Stable Isotope: 1.22‰



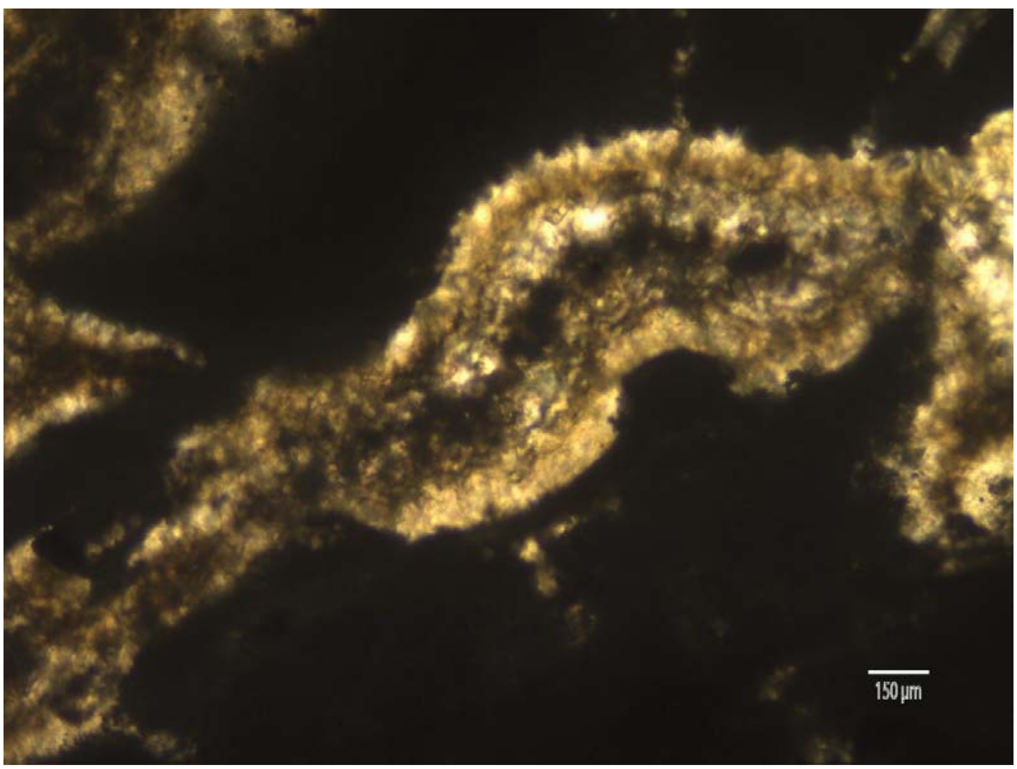
Scan: YS-08-JM59



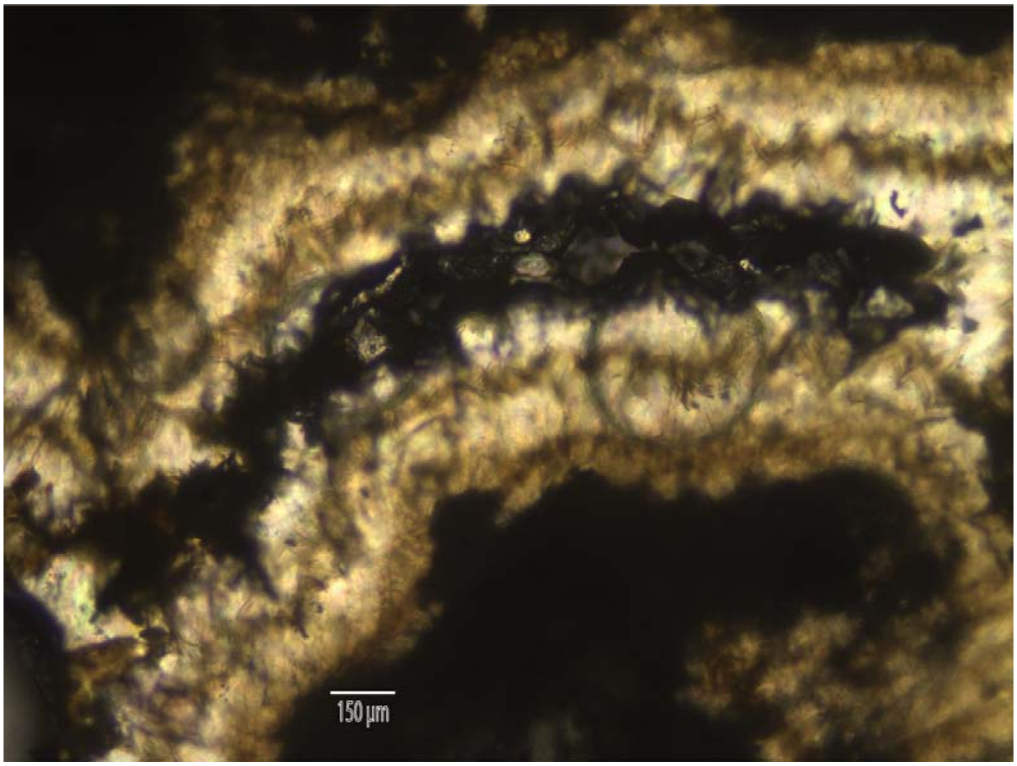
YS-08-JM59: Colloform silica veinlet with drusy quartz.



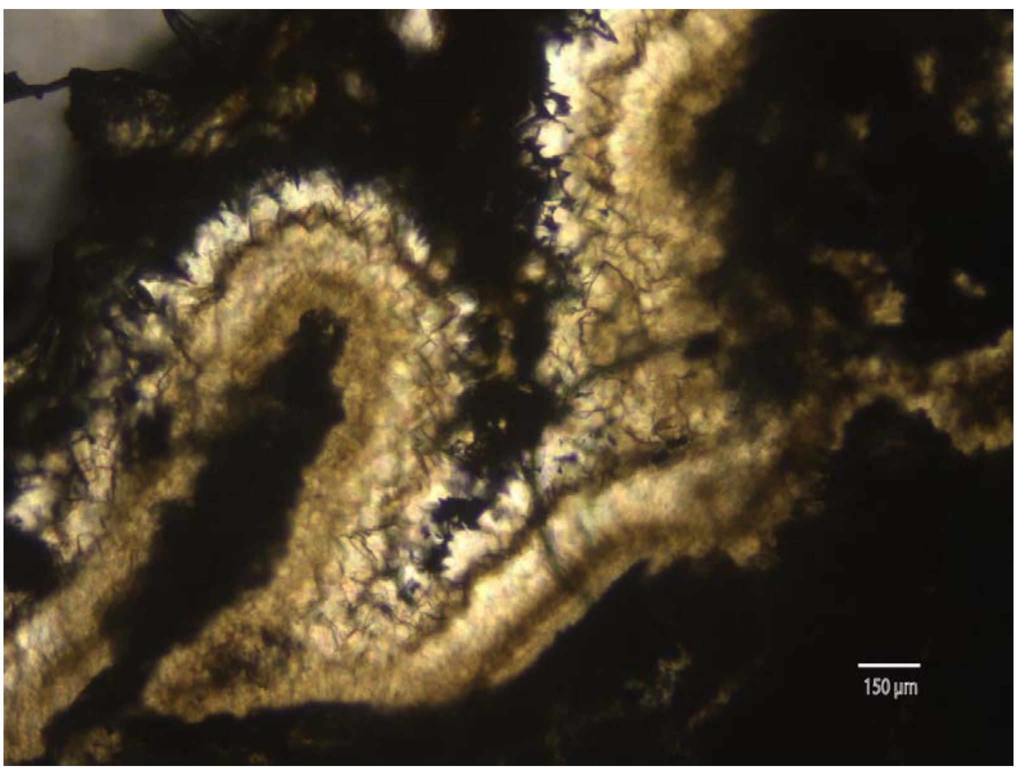
YS-08-JM59: Colloform silica veinlet with minor drusy quartz.



YS-08-JM59: Colloform silica veinlet.



YS-08-JM59: Colloform silica veinlet with drusy quartz.



YS-08-JM59: Colloform silica veinlet with drusy quartz.

YS-08-JM60

Brief Description:

Silicified, light gray tuff

Location:

N 4956117
W 544911
Outcrop 2: Middle (Ridge sample)

Field Notes:

- Upstream (West) from JM59
- Top of section
- Opal with MANY qtz eyes
- Possible some rhyolite structure preserved
- Sugary

Description:

- Silicified, light gray tuff
- Devoid of internal structure
    - except lineated vugs (pumice remnants)
- Most altered in outcrop
    - completely silicified
- "Opalized" qtz

YS-08-JM61

Brief Description:
Silicified tuff

Location:
N 4956144
W 544913
Outcrop 2: Top (Ridge sample)

Field Notes:
- Top most piece sampled from outcrop
- Upstream from JM60
- Only minor clays

Description:
- Silicified tuff
- White to tan clays
- Small sphereulites
- Acid leached
- Qtz eyes

XRD:
Major Minerals:
- Qtz

Mineral Minerals:
- Kaolinite, illite

Mineral Assemblage 1

YS-08-JM62

Brief Description:
	Silicified tuff; Sphereulites in l.gry matrix; wht to tan clays

Location:
	N 4956142
	W 544919
	Outcrop 2: Top

Field Notes:

- Vuggy
    - vugs infilled w/ clays
    - clays cemented by silica
- Near top of section

Description:

- Silicified tuff
- Entire sample devitrified sphereulites and accompanying glass rim
    - wht to tan in l.gry matrix
- Acid leached
- Some qtz eyes in glassy shell but not restricted to this section
- Opal veneer

Thin Section:

- Micro silica veinlets

XRD:
Major Minerals:

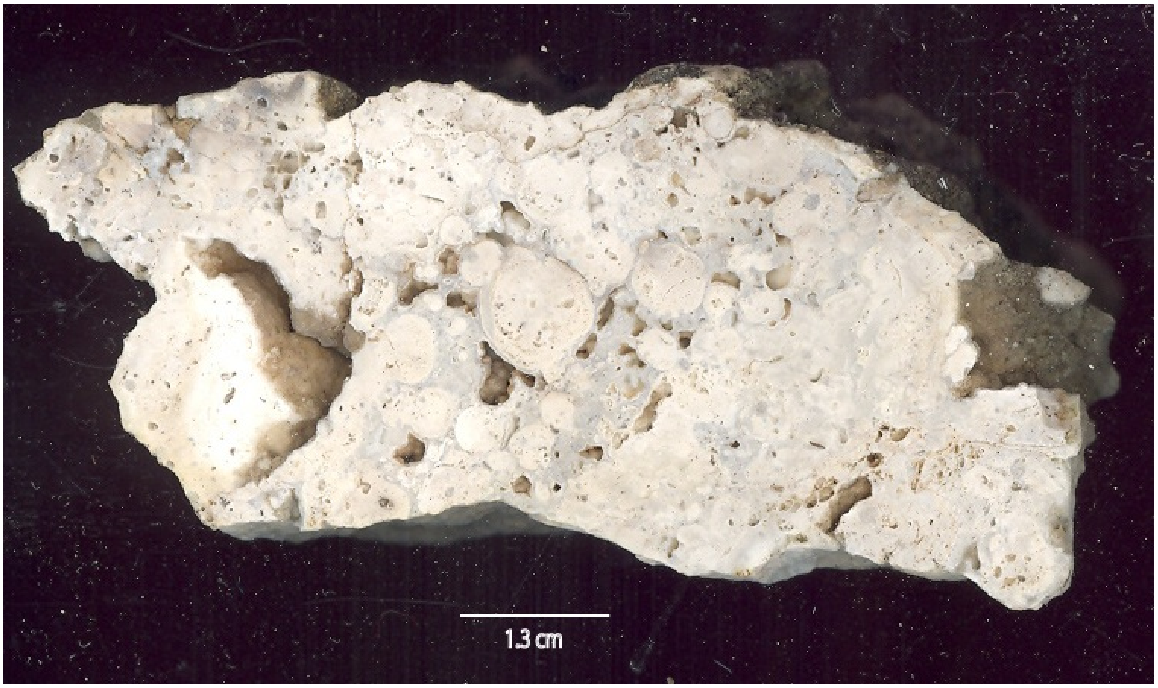
- Qtz

Minor Mineras:

- Illite, kaolinite, mont, al/walth

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM62

YS-08-JM65

Brief Description:
Silicified tuff

Location:
N 4956123
W 544930
Outcrop 2: Base (Ridge Sample)

Field Notes:

- Drusy qtz
- Slightly vuggy
- No clay
- Approx 15ft up from JM55 and to the East

Description:

- Silicified tuff
- Wht to tan clays
- Drusy qtz
- Acid leached
- No veinlets

YS-08-JM66

Brief Description:
Silicified tuff

Location:
N 4956131
W 544934
Outcrop 2: Base (Ridge Sample)

Field Notes:
- Approx 25-30ft East from JM65 along base of outcrop
- Silicified
- Sugary texture
- Slightly vuggy

Description:
- Silicified tuff
- Wht to tan clays: probably kaolinte (sticks to tongue)
- Drusy qtz
- Acid leached

YS-08-JM67

Brief Description:
Silicified tuff

Location:
N4956140
W544926
Outcrop 2: Top (Ridge Sample)

Field Notes:
- Top of Section
- Vugs in filled with opal
- Silicified
- Possible kaolinite

Description:
- Silicified tuff
- Almost as altered as JM60
- "Empty" veinlets
    - probably silica veinlets
- Drusy qtz
- Wht to tan clays
- Acid leached
- Silica replacement
    - vugs- opal

YS-08-JM68

Brief Description:
Silica Vein

Location:
N 4956137
W 544935
Outcrop 2: Base (Ridge Sample)

Field Notes:

- Approx 10ft East along base of outcrop
- Sampled from Silica vein
- Silica, not hydrated?
- Outcrop is homogenous to itself
- ~3" wide; not continuous
- No obvious conduits except JM68

Description:

- Silica Vein
- "Empty" veinlets within silica vein
  - probably Silica
- Possible sulfides
- Acid leached along selvage

YS-08-JM69

Brief Description:
Silicified wht tuff

Location:
N 4956144
W 545079
Outcrop 4B: Middle

Field Notes:
- North Wall
- Upstream edge of outcrop, midway up wall
    - 1st outcrop of rock
- Mostly clay and qtz eyes

Description:
- Silicified wht tuff
- Faintly visible compression banding
- Cream clay
- Qtz eyes

YS-08-JM70

Brief Description:

Brecciated vein with white argillized wall rock

Location:

N 4956144

W 545086

Outcrop 4B: Middle

Field Notes:

- 25ft downstream from JM69 horizontally

Description:

- Strange Rock!
- Arg brx
- Silica veinlets with clay selvage
- Internal breccia healed by silica
    - not aligned; central to rock
    - bigger in center
- Bleached zones around breccia
- Qtz eyes

Thin Section:

- Brx and micro-brx
- Silica veinlets
    - some micro
- Sulfides are concentrated to silica veinlets and wall rock infill proximal to veinlets
- Brx healed mostly by silica but with a fair amt of sulfides
- Sulfides move around grain boundaries

XRD:

Major Minerals:

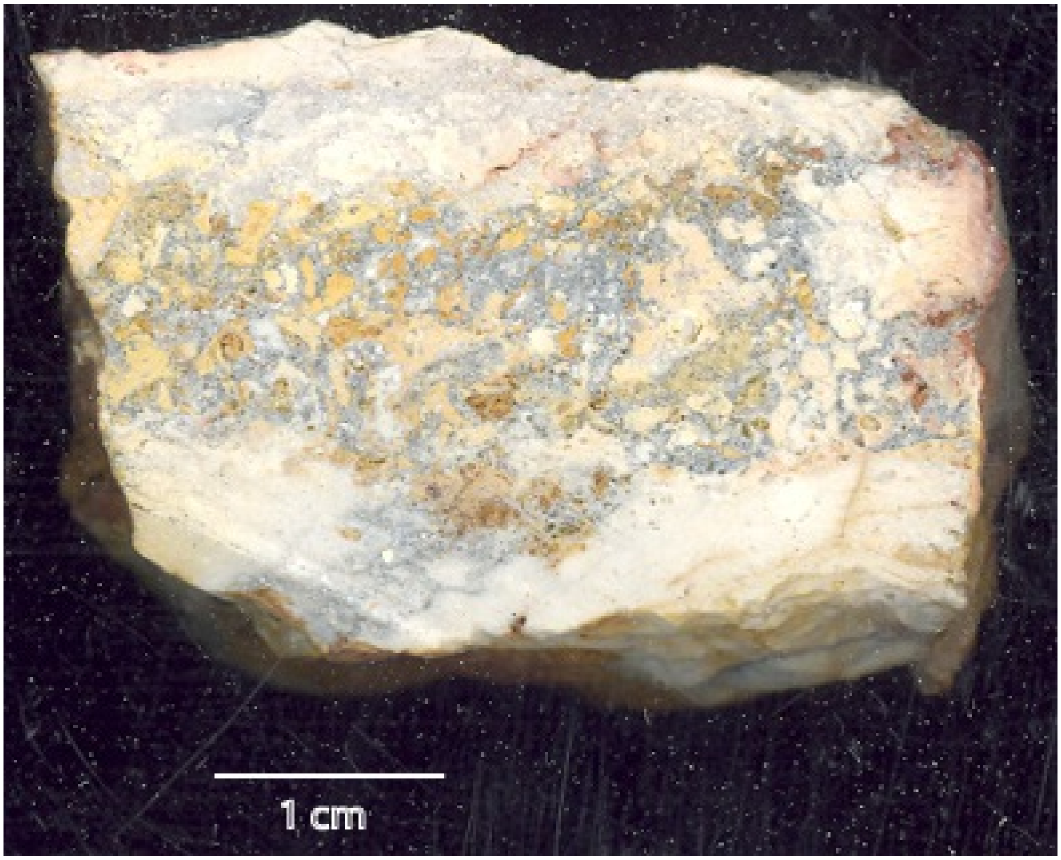
- Qtz, kaol, walth/al, albite

Minor Minerals:

- Illite, huangite

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM70

YS-08-JM71

Brief Description:

Silicified wht tuff

Location:

N 4956143.5
W 545104
Outcrop 4B: Middle

Field Notes:

- Approx 25ft downstream from JM70 horizontally

Description:

- Silicified wht tuff
- Silica and sulfide veinlets
- Possible clays- unsure
- Qtz eyes

YS-08-JM72

Brief Description:

Arg wht to tan tuff

Location:

N 4956144
W 545108
Outcrop 4B: Middle

Field Notes:

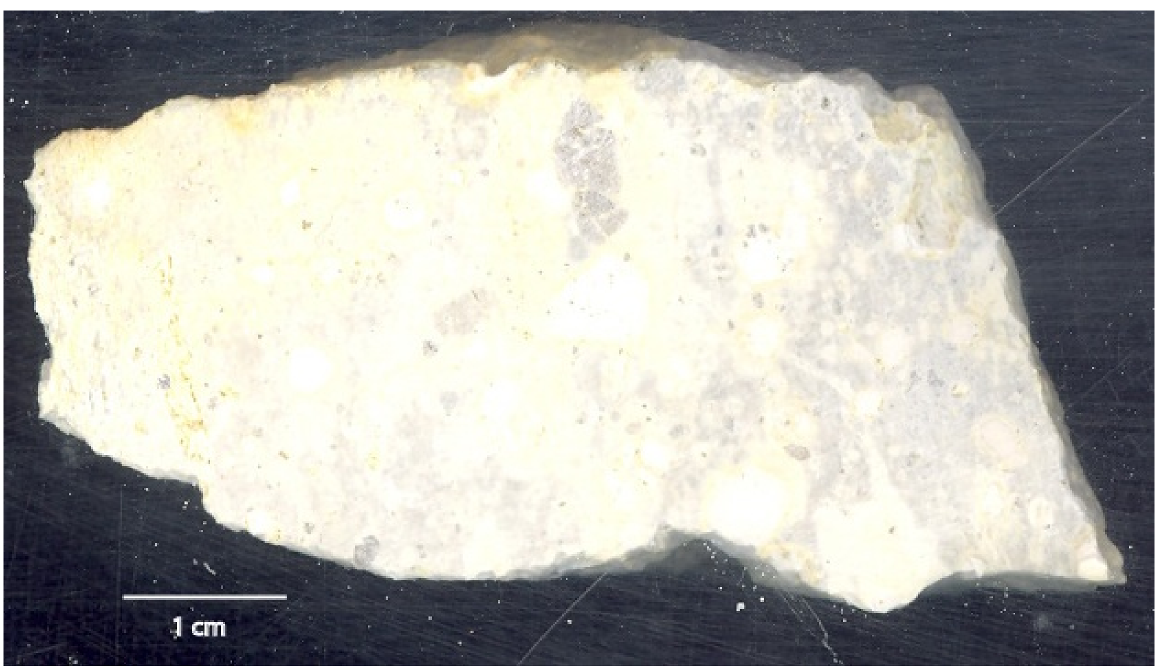
- Approx 10ft from JM71 downstream (east)

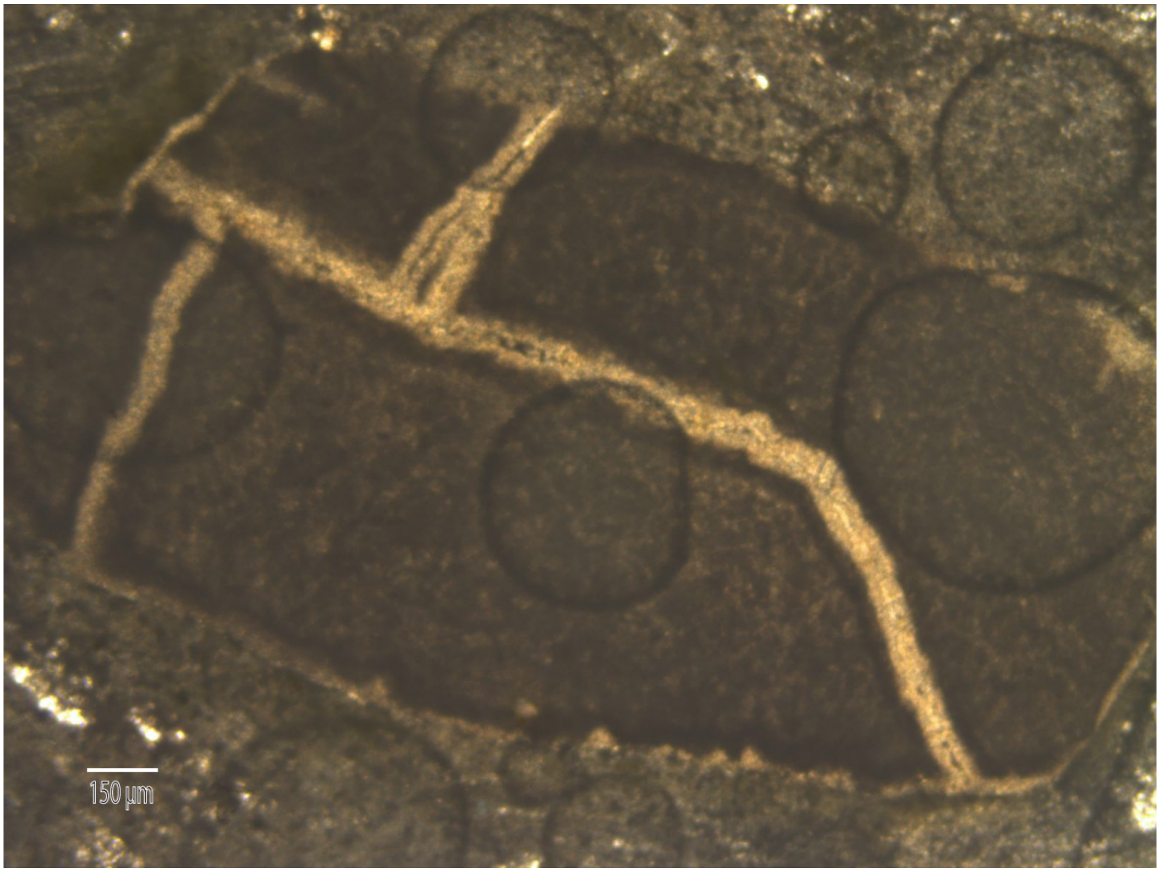
Description:

- Arg wht to tan tuff
- Possible sphereulites
- Clay and silica veinlets
- White clay phenos- kaolinite

Thin Section:

- Bad thin section
- Micrograph: Pheno cut by silica veinlets with clay selvage.
- Primary txt preserved
- Clay and silica veinlets





YS-08-JM72: Feldspar phenocryst segmented by silica veinlets with clay selvage. Note phenocryst rim is wet by clay.

YS-08-JM73

Brief Description:
Silicified, wht tuff

Location:
N 4956152
W 545079
Outcrop 4B: Middle

Field Notes:

- Approx 25ft upslope from JM69

Description:

- Silicified, wht tuff
    - remnant of JM74 (JM74 is "fresher") and JM69 (bleached and silicified)
- Qtz vein at top of sample
- Minor silica veinlets
- Possible white clay
- Lots of qtz eyes

YS-08-JM74

Brief Description:

Bleached tan to light gray tuff

Location:

N 4956155
W 545109
Outcrop 4B: Middle

Field Notes:

- Top of Ridge; downstream from JM72
    - Allie Collected
- Minor sulfides, possibly alunite

Description:

- Slicified with Arg overprint tan-l.gry tuff
- Arg phenos
- Possibly sulfides
- Clay veinlets
- Opal c-t, alunite
- Compression banding with silica replacement

Thin Section:

- Clay veinlets
- Micrograph: Sulfide micro-veinlets with clay selvage
- Ext fine-grained sulfides scattered throughout silicified mtx
- Silica veinlets with scattered sulfides (some micro)

XRD:
Major Minerals:

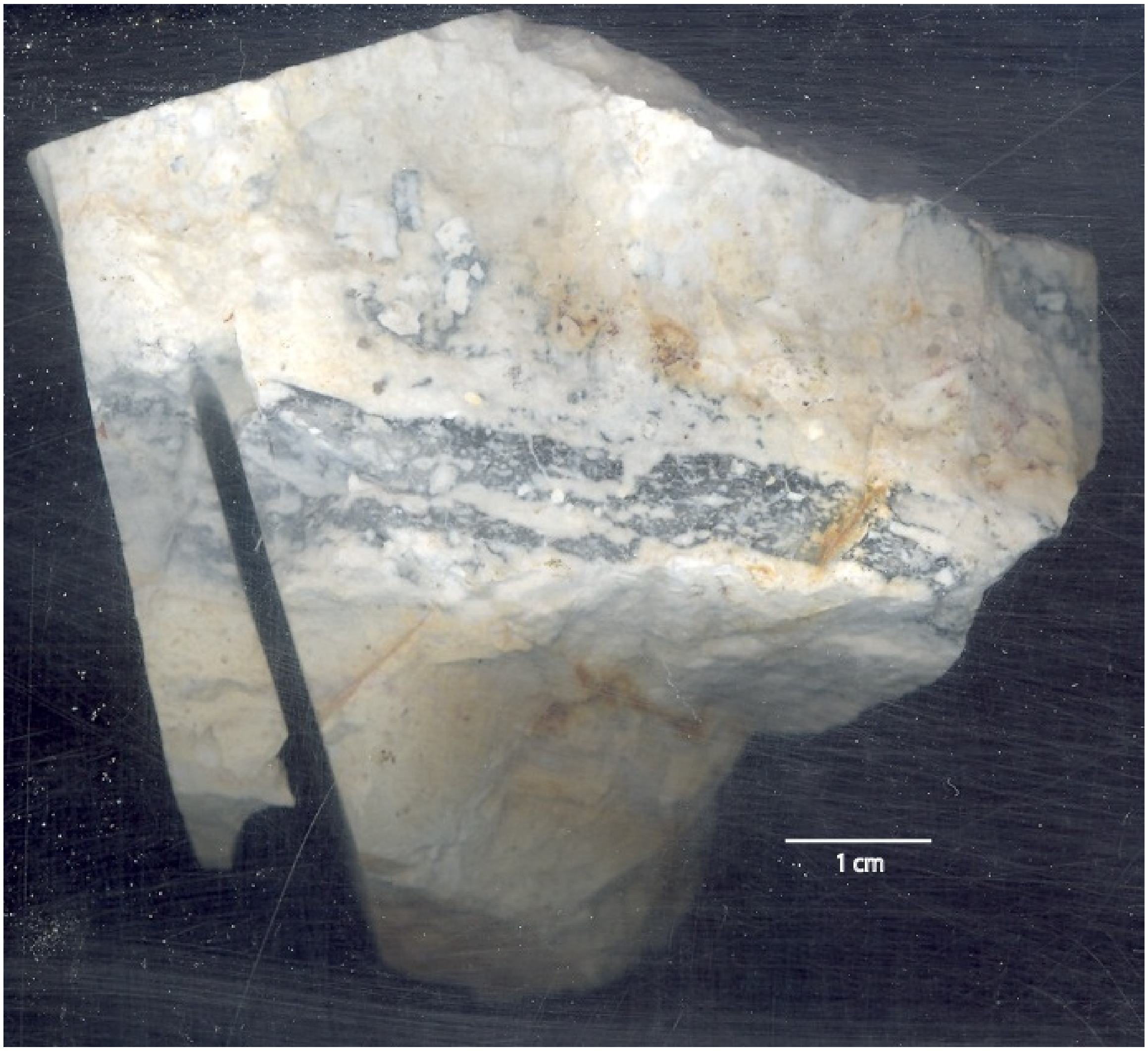
- Opal c-t, walth/al

Minor Minerals:

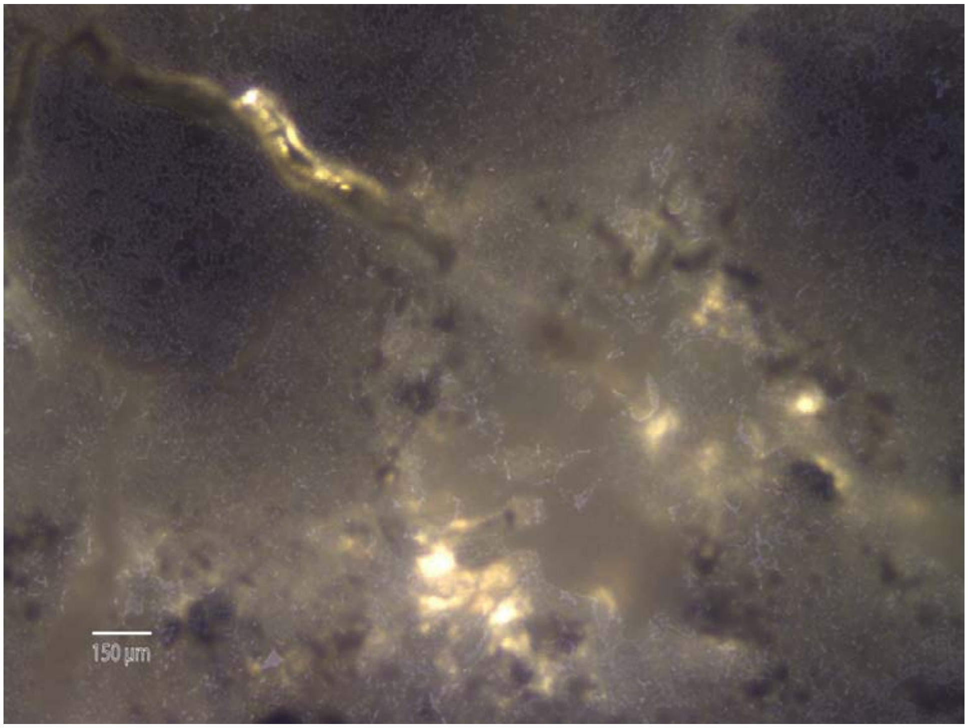
- Illite, pyrophyllite

Mineral Assemblage 2

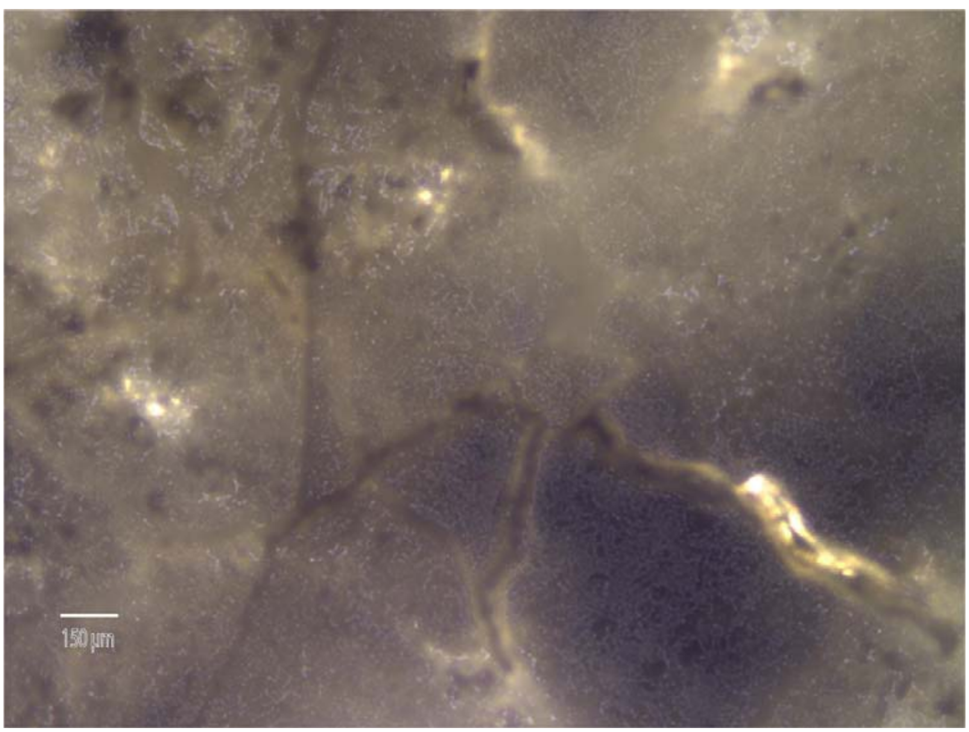
XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM74



YS-08-JM74: Sulfide veinlet with clay and silica selvage. Note fuzzy texture denoting argillization in the sample. Also, note disseminated sulfides throughout matrix.



YS-08-JM74: Sulfide veinlet with clay and silica selvage. Note fuzzy texture denoting argillization in the sample. Also, note disseminated sulfides throughout matrix.

YS-08-JM75

Brief Description:

Wht, weak, leached tuff (hi SiO_2)

Location:

N 4956081
W 545077
Outcrop 5: Middle

Field Notes:

- On South wall
- Downstream from OC 3
- Not a white wall
- Approx 25ft up from stream
- Tuff
- Vuggy

Description:

- Wht, weak, leached tuff (hi SiO_2)
- Silica veinlets

YS-08-JM76

Brief Description:

Silicified, l.gry tuff

Location:

N 4956081
W 545074
Outcrop 5: Middle

Field Notes:

- 5ft upstream (West) from JM75
- Oxidized—possibly due to sulfides?

Description:

- Silicified, l.gry tuff
- Weathered: Fe stained
- Acid leached
- Possible wht clays
- Sulfur
- Drusy qtz
- Silica veinlets
    - minor sulfides in silica veinlets, though no sulfide veinlets

YS-08-JM77

Brief Description:

Silicified buff tuff with heavy arg overprint

Location:

N 4956078
W 545078
Outcrop 5: Middle

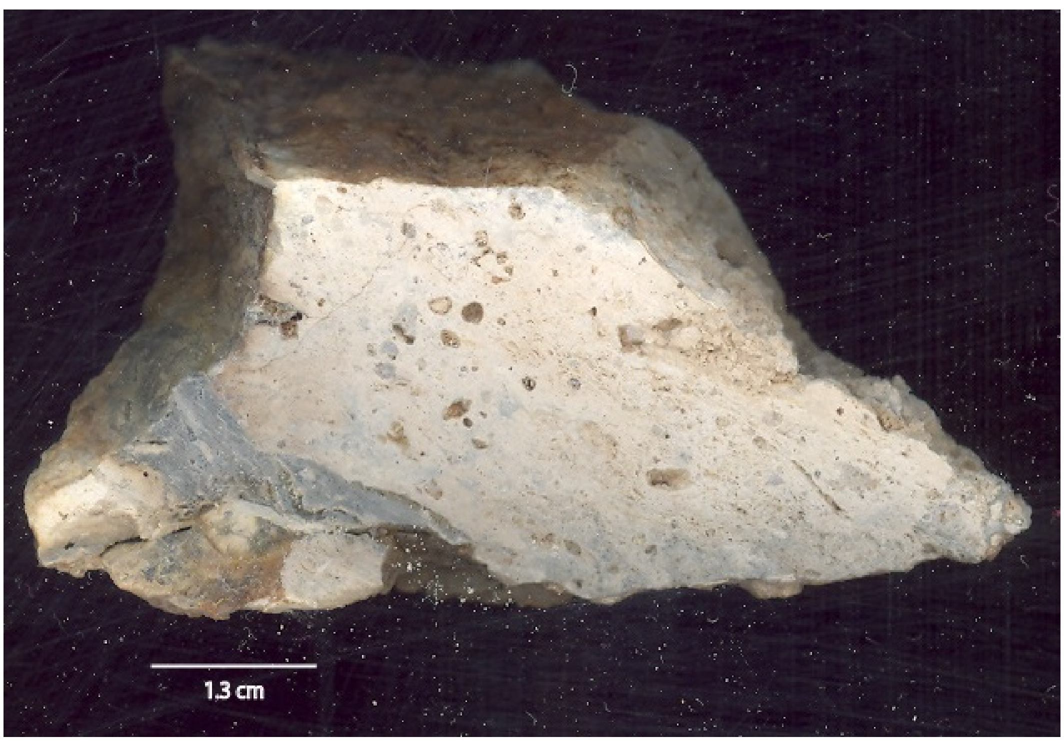
Field Notes:

- Silica Vein

Description:

- Silicified buff tuff with heavy arg overprint
- Acid leached
- Gry silica vein
- Silica veinlets
- Drusy qtz

Stable Isotope: -0.98‰



YS-08-JM78

Brief Description:
Silicified gry tuff

Location:
N 4956093
W 545050
Outcrop 4A: Base

Field Notes:

- North wall
- Downstream extent (East) of outcrop
- <10ft above stream bed
- Silica vein with minor sulfides

Description:

- Silicified gry tuff
- Sulfides
- Alunite
- Euhedral fresh phenos
- Silica Vein
- Looks like “JM40” group from Outcrop 3 (South wall)
- Clay veinlets

Thin Section:

- Pyt- lots
- Silica moves along primary igneous texture
- Fractured, altered phenos with pyt/silica infilling fractures
- Silicified wall rock
- Silica Veinlets

Stable Isotope: 0.57‰

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)

Scan: YS-08-JM78

YS-08-JM79

Brief Description:
Leached white pumice

Location:
N 4956089
W 545047
Outcrop 4A: Base

Field Notes:
- Approx 15ft upriver (West) from JM78
- Directly above (~2ft) stream
- No visible veins
- Lots of clay

Description:
- Leached white pumice

YS-08-JM80

Brief Description:
Silicified gry tuff

Location:
N 4956096
W 545046
Outcrop 4A: Middle

Field Notes:
- Approx 15-20ft upslope from stream bed
- Nearly above JM79
- Qtz and sulfides

Description:
- Silicified gry tuff
- Sulfide vein (marc and pyt) + dissemination throughout silica matrix

YS-08-JM81

Brief Description:

Silicified, brx wall rock

Location:

N 4956103
W 545043
Outcrop 4A: Middle

Field Notes:

- 5ft upstream (West) 10 ft upslope from JM80
- Small outcrop, under/beside tree
- Minor sulfides
- Porcelain qtz

Description:

- Silicified, brx wall rock
- Sphereulites
- Sulfides
- Silica and sulfide veinlets

XRD:
Major Minerals:

- Qtz

Minor Minerals:

- Illite, pyt, marc

Mineral Assemblage 2

YS-08-JM82

Brief Description:

White tuff; silica veinlets with minor crackle breccia

Location:

N 4956087
W 545043
Outcrop 4A: Base

Field Notes:

- 5 ft up from stream base

Description:

- Leached, weak hi silica wht tuff
- Minor breccia
- Silica veinlets
- Qtz eyes

XRD:
Major Minerals:

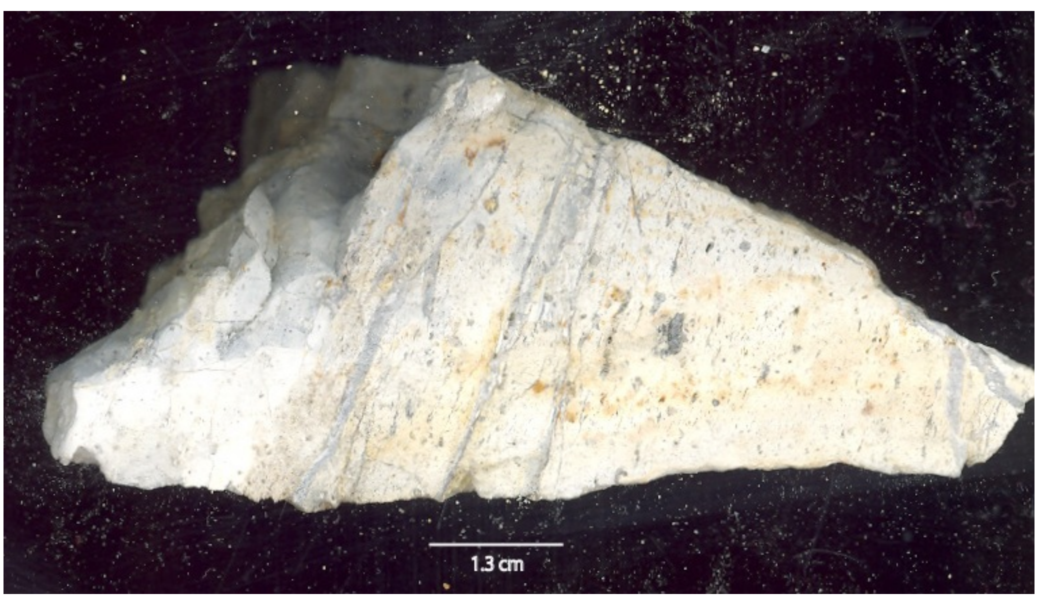
- Qtz

Minor Minerals:

- Opal ct, albite, alunite, kaolinite, illite, barite

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



YS-08-JM83

Brief Description:
Yellow, leached, weak (hi silica) tuff

Location:
N 4956100
W 545085
Outcrop 4B: Base

Field Notes:
- 10ft from active system
- 50% qtz eyes
- Silica veins, breccia, minor sulfides
- Smells like sulfur!
- Outcrop is gnarly and vuggy

Description:
- Yellow, leached, weak (hi silica) tuff
- Silica vein w. breccia and sulfide selvage
  - disseminated sulfides in vein
  - brx wall rock
  - wall rock adjacent to vein is silicified but rest of sample is leached
- Silcia veinlets
  - lead from one vug to another
- Drusy qtz
- White euhedral clay phenos

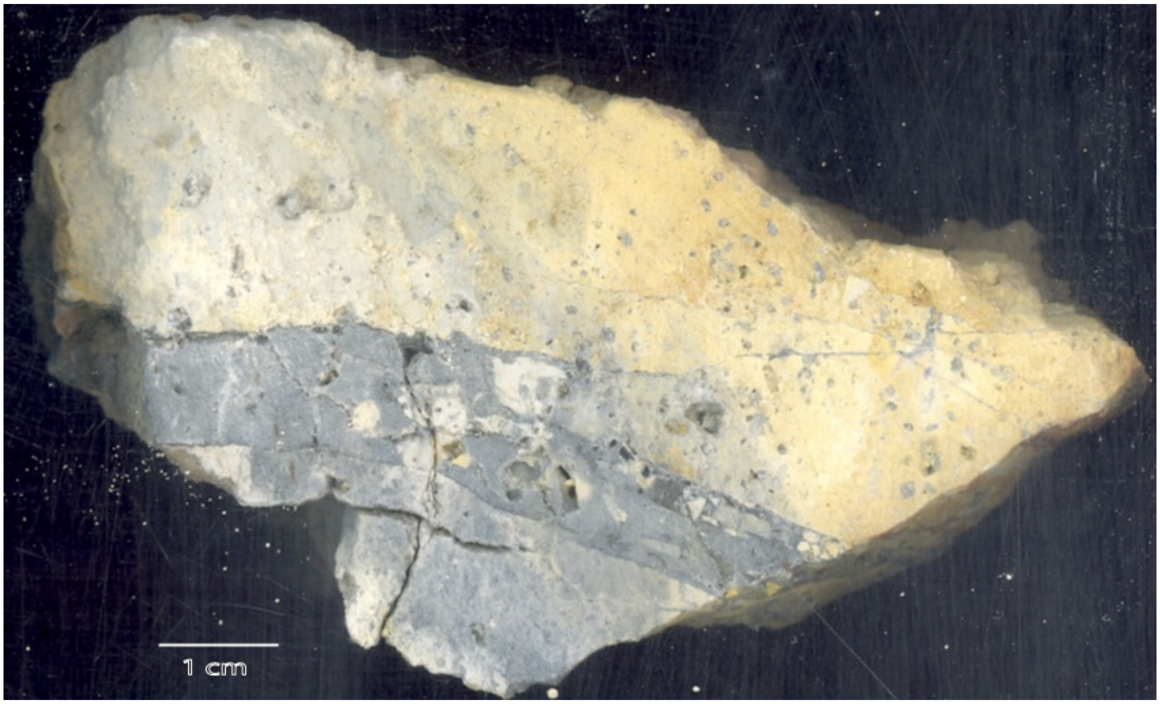
XRD:
Major Minerals:
- Qtz, pyt, walth/alunite, illite

Minor Minerals:
- Marc, pyropholite

Mineral Assemblage 2

Stable Isotope: -0.95‰

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM83

YS-08-JM84

Brief Description:

Leached wht-l.org tuff with gry hi silica mtx

Location:

N 4956110
W 545087
Outcrop 4B: Base

Field Notes:

- Silicified, white!
- Vugs
- Qtz eyes
- ~20ft upslope from JM83
- 10ft downstream from JM83

Description:

- Leached wht-l.org tuff with gry hi silica mtx
- Silica and sulfides veinlets
- Alunite
- Disseminated sulfides
- Qtz eyes
- Minor leaching
- Silicified
- Looks like JM70 and “JM40” group from outcrop 3
- Drusy qtz

YS-08-JM85

Brief Description:

Silicified to wht to l.org tuff

Location:

N 4956100
W 545088
Outcrop 4B: Base

Field Notes:

- Silica vein
- White clay, possible sulfides, qtz eyes, breccia

Description:

- Silicified wht to l.org tuff
- Silica vein w. minor brx
- Acid Leached
- Vuggy qtz
- Silica with sulfide veins
    - random sulfides in vein; not in selvage specifically
- Silica and sulfide veinlets
- Large euhedral phenos
- Qtz eyes

Thin Section:

- Sulfide veinlets
- Sulfides scattered in silicified matrix
- Breccia

XRD:
Major Minerals:

- Qtz, pyt, marc

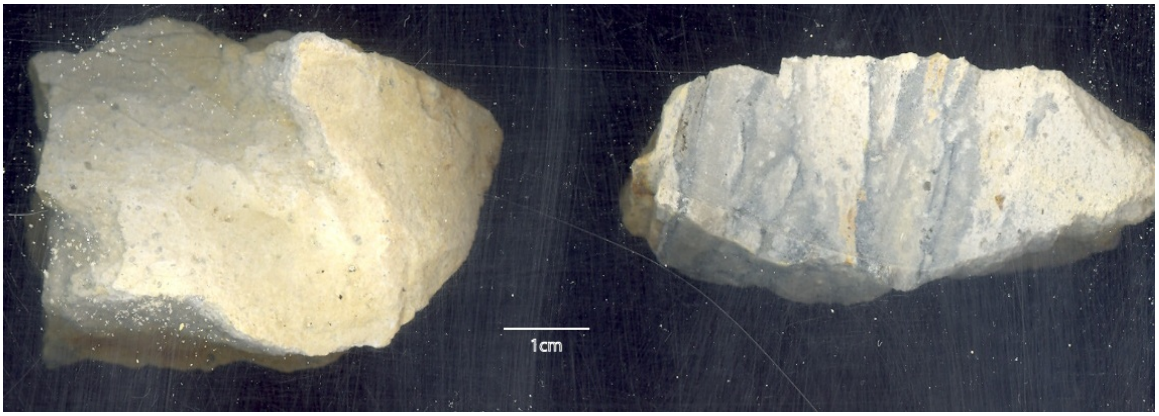
Minor Minerals:

- Illite, pyropholite

Mineral Assemblage 2

Stable Isotope: -1.41‰

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM85

YS-08-JM86

Brief Description:

Silicified wht tuff

Location:

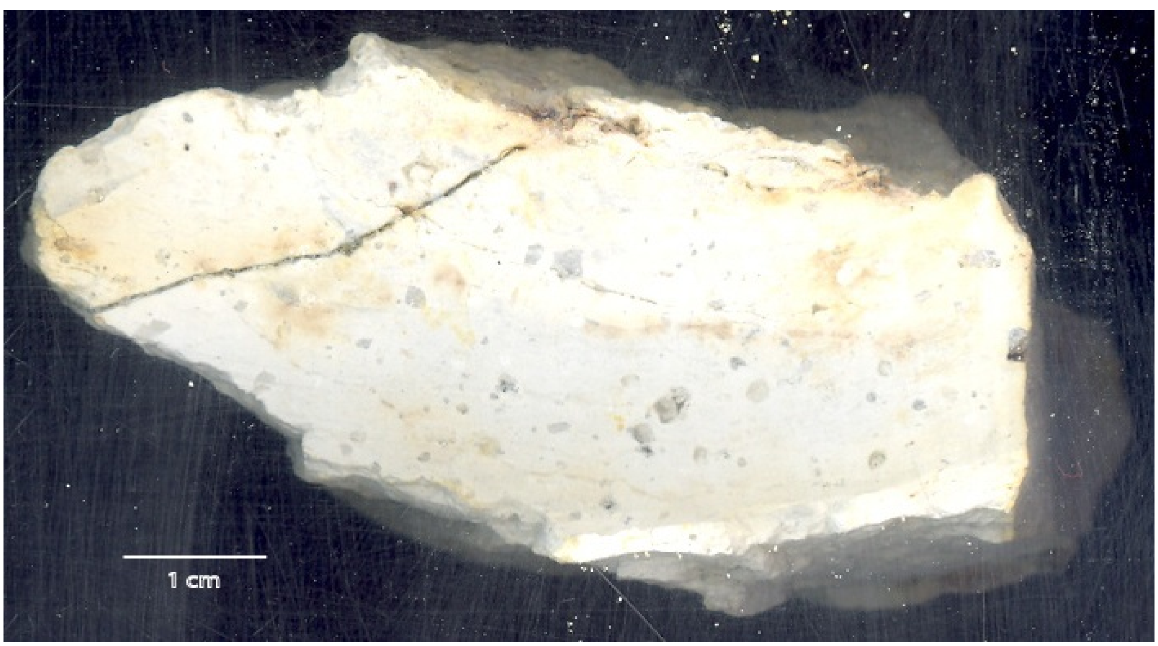
N 4956104.5
W 545089
Outcrop 4B: Base

Field Notes:

- Slight silicification
- Clays
- Wet—too close to active thermal??
- 10ft upslope from stream

Description:

- Silicified in slight arg overprint wht tuff
- Minor sulfides (veinlet)
- "Empty" veinlet
- Silica veinlets
- Qtz eyes
- White clay: kaolinite



YS-08-JM87

Brief Description:

Brx healed by marc, minor pyt/silica -milled to mosaic

Location:

N 4956097
W 545093
Stream/Outcrop 4B: Base

Field Notes:

- Sulfides in veins and not disseminated

Description:

- Brx healed by marc, minor pyt and minor silica -milled to mosaic
    - gry mtx
- Wall rock- silicified wht tuff with previous silica veinlets
- Silica/sulfide veinlets
    - crackle brx
- Silica veinlets with sulfide selvage
- Sulfide veinlets with silica selvage
- Drusy qtz

YS-08-JM88

Brief Description:

"Pure" wht, smooth, porcelain Opal vein

Location:

N 4956102
W 545093
Outcrop 4B: Base

Field Notes:

- Opal, possible porcelain opal
- Chalky white clay, possibly kaolinite

Description:

- "Pure" wht, smooth, porcelain Opal vein
- White clay- kaolinite
  - rip-up clasts along selvage of vein

YS-08-JM89

Brief Description:
Leached, wht tuff with silica veinlets

Location:
N 4956102
W 545098
Outcrop 4B: Base

Field Notes:

- Primary igneous texture
- Sugary, possible alunite
- Vuggy with drusy qtz

Description:

- Leached, wht tuff w. silica veinlets
    - sulfide selvage
- Minor brx
    - arg wall rock
- Barite
- Drusy qtz
- Colloform sulfide veinlets
- 1 small piece looks like JM90 with a veinlet separating "JM89" and "JM90"
    - veinlet: brx healed by silica with sulfide selvage
- Clays

XRD:
Major Minerals:

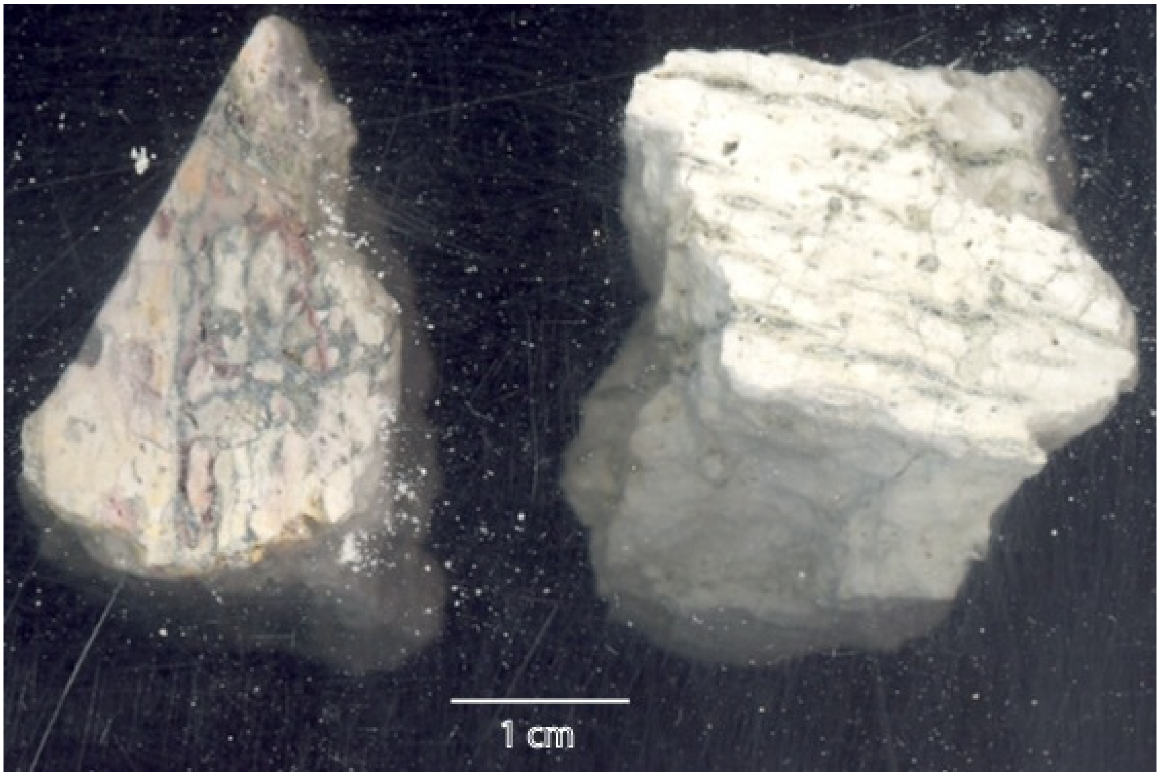
- Qtz

Minor Minerals:

- Cinnabar, barite, illite

Mineral Assemblage 2

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM89

YS-08-JM90

Brief Description:
Argillized gry tuff

Location:
N 4956102
W 545100
Outcrop 4B: Base

Field Notes:
- Primary texture
- Weathered out phenos
- Arg phenos= plag
- Vuggy

Description:
- Argillized gry tuff
- Clay veinlets
- Kaolinite and alunite
- White euhedral phenos
- Acid Leached

YS-08-JM91

Brief Description:
"Opalized" wht, hard tuff

Location:
N 4956102
W 545103
Outcrop 4B: Base

Field Notes:
- Silicified
- Qtz eyes

Description:
- "Opalized" wht, hard tuff
- Opal veneer
- Silica veinlets
- Qtz eyes

YS-08-JM92

Brief Description:

Wht, Weak, leached tuff (hi SiO2)

Location:

N 4956116
W 545157
Outcrop 6: Middle

Field Notes:

- South wall
- White clay
- ~40ft up cliff from stream

Description:

- Wht, weak, leached tuff (hi SiO_2)
- Silica veinlets
- Silica replacement in vugs
- Qtz eyes

YS-08-JM93

Brief Description:

Argilized wht to tan tuff

Location:

N 4956127
W 545156.5
Outcrop 6: Middle

Field Notes:

- Flow banding
- Qtz eyes and clays

Description:

- Argilized wht to tan tuff
- Silica veinlets
  - clear to dark
  - perpendicular to flow
  - stress fractures
- Compression banding preserved
- Minor sulfides
- Qtz eyes

YS-08-JM94

Brief Description:

Silcified gry tuff with arg overprint

Location:

N 4956135
W 545169
Outcrop 6: Middle

Field Notes:

- Black qtz vein
- Red oxidation
- White “clay” under vein

Description:

- Silcified gry tuff with arg overprint
- Silicified remnant compression banding
- Arg phenos: clays and sulfates
- Oxidized (red)

YS-08-JM95

Brief Description:
Arg, wht tuff

Location:
N 4956144
W 545168
Outcrop 6: Middle

Field Notes:
- Silicified
- Qtz eyes
- Fe staining follows flow
- Possible cause for Fe?
    - run trace elements

Description:
- Arg, wht tuff
- Compression banding- silica replacement
- Fe staining
- Qtz eyes

YS-08-JM96

Brief Description:

Silicified gry tuff with wht-tan arg overprint

Location:

N 4956127
W 545177
Outcrop 6: Middle

Field Notes:

- No notes

Description:

- Silicified gry tuff with wht-tan arg overprint
- Silica and clay veinlets
- BARITE, alunite, clays
- Qtz eyes

YS-08-JM97

Brief Description:
Silicified gray tuff with arg white overprint

Location:
N 4956127
W 545182
Outcrop 6: Middle

Field Notes:

- Qtz eyes
- Silicified
- Compression banding
- Vugs w/ minor drusy qtz

Description:

- Silicified gray to white tuff with arg overprint
- Silica veinlets (some hairline)
    - parallel to flow
- Drusy qtz
- Arg phenos
- Qtz eyes
- Compression banding

Thin Section:

- Microfractures
- Silicified
- Igneous texture mostly preserved
- Silica veinlets
    - Some mirco
- Sulfides scattered throughout silicified wall rock
- Clay veinlets with some silica

XRD:
Major Minerals:

- Qtz

Minor Minerals:

- Tridymite, alunite, huangite, barite

Mineral Assemblage 4

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM97

YS-08-JM98

Brief Description:
Silicified gray tuff

Location:
N 4956102
W 545167
Outcrop 6: Base

Field Notes:
- Sample from bottom of section
- Silicified

Description:
- Silicified gray tuff
- Minor arg phenos
- Compression banding preserved
- Qtz eyes

Thin Section:
- Minor brx in sulfide vein (minor silica)
- Silica veinlets- minor sulfides
- Fine-grained disseminated sulfides throughout silica matrix

Stable Isotope: -0.33‰

Scan: YS-08-JM98

YS-08-JM99

Brief Description:
Silicified wht tuff

Location:
N 4956095
W 545184
Outcrop 6: Base

Field Notes:
- Silica vein in tuff
- Qtz eyes
- White clay

Description:
- Silicified wht tuff
- D.gray silica vein w breccia
- Silica veinlets
- Qtz eyes

YS-08-JM100

Brief Description:
Arg wht tuff

Location:
N 4956103
W 545184
Outcrop 6: Middle

Field Notes:
- No Notes

Description:
- Arg wht tuff
- Clay veinlets- "spider web veinlets"
- White euhedral clay phenos

YS-08-JM101

Brief Description:

Crackle breccia of Arg wht and gry tuff healed by silica veinlets

Location:

N 4956116
W 545184
Outcrop 6: Middle/Base

Field Notes:

- Original waypoint is the same as JM100

Description:

- Crackle breccia of Arg wht and gry tuff healed by silica veinlets
- Clay and silica veinlets
- Minor sulfides
- Minor compression banding

YS-08-JM102

Brief Description:

Silicified, gray tuff with minor arg (wht-tan) overprint

Location:

N 4956125
W 545186
Outcrop 6: Middle

Field Notes:

- Vuggy
- Silicified
- Veins-clear qtz
- Qtz eyes
- Minor clay

Description:

- Silicified, gray tuff with minor arg (wht-tan) overprint
- Silica and clay veinlets
- Compression banding
- Minor white clay

YS-08-JM103

Brief Description:

Wht, weak, leached (hi silica) tuff

Location:

N 4956136
W 545196
Outcrop 6: Middle

Field Notes:

- Sample in float but close to original location based on surrounding rocks
- Vuggy w. drusy qtz
- Qtz veins
- Chalcedony

Description:

- Wht, weak, leached (hi silica) tuff
- Silica (opal) veins
  - clear
  - wall rock surrounding vein is silicified but other wall rock is leached
- Drusy qtz
- Pink possibly from rose qtz

YS-08-JM104

Brief Description:

Silicified wht tuff

Location:

N 4956109
W 545197
Outcrop 6: Middle

Field Notes:

- Clay, flow bands, qtz eyes

Description:

- Silicified wht tuff
- Silica veinlets
  - perpendicular to flow
- Minor sulfides
- Qtz eyes
- Minor white clays
- Compression banding

YS-08-JM105

Brief Description:

Silica vein with silicified wall rock surrounding

Location:

N 4956125
W 545195
Outcrop 6: Middle

Field Notes:

- Qtz vein
- Red staining
- White clay
- Brx

Description:

- Wall Rock: silicified wht tuff
    - alunite
- Silica vein: gry silica
    - clay veinlets

YS-08-JM106

Brief Description:
Silicified gry tuff with arg wht-tan overprint

Location:
N 4956125
W 545219
Outcrop 6: Middle

Field Notes:
- Brecciated veins like in stream
- Pink
- Powder at bottom of bag= drusy qtz

Description:
- Silicified gry tuff with arg wht-tan overprint
- Clay and silica veinlets
- Alunite
- White brx
  - euhedral arg clasts
- Pink from Fe stain

YS-08-JM107

Brief Description:

Arg wht-tan tuff; minor clay and silica veinlets

Location:

N 4956125
W 545216
Outcrop 6: Middle

Field Notes:
- Pink
- 10ft upstream from JM106

Description:
- Silicified (gray) tuff with arg overprint (wht-tan)
- Hairline silica and clay veinlets
- Alunite
- Qtz eyes

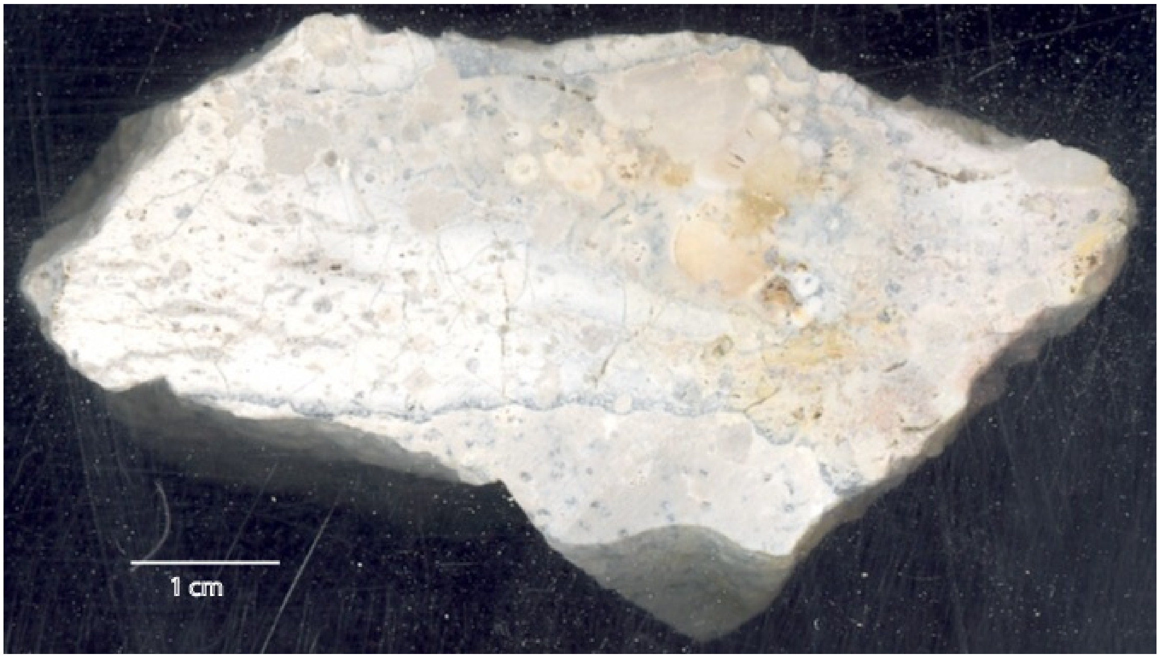
Thin Section:
- Micrograph: Qtz eye- silica veinlet leading to and from grain
    - highly fractured phenos
- Arg overprint silicified wall rock
- Silica and clay veinlets (some micro)
- V. minor relict igneous texture
- High concentration of veinlets
- Sulfides in matrix
    - encrusting arg phenos
    - in silica veinlets
    - oxidized

XRD:
Major Minerals:
- Qtz, kaolinite, huangite, al/walth

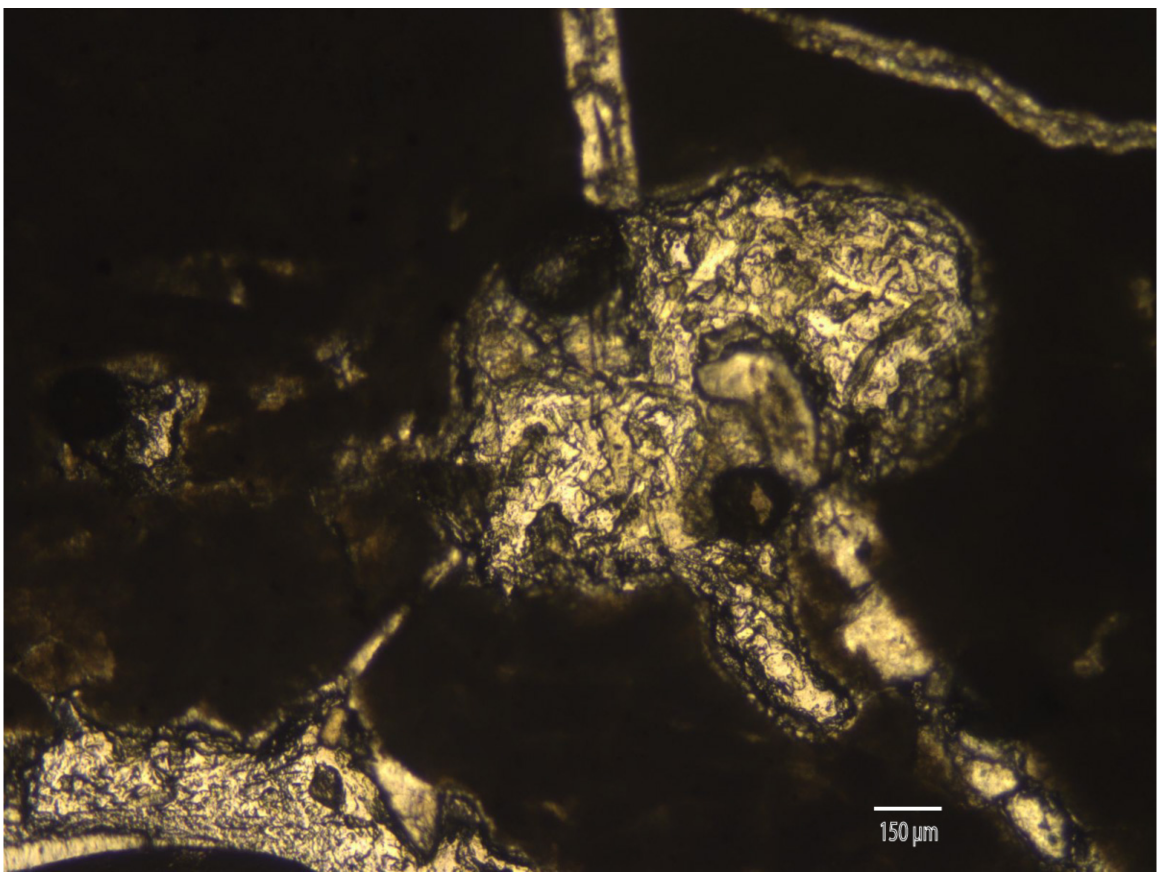
Minor Minerals:
- Illite, dickite, diaspore

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM107



YS-08-JM107: Fractured quartz phenocryst with silica veinlets cutting phenocryst.

YS-08-JM108

Brief Description:

Slightly silicified wht-tan tuff with major arg overprint

Location:

N 4956119
W 545226
Outcrop 6: Middle

Field Notes:

- Weathered feldspars: clay

Description:

- Slightly silicified wht-tan tuff with major arg overprint
- Hairline silica veinlets
- Wht euhedral clay phenos
- Weathered out phenos (external)

YS-08-JM109

Brief Description:

Silicified d.gry tuff

Location:

N 4956088
W 545233
Outcrop 4C: Base

Field Notes:

- North wall

Description:

- Silicified d.gry tuff
- Wht clay/sulfate phenos: kaolinite/alunite
- Well preserved compression banding
- Spider-like silica/sulfide veinlets
    - perpendicular to flow
    - hairline sulfide veinlets
- Light gry silica vein w. clay veinlet
    - parallel to JM113; which is also a silica vein

YS-08-JM110

Brief Description:

Silica vein w brx

Location:

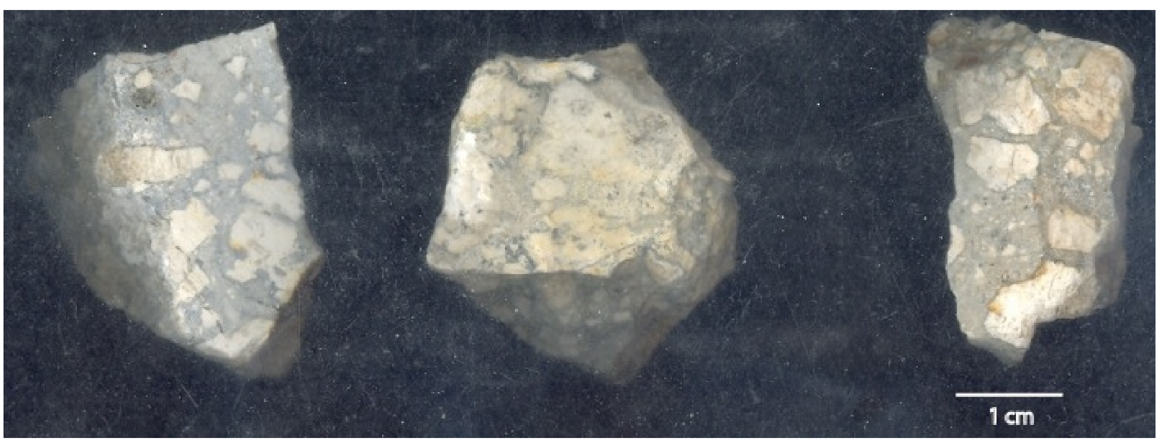
N 4956103
W 545233
Outcrop 4C: Base

Field Notes:

- Vein with brx
- ~25ft upslope from JM109

Description:

- Silica vein w brx
- Wht euhedral arg clasts
- Some brx lined by sulfides
- Silica veinlets inside brx
- Clay veinlet



YS-08-JM111

Brief Description:
Silicified gry tuff

Location:
N 4956113
W 545235
Outcrop 4C: Middle

Field Notes:
- No Notes

Description:
- Silicified gry tuff with a slight arg overprint
- Remnant compression banding
- Alunite, kaolinite, barite, opal
- Small wht euhedral to round clay phenos

YS-08-JM112

Brief Description:

Arg buff tuff; slightly silicified

Location:

N 4956127
W 545245
Outcrop 4C: Middle

Field Notes:

- Top of Section
- Weathered out phenos in tuff

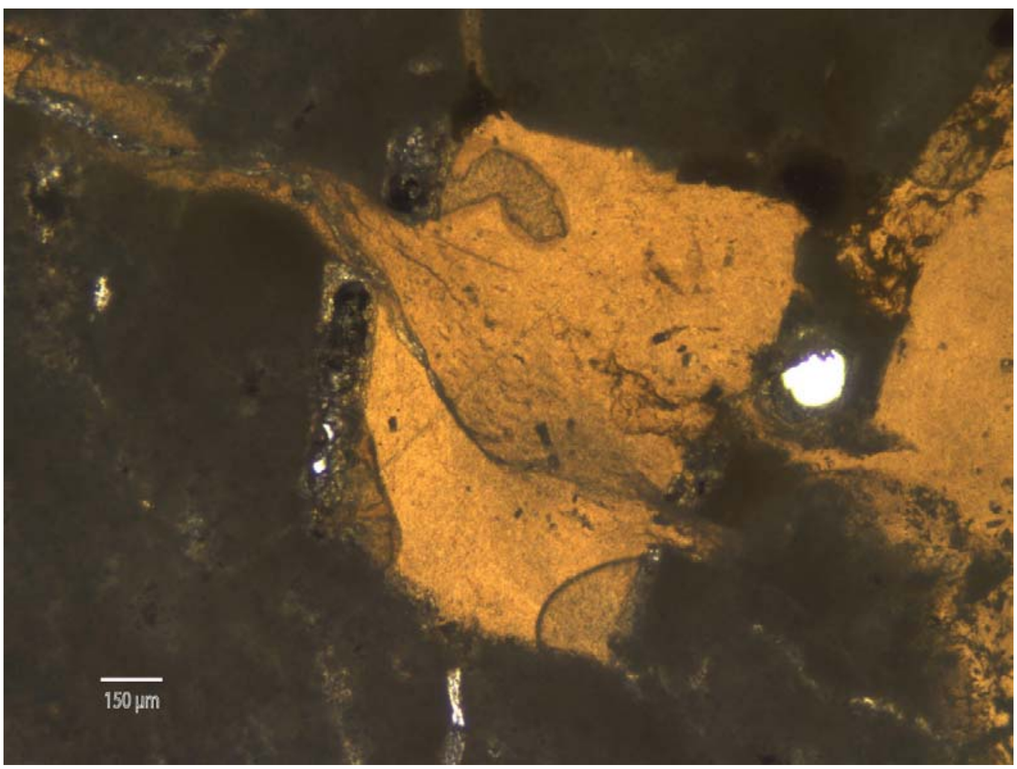
Description:

- Silicified white to tan tuff with arg overprint
- Clay veinlets connecting arg phenos
- Kaolinite and alunite
- White clay phenos

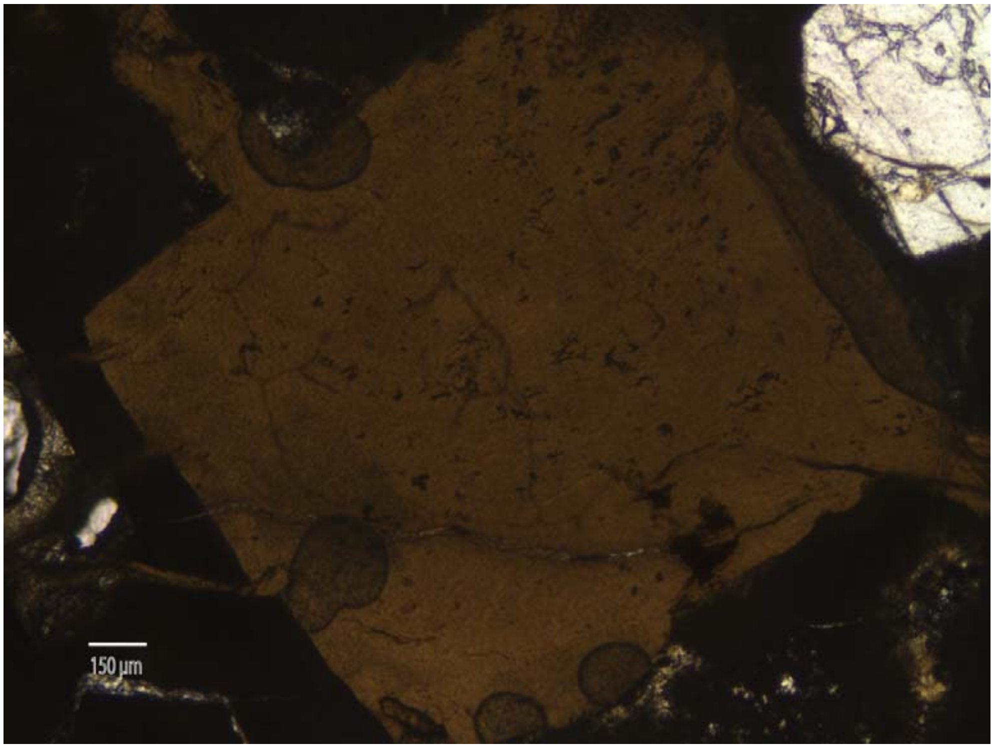
Thin Section:

- Micrograph (2): Clay veinlet leading to pheno to pheno to pheno, etc.
- Micrograph: Sulfates around edge of argillized pheno
- Sulfides scattered and linear in silica mtx (replacement)
- Sulfides- around edges of arg phenos and sometimes encrusting phenos
- Single veinlets with clay, sulfides, and silica
- Veinlets cut primary and secondary phenos
- Sulfide microveinlets
- Silica and clay veinlets
- Primary texture vaguely preserved

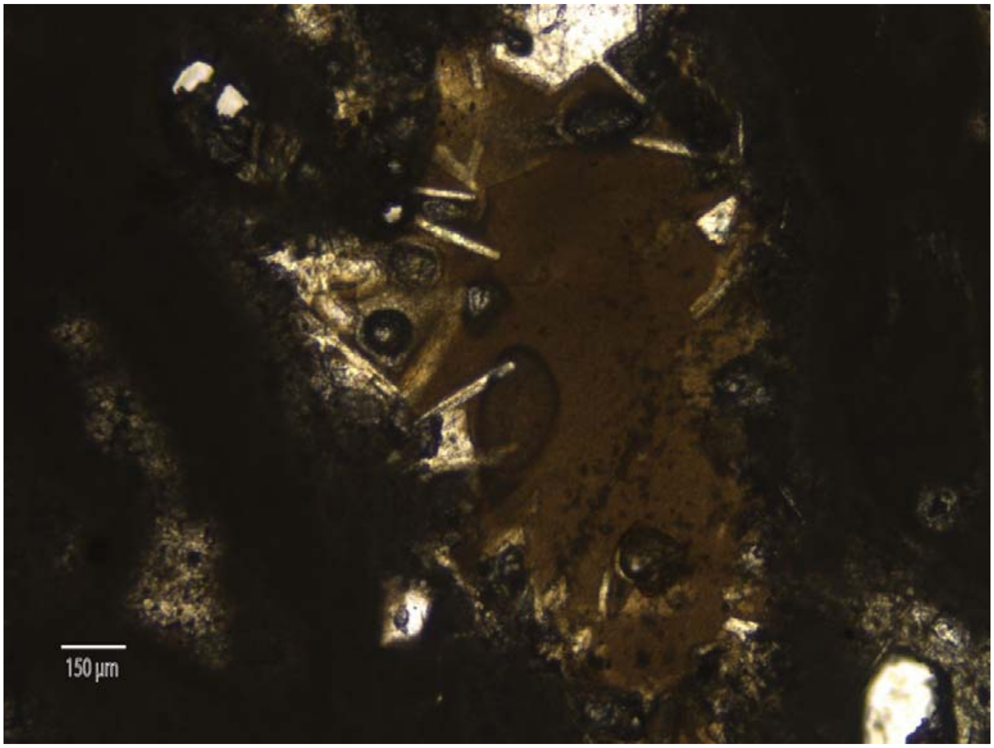
Scan: YS-08-JM112



YS-08-JM112: Argillized phenocryst with cross-cutting clay veinlet. Veinlet contains some silica and sulfides. Sulfides are around the edge of the argillized phenocryst.



YS-08-JM112: Argillized phenocryst with cross-cutting clay veinlet. Phenocryst contains silica veinlets and sulfides. From the same veinlet as above.



YS-08-JM112: Argillized phenocryst with bladed sulfate around the edge of the grain.

YS-08-JM113

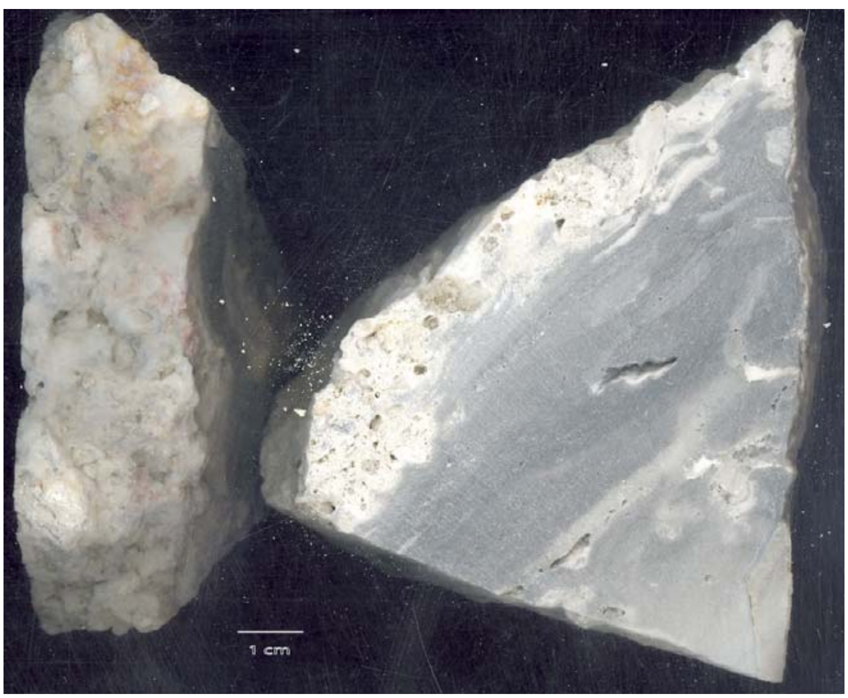
Brief Description:
Silica vein: ~7.5 cm wide

Location:
N 4956081
W 545237
Outcrop 4C: Base

Field Notes:
- Sugary qtz
- Pink clay

Description:
- Dark gry silica vein: ~7.5 cm wide
  - minor amethyst and rose qtz
- Minor brx of wall rock inside colloform section
  - rip-up clasts
  - arg wall rock
- Opal veneer
- Sugary texture

Stable Isotope: 0.97‰



YS-08-JM114

Brief Description:
Arg wht tuff

Location:
N 4956072
W 545240
Outcrop 4C: Base

Field Notes:

- From ~1ft above creek bed
- Qtz eyes

Description:

- Arg wht tuff
- <mm silica and sulfide veinlets
- Weak
- Qtz eyes
- Acid leached

YS-08-JM115

Brief Description:
Arg buff-tan tuff w large arg phenos

Location:
N 4956080.5
W 545244
Outcrop 4C: Base

Field Notes:
- Compression banding preserved
- Weathered out phenos
- Qtz eyes

Description:
- Arg buff tuff
- Arg phenos: alunite/walth
- Gry qtz, opal
- Drusy qtz
- Silica veinlets
- Qtz eyes

XRD:
Major Minerals:
- Alunite/walth, illite, qtz

Minor Minerals:
- Opal ct

Mineral Assemblage 2

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM115

YS-08-JM116

Brief Description:

Silicified gry tuff with arg overprint

Location:

N 4956067.4
W 545244.8
Stream: Base

Field Notes:

- From stream
- Brx
- Silica

Description:

- Silicified gry tuff with arg overprint
- Clay veinlets perpendicular to flow
    - connect small arg phenos
- Silica veinlets
- Alunite/kaolinite
- Drusy qtz

Thin Section:

- Clay and silica veinlets
- Primary igneous fabric wrapping around phenos
- Silica veinlet w. sulfides

YS-08-JM117

Brief Description:
Silicified wht tuff

Location:
N 4956072
W 545251
Outcrop 4C: Base

Field Notes:
- Silicified
- Qtz eyes
- Vuggy

Description:
- Silicified wht tuff
- Hairline silica veinlets
- "Empty" veinlets
- Drusy qtz
- Barite
- Preserved compression banding
- Qtz eyes
- White euhedral clay phenos

XRD:
Major Minerals:
- Qtz, opal ct, barite

Minor Minerals:
- Rostite, illite
    - Note: Qtz and Opal C-T are BOTH major minerals

Mineral Assemblage 2

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM117

YS-08-JM118

Brief Description:

Milled 2.5cm brx vein healed by silica and sulfide

Location:

N 4956069
W 545261.2
Stream: Base

Field Notes:

- Sulfides!
- Vein from creek

Description:

- Milled 2.5 cm brx vein healed by silica and sulfide
- Wall rock silicified
- Some arg brx
- Brx: ~5 cm to mm

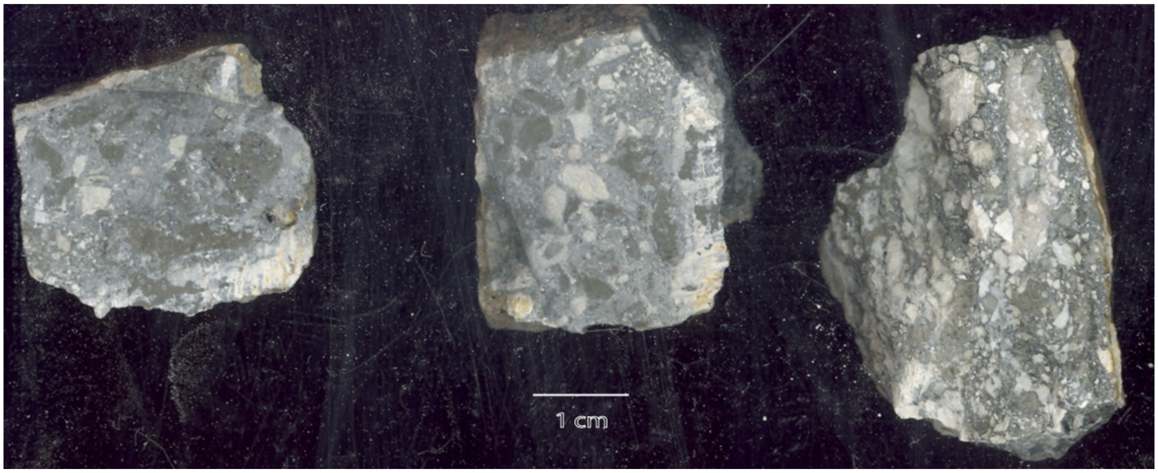
Thin Section:

- Botryoidal marcasite and massive pyt
- Silica and sulfide microveinlets
- Lots of silica and sulfides
- Minor/weak primary txt

Microprobe:

- Zircon phenos
- Ti-Silicate (Al)
- As-Pyt
- Ba-zeolite
- Pink "mineral"
    - Outside pink- Si with minor Al
    - Inside pink- More Al than Si
    - Possibly: Kaolinite when Si is higher than Al
    - Possibly: Illite when Al is higher than Si
- SiO+Al+K: In pink region
- SiO+Al+Na+K: Alkali feldspar
- SiO+Al±K
- Andalusite: AlSiO
- Microbrx: fld brx healed by pyt/marc
- Smectite: SiO+ Al+ Fe+ Na+Mg+P+K
- Pink: possibly due to Ba staining

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)



Scan: YS-08-JM118

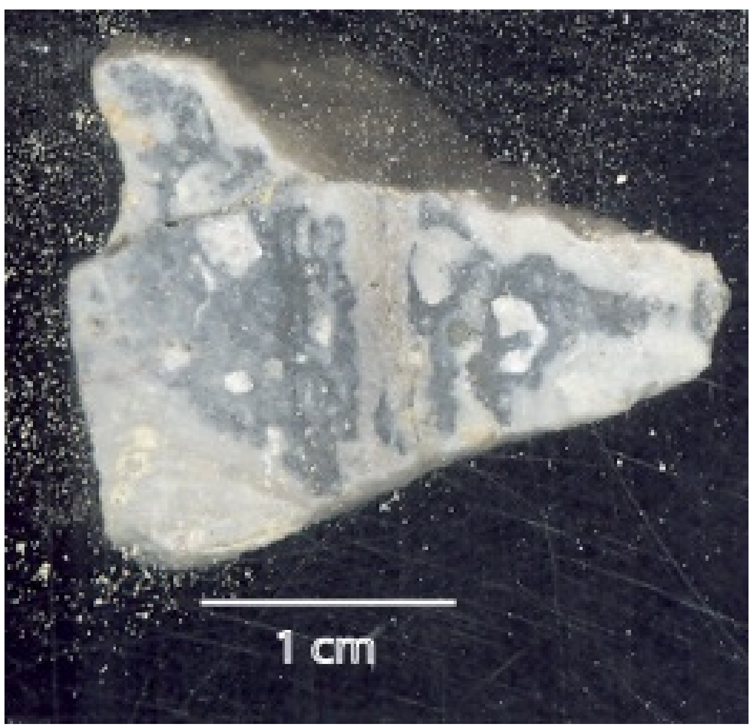
YS-08-JM119

Brief Description:
Arg gry Tuff

Location:
N 4956080
W 545257
Outcrop 4C: Base

Field Notes:
- Vein ~10ft above stream bed on North wall
- Near perpendicular to bedding

Description:
- Arg gry tuff
- Kaolinite, alunite, opal
- Sulfide vein
- Sulfides
- Silica veinlets
- Arg wht clasts (looks brx)



YS-08-JM120A

Brief Description:

Silica Nodule (opal)

Location:

N 4956073.5
W 545269.4
Stream: Base

Field Notes:

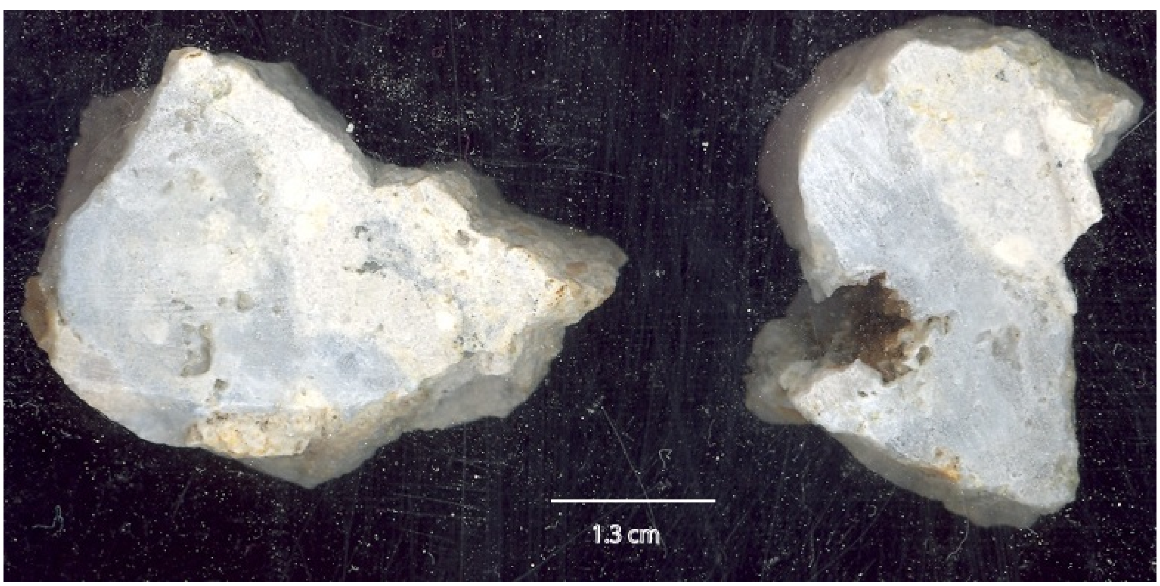
- From stream bed
- Silica nodule

Description:

- Silica Nodule (opal)
- Silicification of wall rock
- Minor arg of wall rock
- Sulfides and some sulfates
- Drusy qtz in vugs

Stable Isotope: 3.92‰

- So high because sample is made of opal



YS-08-JM120B

Brief Description:

Silicified l.gry tuff

Location:

N 4955973
W 545418
South Ridge: Top

Field Notes:

- Tuff with opal and chalcedony

Description:

- Silicified l.gry tuff
- Sphereulites
- Drusy qtz
- Opal, alunite, barite

YS-08-JM121

Brief Description:

Silicified wht-tan tuff with minor arg overprint

Location:

N 4955992
W 545405
South Ridge: Top

Field Notes:

- South Ridge
- Qtz eyes
- Clay

Description:

- Silicified wht-tan tuff with minor arg overprint
- Sphereulites
- Alunite, barite
- Qtz eyes
- White clay
- Possible minor sulfides

Thin Section:

- Sulfides: extremely fine grained
- Clay veinlets leading to and from arg phenos
- Micro silica veinlets

XRD:
Major Minerals:

- Opal C-T, kaol, alunite/walth, diaspore

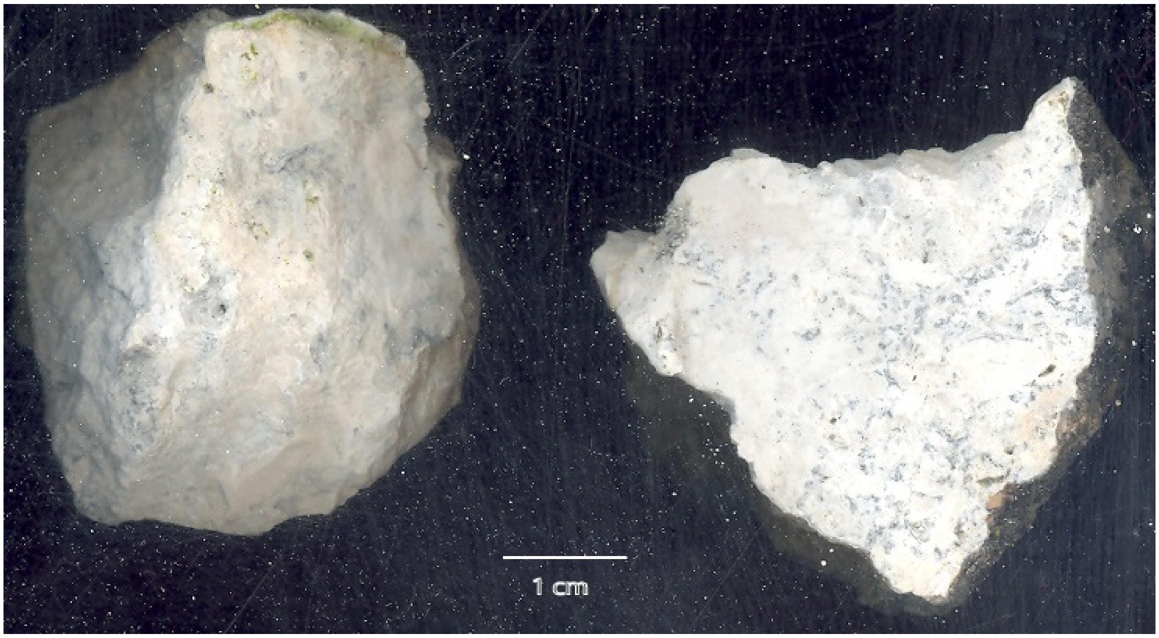
Minor Minerals:

- Dickite, qtz, illite

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2 and 3 (Appendix III)

* ICP-MS data lost



Scan: YS-08-JM121

YS-08-JM122

Brief Description:
Silicified buff tuff with arg overprint

Location:
N 4955953
W 545454
North Ridge: Top (float)

Field Notes:
- Float but at top of ridge
- White clay phenos

Description:
- Silicified buff tuff with arg overprint
  - Silicified zone is light gray
- Oxidized
- Kaolinite
- Euhedral to round clay phenos

YS-08-JM123

Brief Description:

Silicified wht-l.gry tuff with arg overprint

Location:

N 4955959.5
W 545419
North Ridge: Top (float)

Field Notes:

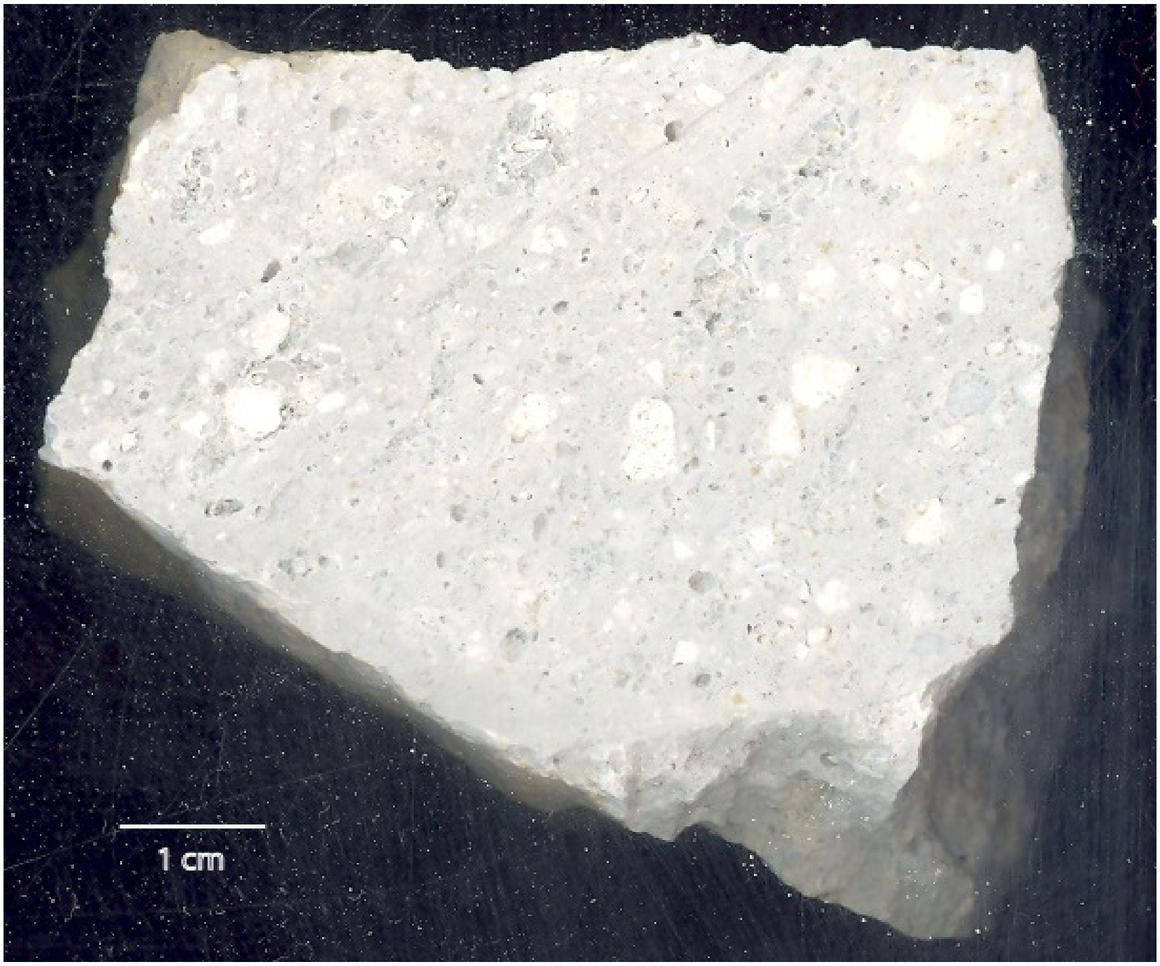
- Float but at top
- White clay with phenos

Description:

- Silicified wht-l.gry tuff with arg overprint
- Acid leaching
- Kaolinite
- White arg phenos
- Similar to "JM122" but leached and not oxidized

Thin Section:

- Argillized
- Sulfides
- Igneous texture persevered
- Silica and clay veinlets
- Argillized phenos



Scan: YS-08-JM123

YS-08-JM124

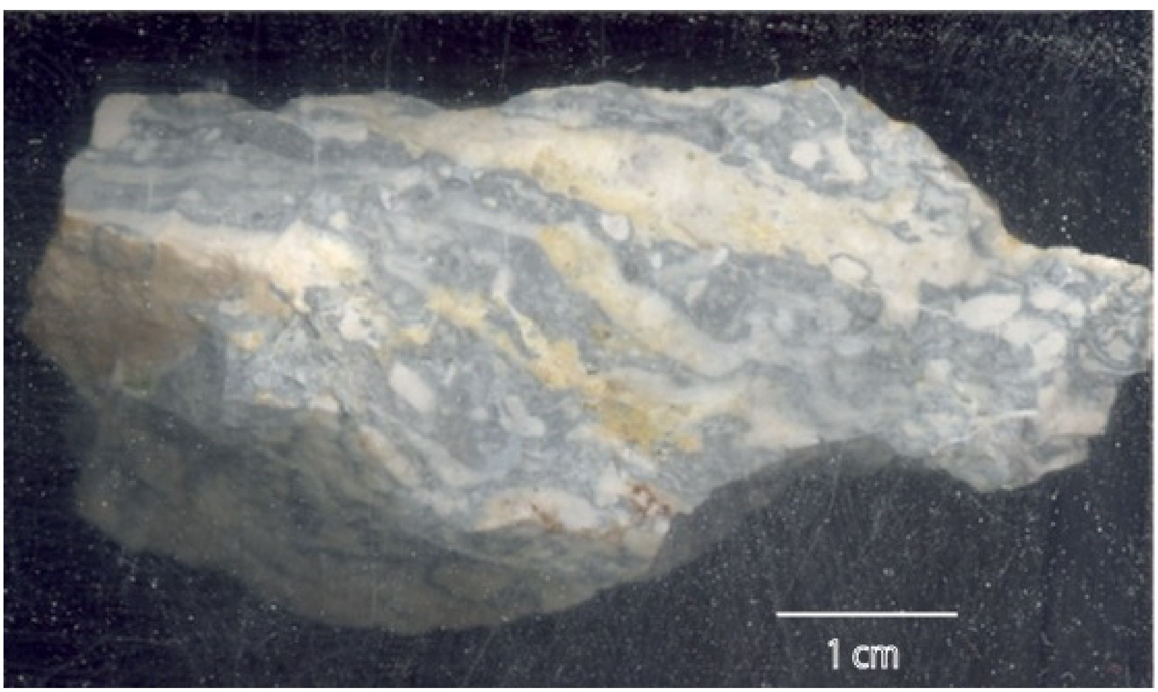
Brief Description:
Silicified l.gry tuff

Location:
N 4956022.5
W 545229
North Ridge: Top

Field Notes:
- Silica tuff with elongated phenocryst

Description:
- Silicified l.gry tuff with very minor arg overprint
- Well preserved compressed banding
- Alunite, opal, kaolinite
- Qtz eyes
- Similar to "JM121" but minor hairline clay veinlets

Stable Isotope: -2.48‰



YS-08-JM125

Brief Description:

Ext. silicified wht tuff (opalized)

Location:

N 4956020
W 545266
North Ridge: Top (float)

Field Notes:

- Float but at top
- Vuggy
- Silicified

Description:

- Extremely silicified wht tuff (opalized)
- Internal structure obliterated
- Heavily oxidized
- Heavily acid leached
- Drusy qtz in large vugs

Stable Isotope: 3.06‰

YS-08-JM126

Brief Description:

Opalized tuff

Location:

N 4956015
W 545218
North Ridge: Top

Field Notes:

- Not sure if float or not

Description:

- Opalized tuff
- Drusy qtz

YS-08-JM127

Brief Description:
Sil wht-l.pink tuff

Location:
N 4956039
W 545116
South Ridge: Top

Field Notes:
- Pink!

Description:
- Sil wht-l.pink tuff
- Compressed vugs replaced by silica
- Drusy qtz
- Fe stain
- Silica veinlets
- Outer shell is oxidized
- Slightly vuggy
- Minor pink areas (oxidation)
  - associated with silica flow
  - sometimes as selvage, sometimes inside vein
- Qtz eyes: 2 cm and smaller
- Drusy qtz infilled vuggy spaces
- Hairline silica veinlets cutting linear compression zone
  - few veinlets are colloform

YS-08-JM128

Brief Description:
Opalized wht tuff

Location:
N 4956032.5
W 545039.4
South Ridge: Top

Field Notes:
- Clay

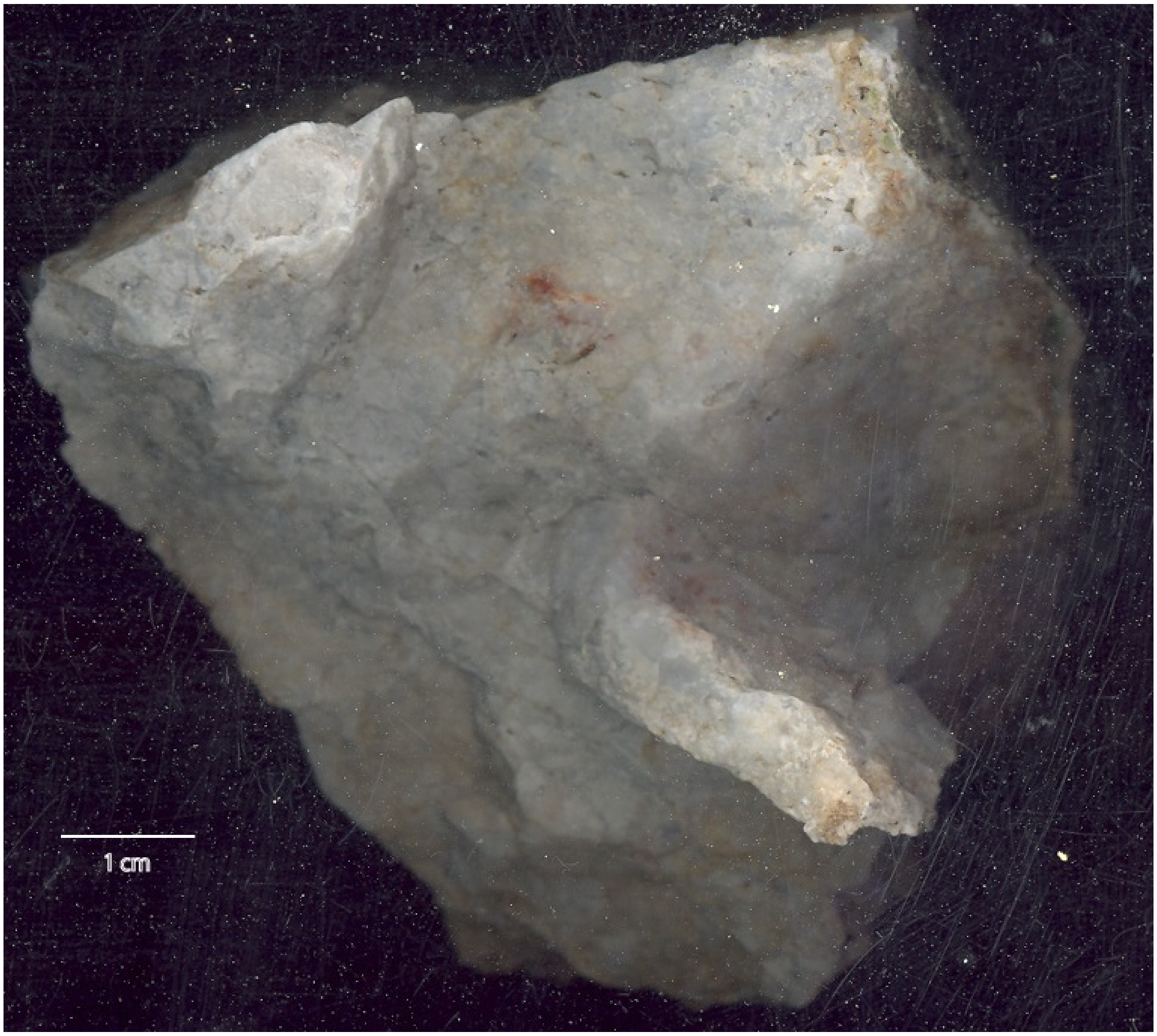
Description:
- Opalized wht tuff
- Acid leached
- No internal structure
- Minor white clay
- Minor silica veinlets

XRD:
Major Minerals:
- Qtz

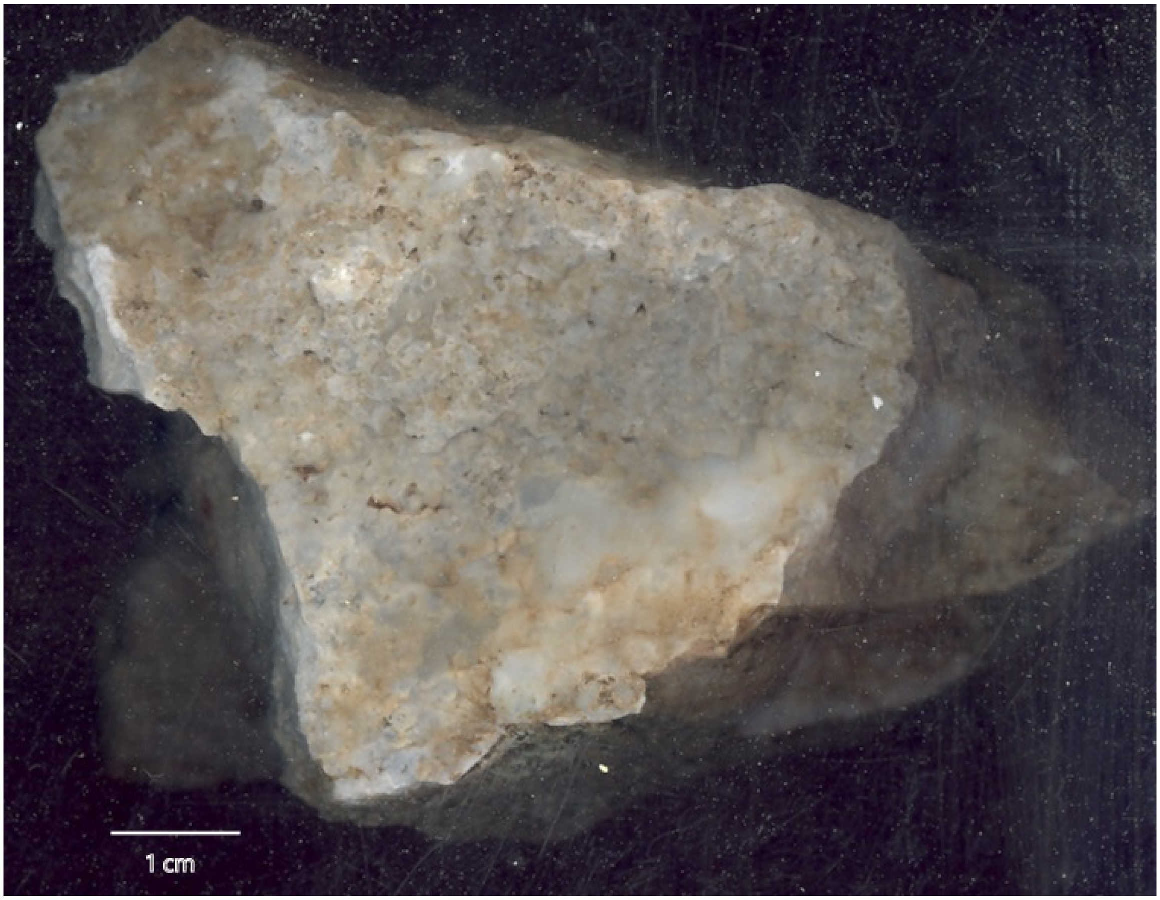
Minor Minerals:
- Opal C-T, barite, illite, kaol

Mineral Assemblage 1

Stable Isotope: 5.87‰



Scan: YS-08-JM128



Scan: YS-08-JM128

YS-08-JM129

Brief Description:
Sil wht-l.gry tuff

Location:
N 4956027
W 545033
South Ridge: Top

Field Notes:

- Original waypoint same as JM128
- Silica
- Vugs

Description:

- Sil wht-l.gry tuff
- Hairline silica veinlets
- Minor clay

YS-08-JM130

Brief Description:
Silicified tuff with dark gray silica vein and veinlets

Location:
N 4956028
W 545021
Outcrop 3: Top/South Ridge

Field Notes:
- Silica veins

Description:
- Silicified white tuff
- Qtz eyes vary in size from ~0.5 cm to 3 cm in diameter
- Oxidized
- Acid leached with drusy qtz
- See Realgar in vein and selvage
    - o <1% of vein mineralogy
- Silica veins/lets
    - o Light to dark gray
    - o Veins cross-cut at various angles
    - o ~1mm to 5 cm
- Possible sulfides
- White clay

Thin Section:
- Silica veinlets
- Minor sulfides

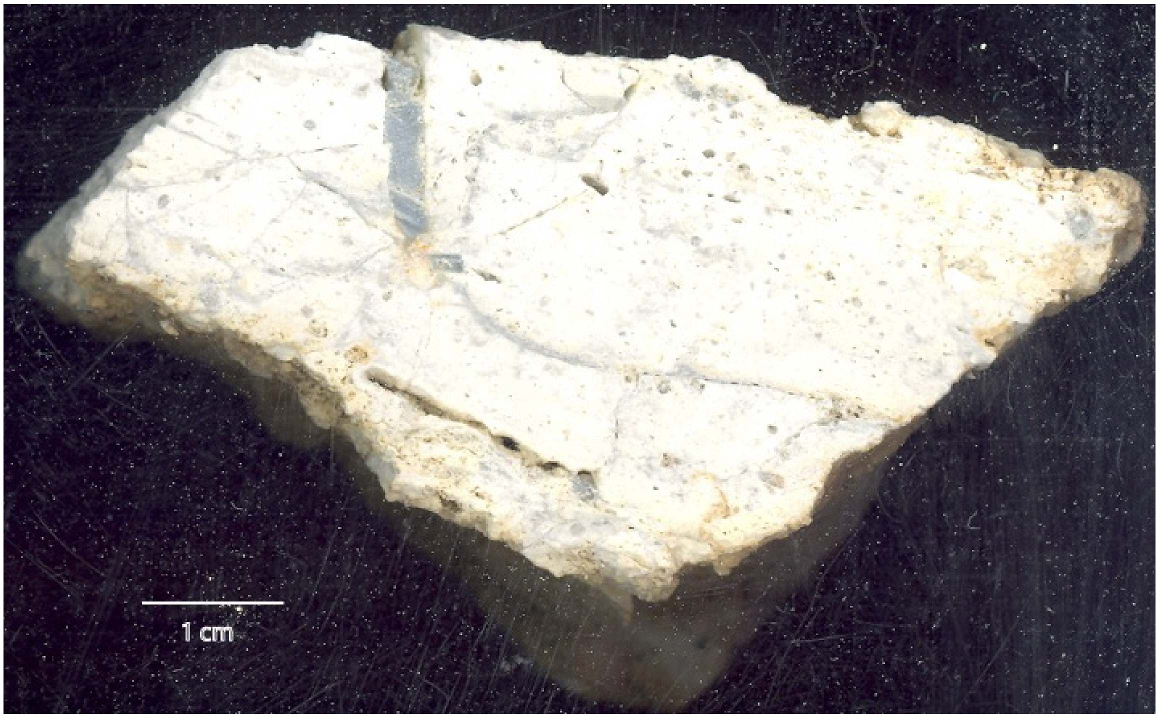
XRD:
Major Minerals:
- Qtz

Minor Mineral:
- Kaol, alunite, illite

*For whole rock and silica vein

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM130

YS-08-JM131

Brief Description:
Two samples: Silicified white tuff and Silica nodule

Location:
N 4955935
W 544951
South Ridge: Top

Field Notes:
- Tuff w. qtz eyes in float but at top
- Silica nodule

Description:

Tuff

- White
- Minor hairline silica veinlets
- Silicified
- Acid leached
- Qtz eyes: < ~1 cm
- Native sulfur

Silica Nodule

- Yellow-gray-clear
- Contains wall rock clasts

*Note: These samples are both float and are not related other than they were picked up from the same location.

XRD:
Major Minerals:
- Opal ct, barite

Minor Minerals:
- Qtz, illite

Mineral Assemblage 2
* From tuff and silica nodule

YS-08-JM132

Brief Description:

Silicified wht- l.gry tuff

Location:

N 4955855
W 544844
South Ridge: Top

Field Notes:

- Phenocrysts in gray matrix
- Two samples

Description:

- Silicified wht- l.gry tuff
- Wht clay phenos
- High concentration of qtz eyes
- No veinlets

First sample (top picture below)

- Arg overprint
- Featureless except pyroclastic shard
- Gray matrix is visibly bleached
- Weathered out phenos
- Acid leached

Second Sample (bottom picture below)

- Slightly more silicified than first sample
- Minor igneous texture
- Phenos not weathered out
- "Freshest" sample from outcrop
- Angular to sub angular phenos
  - Fresh and argillized

XRD:

Major Minerals:

- Opal ct, kaol, barite

Minor Minerals:

- Qtz, zunyite, alunite, illite

Mineral Assemblage 1

* From first sample

Scan: YS-08-JM132

YS-08-JM133

Brief Description:
Silicified pink tuff

Location:
N 4956181.8
W 544956.6
North Ridge: Top

Field Notes:
- No notes

Description:
- Silicified wht-l.pink tuff
    - rose qtz
- 99% silica
- Drusy qtz
- Qtz eyes

Thin Section:
- Brecciated
- Silicified
- Disseminated sulfides throughout silica mtx
- Colloform silica infilling vugs

XRD:
Major Minerals:
- Qtz

Mineral Assemblage 4

Stable Isotope**:** 5.99‰

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM133

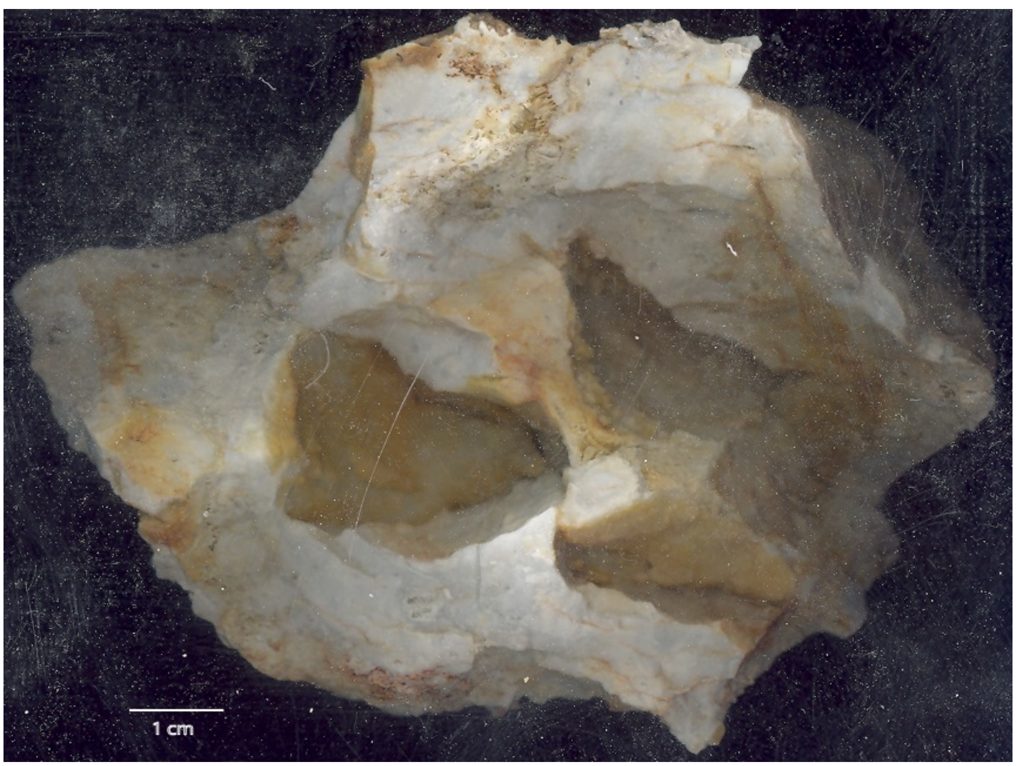
YS-08-JM134

Brief Description:
Silicified white tuff

Location:
N 4956181.7
W 544961.2
North Ridge: Top

Field Notes:
- 10ft downstream (East) from JM133
- Vuggy

Description:
- Silicified white tuff
- Large vugs
- Drusy qtz



YS-08-JM135

Brief Description:

Silicified wht-l.gry tuff (opalized)

Location:

N 4956198.1
W 545046.5
North Ridge: Top

Field Notes:

- Vuggy with silica veins

Description:

- Silicified wht-l.gry tuff (opalized)
- Drusy qtz
- Silica veins

XRD:

Major Minerals:

- Qtz

Minor Minerals:

- Albite

*From silica vein

Mineral Assemblage 4

YS-08-JM136

Brief Description:
Silicified, fractured tuff healed by qtz veins

Location:
N 4956216
W 545127
North Ridge/Outcrop 4B: Top

Field Notes:
- Silica veins and large bladed crystals

Description:
- Silicified white to slightly yellow tuff
  - opalized
- Slight arg overprint
- Qtz eyes <2 mm
- Possible we are looking at brecciation, but sample is too small to see entire piece
- Minor vugs
- White to gray silica
  - ~2 cm to mm thick veins
  - massive to slightly banded- colloform
- Minor sulfides
- Silica veinlets
- Well preserved compression banding
- Acid leached

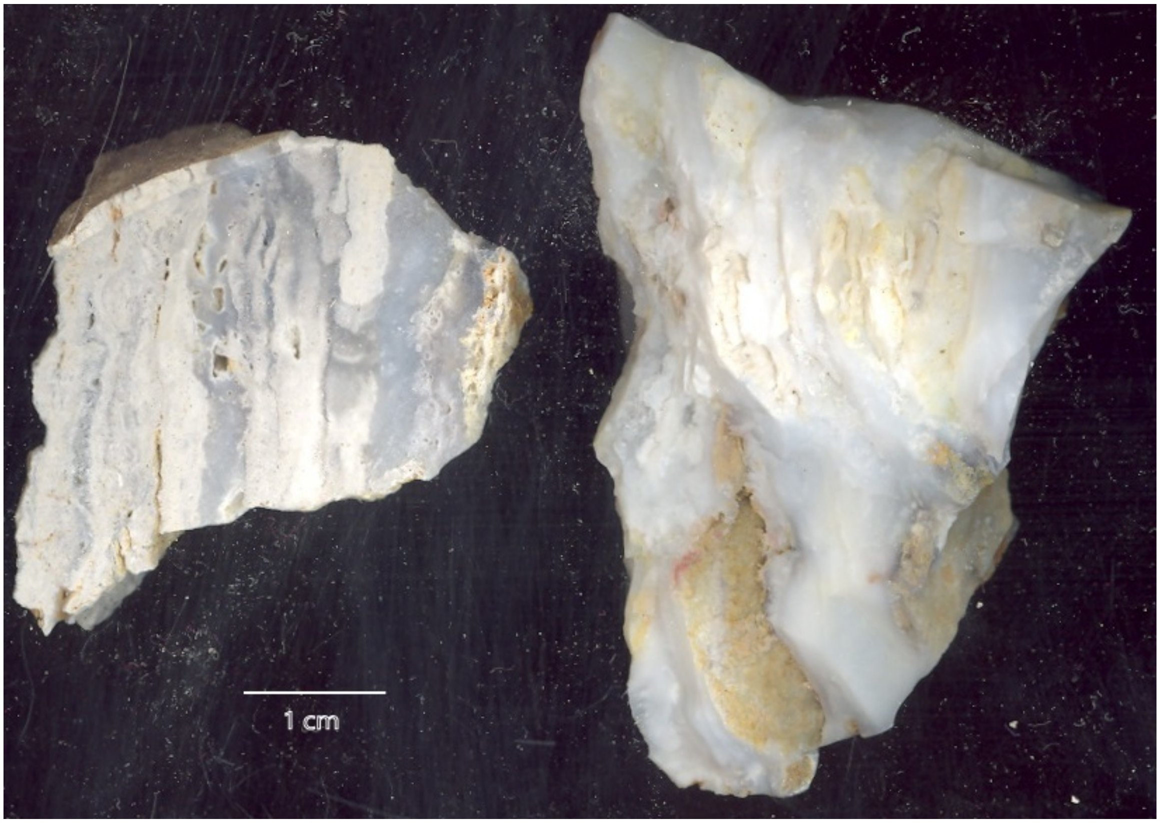
Thin Section:
- Silica veins
  - sulfides scattered throughout selvage
- Fine grained, disseminated sulfides throughout silica mtx

XRD:
Major Minerals:
- Whole Rock: Qtz
- Silica Vein: Qtz

Minor Minerals:
- Whole Rock: Albite, illite, pyt, marc
- Silica Vein: Albite

Whole Rock: Mineral Assemblage 2
Silica Vein: Mineral Assemblage 4

Stable Isotope: 6.44‰
*So high because opal.



Scan: YS-08-JM136

YS-08-JM137

Brief Description:

Silicified with arg overprint wht-l.gry tuff

Location:

N 4956176
W 545129
North Ridge/Outcrop 4B: Top

Field Notes:

- No notes

Description:

- Silicified with arg overprint wht-l.gry tuff
- White arg phenos
- Silica veinlets
- Sugary texture

Thin Section:

- Clay veinlets lead to and from arg phenos
- Silica veinlets (some micro)
- Mirco sulfide veinlets
- Sulfides scattered in silicified matrix
- Silica replacement moved in through primary texture
- Sulfide encrusting argillized feldspars

XRD:
Major Minerals:

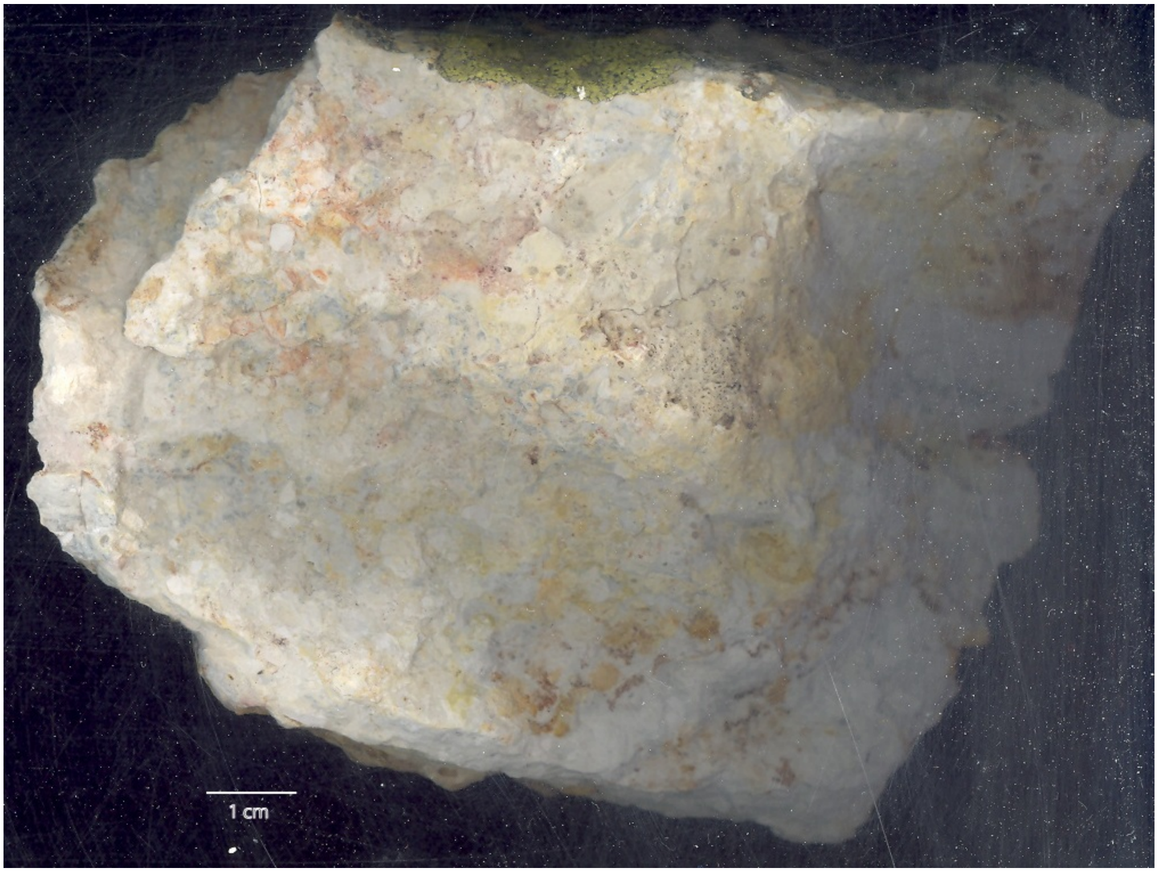
- Walth/Al, opal ct, Kaol

Minor Minerals:

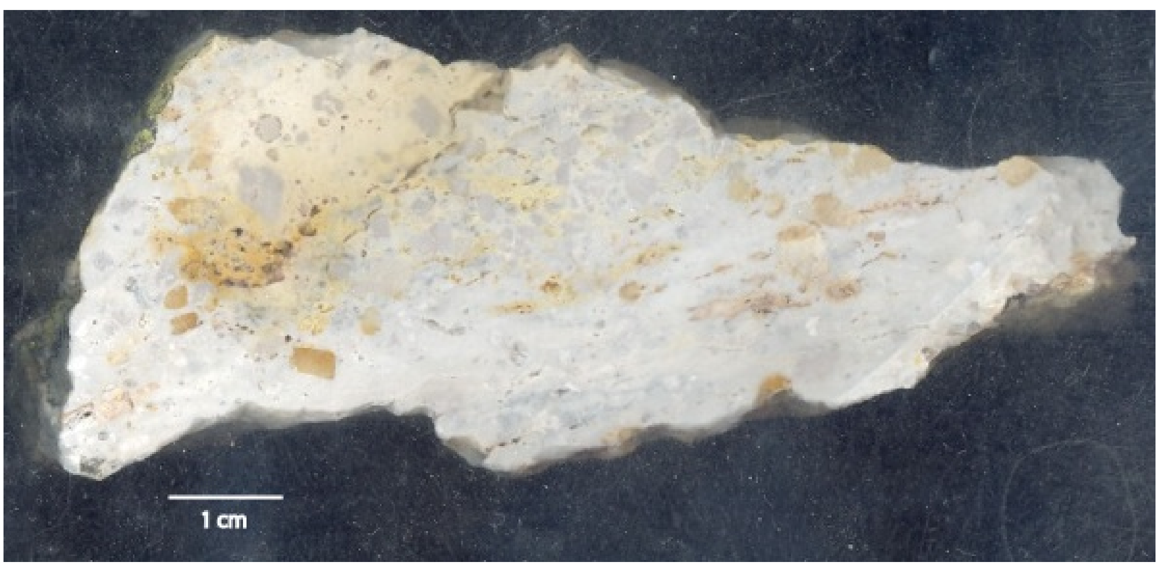
- Qtz, illite, rostite, diaspore

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM137



Scan: YS-08-JM137

YS-08-JM138

Brief Description:

Slicified gry -d.gry tuff (v. minor arg overprint)

Location:

N 4956178
W 545210
North Ridge/Outcrop 4C: Top

Field Notes:

- Clay phenos in gry matrix

Description:

- Slicified gry -d.gry tuff (v. minor arg overprint)
- High concentration of phenos
- Drusy qtz infill vugs
- Sphereulites
- Alunite/barite
- White clay phenos
    - arg phenos vary in size
- Looks like JM112

YS-08-JM139

Brief Description:
Silicified d. gry tuff

Location:
N 4956161
W 545244
Outcrop 4C: Top

Field Notes:
- No notes

Description:
- Silicified d. gry tuff
- Compressed pumice
- Sphereulites
- Drusy qtz
- Compression banding
    - wht clay in banding

YS-08-JM140

Brief Description:

Silicified wht-gry tuff w sphereulites

Location:

N 4956174.9
W 545291.7
Outcrop 4C: Top

Field Notes:

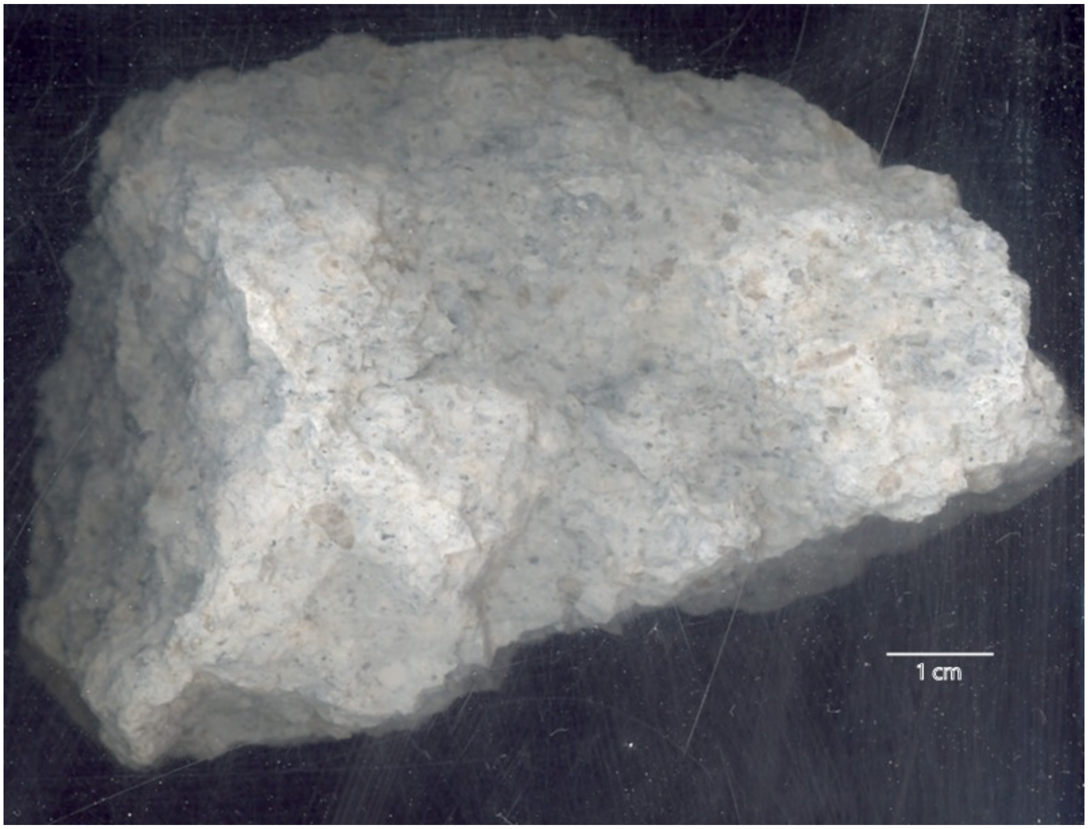
No Notes

Description:

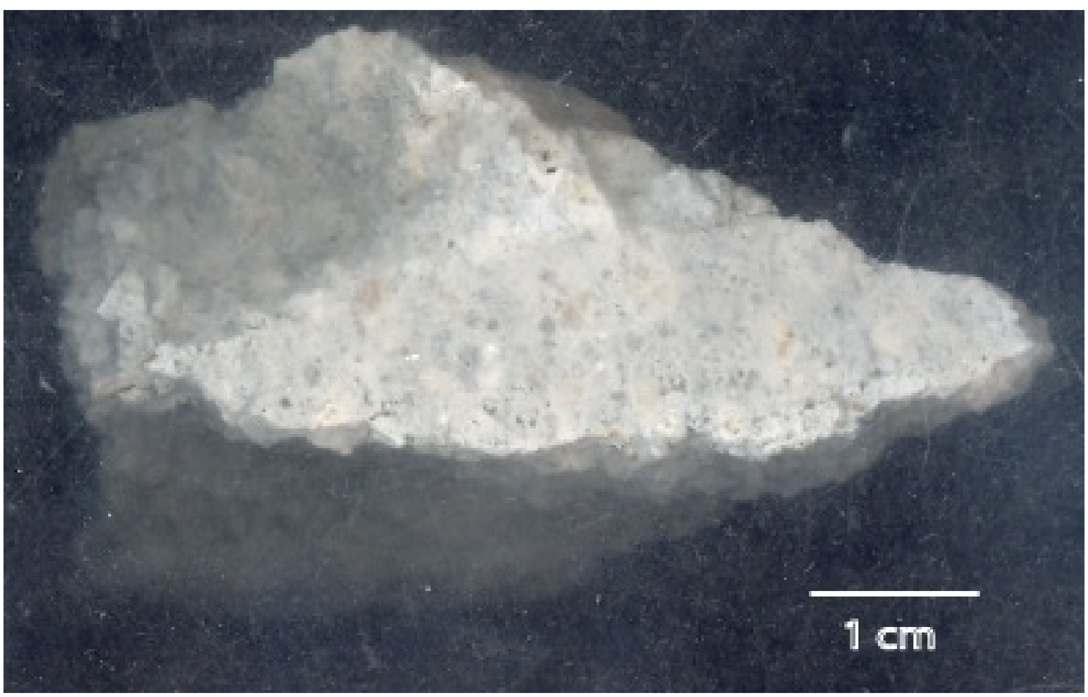
- Silicified wht-gry tuff (slightly argillized)
- Sphereulites
- Silica veinlets
- Acid leached

Thin Section:

- Discontinuous sulfide veinlets
- Scattered disseminated sulfides in silicified matrix



Scan: YS-08-JM140



Scan: YS-08-JM140

YS-08-JM141

Brief Description:

Silicified gry tuff

Location:

N 4956156.4
W 545291.8
Outcrop 4C: Top

Field Notes:

- From below JM140

Description:

- Silicified gry tuff
- Wht silica veinlets
- Large clay phenos
- Looks like JM115

YS-08-JM142

Brief Description:

Silicified wht-l.gry tuff with minor arg overprint

Location:

N 4956139.8
W 545291.9
Outcrop 4C: Top/Middle

Field Notes:

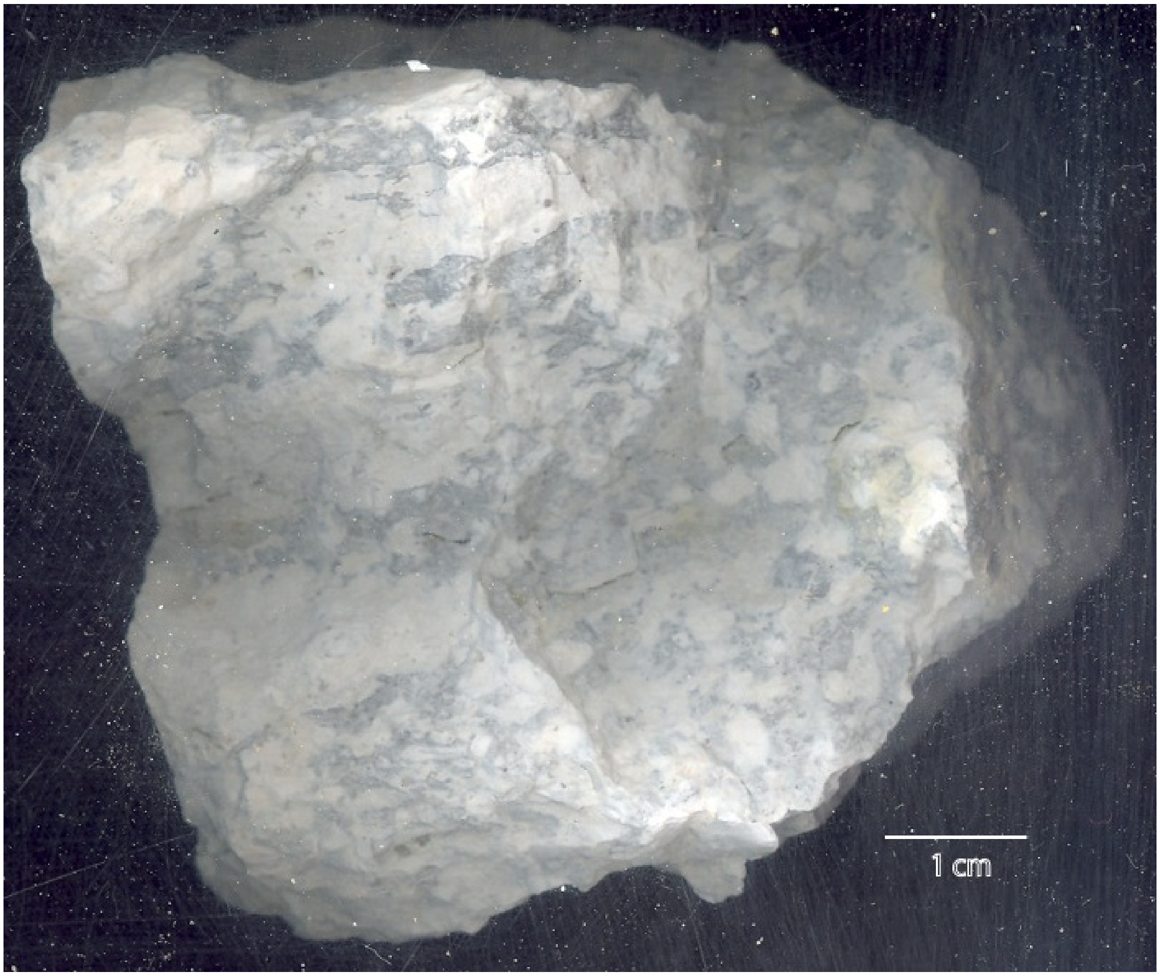
- Sample from base of spire

Description:

- Silicified wht-l.gry tuff
- Minor arg overprint
- Arg phenos
- Compression banding preserved
- Clay veinlets
- Qtz eyes

Thin Section:

- Primary igneous texture preserved
- Arg phenos
- Lots of sulfides
    - scattered in silicified matrix
- Silica veinlets
    - high concentration but not continuous
- Clay veinlets
- Large oxidized pyt grains



Scan: YS-08-JM142

YS-08-JM143

Brief Description:
Silicified wht tuff w hairline silica veinlets

Location:
N 4956171.5
W 545339.2
NR/Outcrop 4C: Top

Field Notes:
- Clay
- Qtz eyes

Description:
- Silicified wht tuff
- Hairline silica veinlets
- Vuggy
- Minor clay
- Qtz eyes

YS-08-JM144

Brief Description:
Silicified wht tuff

Location:
N 4956175.5
W 545385.3
NR/Outcrop 4C: Top

Field Notes:
- Qtz eyes
- Vuggy

Description:
- Silicified wht tuff
- Heavily acid leached
- Qtz eyes

XRD:
Major Minerals:
- Opal ct

Minor Minerals:
- Barite, illite, qtz

Mineral Assemblage 2

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

YS-08-JM145

Brief Description:

Silicified l. gray tuff with replacement along compression banding

Location:

N 4956144.5
W 545426
NR/Outcrop 4C: Top

Field Notes:

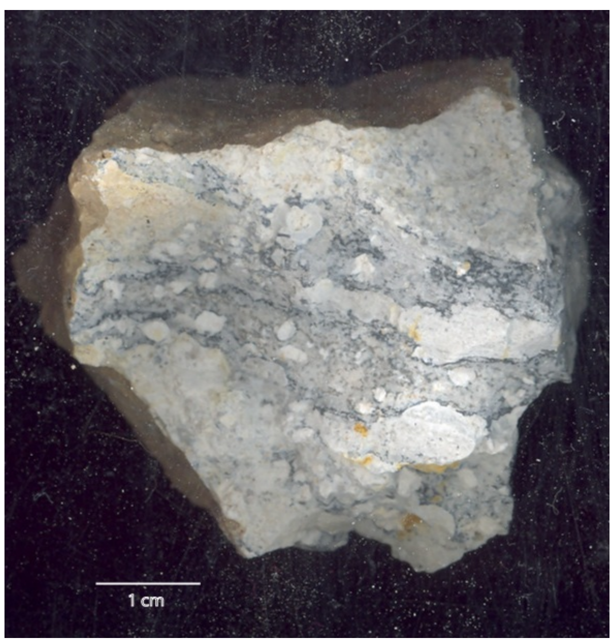
- No notes

Description:

- Silicified white to gray tuff w. arg overprint
- Silica replacement along well preserved compression banding
- Sphereulites
- White amorphous clay phenos
- Silica veinlets

Thin Section:

- Sphereulites
- Clay veinlets
- Arg phenos
- Primary igneous texture



YS-08-JM146

Brief Description:
Argillized and silicified d.gry tuff

Location:
N 4956169
W 545508.3
North Ridge: Top

Field Notes:
- Weathered out phenos

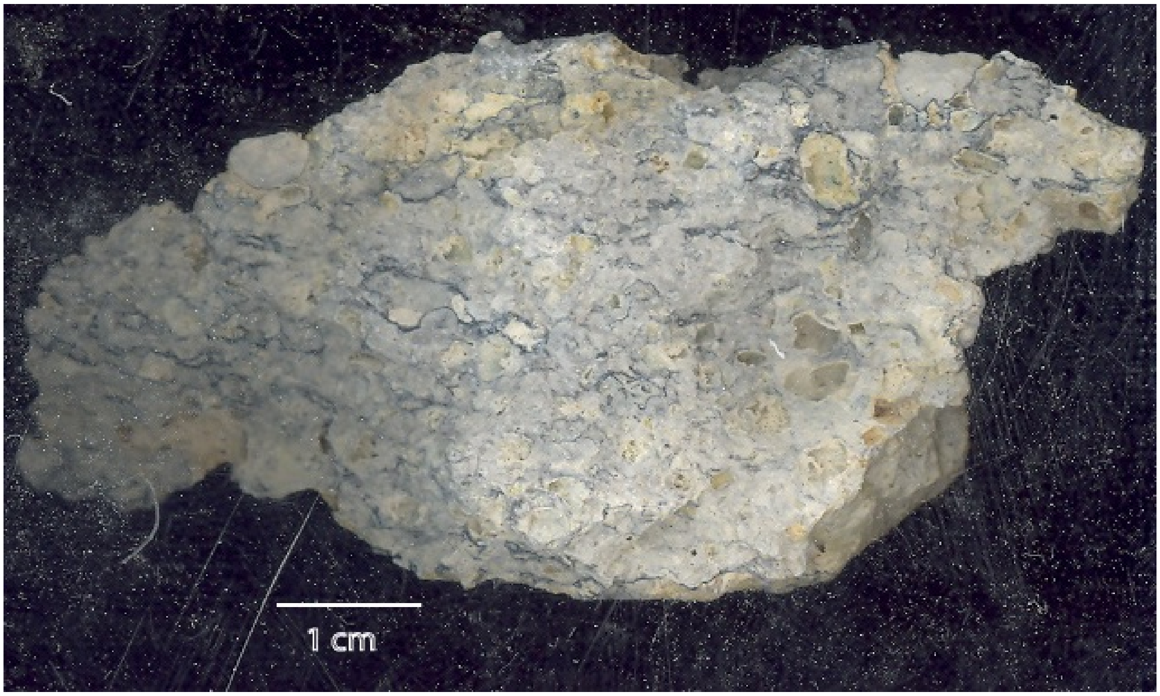
Description:
- Silicified gry tuff with arg overprint
- Acid leached
  - in-filled w sulfur
- Compression banding poorly preserved
- Sphereulites
- Alunite, kaolinite

XRD:
Major Minerals:
- Opal Ct, kaol, alunite/Walth, sanidine

Minor Minerals:
- Opal A, mont, illite

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)



Scan: YS-08-JM146

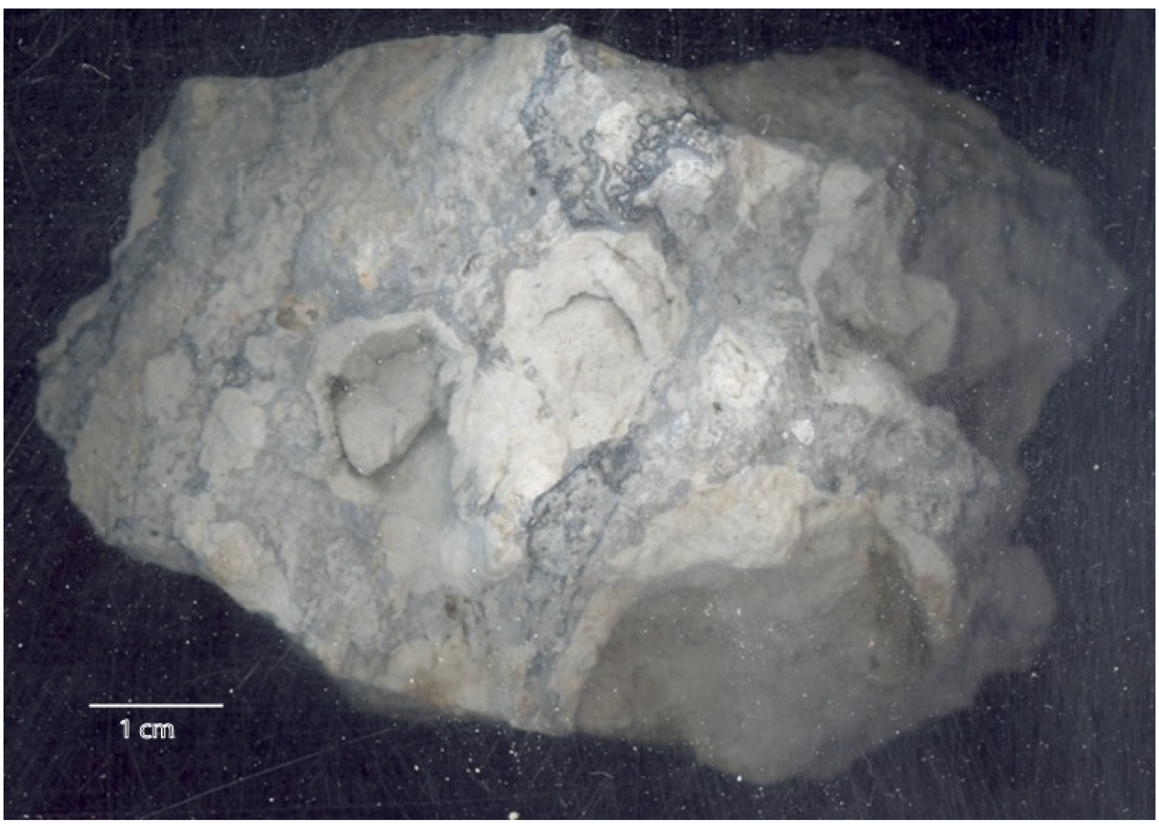
YS-08-JM147

Brief Description:
Silicified gry tuff with v. minor arg overprint

Location:
N 4956159.6
W 545521.9
North Ridge: Top

Field Notes:
- No Notes

Description:
- Silicified gry tuff with v. minor arg overprint
- Large sphereulites
- Large vugs



Scan: YS-08-JM147

YS-08-JM148

Brief Description:
Silicified, gry tuff

Location:
N 4956137
W 545360
Outcrop 4C: Middle

Field Notes:
- No Notes

Description:
- Silicified white to gray tuff
- Acid leached
- Silica veinlets
- Qtz eyes
- Minor wht clay

YS-08-JM149

Brief Description:
Milled-mosaic sulfide vein (minor silica)

Location:
N 4956060.4
W 545439.4
Stream: Base

Field Notes:
- Float but from stream!

Description:
- Milled-mosaic sulfide vein with minor silica
- High concentration of silicified wall rock brx in center
    - cm-mm
- Wall rock: drusy qtz
- Sulfide/silica veinlets
- Alunite

Thin Section:
- Micrograph: Globular pyt
- Micrograph (2): Micro-brx silica vein
- Pyt - fractured and scattered
    - round
- Brx on right healed by silica and sulfides
    - silica/sulfides “wet” brx
- Sulfide has been hit pretty hard
- Silica veinlets
- Silicified wall rock
- Sulfide veinlets- minor silica

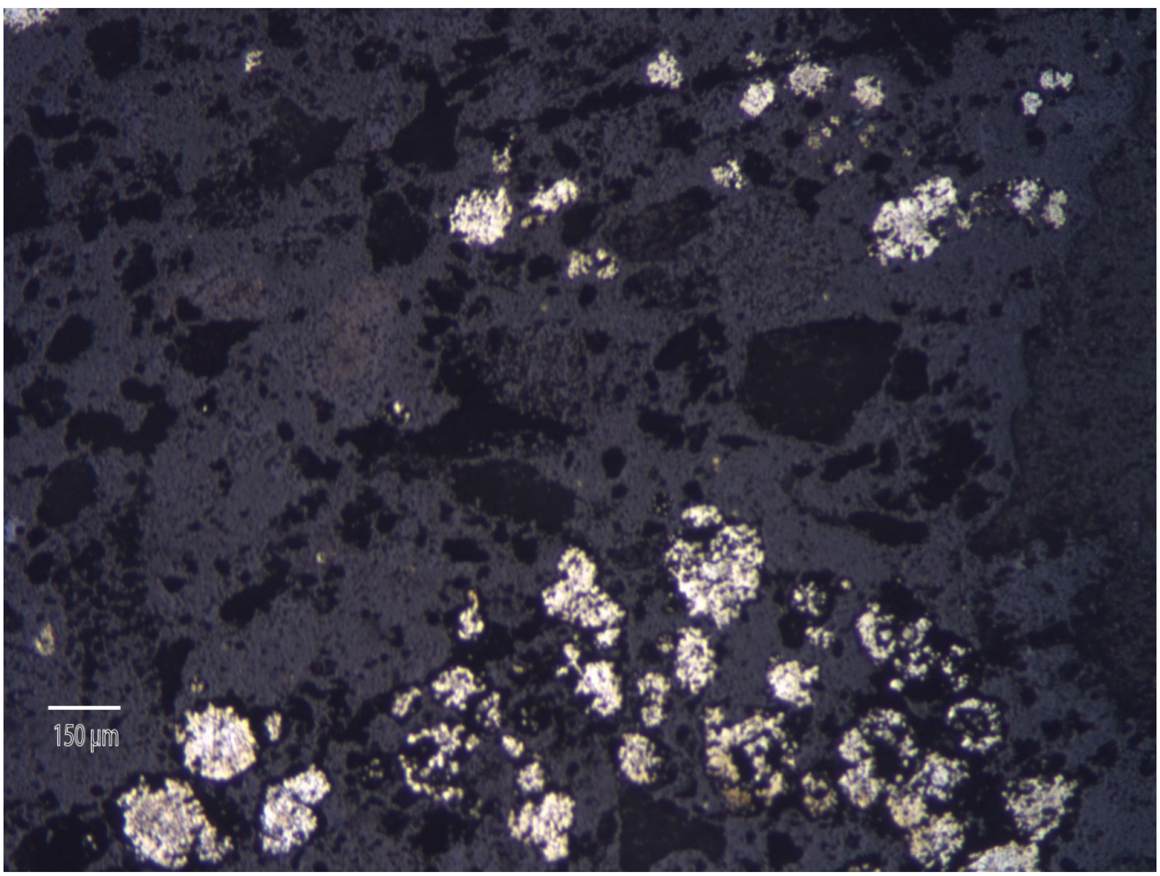
XRD:
Major Minerals:
- Wall Rock: qtz, huangite, kaolinite
- Silica Vein: qtz, pyt (ni), kaol

Minor Minerals:
- Wall Rock: Illite, diaspore, al/walth, pyt, albite
- Silica Vein: Marcasite, mont, al/walth, albite

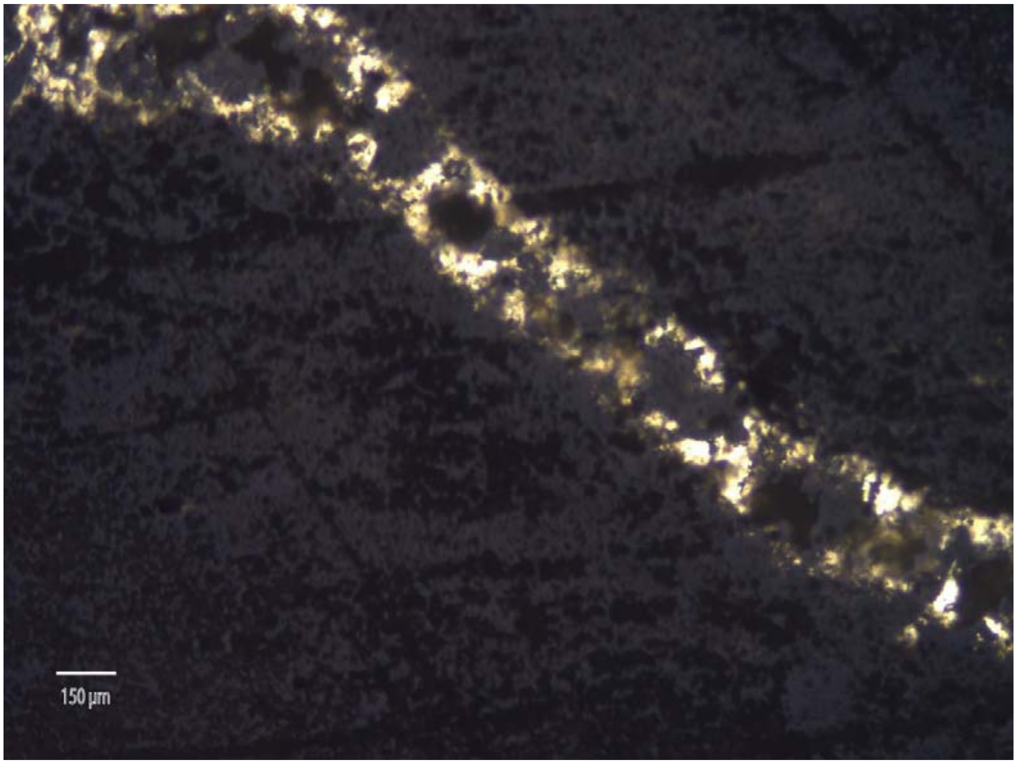
Wall Rock: Mineral Assemblage 1
Silica Vein: Mineral Assemblage 3

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)

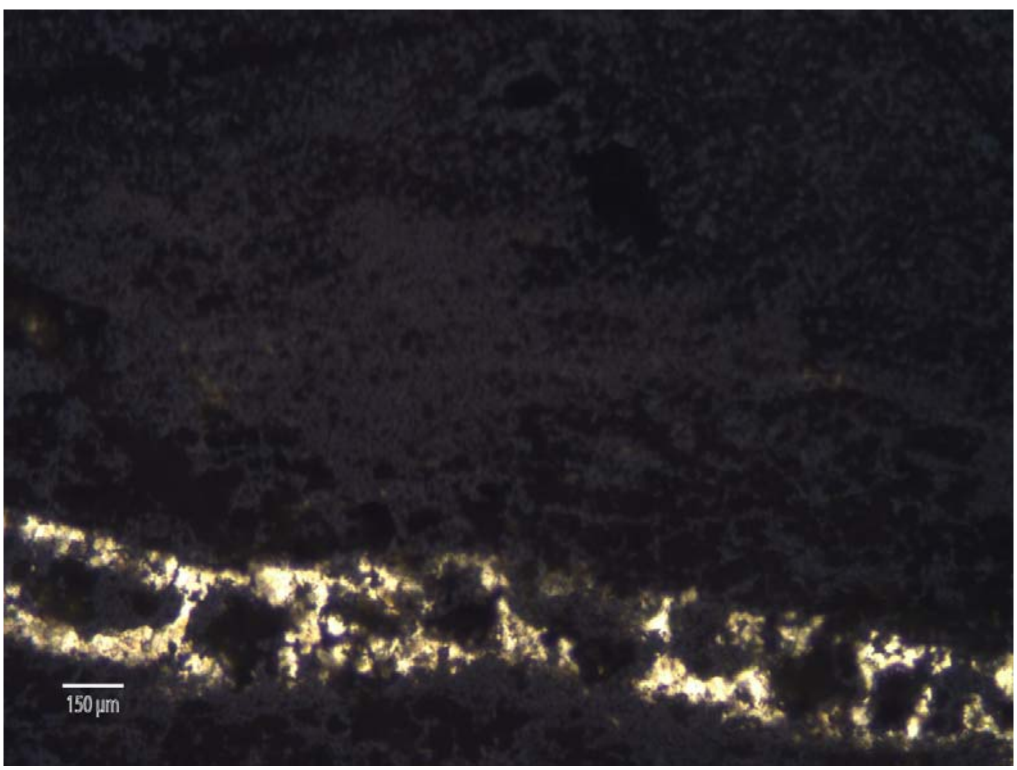
Scan: YS-08-JM149



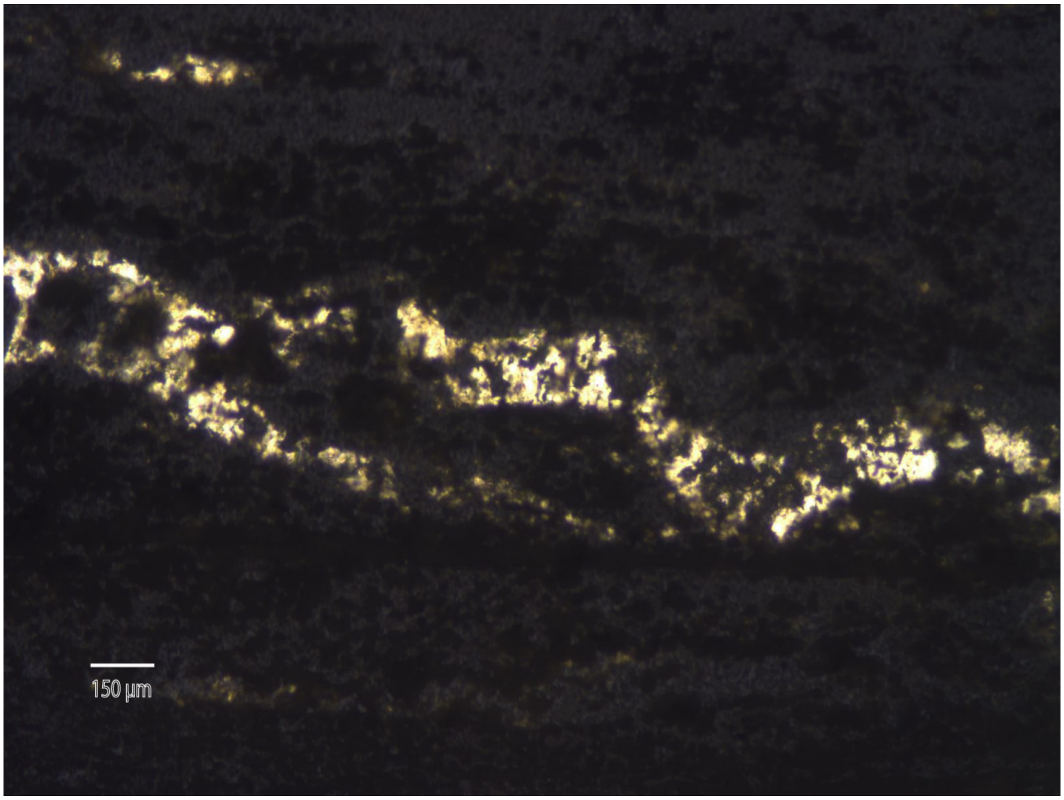
YS-08-JM149: Rounded pyrite grains.



YS-08-JM149: Silica veinlet with micro-breccia.



YS-08-JM149: Silica veinlet with micro-breccia. Same veinlet as above.



YS-08-JM149: Silica veinlet with micro-breccia. Same veinlet as above.

YS-08-JM150

Brief Description:
Silica nodule

Location:
N 4956064
W 545439.2
Stream: Base

Field Notes:
- Silica vein in wall 1 cm above stream bed

Description:
- Silica nodule
- Wall rock silicified
- Alunite

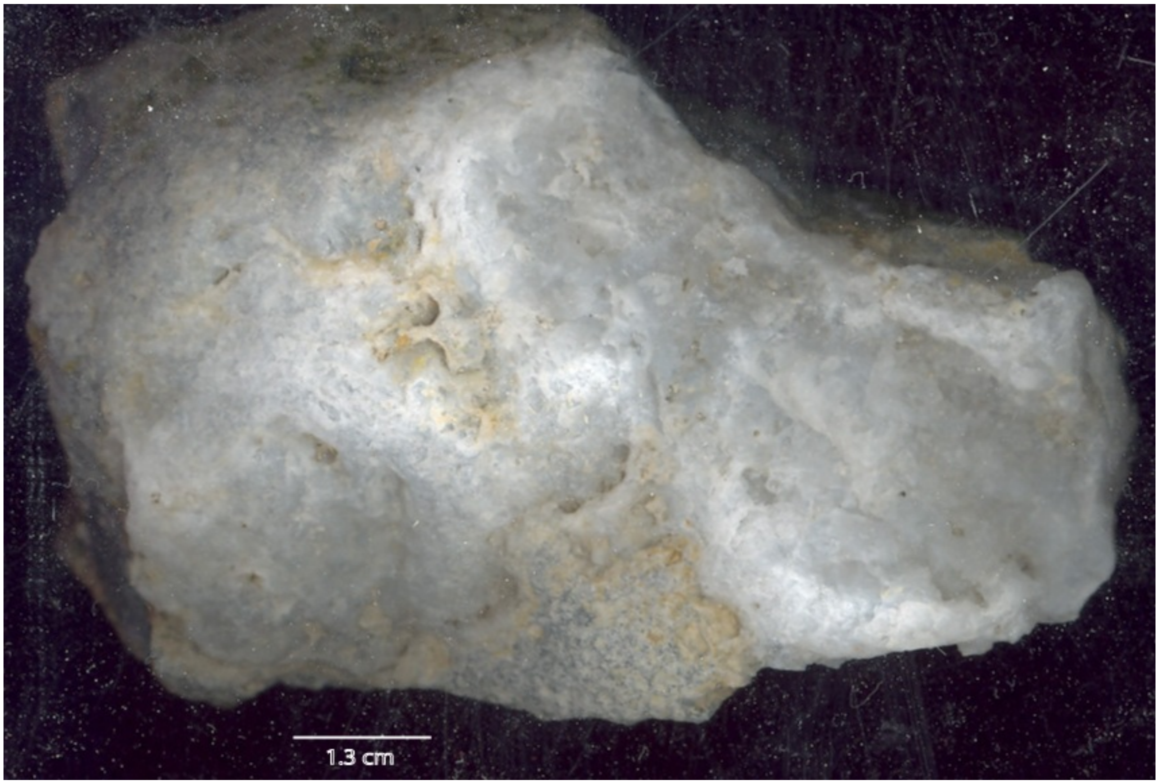
XRD:
Major Minerals:
- Wall Rock: Qtz, opal ct, alunite/walth, kaol, albite
- Silica Nodule: Qtz, pyrophylite

Minor Minerals:
- Wall Rock: Illite, mont
- Silica Nodule: Pyt, marc

  * Note that the wall rock contains BOTH qtz and opal ct as a major mineral!

Wall Rock: Mineral Assemblage 1
Silica Nodule: Mineral Assemblage 4

Stable Isotope: -0.30‰
- Higher because opal



Scan: YS-08-JM150

YS-08-JM151

Brief Description:

Milled- mosaic with minor crackle brx healed by silica with sulfide selvage

Location:

N 4956061.6
W 545441.4
Stream: Base

Field Notes:

- Original waypt is the same as JM149 and 150
- From vein in stream

Description:

- Milled- mosaic with minor crackle brx healed by silica with sulfide selvage
- Brx: cm-mm
- Minor sulfides
- Wall rock silicified

XRD:
Major Minerals:

- Qtz, kaol

Minor Minerals:

- Diaspore, albite, alunite/walth, pyt, opal ct, pyro

Mineral Assemblage 3

YS-08-JM152

Brief Description:
Sulfide vein with alunite and minor silica

Location:
N 4956060
W 545443
Stream: Base

Field Notes:

- Sulfide vein from stream bed

Description:

- Sulfide vein
  - massive and fine grained sulfide
- Alunite
- Minor silica in sulfide vein
- Minor wall rock rip-up brx

Thin Section:

- Micrograph: Botryoidal marc, fractured, infilled with pyt
- Vein Sample: Sulfides (marc and pyt) with silica
- Silica veinlets and mircoveinlets
- Sulfide is brx and healed by silica
- Sulfide veinlets

XRD:
Major Minerals:

- Silica vein: Qtz, kaol, albite, alunite/walth
- Sulfide Vein: Qtz, galena, pyt, marc, kaol, albite

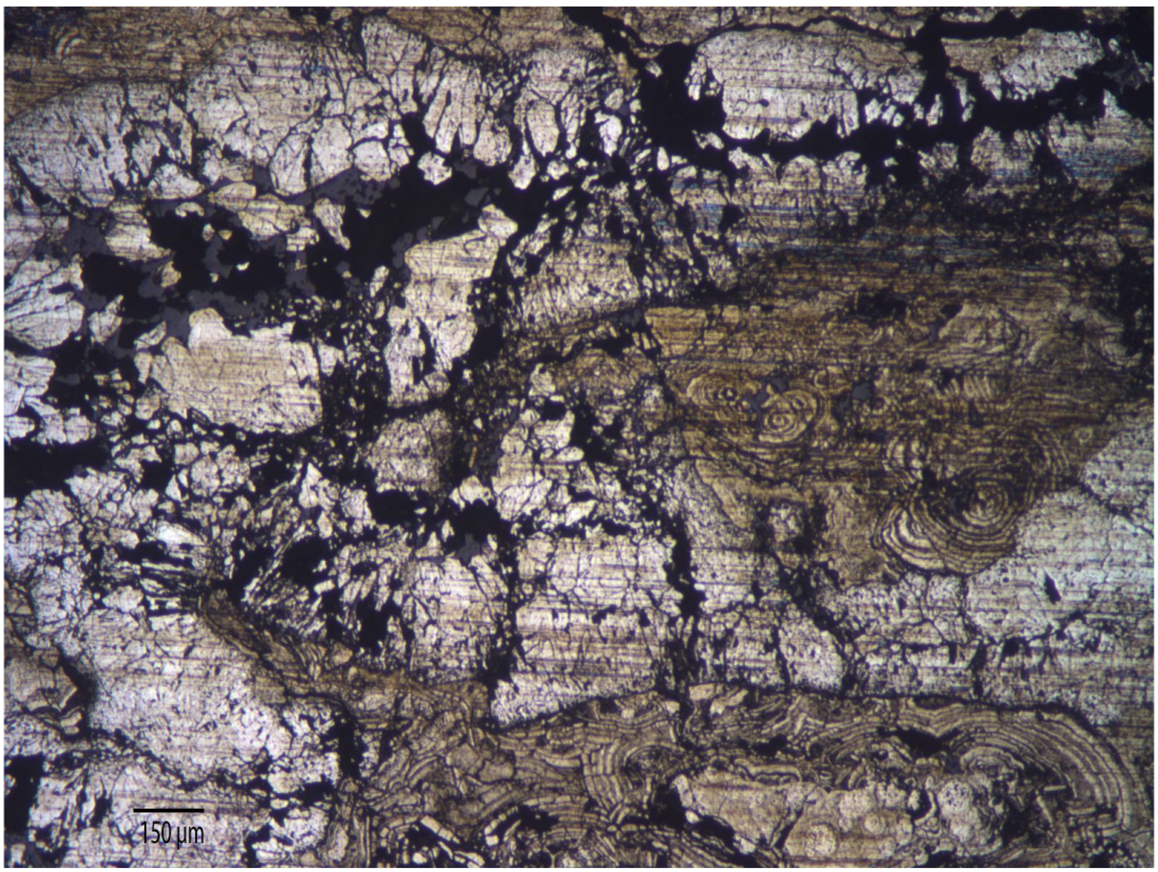
Minor Minerals:

- Silica Vein: Marc, pyt (ni), mont, opal ct, illite
- Sulfide Vein: Illite, sphalerite, alunite

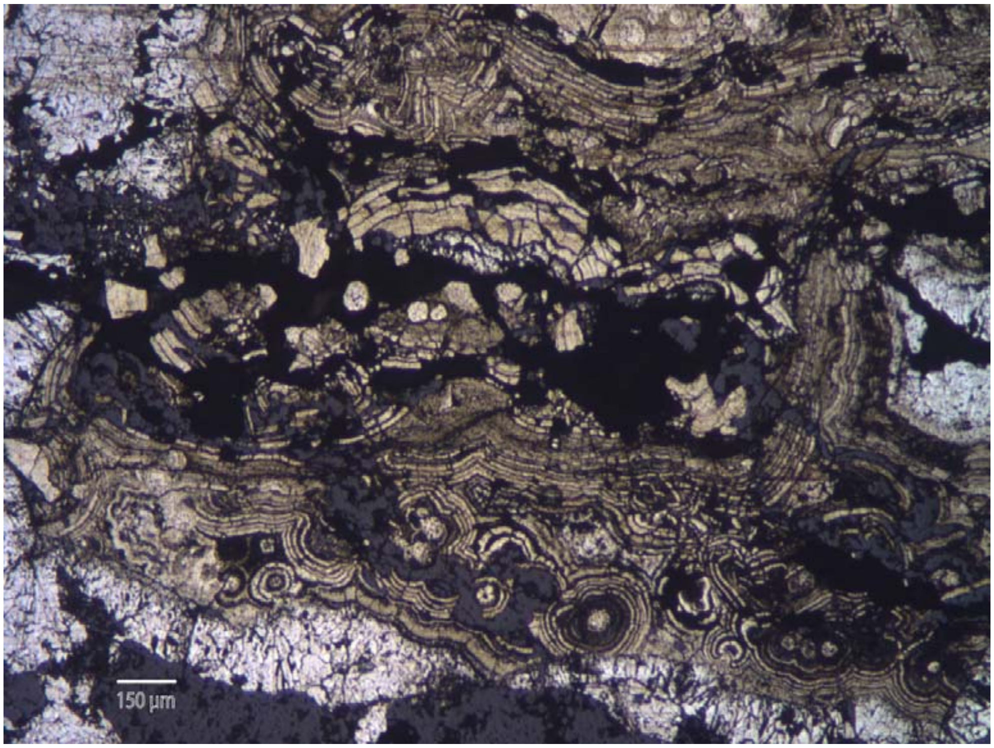
Mineral Assemblage 1

Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)

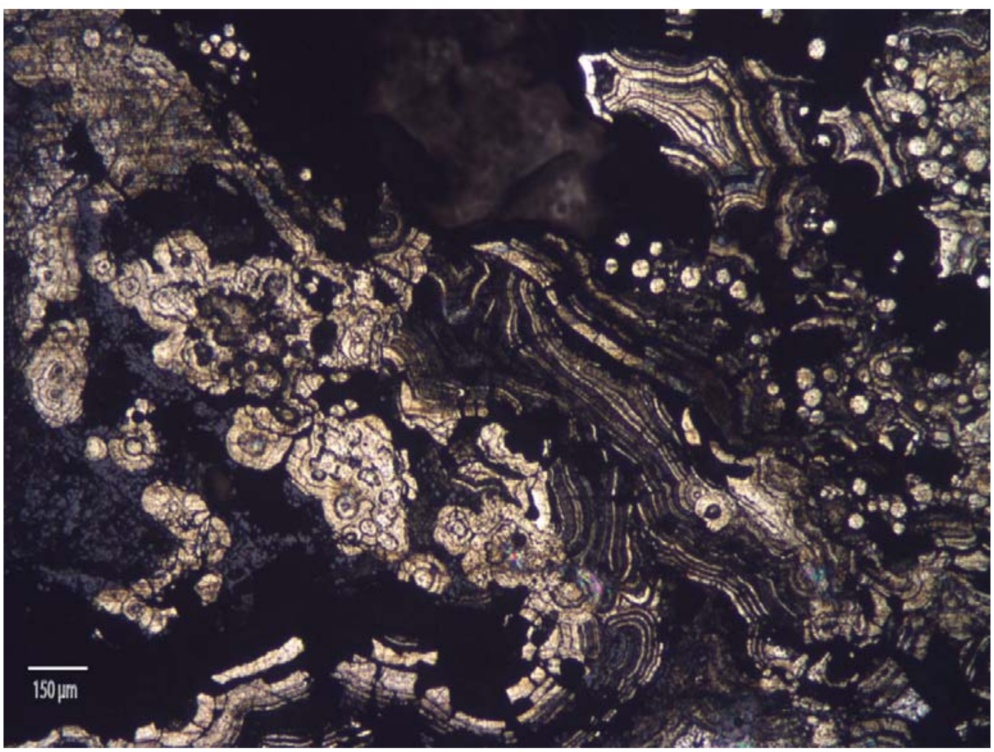
Scan: YS-08-JM152



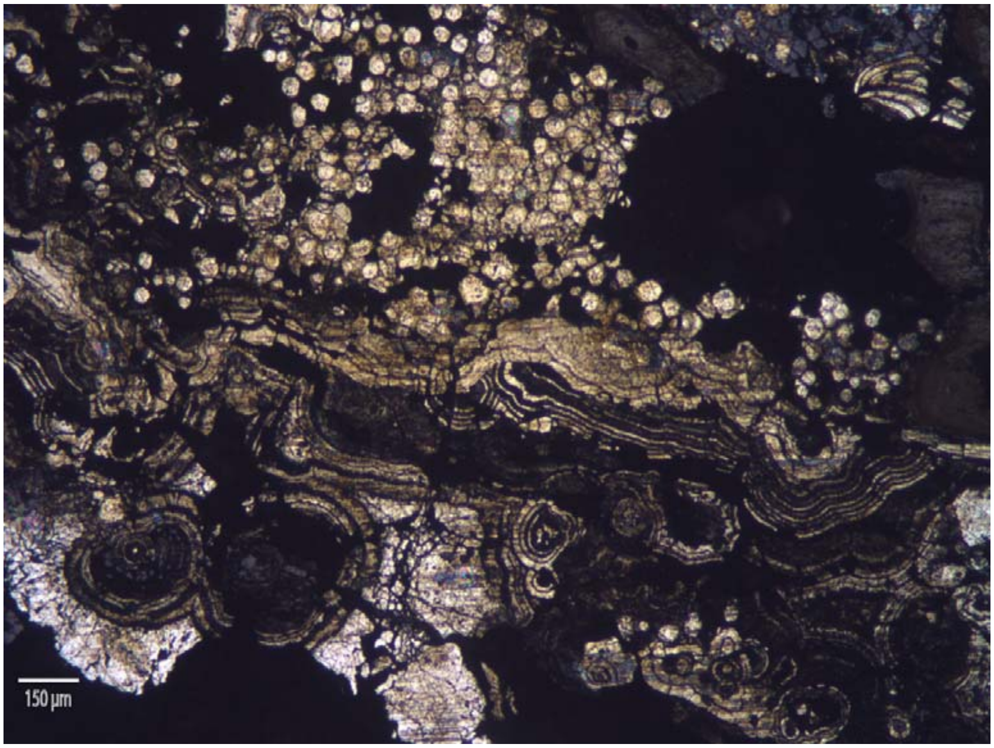
YS-08-JM152: Fractured, botryoidal, colloform marcasite (copper-colored) healed by brecciated pyrite.



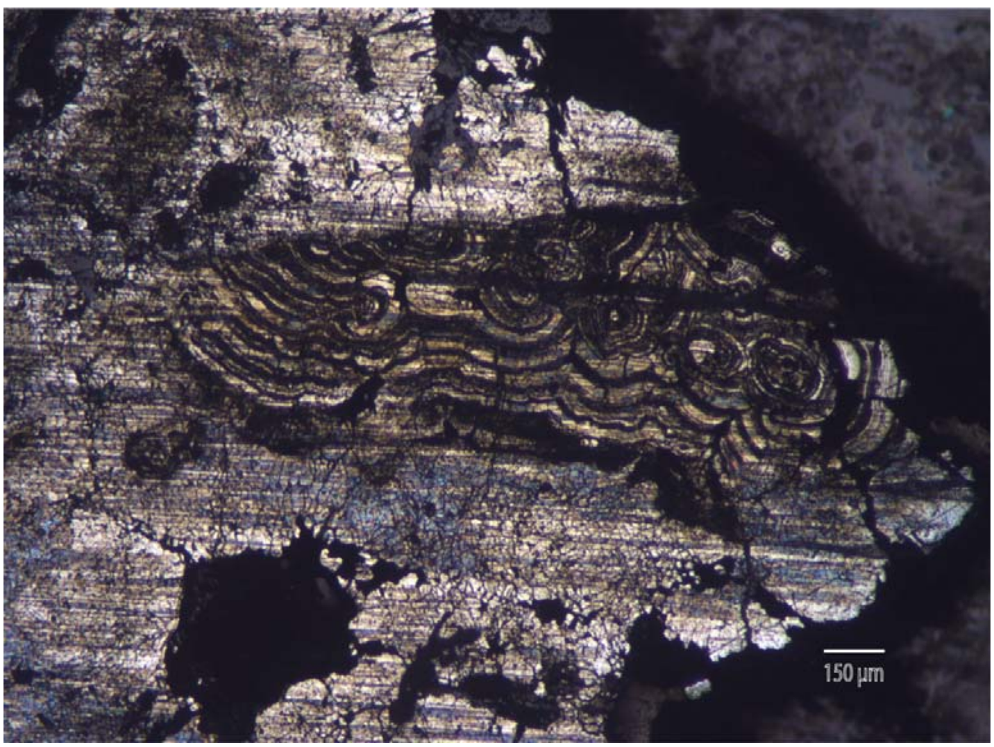
YS-08-JM152: Fractured, botryoidal, colloform marcasite (copper-colored) healed by brecciated pyrite.



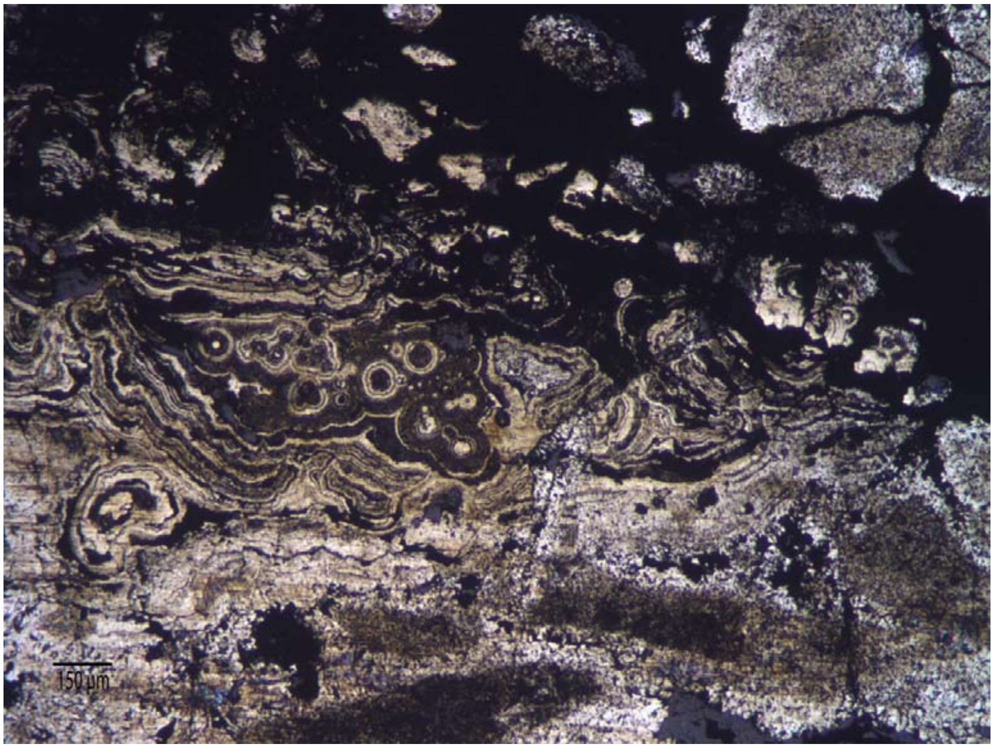
YS-08-JM152: Brecciated, botryoidal, colloform marcasite.



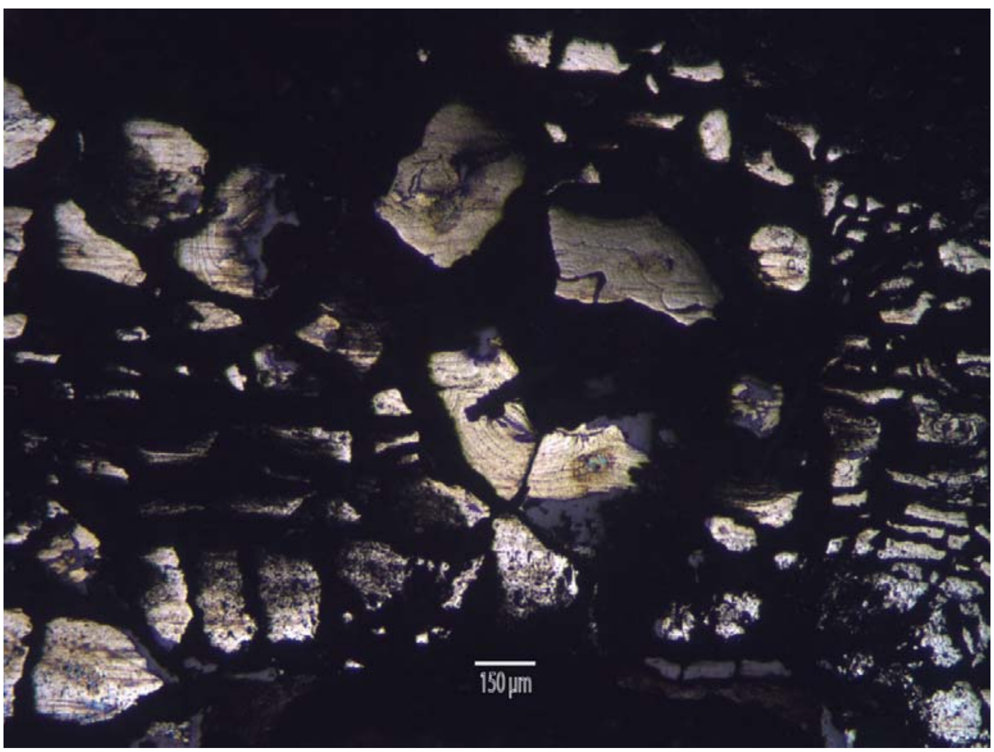
YS-08-JM152: Brecciated, botryoidal, colloform marcasite.



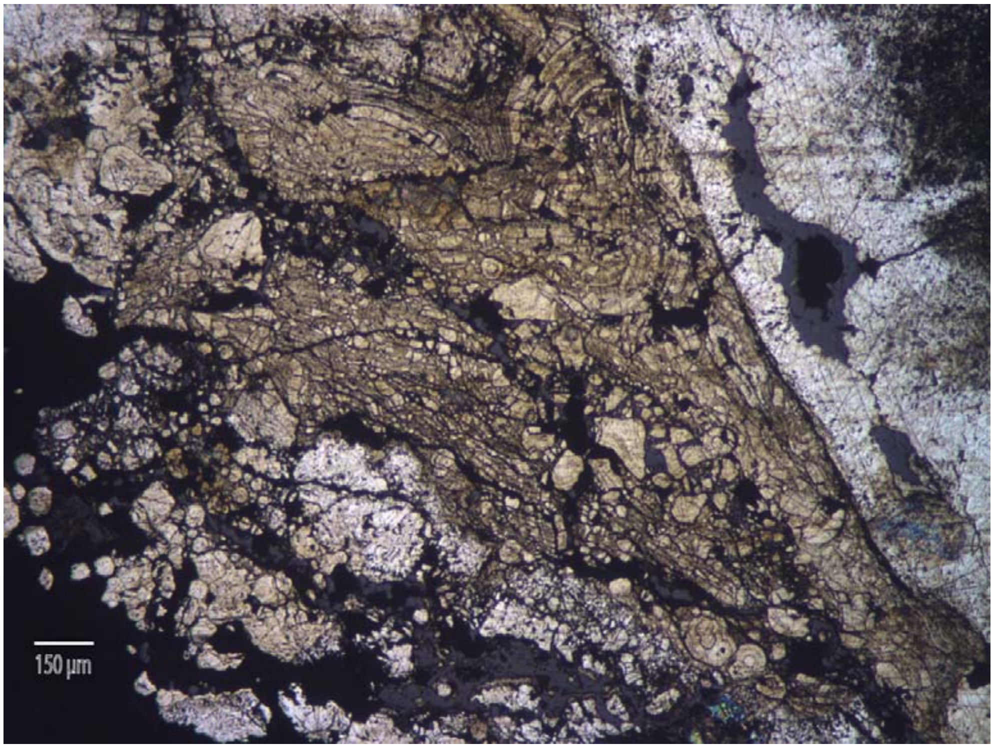
YS-08-JM152: Fractured, botryoidal, colloform marcasite (copper-colored) healed by brecciated pyrite.



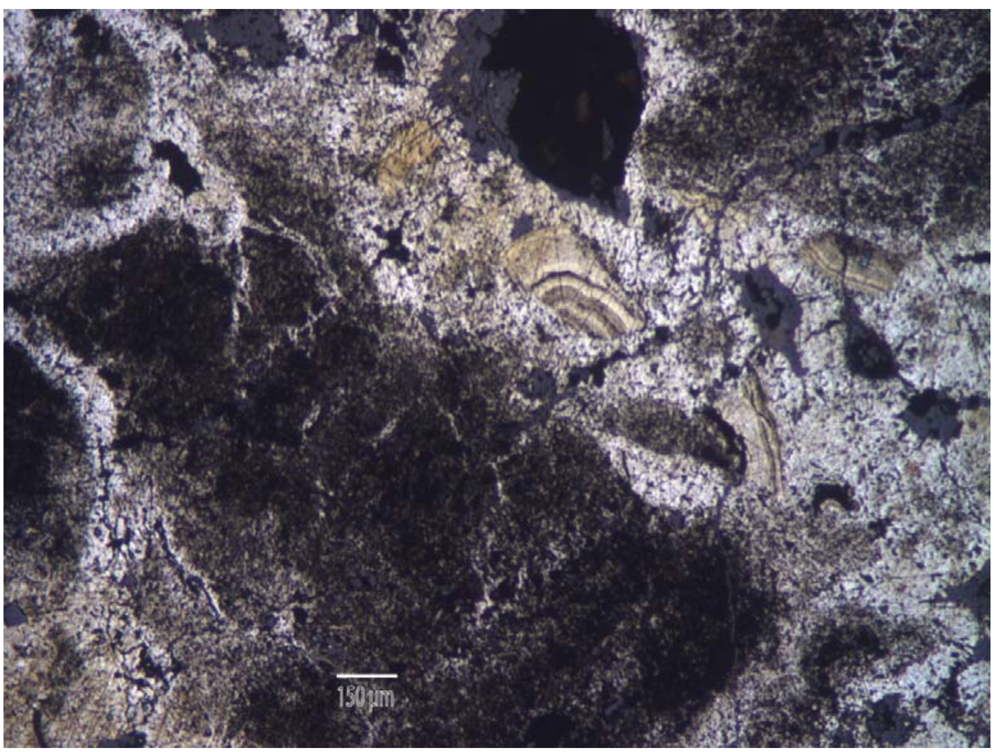
YS-08-JM152: Fractured, botryoidal, colloform marcasite (copper-colored) healed by brecciated pyrite.



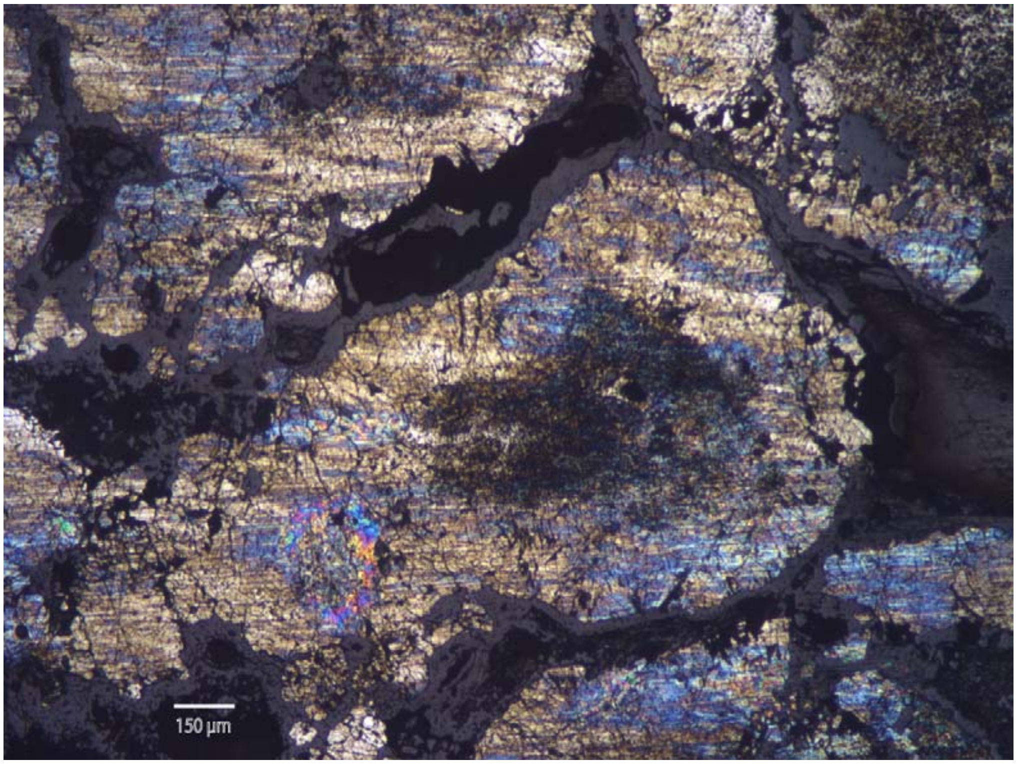
YS-08-JM152: Brecciated marcasite.



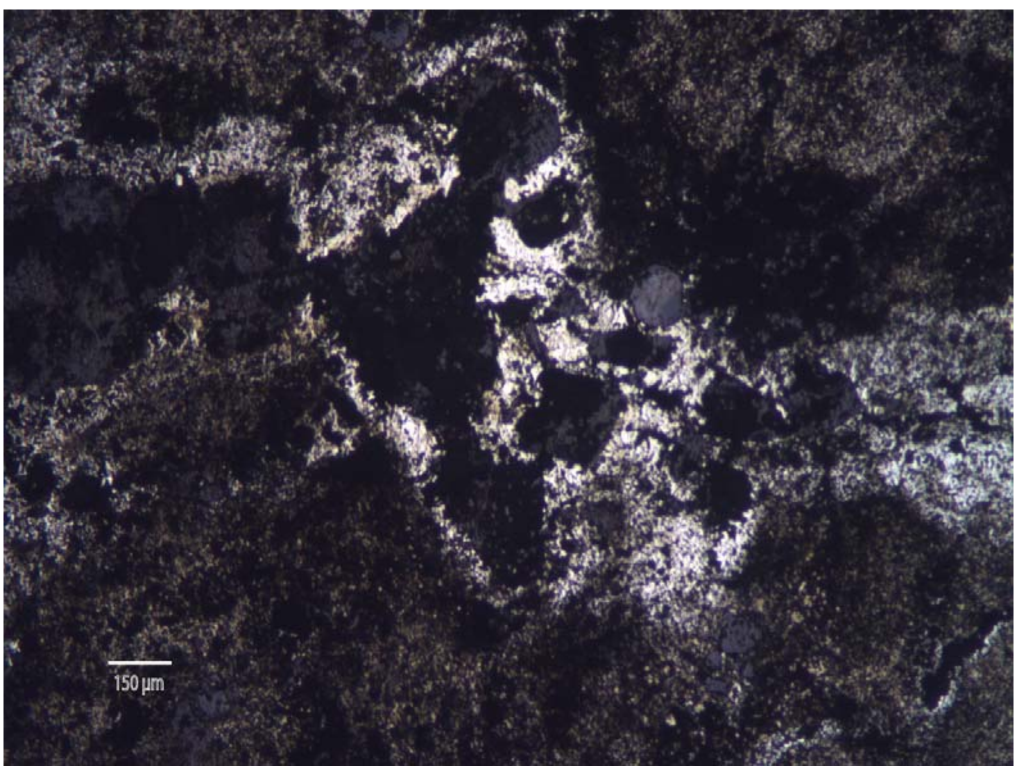
YS-08-JM152: Fractured, botryoidal, colloform marcasite (copper-colored) healed by brecciated pyrite.



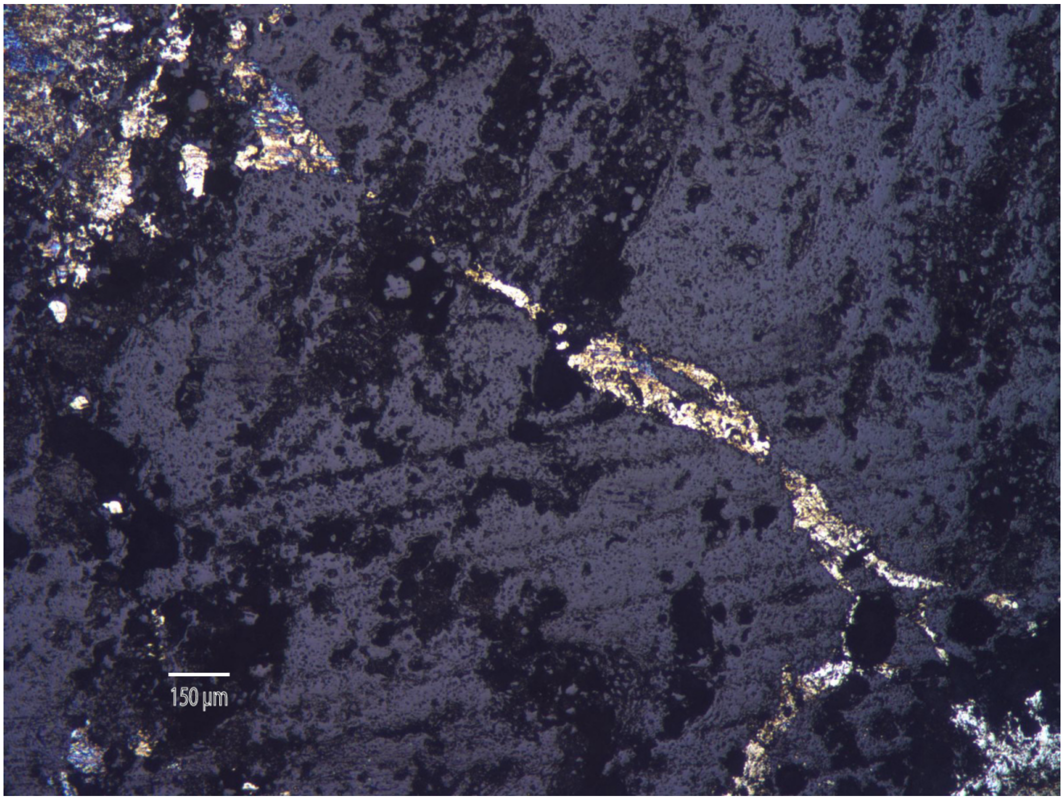
YS-08-JM152: Brecciate marcasite healed by fine-grained pyrite.



YS-08-JM152: Massive pyrite. (Poor polish)



YS-08-JM152: Mosaic breccia healed by pyrite.



YS-08-JM152: Sulfide veinlet.

YS-08-JM153

Brief Description:

Silicified wht tuff

Location:

N 4956060
W 545444.5
Stream: Base

Field Notes:

- Original waypt is the same as JM152
- Silica vein from stream

Description:

- Silicified wht tuff
- Silica vein with sulfide selvage
    - colloform banding with sulfide veinlets inside
- Sulfide veinlets
- Minor wall rock breccia
- Very small sample

XRD:

Major Minerals:

- Whole Rock: qtz, kaol, marcasite
- Silica vein: qtz

Minor Minerals:

- Wall Rock: Opal c-t, illite, mont, al/walth, pyrite, sanidine
- Silica Vein: opal c-t, kaolinite, illite, barite, alunite/Walth

Mineral Assemblage 1

Stable Isotope: 0.00‰

Scan: YS-08-JM153

YS-08-JM154

Brief Description:
Crackle- mosaic brx healed by sulfide/silica

Location:
N 4956060
W 545446.1
Stream: Base

Field Notes:
- Original waypt is the same as JM152 and 153
- Another sulfide vein with brx

Description:
- Crackle- mosaic brx healed by sulfide/silica
- Wall rock brx- arg to fresh
- ~2.5 cm– mm
- Colloform silica in sulfide vein
- Wall rock- silicified

XRD:
Major Minerals:
- Sulfide vein 1: Qtz, marc, pyt, kaolinite
- Sulfide vein 2: Qtz, kaol, al/walth, albite
- Wall Rock: Qtz, kaol, walth/al, albite

Minor Minerals:
- Sulfide vein 1: Mont, opal c-t, al/walth, albite, galena, sphalerite, illite
- Sulfide vein 2: Pyt, marc, gal, illite, opal ct
- Wall Rock: Opal c-t, illite, dickite

Mineral Assemblage 1

YS-08-JM155#1

Brief Description:

L.gry silica vein with lighter gry, brx, silicified tuff

Location:

N 4956059
W 545449
Stream: Base

Field Notes:

- 1#: Vein from river; smooth, grey

Description:

- L.gry silica vein
    - sulfides masses in vein
- L.gry, brx, silicified tuff
    - some wall rock is Arg
- Minor arg phenos
- "Flame structures" and rip-up clasts
- Sulfides (pyt/marc)
- Sulfide veinlets

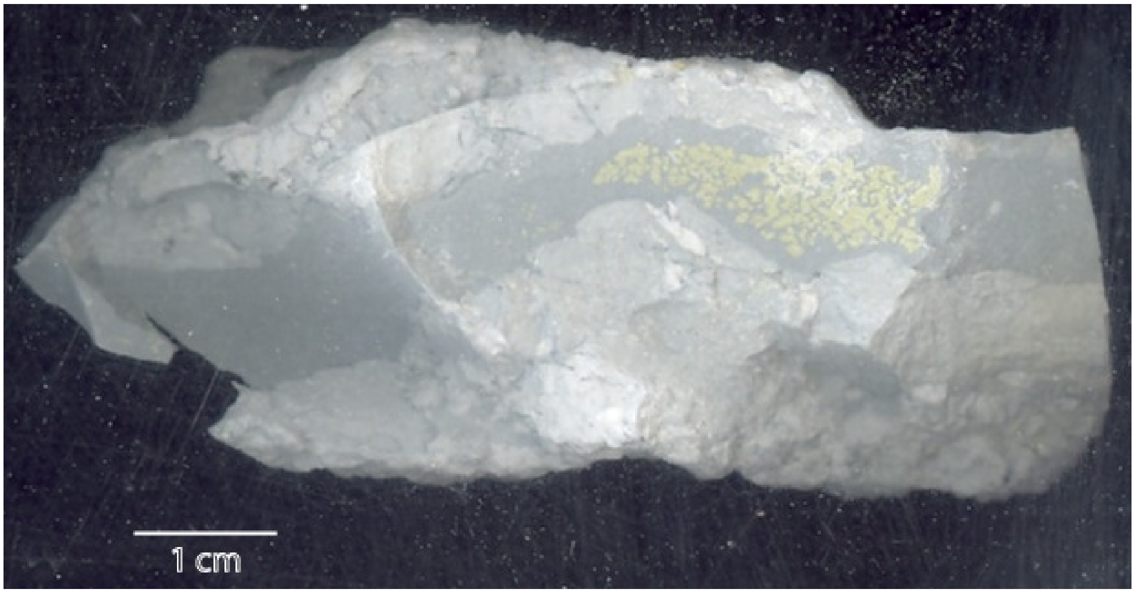
XRD:
Major Minerals:

- Silica Vein: Qtz, kaol

Minor Minerals:

- Silica Vein: Diaspore, pyrophylite, opal ct, illite, al/walth, marc, sanidine

Mineral Assemblage 1



Scan: YS-08-JM155#1

YS-08-JM155#2

Brief Description:

Silicified buff tuff with ~ 1cm sulfide vein

Location:

N 4956061
W 545449
Stream/Outcrop 4C: Base

Field Notes:

- Sulfide vein from wall

Description:

- Silicified buff tuff
- ~ 1cm sulfide vein
- Wall rock brx
    - silicified
    - healed by silica and sulfide veinlets

Thin Section:

- Micrograph (9): Botryoidal marcasite and massive pyrite.
- Micrograph (4): Silica veinlet.
- Micrograph: Marc/pyt with bladed sulfates
- Microveinlets- sulfides
    - Crackle brx
- Sulfides heavily fractured
- Cannot see a primary fabric
    - Obliterated by silica
- Silicified wall rock with patches of sulfides and globs of silica
- Sulfides are beginning to oxidize
- Silica veinlets
- Possibly clay veinlets

XRD:

Major Minerals:

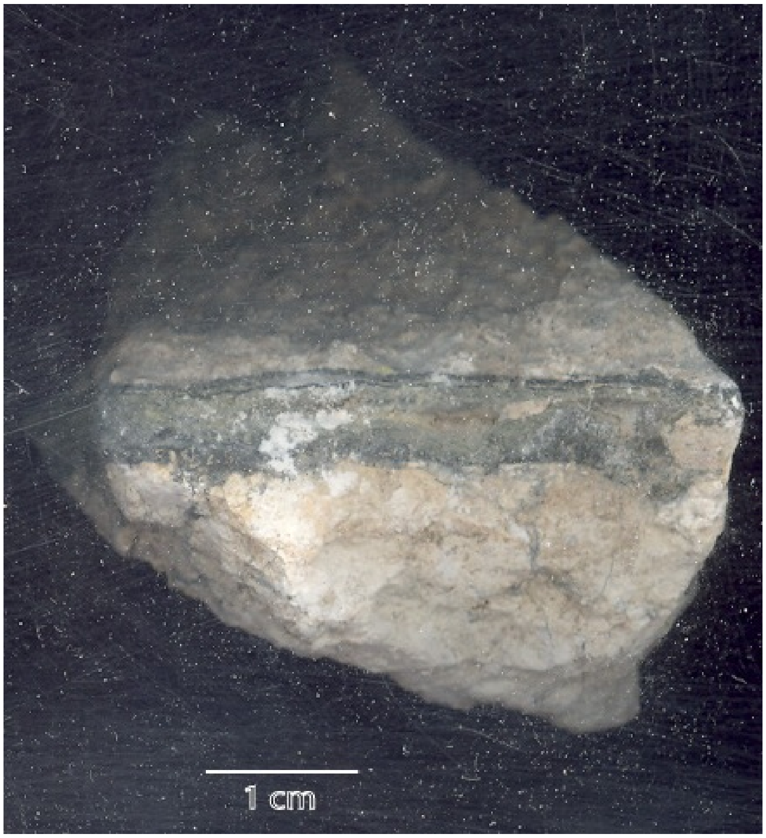
- Qtz, albite, marc, pyt

Minor Minerals:

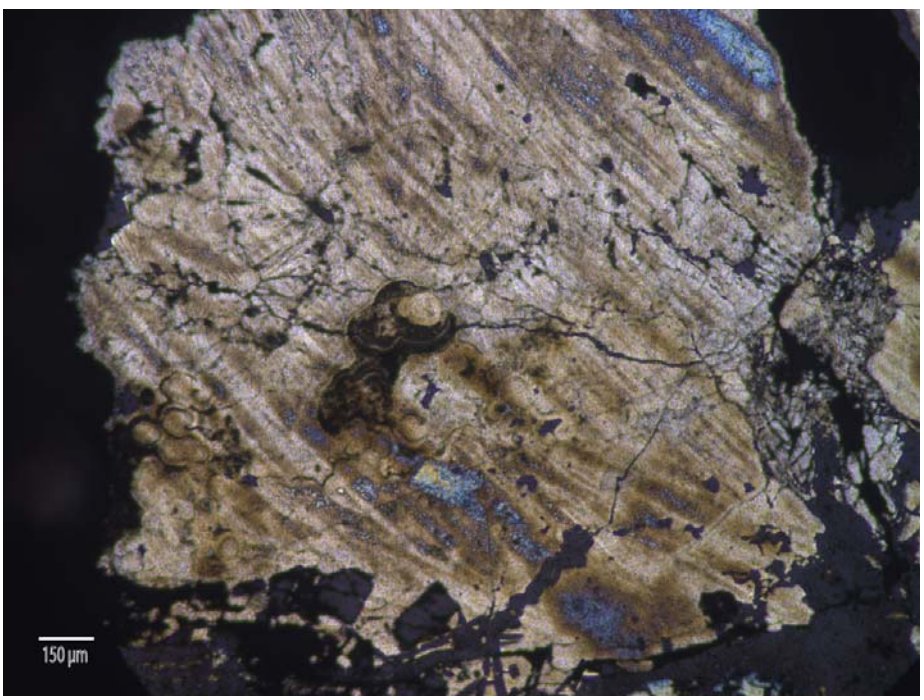
- Kaol, galena, sphalerite, opal ct, al/walth

Mineral Assemblage 3

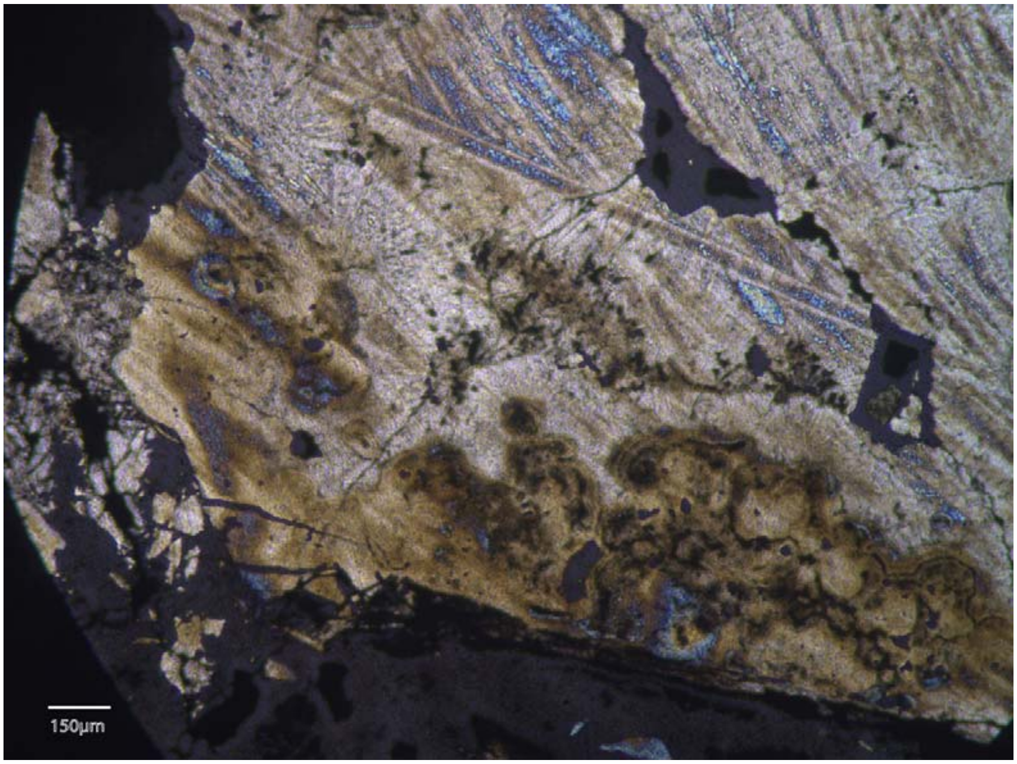
Au + 49 Element Assay: See Tables III-6 and 7 (Appendix III)



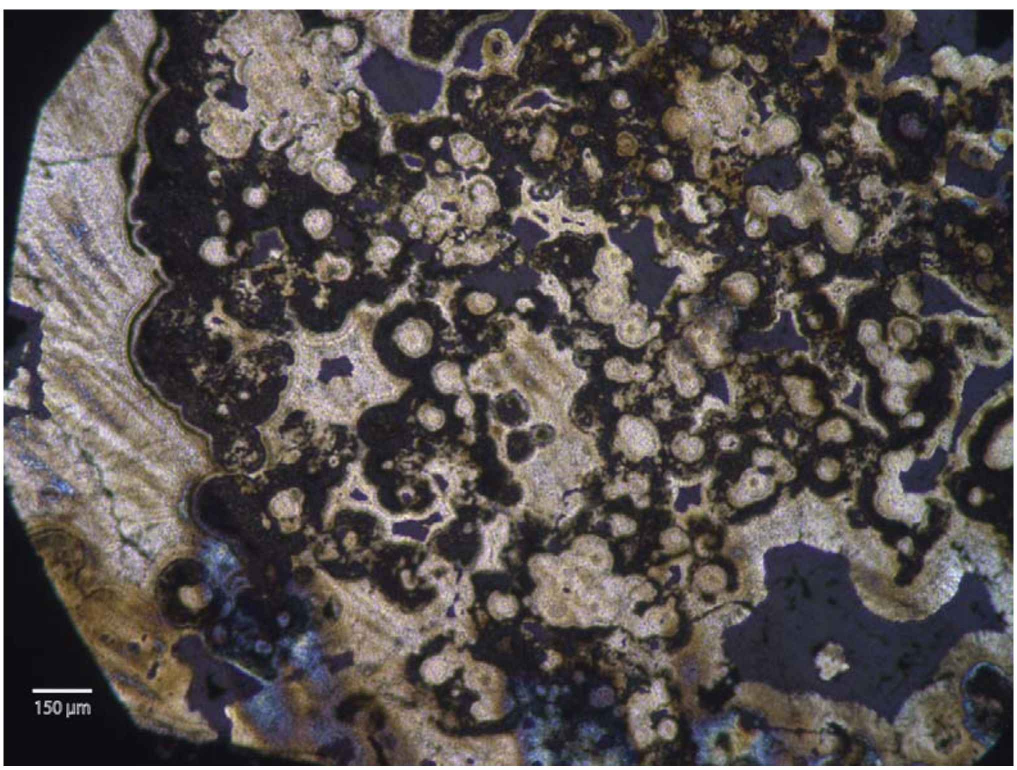
Scan: YS-08-JM155#2



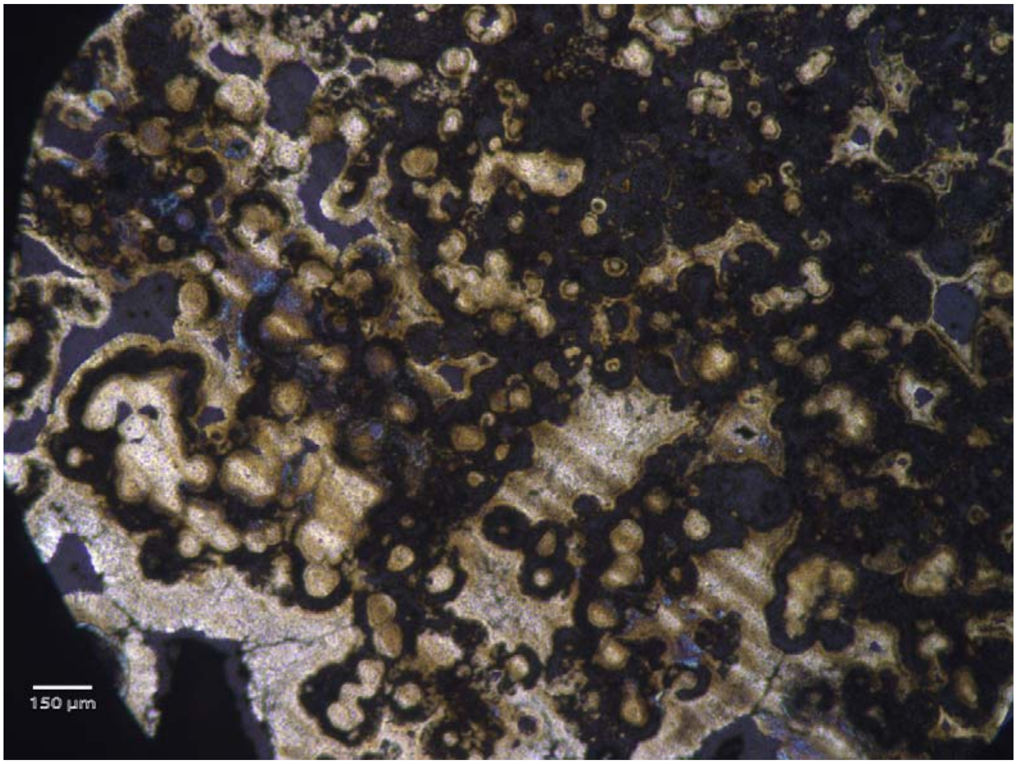
YS-08-JM155#2: Fractured massive pyrite. Note brecciated sulfides.



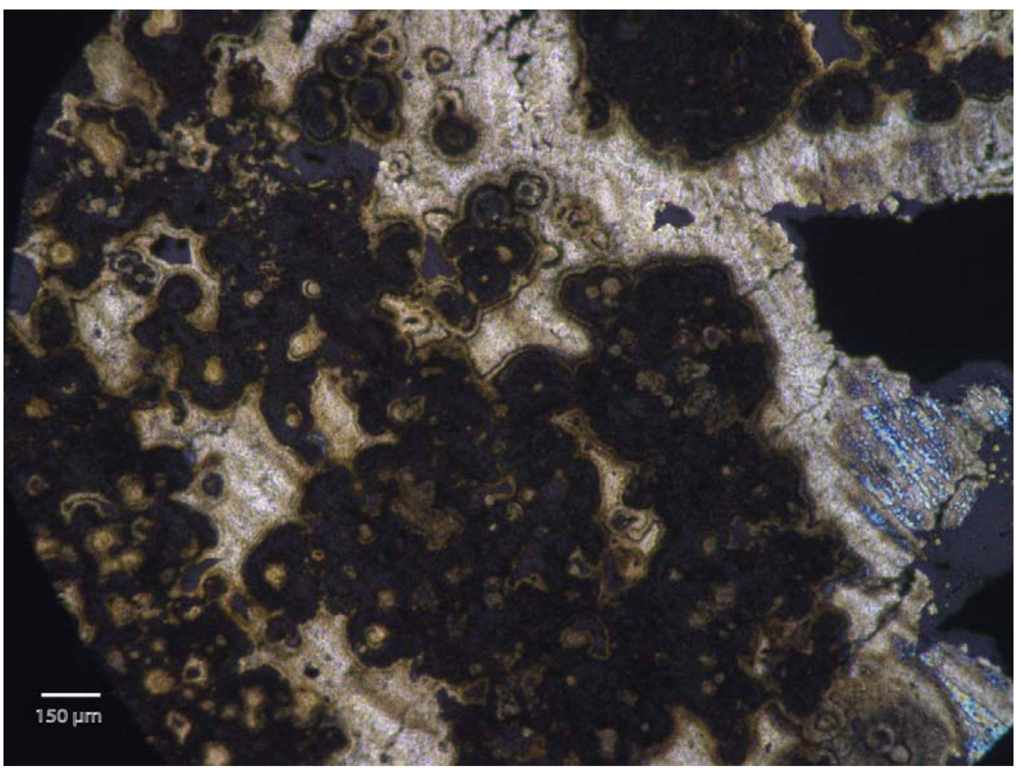
YS-08-JM155#2: Massive pyrite with marcasite. Note the brecciated sulfides.



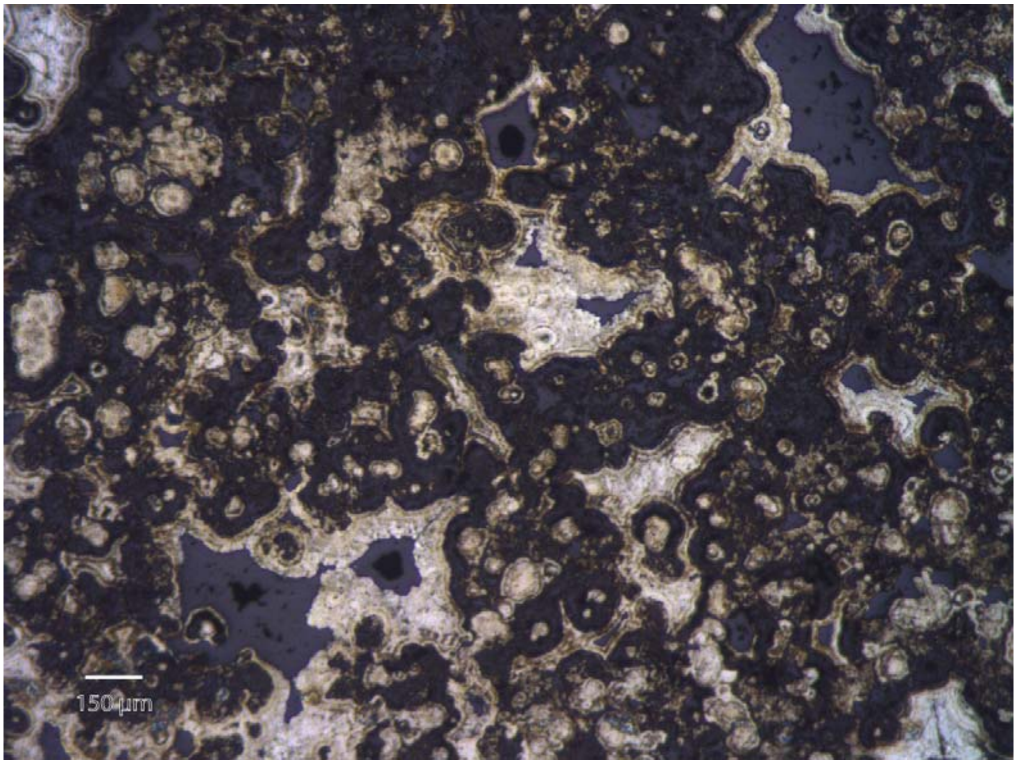
YS-08-JM155#2: Botryoidal marcasite.



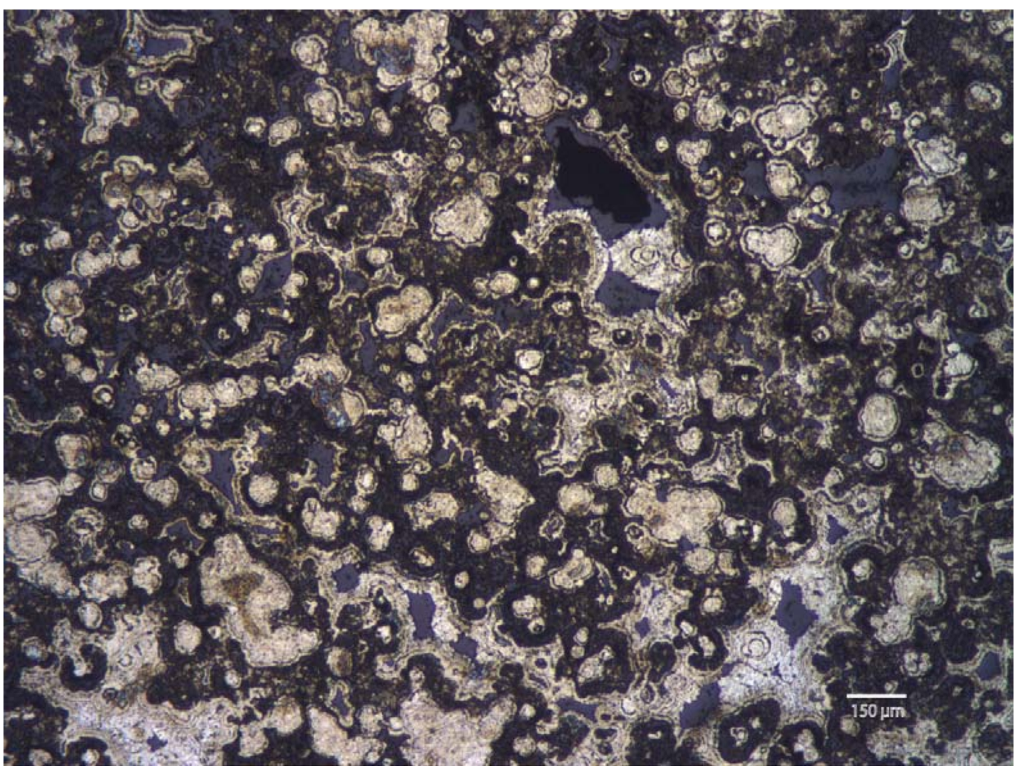
YS-08-JM155#2: Botryoidal marcasite.



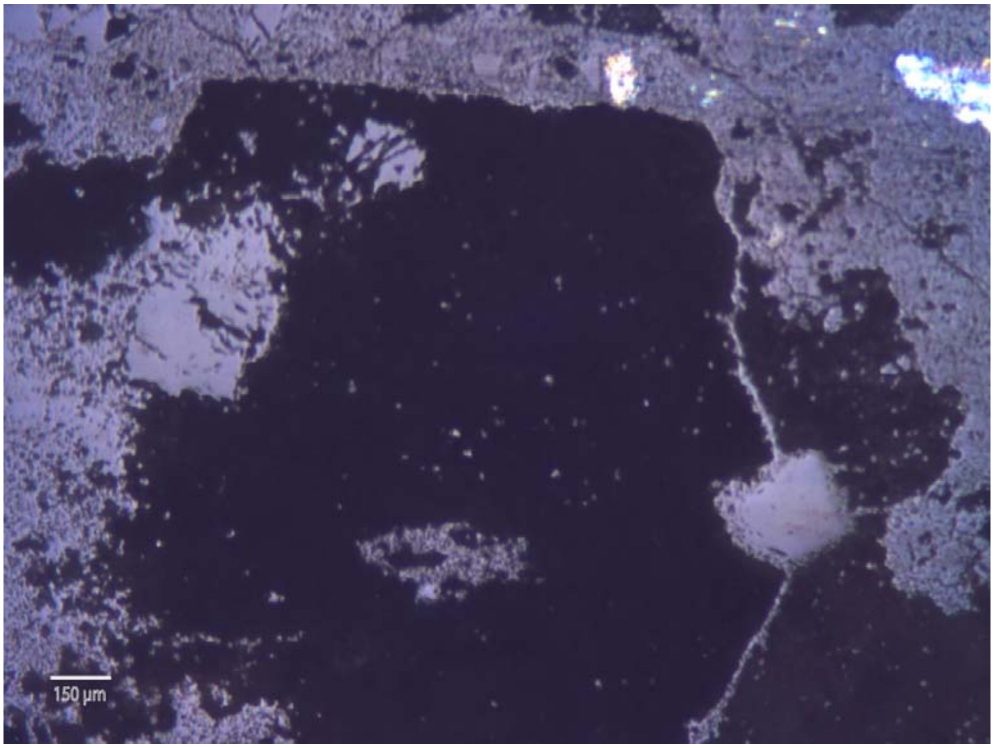
YS-08-JM155#2: Botryoidal marcasite.



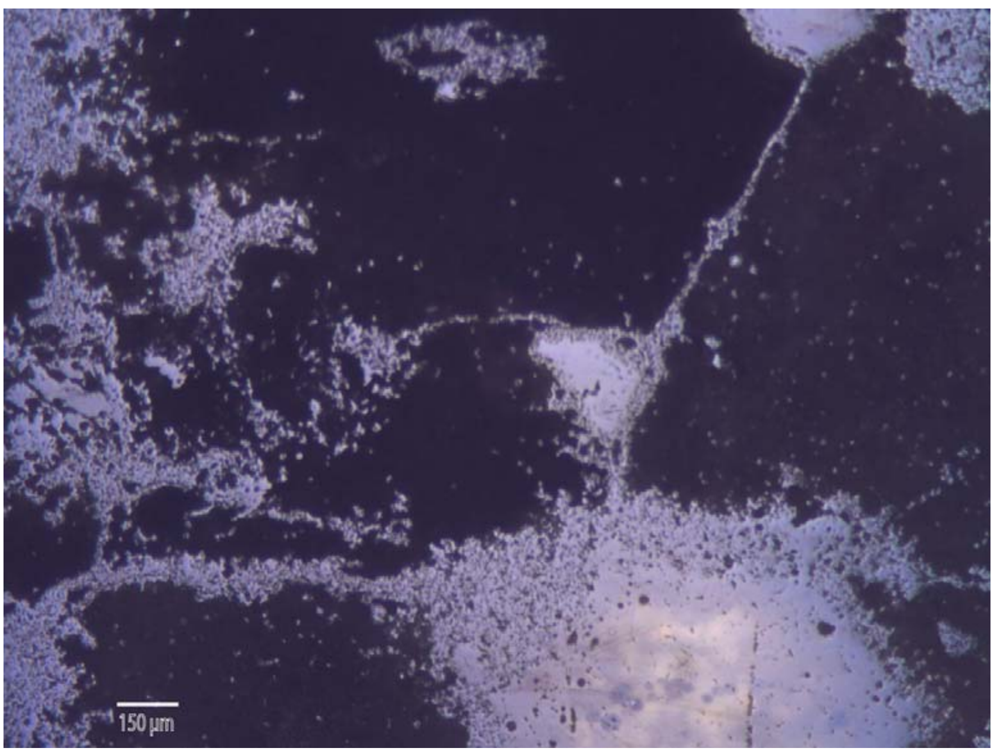
YS-08-JM155#2: Botryoidal marcasite.



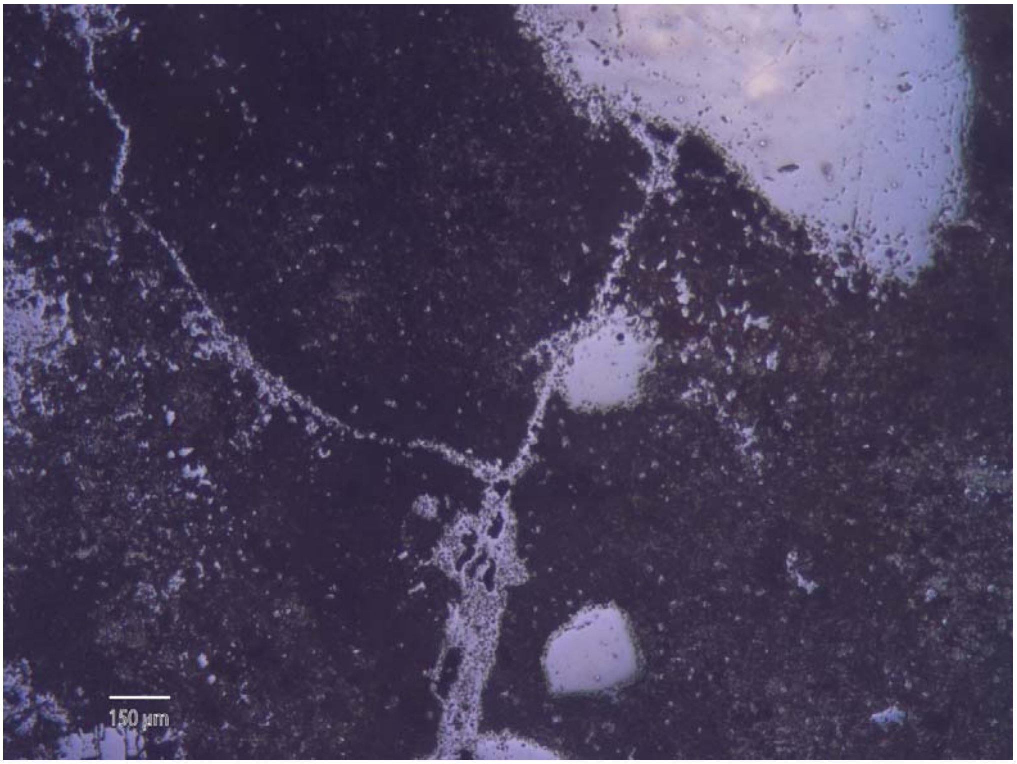
YS-08-JM155#2: Botryoidal marcasite.



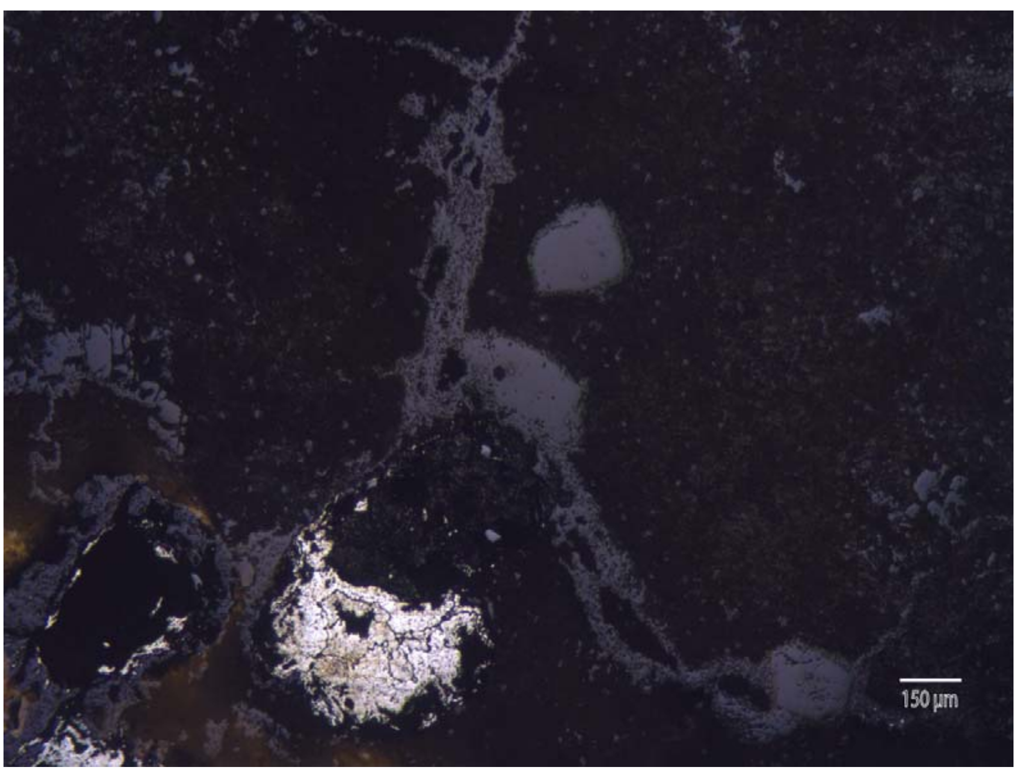
YS-08-JM155#2: Crackle breccia. The silica veinlet contiues through the next three pictures.



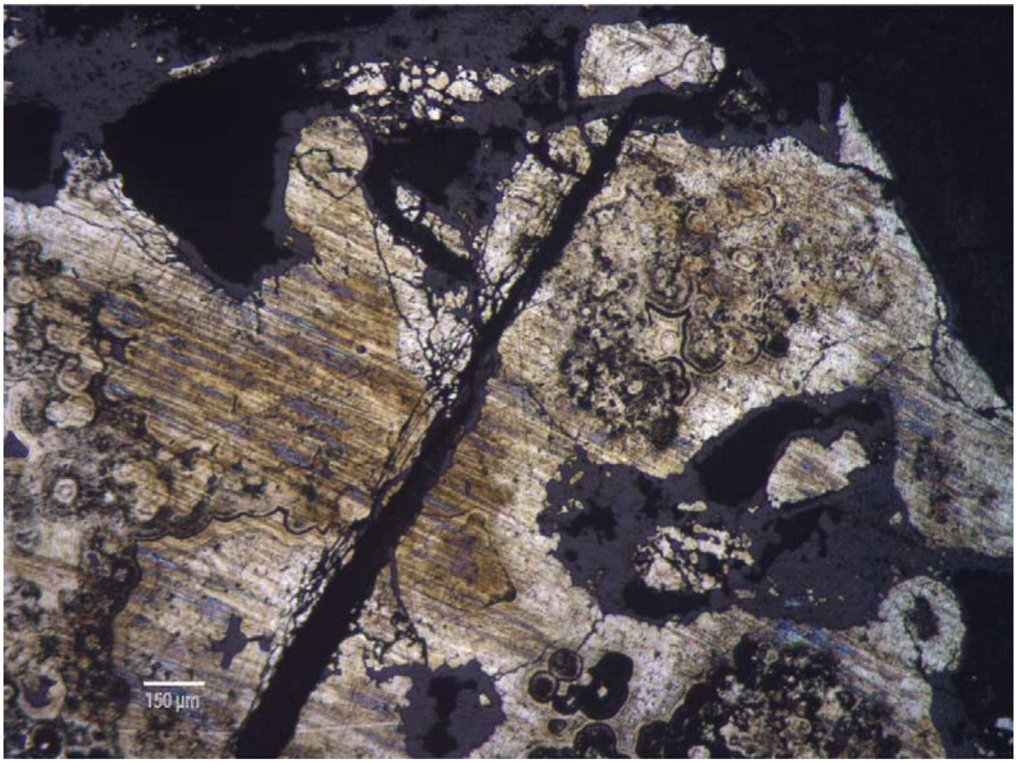
YS-08-JM155#2: Silica veinlet causing crackle breccia and alteration.



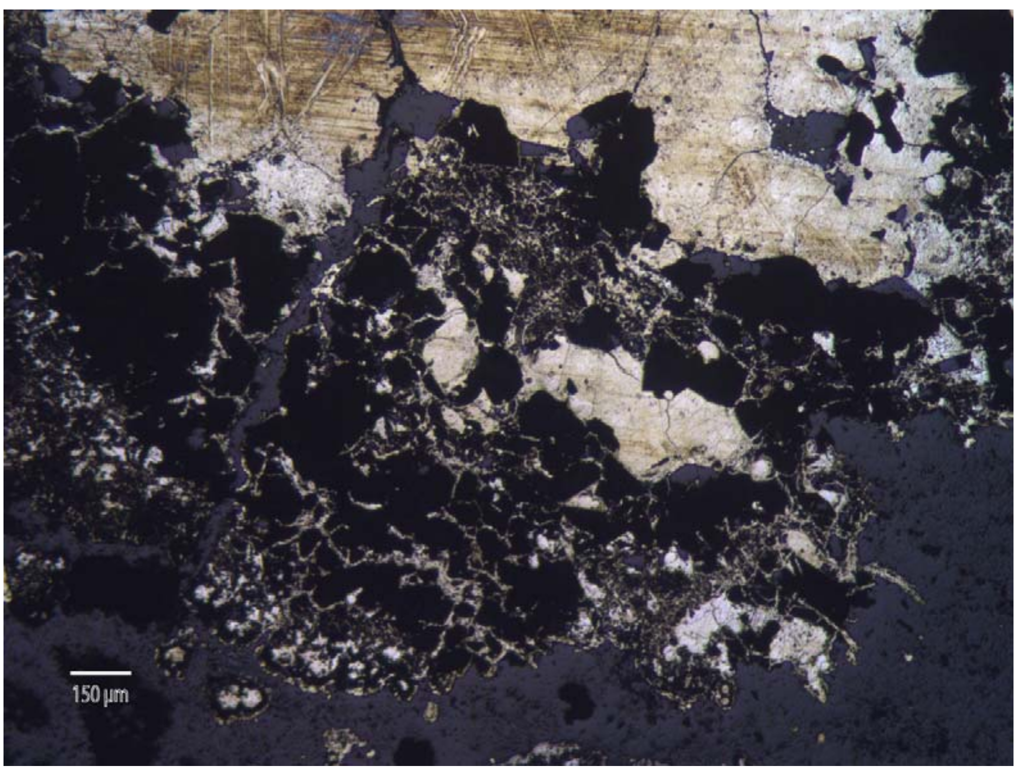
YS-08-JM155#2: Silica veinlet causing crackle breccia and alteration.



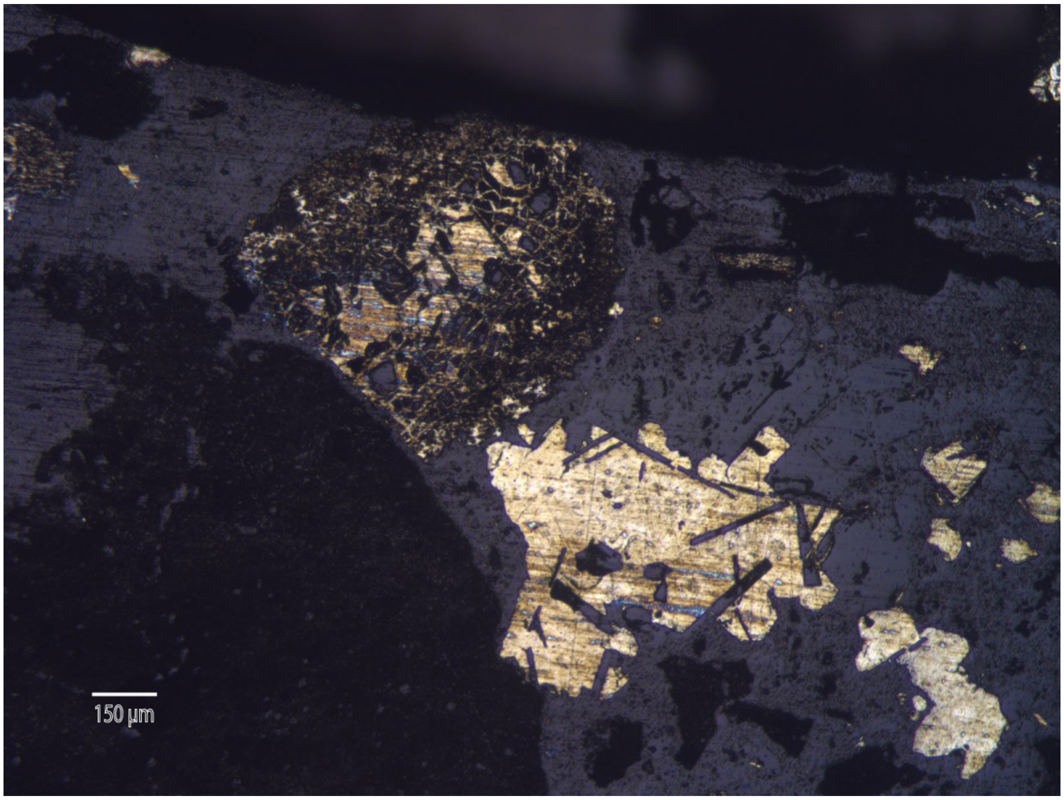
YS-08-JM155#2: Silica veinlet causing crackle breccia and alteration. Note sulfides.



YS-08-JM155#2: Botryoidal marcasite and massive pyrite with crackle breccia.



YS-08-JM155#2: Crackle breccia healed by massive pyrite.



YS-08-JM155#2: Sulfide with sulfate overgrowths. Top grain highly fractured and brecciated.

YS-08-JM155#3

Brief Description:

Silicified gry tuff

Location:

N 4956062
W 545449
Stream/Outcrop 4C: Base

Field Notes:

- White tuff from wall

Description:

- Silicified gry tuff
- Poss wht clays
- Sulfides
- Sulfide veinlets

Thin Section:

- Scattered sulfides throughout silicified matrix
- Primary texture scattered
- Arg phenos

XRD:
Major Minerals:

- Qtz, kaol, albite, al/walth, marc

Minor Minerals:

- Pyrophyllite, dickite, illite, diaspore, opal ct

Mineral Assemblage 1

Scan: YS-08-JM115#3

YS-08-JM156

Brief Description:

Silicified gry tuff

Location:

N 4956109
W 545387
Outcrop 4C: Middle

Field Notes:

- Middle

Description:

- Light– dark gry silicified tuff
- Vuggy
- Drusy quartz
- Arg phenos: kaolinite, alunite, walth
- Primary phenos: albite (ca)
- Opal ct and quartz
- High abundance of euhedral arg phenos
- Compression banding preserved

XRD:
Major Minerals:

- Opal ct, kaol, al/walth, albite

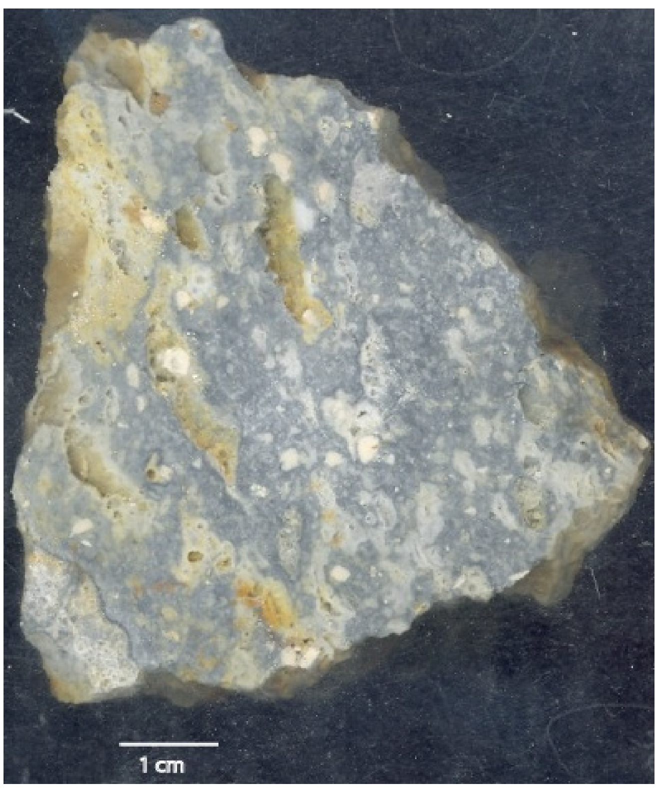
Minor Minerals:

- Qtz, illite, diaspore

Mineral Assemblage 1

XRF/ICP-MS: See Tables III-2, 3, 4 (Appendix III)

Scan: YS-08-JM156



Scan: YS-08-JM156

YS-08-JM157

Brief Description:

Silicified l.gry tuff

Location:

N 4956053.4
W 545392.8
Stream: Base

Field Notes:

- Tuff from stream bed

Description:

- Silicified l.gry tuff
- Minor kaolinite
- Sulfides in mtx