DISTRIBUTION OF ARSENIC AND MERCURY IN TERRESTRIAL AND MARINE ENVIRONMENTS IMPACTED BY GOLD MINE TAILINGS, WINE HARBOUR, NOVA SCOTIA

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ABSTRACT

From 1862 to 1939, intermittent gold mining and milling at Wine Harbour, Guysborough County, Nova Scotia produced a total of 42,726 oz. of Au from 72,413 tonnes of crushed rock. The gold occurs in a series of quartz veins, typically associated with arsenopyrite, that are hosted by the Goldenville Formation of the Meguma Group. Stamp milling and mercury amalgamation were the primary gold extraction methods. The tailings were slurried directly into surrounding streams and low-lying areas around the shores of Wine Harbour. In July 2005, mine tailings, waters and marine sediment samples were collected throughout the Wine Harbour gold district. Chemical analyses of 10 tailings samples collected on-land show very high concentrations of both As (200 to 200,000 ppm) and Hg (4900 to 320,000 ppb). The distribution of As and Hg in marine sediments confirms that most areas of Wine Harbour have been impacted by historical gold milling activities. Chemical analyses of 233 marine sediment subsamples show a wide range in both As (4 to 1500 ppm) and Hg (5 to 9500 ppb) concentrations. In general, the highest As and Hg values are located close to known stamp mill structures along the shores of Wine Harbour. However, high levels of both As and Hg also occur in the bottom sediments of a small inlet at the western end of the harbour, within the bounds of an active mussel aquaculture operation. Contamination of this latter site is likely related to a mill site(s) that is not shown on the historical maps for this gold district. This investigation is part of an ongoing multidisciplinary project which is assessing the marine and terrestrial environmental impacts of historical gold mining activities throughout Nova Scotia. Results from this study can be used to help assess potential ecosystem and human health risks associated with high levels of As and Hg in Wine Harbour.

Key Words: gold mining and milling, Wine Harbour, Nova Scotia, arsenopyrite, mercury, amalgamation, tailings, active mussel aquaculture operation, contamination, risks.

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CHAPTER 1: INTRODUCTION

1.1 Opening Statement

Gold mining began in Nova Scotia in 1861, three years after the first authenticated discovery of gold in Mooseland (Bates 1987). There were 64 gold mining districts in operation from 1861 to 1942, producing a total of 1.2 million ounces of gold (Smith & Kontak 1996). Primary gold occurrences in Nova Scotia are in the form of vein (lode) deposits, with lesser quantities found in modern and paleoplacers, in addition to disseminated gold found in various rock types (Bates 1987). The principal extraction method used in the majority of the mines during the early years was amalgamation. This process used mercury to recover the free gold within the crushed ore. During the 1880s, the process of cyanidation was introduced (Bates 1987). This more efficient process used a mixture of lime and cyanide to extract the gold, and was used to supplement the amalgamation process at some mines.

This period in history led to environmental degradation across many of the gold districts. Once mining ceased, mills were abandoned in many districts, leaving behind a considerable amount of the waste produced through milling operations. In most cases the waste was not contained, but was instead slurried directly into surrounding low-lying areas, streams, lakes, and into the ocean. The wastes produced from the milling process are referred to as tailings, and are composed of fine silt- to sand- sized material produced when the gold ore is crushed. Tailings contain varying amounts of mercury and cyanide, lost throughout the amalgamation and cyanidation processes, respectively. In addition, there are often naturally occurring metal(loid)s such as arsenic in these wastes. Arsenic is hosted in minerals associated with the gold ore deposit (e.g. arsenopyrite), and is potentially toxic (Azcue *et al.* 1994*a*, cited in Savage *et al.* 2000). The highest concentrations of contaminants are found in the vicinity of the old milling structures. However, if the appropriate mechanisms are available, the effects can be transported many kilometers away.

There are many tailings deposits dispersed throughout Wine Harbour, Nova Scotia. The area was an active gold district, with intermittent mining between 1862 and 1939 (Smith *et al.* 1985). This study focuses on the impact that this period of mining had, and continues to have, on the surrounding terrestrial and marine environments.

1.2 Environmental Impacts of Gold Mining and Milling

Widespread environmental degradation is commonly associated with past-producing gold districts, not only in Nova Scotia, but also in many regions of the world. In the early days of mining, very little was known about the negative impacts of mining processes on the surrounding land, and therefore no precautions were taken to prevent the release of contaminants to the environment. Once the consequences of contaminating the land were realized, strict regulations were introduced in an attempt to reduce the negative impacts of mining and milling processes. However, this has still not happened in many developing countries. Mining is vital to the economic well being of many Third World nations, and costs are often kept to a minimum by avoiding the expensive precautionary measures required to reduce environmental damage.

Much of the environmental degradation directly associated with gold mining operations rises from the use of mercury (Hg) in milling processes. Mercury is used in an extraction method known as amalgamation. The amalgamation process uses Hg to dissolve the gold (Bates 1987). The ore is crushed to sand- or silt-sized material, and later washed over Hg-coated copper plates. The Hg on the plates absorbs the free gold and forms what is referred to as an amalgam (a mercury-gold mixture). The amalgam is then scraped off the plates and heated in a closed system to recover the gold (Parsons & Percival 2005). Meanwhile, any remaining ore is disposed of in tailings (Nriagu & Wong 1997). Amalgamation was used extensively throughout early mining history, and continues to be used today in many developing countries. It is estimated that approximately 90% of all Hg purchased between 1850 and 1900 was used within gold and silver mines worldwide (Nriagu & Wong 1997). The percentage of Hg lost to the environment through milling processes such as amalgamation is estimated at 10-25% of the initial amount (Henderson 1935; EPS 1978, cited in Parsons & Percival 2005).

During the late 1800s the cyanidation extraction method was introduced. Cyanidation is an efficient, two-stage process which uses cyanide (CN^-) to dissolve the gold from the crushed ore. In the absence of other metals gold forms a strong complex with cyanide (Smith & Mudder 1998). In the first stage of the process, lime and cyanide are added to form a cyanide complex, this reacts to dissolve the gold held in the ore. Filtering processes remove any unwanted solids from the mixture. The second stage of the process involves the addition of zinc dust to the mixture, which precipitates the gold out of the solution for easier collection (Bates 1987). Following the extraction of gold, many different forms of cyanide remain in solution, including aqueous cyanide and metallo-cyanide, as well as other chemical species dissolved from the ore (Smith &

Mudder 1998). Like mercury, much of the initial cyanide at historical gold mines was lost to the environment throughout the extraction process.

Naturally occurring elements such as arsenic (As) are also found in large quantities throughout these districts. A highly toxic and carcinogenic element, As is found embedded in the gold ore, often in the form of arsenopyrite (FeAsS). The mobilization of As occurs during weathering of tailings piles and waste rock. In the early days As was often extracted from the ore as a byproduct and used in the manufacturing of As-pesticides (Azcue *et al.* 1994*b*). However, with the discovery of its toxic effects to humans, the demand for As decreased significantly, and subsequently most As in the ore was disposed in the tailings and waste of the gold mines.

The improper disposal of gold mine tailings has degraded the environment near both historical and modern mining operations. Extensive studies have been carried out across North America looking at the environmental effects of abandoned gold mine tailings. Case studies have shown that gold and silver mining in Nevada during a period from 1860 to 1890, released an estimated 7100 metric tons of metallic Hg into the Carson River-Lahonta Reservoir watershed as a result of ore refining by Hg amalgamation (Wayne *et al.* 1996). At approximately the same time, from 1860 and into the early 1900s, hundreds of hydraulic placer-gold mines operating throughout California, released an estimated 4500 metric tons of Hg to the environment, 80-90 percent of which was in the Sierra Nevada (Churchill 2000, cited in Alpers *et al.* 2005). Further north, in the Jack of Clubs Lake region, British Columbia, abandoned gold mine tailings have had a substantial effect on the As concentration in both the water and sediments. Arsenic concentrations in the sediments from Jack of Clubs reach a high of 1,104 μg/g and as high as 556 μg/L in water samples (Azcue *et al.* 1994*b*).

Prime examples of poor tailings disposal procedures continue today in developing countries such as Papua New Guinea and Ghana. Management strategies used in waste disposal in these areas are concerned mainly with minimizing costs and maximizing production. At the Lihir Gold Mine, in Papua New Guinea, the disposal of mine waste is a major issue. Mining wastes are disposed of in one of three ways: (1) barges ship the rock out 1 km from the shoreline and dump it directly into the sea; (2) the submarine tailings disposal (STD) method aims to deposit mine waste at ocean depths below the mixed surface layer through pipelines, where it will safely be deposited on the ocean floor; (3) any low-grade ore can be stockpiled for up to 25 years before beginning processing (McKinnon 2002). In Ghana the liners used to contain the cyanide used in the leaching process frequently leak and even fail. One particular spill at the Teberebie Goldfields, Ghana released 36 million litres of cyanide solution into a nearby stream (Ismi 2003). Ghana also continues to lose much of its forested areas due to the influx of gold mining companies. In 2003, the Ghanaian government was prepared to allow the removal of its remaining forest reserves in order to accommodate more gold mining operations in the area (Ismi 2003).

When suitable conditions are present, contaminants lost through gold extraction processes, waste disposal, and weathering of crushed ore are easily mobilized and subsequently may be carried large distances away from their sources, often deposited in surrounding streams, groundwater aquifers, and the ocean. If the toxins are present in sufficiently high concentrations and in a bioavailable form, they can present significant risks to both ecosystem and human health.

1.3 Overview of Arsenic and Mercury Geochemistry

The transport of elements such as arsenic and mercury through the environment is complex. Both elements are found in a variety of chemical forms, dependent on a set of variables (e.g. pH, redox conditions, etc.), which influence their mobility and toxicity in certain environments, including, sediment, water and air. Prevailing environmental conditions determine the *in situ* chemical forms of the elements. Understanding the source(s) of these metal(loid)s, as well as the processes controlling their mobility will give a better understanding of their distribution throughout the environment (Hinkle & Polette 1999).

1.3.1 Arsenic

Arsenic in the environment may be naturally occurring or derived from anthropogenic sources, and is distributed throughout aquatic, terrestrial and atmospheric environments (Fig. 1.1). Commonly it originates from the bedrock and soil, where As is naturally occurring in various minerals including arsenopyrite (FeAsS), niccolite (NiAs), cobaltite (CoAsS) and tennantite ($(Cu, Fe)_{12}As_4S_{13}$) (Boyle 1973, cited in Azcue *et al.* 1994*b*). The dissolution of the As-bearing bedrock and soil by infiltrating water mobilizes As (Cullen & Reimer 1989), allowing for its exchange between the different environmental compartments, such as air, sediment, soil, water or bedrock.

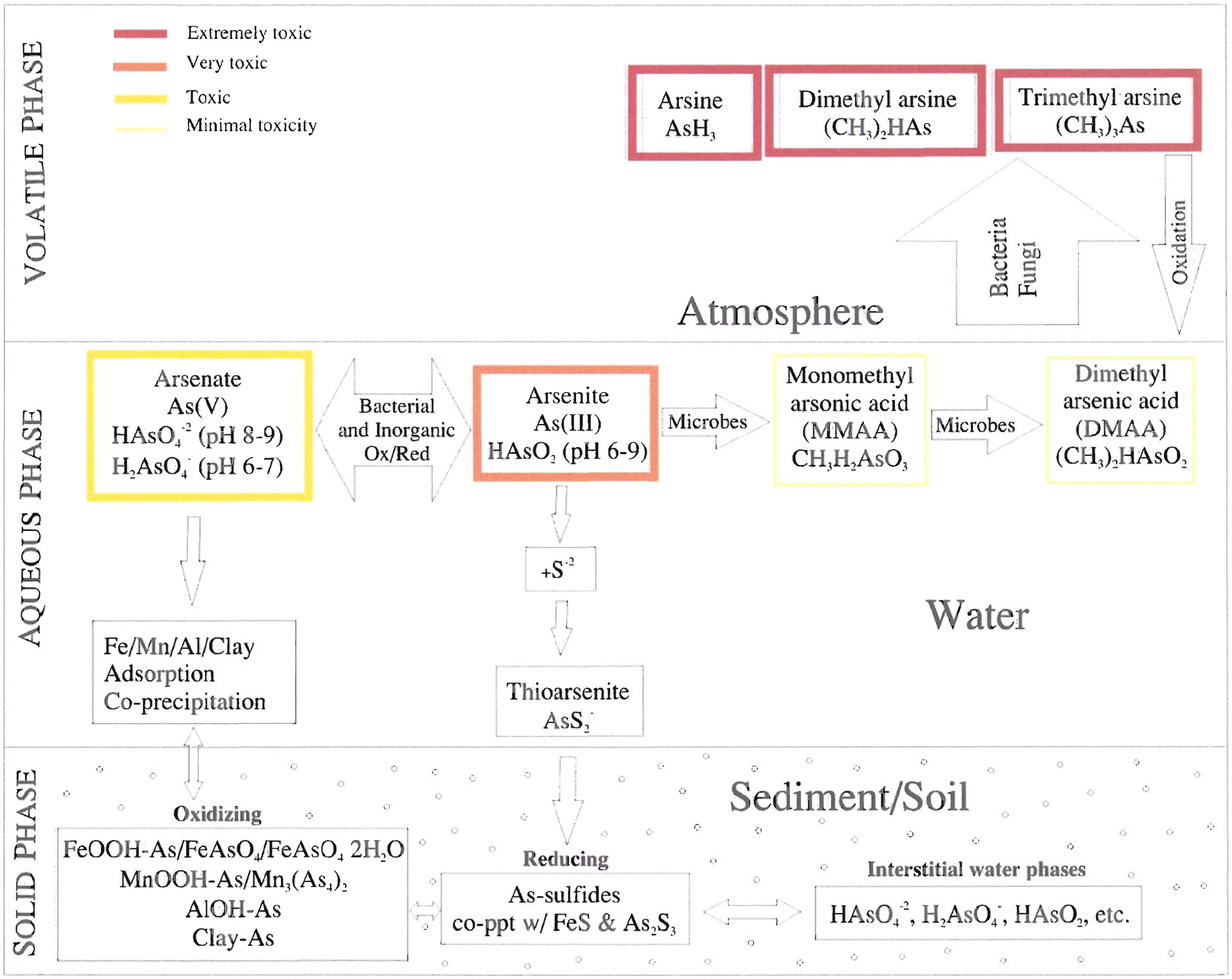


Figure 1.1 Hypothetical cycling of arsenic in a freshwater system (Modified from Bhumbla & Keefer, 1994; Nicholas *et al.* 2003)

Arsenic transfer to the atmosphere can result from a number of natural processes, including wind erosion, volcanic emissions, low-temperature volatilization from soils, marine aerosols, and anthropogenic pollution (Plant *et al.* 2005). Processes of wet and dry deposition return the atmospheric As back to the Earth's surface. There have been few reports on the speciation of As in the atmosphere (Cullen & Reimer 1989). The bulk of atmospheric As is introduced through anthropogenic means, most commonly from smelter operations and fossil-fuel combustion, which release As in the form of As_2O_3 vapour (Plant *et al.* 2005). Adsorption and complexation reactions between the emitted gases and air particulates produce a dominantly particulate form of As, as opposed to As in its vapour phase (Cullen & Reimer 1989). Arsenic in the form of highly toxic and volatile, arsine (AsH_3) and methylarsines, are also found in the atmosphere, released from soil by microbial activity (NRCC 1978, cited in Government of Canada 1993). The residence time of atmospheric As is estimated at approximately 9 days (Walsh *et al.* 1979b, cited in Government of Canada 1993).

The forms of As present in both soil and water environments depend on the pH (Fig. 1.2) and redox potential, as well as the type and amounts of sorbing components found in a given environment (Nriagu 1994). Arsenic in terrestrial soils typically originates from the parent rocks that form the soils (Nriagu 1994). However, additional As in soils can result from industrial waste discharges and the use of arsenical pesticides in agriculture (Nriagu 1994). Inorganic As dominates over organic As in soils. Arsenic bound to organic material in soils is a result of the interaction of inorganic As with soil microorganisms (Nriagu 1994). The dissolution and mobilization of As in terrestrial soils accounts for the majority of As entering natural waters, while other sources of As to

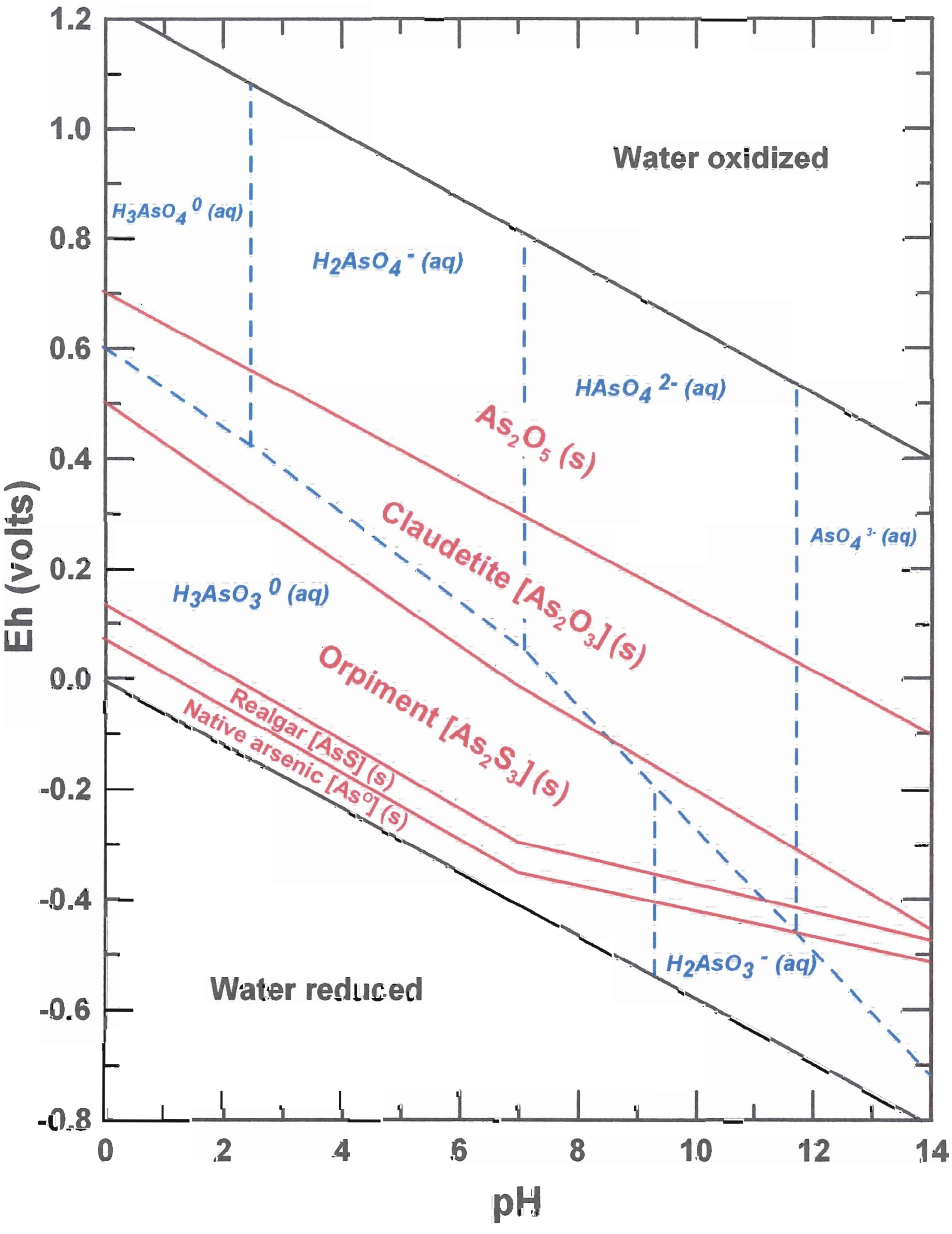


Figure 1.2 Eh-pH diagram for arsenic in its solid and aqueous states at equilibrium at 25°C and 1 atmosphere pressure. The dashed lines represent the stability field of aqueous species, and solid lines outline stability fields of solid phases in the As-O-S-H_2O system with total dissolved sulphur = 10^{-4} m. (Modified from Nordstrom & Archer 2002).

aquatic environments can include atmospheric fallout and anthropogenic input. Arsenic is most commonly found in its pentavalent state as arsenic acid (arsenate), and in the trivalent state (arsenite) in soil solution and natural waters (Nriagu, 1994). Arsenite [As(III)], is dominantly found in reducing environments, while arsenate [As(V)], the less toxic, and less soluble form (Bodenan *et al.* 2004), is predominant in oxidized waters (Hinkle & Polette 1999). Factors controlling the speciation of As in these two environments include redox and methylation reactions (Plant *et al.* 2005).

The mobility of arsenite and arsenate in waters is dependent on two main processes: (1) adsorption and desorption, and (2) precipitation and dissolution (Hinkle & Polette 1999). The greater ability of arsenate to adsorb to particulate matter in a water column (Holm *et al.* 1979; Pierce and Moore 1982, cited in Nriagu 1994), and coprecipitate with hydrous iron oxides, contributes to its low mobility. In contrast, arsenite has a lesser ability to adsorb to particulate matter, and is therefore the more mobile of the two species. The process of adsorption is governed by variations in pH (As sorbs mainly at low pH), redox reactions, the availability of competing anions, as well as structural changes of the solid-phase surface at the atomic level (Hinkle & Polette 1999). Precipitation acts to regulate the dissolved content of As in natural waters. Dissolved As may be removed from solution with the precipitation of a solid-phase. The As can be present as a primary component (e.g. scorodite) or as an impurity in another phase. The subsequent dissolution of these precipitates will release dissolved As back into the aquatic system (Hinkle & Polette 1999).

1.3.2. Mercury

The rising concern about Hg in the environment is due to its toxic effects on human health, as well as the ease with which it undergoes bioaccumulation. Mercury has three main oxidation states, dependent on the redox conditions present: Hg^0, Hg^+, Hg^{2+} (Andersson 1979, cited in Gabriel & Williamson 2004). The Hg^{2+} form of mercury is of most concern because it is both highly soluble in water and highly reactive with dissolved ligands (Gabriel & Williamson 2004). The speciation of Hg in solution is dependent on a number of factors. These controlling factors include pH, redox potential, ionic strength and the concentration of dissolved oxygen, sulphides, dissolved organic matter, as well as the suspended solids in solution (Winfrey & Rudd 1990; Babiarz *et al.* 1998; Jackson 1998, cited in Gabriel & Williamson 2004).

There are many chemical forms of each Hg oxidation state existing as either a solid, aqueous, or gaseous phase (Krabbenhoft *et al.* 2005) (Fig. 1.3). However, any slight variation in surrounding conditions (e.g. biological, chemical, etc.) can change the valence state of a Hg species over a range of time scales (Krabbenhoft *et al.* 2005).

Mercury found in the atmosphere is dominantly in its elemental form, Hg^0. Its abundance is attributed to its physicochemical properties and the speciation of Hg emissions from anthropogenic/natural sources, which is a dominance of Hg^0 (Krabbenhoft *et al.* 2005). The main sources of Hg to the atmosphere include natural sources such as volcanoes, Hg deposits, forest fires, soils, and volatilization from the ocean. In addition, there are sources resulting from anthropogenic activities, including coal combustion, waste incineration and metal processing (Krabbenhoft & Rickert 1997). The atmospheric Hg is deposited on the Earth's surface as oxidized Hg(II) in the

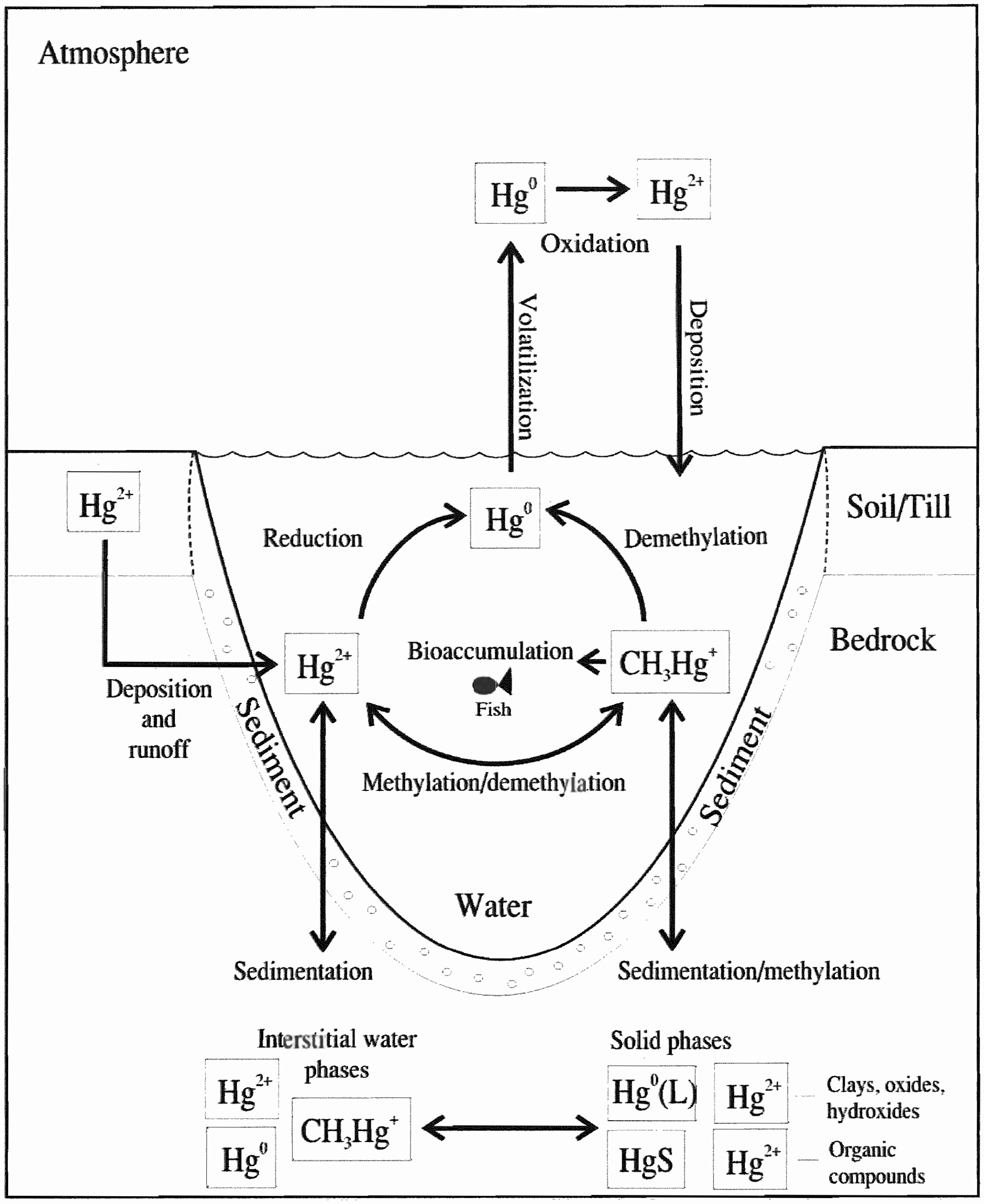


Figure 1.3 Cycling of mercury in an aquatic environment (Modified from Krabbenhoft & Rickert, 1997)

sediments and soil, where it is sorbed by plants and the soil humus layer (Hintelmann *et al.* 2002).

Mercury distribution in terrestrial environments is heterogeneous. This characteristic makes mass estimates and generalizations about the speciation and concentrations of Hg difficult. The majority of terrestrial Hg has been linked to mining activities and secondary processing (Rytuba 2003). The dominant Hg species found in terrestrial soils is Hg(II). Living plants and the soil humus layer (Hintelmann *et al.* 2002) quickly sorb the Hg upon deposition. In addition, Hg is secondarily sorbed to the mineral constituents in the sediments. The release of Hg to the environment is dependent on the medium to which it is sorbed. Mercury sorbed in the humus soil layer is more susceptible to reactivity and transport than that Hg held within mineral constituents (Krabbenhoft *et al.* 2005).

Mercury in soils and sediments is commonly associated with organic matter, iron oxides and sulphides (Krabbenhoft *et al.* 2005). Its association with these components is dependent on the oxidizing and reducing conditions present in the host material. Under oxidizing conditions, Hg partitions to iron oxides and organic matter. In contrast, under reducing conditions, Hg is sequestered by sulphides and organic matter. Mercury is a soft metal that bonds readily with soft ligands (e.g. sulphide groups in organic matter), therefore it is commonly associated with organic matter in most soils and sediments (Krabbenhoft *et al.* 2005).

Mercury in the terrestrial environment can be mobilized by the infiltration of water, and may subsequently be released into surrounding groundwater reservoirs, streams, lakes and the ocean. Once Hg enters an aquatic environment, it can easily be transformed into other chemical forms (Krabbenhoft & Rickert, 1997). Mercury speciation in water is controlled by a number of factors, which include the pH (Fig. 1.4), Eh and the water matrix composition (e.g. type of particulate matter held in the water column) (Krabbenhoft *et al.* 2005). Mercury has a strong affinity for suspended solids within aquatic ecosystems (Hurley *et al.* 1994).

The most toxic organic Hg complex, methylmercury [CH_3Hg^+], is formed in aquatic environments. Sulphate-reducing bacteria take up the inorganic Hg and convert it to the organic form, methylmercury (through metabolic processes) (Krabbenhoft & Rickert, 1997). Methylmercury can also be found in terrestrial soils, but in significantly lesser quantities. Upon formation, methylmercury has the ability to bioaccumulate rapidly through an aquatic food chain (Krabbenhoft *et al.* 2005). Bioaccumulation occurs when an organism takes up a contaminant more rapidly than it can be eliminated from the body (Krabbenhoft & Rickert, 1997). Any remaining Hg in the aquatic environment may be deposited into bottom sediments, thus continuing the cycling of Hg through the environment.

The exchange of Hg between environmental compartments is largely dependent on speciation (Krabbenhoft *et al.* 2005). Mercury exchange from the atmosphere to the Earth's surface results from the oxidation of Hg^0 to Hg(II). In contrast, moving from the Earth's surface to the atmosphere, Hg(II) is reduced to gaseous Hg^0. In biotic environments, Hg is taken in through methylation and released through demethylation (Krabbenhoft *et al.* 2005).

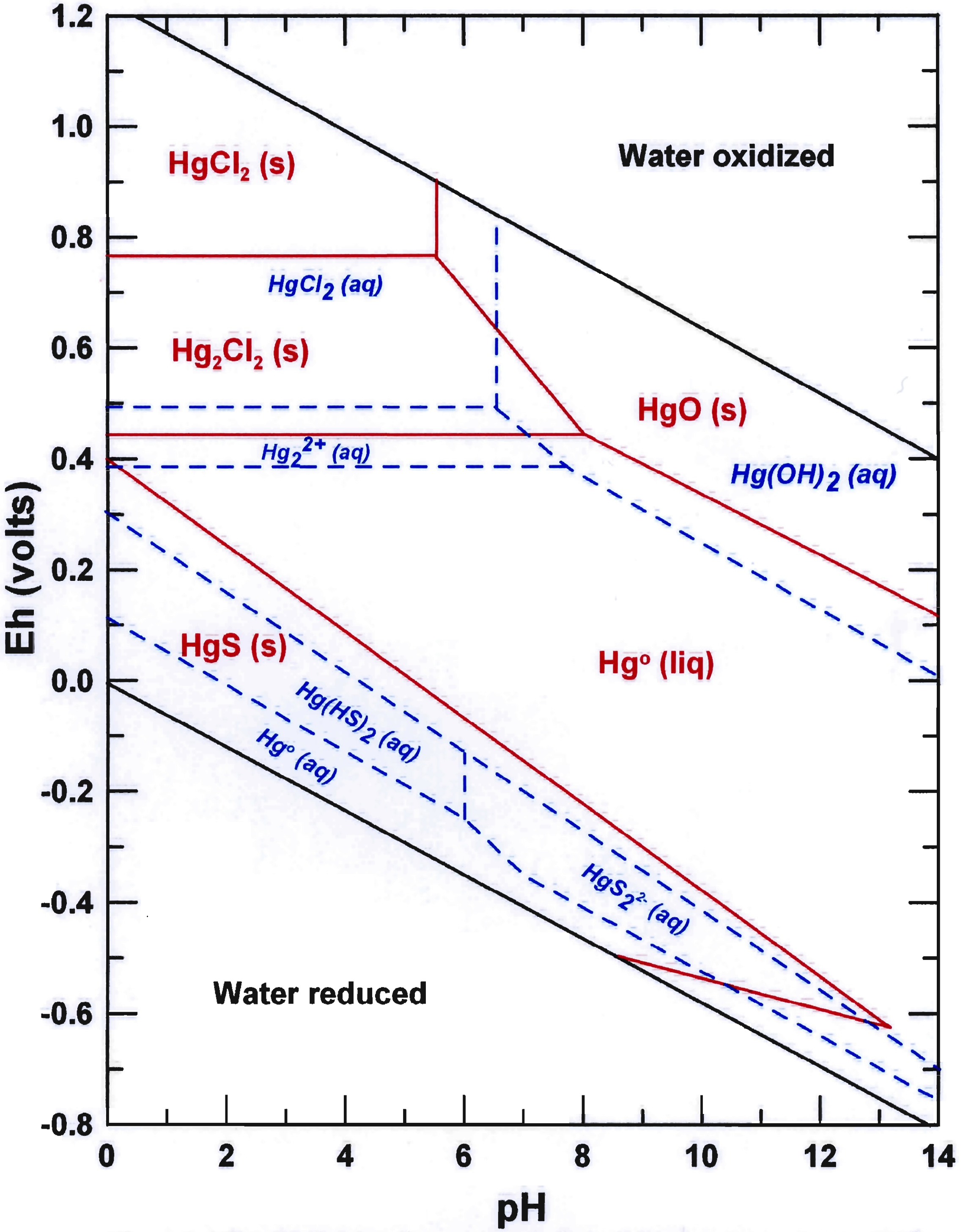


Figure 1.4 Eh-pH diagram for mercury in its solid and aqueous states at 25°C and 1 atmosphere pressure. The dashed lines represent the stability field of aqueous species, and solid lines outline stability fields of solid phases. System includes water containing 36 ppm Cl^-, total sulphur 96 ppm as sulphate (Modified from Hem 1985).

1.4 Problem and Objectives

There are various tailings deposits distributed throughout the Wine Harbour area of Nova Scotia, both on land and extending into the harbour. Because of the close proximity of the harbour to old milling sites, there is reason to believe that the tailings were slurried directly into the ocean. During the period of active mining, Hg amalgamation was the primary extraction method in use. At the time, very little was known about the potential adverse impacts this type of milling waste could have on the surrounding environment; therefore, no precautionary measures were taken to prevent the release of As and Hg to the surrounding land.

With this information, the main objectives of this thesis are as follows:

1. Document the spatial extent of gold mine tailings in both the terrestrial and marine environments;
2. Determine the concentrations of As, Hg, and other elements in the tailings, sediments, and waters;
3. Provide geoscience data that can be used to assess the potential risks to ecosystems and human health.

1.5 Thesis Organization

The main focus of this thesis is to examine the composition and distribution of the tailings throughout the Wine Harbour Gold District. Because of this, emphasis will be placed on the environmental cycling of As and Hg, as well as the geochemistry of the tailings. The geological setting, nature of the deposits, and a history of mining and milling will briefly be described for general background.

Chapter 2 presents the geological setting, nature of the Wine Harbour gold deposits, a history of mining and milling, as well as previous studies of mine waste distribution throughout the area. A description of laboratory procedures and sampling methods conducted in the field is outlined in Chapter 3. Chapter 4 focuses on the results, including the location of tailings deposits, their chemistry and mineralogy, marine sediment chemistry, and water chemistry. A detailed discussion on the observed distribution of tailings in Wine Harbour and the controls on cycling and bioavailability of As and Hg is given in Chapter 5. Chapter 6 summarizes the primary results of this study and provides recommendations for any future studies in the Wine Harbour area.

CHAPTER 2: THE WINE HARBOUR GOLD DISTRICT

2.1 Introduction

Gold production in the Wine Harbour area began in 1862 (Smith *et al.* 1985), two years after Joseph Smith made the first documented discovery of gold in the sands at Barachois, on the coast of neighboring Indian Harbour (Malcolm 1976). After this discovery, seven leads were found to be auriferous and mining began. Over the period between 1862 and 1939, 42,726 ounces of gold were extracted from 79,822 tons of rock before mining ceased (Smith *et al.* 1985). Mining at Wine Harbour was episodic as a result of low returns, inefficient milling methods, changes in mine ownership and unforeseen problems with geological structures (e.g. faults cutting the leads). The majority of the gold production was carried out at the Plough Lead belt beginning in 1872 (Malcolm 1976). Stamp-milling, followed by mercury amalgamation, were the primary means of extracting the gold from the crushed ore. A cyanide plant was erected in 1899 on Coopers Brook (Malcolm 1976) to treat tailings through the process of cyanidation. Despite this process being the most efficient method of extraction in neighboring districts (e.g. Cochrane Hill (Mosher 2004)) at the time, amalgamation remained the primary method used at the Wine Harbour mines.

The gold at Wine Harbour is found associated with a series of quartz veins rich in sulphides, primarily arsenopyrite. The area has undergone regional greenschist facies metamorphism (Smith *et al.* 1985). This is consistent with the majority of other Nova Scotia gold mines situated within the Meguma Terrane.

2.2 Location and Geological Setting

The Wine Harbour gold district is located in Guysborough County, on the eastern shore of mainland Nova Scotia (Fig. 2.1). It is one of 64 historical gold districts hosted in the Cambro-Ordovician Meguma Terrane. This terrane forms the southern portion of Nova Scotia and hosts most of Nova Scotia's former gold mining districts (Fig. 2.1). Extending to a length of 440 km by 110 km wide, the Meguma Terrane is a narrow wedge of allochthonous crust (Sangster 1990) that docked with the Avalon Platform during the Middle Devonian Acadian Orogeny (Keppie 1985, cited in Sangster 1990). The Cobequid-Chedabucto fault system marks the boundary between the two terranes.

The Meguma Group defines the Meguma Terrane and consists of a thick siliciclastic sequence (Ryan & Smith 1998), subdivided into the Goldenville and Halifax Formations. The Upper Cambrian Goldenville Formation forms the base of the Meguma Group, and has an exposed thickness of 5500 m. This unit is composed of thick, alternating beds of meta-greywacke and slates (Smith *et al.* 2005). The multiple slate, meta-siltstone and meta-greywacke lithologies of the Meguma Terrane have been tightly folded and metamorphosed as a result of the Acadian orogenic event. Lying conformably on top of this unit is the Ordovician Halifax Formation. With a thickness of 3700 m, this formation consists of slate, shale, and siltstone and minor sandstone (Smith *et al.* 2005). Sulphides such as pyrite, pyrrhotite and arsenopyrite are abundant throughout parts of both the Goldenville and Halifax Formations.

The beds of the Goldenville Formation are interpreted as a series of submarine mid-fan turbidite deposits (Harris & Schenk 1976, cited in Smith *et al.* 1985). The

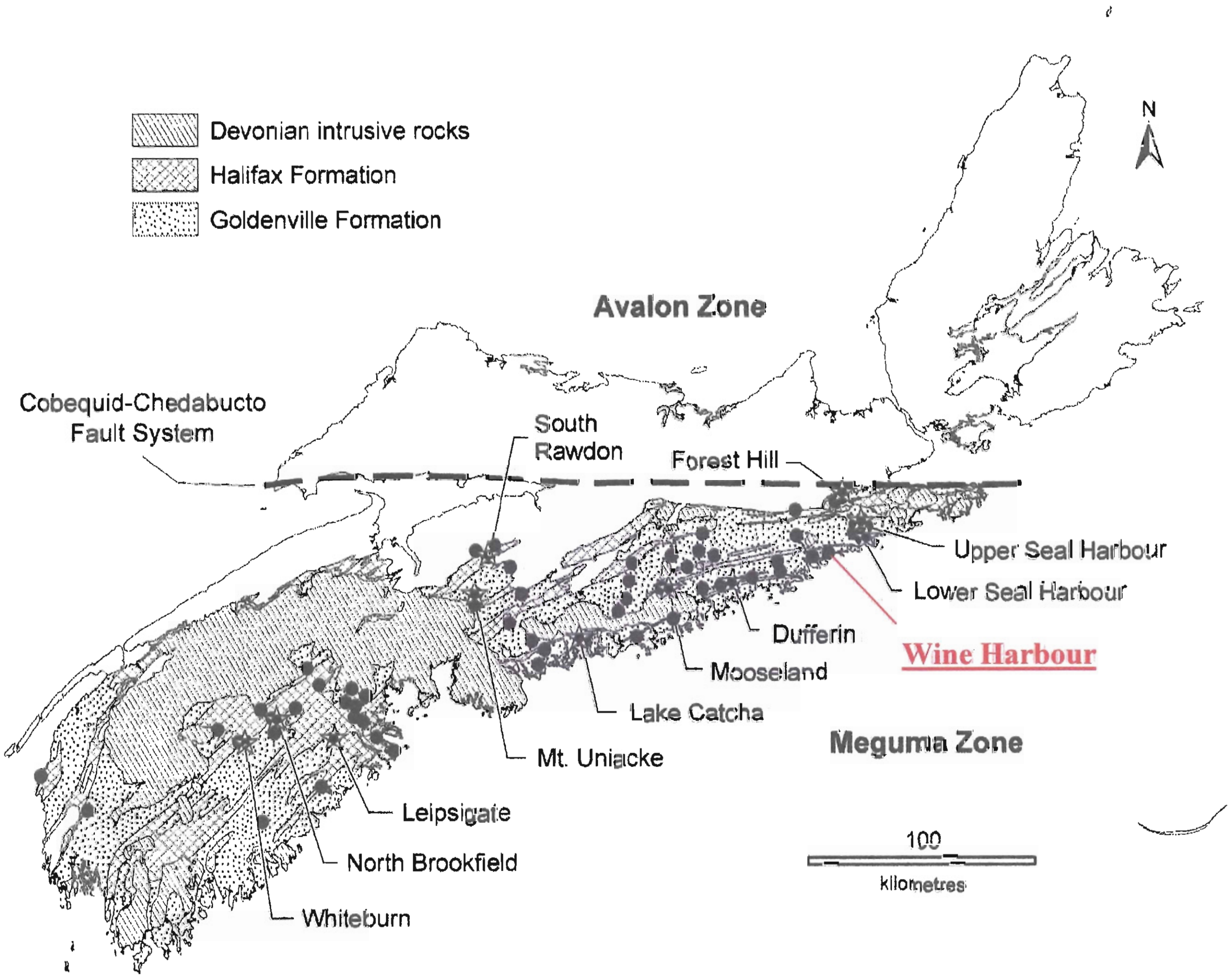


Figure 2.1 Geological map of southern Nova Scotia showing the past-producing gold mining districts (dots) (Smith *et al.* 2005).

Halifax Formation is associated with a number of different environments, including basin plain, interchannel areas of the inner fan, distal turbidite fan, continental rise and slope, as well as the outer shelf (Harris & Schenk 1976; Lane 1976, cited in Smith *et al.* 1985).

A history of regional metamorphism is evident in the eastern portion of the Meguma Terrane (Smith *et al.* 1985). The rocks of the Meguma Group range from the greenschist to amphibolite facies. Most of the central terrane is composed of rocks within the greenschist facies, while eastern and western portions are within the amphibolite facies (Ryan & Smith 1998). This period of regional metamorphism is dated at a minimum age of 415-405 Ma (Reynolds *et al.* 1987, cited in Ryan & Smith 1998). Index minerals associated with regional metamorphic events include biotite, garnet, cordierite, staurolite, andalusite and sillimanite (Raeside & Jamieson 1992, cited in Ryan & Smith 1998). In addition to regional metamorphism, contact metamorphism around numerous Acadian granitoid plutons increases the grade of the immediately surrounding Meguma rocks from greenschist to amphibolite facies (i.e. hornfels) (Smith *et al.* 1985). Characteristic mineral assemblages in the areas of contact metamorphism include sillimanite-chiastolite or garnet-cordierite (Ryan & Smith 1998). The plutons crosscut through regional metamorphic isograds indicating that the plutons were emplaced following the period of regional metamorphism (Ryan & Smith 1998).

Gold occurrences in the Meguma Terrane are primarily associated with quartz veins. The majority of gold mined in Nova Scotia has come from bedding concordant vein deposits (Smith & Kontak 1996). Disseminated gold mineralization is also associated with highly altered meta-siltstone, argillite, slate and meta-greywacke of the Goldenville Formation at Moose River (P.K. Smith, pers. comm. 2005).

Greenschist facies slate and meta-greywacke of the Goldenville Formation comprise most of the bedrock in the Wine Harbour area (Smith *et al.* 1985). Deformation in the region has produced three major regional folds. The vertical beds of the Goldenville Formation are oriented about the axial trace of the Wine Harbour Anticline (Smith *et al.* 1985). The upright stratigraphy of the Halifax Formation is oriented about the axial trace of two synclines located to the north (St. Mary's Bay Syncline) and south (Sonora Syncline) of the Wine Harbour Anticline (Fig. 2.2). The northwest-southeast trending Indian Harbour Fault in neighboring Indian Harbour has produced a sinistral displacement of the folds in the Wine Harbour area (Smith *et al.* 1985).

2.3 Nature of the Wine Harbour Gold Deposits

The gold-bearing quartz veins at Wine Harbour are typically located either within, or adjacent to the crest of the southwest-trending Wine Harbour anticline. Mineralized quartz veins that occur in the hinge of anticline folds are often referred to as a saddle reef deposit (Sheppard & Barrie 1988). However, with present erosion levels the fold hinges are devoid of such vein types. In addition to the saddle reef type deposits, Smith *et al.* (1985) separated the veins into six different types, as described at the Barachois area of Wine Harbour. Figure 2.2, a geological map of Wine Harbour, shows the position of the Wine Harbour anticline within the Goldenville Formation.

The groups of veins vary in age with respect to folding (O'Brien 1982; Haynes 1987, cited in Smith *et al.* 1985). The structures show evidence to support both pre- and post-major folding ages (Smith *et al.* 1985). The veins as described by Smith *et al.*

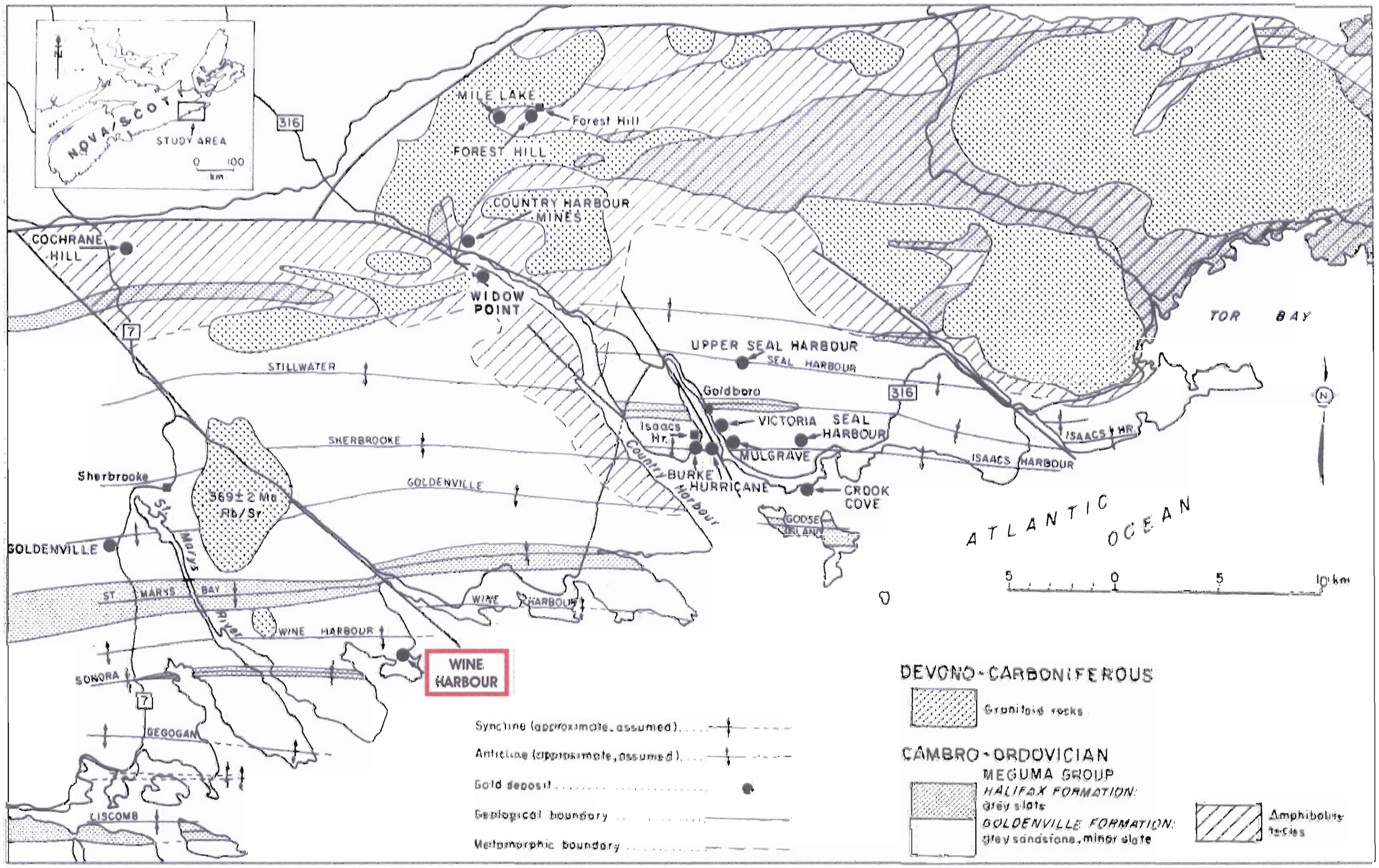


Figure 2.2 Geological setting of Wine Harbour (Modified from Haynes 1983; Smith *et al.* 1985).

(1985) include stratiform (bedding parallel), stratabound, side, step, discordant and vertical.

Stratiform veins are found within the slate horizons and form parallel to the bedding. They are composed of layers of laminated quartz often alternating with carbonate and phyllosilicates. Veins of this type also show variable degrees of deformation resulting from synchronous deformation with the surrounding rocks. Strataform veins contained most of the documented gold found at Wine Harbour (Smith *et al.* 1985).

The stratabound veins can be found in all rock types although they are most common in slate and meta-siltstone. They are typically characterized by inclusions of chloritized wallrock slate. Thickening and thinning of the vein materials commonly produces pinch-and-swell structure within the vein. These veins typically crosscut slate beds at low angles (<10°) and continue through meta-greywacke beds at higher angles (~60°). Arsenopyrite porphyroblasts are often a good indication of a stratabound vein. These veins contain gold in association with other sulphide minerals (Smith *et al.* 1985).

Step veins are a discordant type of vein. They crosscut the rocks of the Goldenville in a step-like form following the bedding plane. These veins occur in two rock types, psammites and slates. In psammites the veins have undergone very little deformation and are composed primarily of massive quartz. In the slates of the Goldenville, step veins are much different in composition. The following composition is common: muscovite +/- K-feldspar +/- sulphide +/- carbonate assemblages. Pinch-and-swell structures are also common in these veins (Smith *et al.* 1985).

Veins that taper away from T-junctions, that are tightly folded, are known as side veins. The mineralogy of this type of vein is dependent on the parent vein. Rich concentrations of gold are often found where side veins taper away from stratiform and stratabound veins (Smith *et al.* 1985).

Discordant veins at Wine Harbour have been found only in psammites, although they commonly crosscut all lithologies in other areas. These veins are found crosscutting folded tension gash infillings (Smith *et al.* 1985). Due to their structural position, they are thought to have been emplaced during folding. These veins do not typically yield large quantities of gold.

The final type of gold-bearing quartz vein observed at Wine Harbour is the vertical vein, the youngest of the group. These veins cut across all previously mentioned vein types. Vertical veins fill extensional fractures produced through shear movement of bedding. Minerals in the veins include quartz +/- chlorite +/- carbonate +/- K-feldspar +/- muscovite +/- sulphides (Smith *et al.* 1985).

2.4 History of Mining and Milling Operations

The documented history of mining and milling operations in the Wine Harbour area mainly focuses on the development of different leads and the quantity of gold extracted each year. There is little written on aspects such as the dates of mill construction. The information gathered for this section was taken from the 1927 Annual Report on Nova Scotia mines by Brunton and The Gold Fields of Nova Scotia by Malcolm (1976).

The history reveals the episodic pattern of mining and milling at Wine Harbour (Table 2.1). This intermittent activity was the result of depleted reserves, inadequate techniques in mining and milling operations, expensive power sources as well as the lure of richer gold and silver discoveries being made in Ontario at the same time (Sheppard & Barrie 1988).

There were no annual reports published after 1907, and no documented mining activity from 1907 until 1926, when the largest documented amount of ore and gold ever recorded in the district were extracted (Sheppard & Barrie 1988). The most recent period of mining took place between 1934 and 1939 (Sheppard & Barrie 1988). Figure 2.3 is a photo of the Wine Harbour gold district in 1902, taken by E.R. Faribault.

2.5 Previous Studies of Mine Waste Distribution

All of the mines operating in Wine Harbour used mercury amalgamation as the preferred method of extraction. There were five separate stamp mills constructed in the district (Faribault 1905), with some mills containing up to 15 stamps (Fig. 2.4). Each produced gold and associated waste rock and tailings from distinct areas of the district.

Seabright Resources conducted a study of the distribution of tailings throughout the Wine Harbour area in the early 1980s. These studies discovered that the tailing deposits correlated with the locations of old stamp mill structures. At the time of milling there were no precautionary measures taken to prevent the release of tailings into the environment. More often than not, the tailings were dumped directly onto the surrounding land.

Table 2.1 Timeline of gold production at Wine Harbour, Nova Scotia

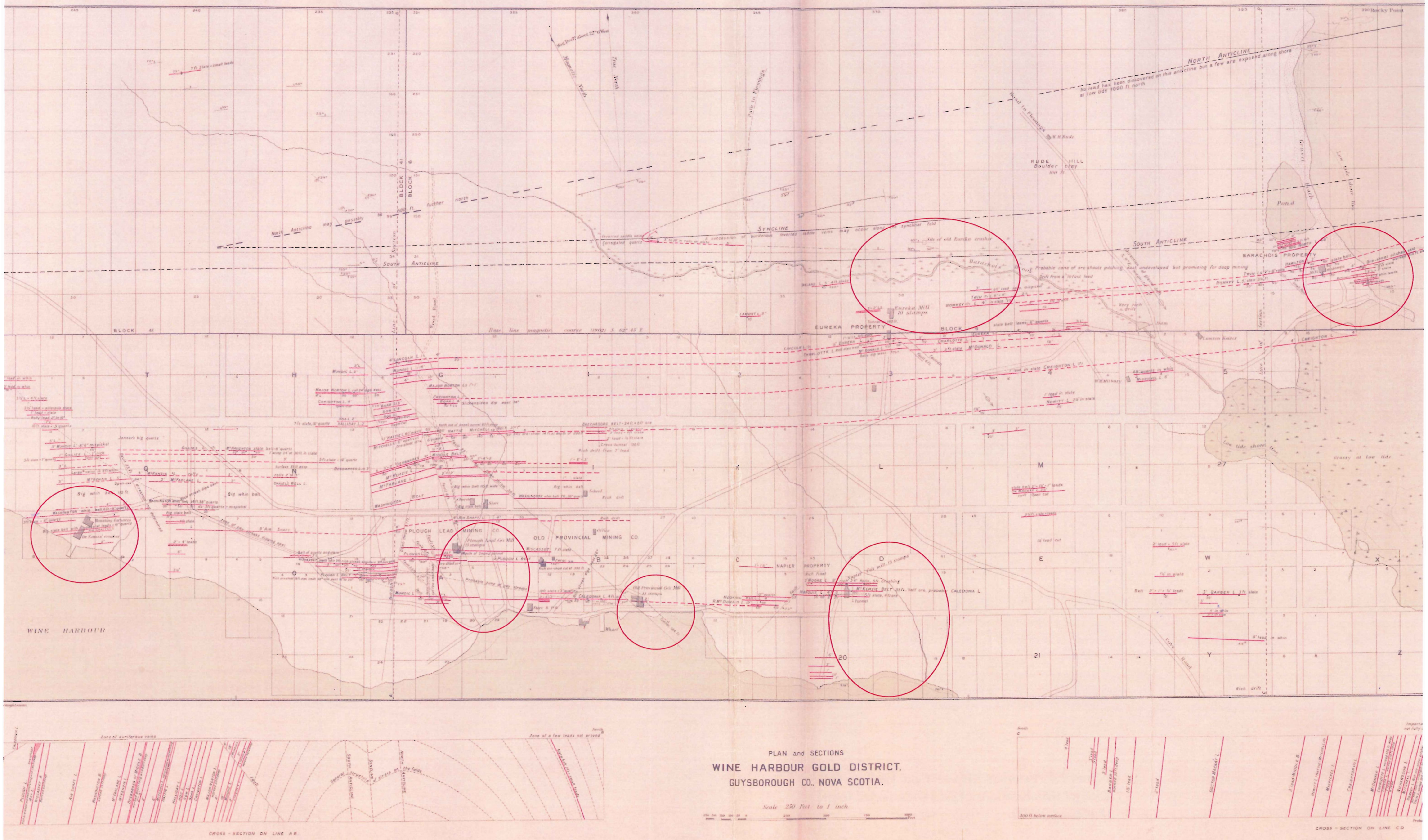
Year	Event
1861	First discovery of auriferous quartz in Wine Harbour. Government took formal possession in September of the same year.
1862	Seven leads prove auriferous: Smith, Middle, Major Norton, Barachois, Halliday, Wiscassett and Gillespie leads.
1863	Wine Harbour produced the largest amount of gold of any other district in Nova Scotia during the same year. Second only to Sherbrooke in the average amount of gold produced per man.
1864-67	A steady decline in mining production. Production fell from greater than 4000 ounces in 1864 to 845 ounces in 1867.
1866	The principle mining companies during this year were the Caledonia, Glenelg and Eldorado. Shafts on the scale of 70-183 feet were sunk into the Caledonia lead intersecting veins of little value. The Eldorado Company began construction on a tunnel going northward from the shore. The purpose being, to cut the Middle lode to explore the intervening ground and to provide drainage.
1867	Mining was slow for the most part until a change in ownership of some properties led to renewed activity. Some previously dug shafts were deepened at Caledonia and Glenelg Companies. The tunnel was extended to 300 feet in length.
1868	Principle operators during this year included the Orient, Eureka, Eldorado, and the Provincial Companies. The Orient Company suspended operations later in the year.
1870	There was a large decrease in the amount of work done but production increased slightly. The Eldorado and Globe Companies were the only remaining mines in operation. During this year a width of 6 to 8 feet was stoped out.
1871	Small returns were made during this year by the Provincial mine and Gladstone Company.
1872	Work resumed on the Eldorado tunnel. Intention was to drain any leads lying within 560 ft of the Desbarres lead.
1874-98	Operations at the Eldorado Company mines ceased. After sinking a shaft 20 ft below the 130 ft level it was discovered that the lead pinched to less than two inches thick and carried no gold. This began a 20-year low in the gold mining operations at Wine Harbour. There was very little mining done during this period and production was exceptionally low.
1899	Production was greatly increased within the district. Greater than 1,500 ounces of gold were recovered, a majority of which was recovered by the Guysborough Gold Mining Company, Limited on the old Eureka property. Messrs erected a cyanide plant on Coopers Brook.

1900	The shaft at the Plough Lead mine was dug to a depth of 177 ft. The old fault on which this lead was once lost was encountered at the new depth. Measuring 20 feet wide, 75% of the belt was milled. This gave the Plough Lead Company the largest returns that year. The old Middle Lead mine was reopened a year earlier producing a large amount of low-grade ore during 1900 where it was later crushed at a new 5-stamp mill.
1902	Principle production made by the Plough Lead Mining Company. A new shaft was connected with old underground workings and the ore extracted from this new shaft was crushed at a 15-stamp mill.
1904	The last year for returns at the Plough Lead Mining Company.
1905	The Old Provincial Mining Company was the only mine to make returns.
1906	The Little South Lead, which formed part of the Plough Lead belt, previously owned by the Old Provincial Mining Company, was reopened by the Wine Harbour Mining Company in March of 1906.
1907	The Wine Harbour Mining Company mined 6,333 tons of ore from the Little South Lead, yielding 1,017 ounces of gold.

Figure 2.3 Historical photo of Wine Harbour, Guysborough County, Nova Scotia. 1902. Photo by E.R. Faribault, Geological Survey of Canada. Reproduced with permission from the Earth Sciences Sector Photo Library Collection, Ottawa.

Geological Survey of Canada

ROBERT BELL, Sc.D. (Cantab.), LL.D., M.D., F.R.S., I.S.O., ACTING DIRECTOR



PLAN and SECTIONS

WINE HARBOUR GOLD DISTRICT,

GUYSBOROUGH CO., NOVA SCOTIA.

Scale 250 Feet to 1 inch

sion of the original map
pier

Seabright Resources produced a map showing this distribution. The bulk of the tailings are shown on land. However, the deposits that surround old mills situated close to the coast often stretch out into the harbour short distances (Glover *et al.* 1983). Seabright also recorded findings of tailings in streams, in particular at Barachois, where the Eureka Mining Company had constructed a 10-stamp mill. The largest tailings deposit, according to Seabright, is located around this mill and has drained directly into Barachois Brook. This brook flows down into Indian Harbour, although according to Faribault's 1905 map, there is a dam just before it reaches the harbour (Fig. 2.4).

Most of the tailings areas are currently overgrown by thick bush, including primarily spruce, fir, alder and other low bushes. As a result, the tailings footprint is often difficult to locate and therefore has made characterization of accurate limits for these mine wastes difficult.

CHAPTER 3: METHODOLOGY

3.1 Introduction

To assess the distribution, composition, mineralogy and environmental impact of the Wine Harbour gold mine tailings, a series of field and laboratory studies were undertaken, commencing in the summer of 2005. Areas of particular interest for on-land sampling included mill structure locations and tailings deposits mapped previous to this study (Faribault 1905 & Glover *et al.* 1983). As part of this study, samples were initially taken from these sites, and from adjacent intertidal areas. Marine sampling used a small Boston Whaler, with the majority of the samples collected from areas in the vicinity of on-land tailing deposits. A limited number of samples were also taken further from the shore to assess the dispersion of tailings throughout the harbour. The methods used in this study followed those used in previous studies carried out at other gold mine sites in Nova Scotia (Parsons *et al.* 2004). The final section of the chapter describes a GIS compilation put together to show the sample sites, and distribution of contaminants throughout the Wine Harbour Gold District.

3.2 Land-Based Fieldwork

Field sampling for this study was completed on two different occasions in the summer of 2005. Tailings samples were collected on July 12th, and water and marine sediment samples on July 19th, 2005 by Dr. Michael Parsons, Tim Milligan and Brent Law, assisted by the author.

Field observation determined that the tailings deposits at Wine Harbour were not as extensive as those documented by Seabright Resources in the 1980s. Stamp mill remains, historical artifacts, as well as numerous mine shafts were found located in the woods, based on Faribault's map (Fig. 2.4). Also, an unsuccessful search for a cyanide plant on Coopers Brook was carried out, based on information filed in a report by Malcolm (1976).

3.2.1 Tailings sampling

A total of 14 tailings samples were collected from 10 sites, located in the vicinity of old stamp mill structures, as mapped by Faribault in the early 1900s (Fig. 2.4). A shovel was used to dig holes for sampling, with typical dimensions of 20-50 cm deep by 30-40 cm wide. Sampling locations within the holes were chosen based on tailings stratigraphy. At a majority of the sites, the vertical stratigraphy consisted of a top-most layer of organic-rich soil, overlying rusty-brown oxidized tailings, transitioning into grey, unoxidized tailings at greater depths. Those sites located within marsh-type and other water-logged areas were dominated by dark-grey unoxidized tailings, without any oxidized layers. In drier areas, samples were typically taken from both the oxidized and unoxidized layers. At water-logged sites, one sample from the unoxidized tailings was generally considered sufficient. Figure 3.1, a general map of the Wine Harbour area, shows the distribution of sampled sites. Appendix A contains descriptions of all on-land tailings sample sites.

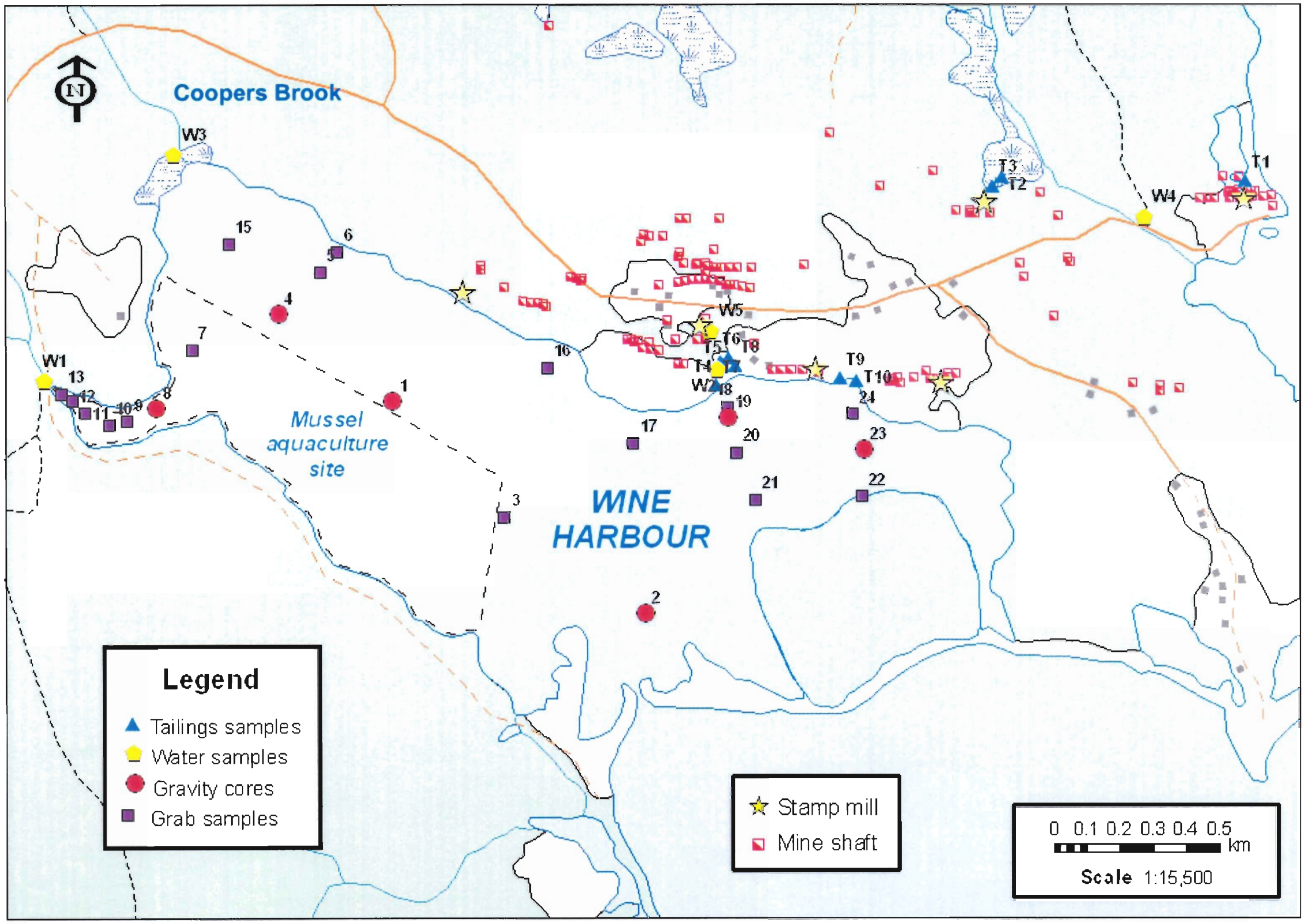


Figure 3.1 Sample locations for tailings, waters and marine sediments in the Wine Harbour Gold District.

3.2.2 Water sampling

Water was sampled from five different streams within the Wine Harbour area, to assess the loadings of As and Hg to the harbour, from freshwater sources (Fig. 3.1). Four of these streams empty directly into Wine Harbour, while another (sample site W4 on Fig. 3.1) discharges at Barachois Cove, into neighboring Indian Harbour. The streams were tested due to their close vicinity to old mill structures, with the exception of W3. Site W2, just downstream of W5, was collected within a stream draining from the site of the Plough Lead Co's Mill (Fig. 2.4), which passes through a known tailings deposit. Site W5 is a stream draining directly from a shaft at the same mill, through the remains of what may be an old tailings sluice.

Initial measurements of pH, temperature and conductivity were conducted at each site before water sampling began. Standard pH buffer solutions at pH 4, 7, and 10 were used in the calibration of the pH meter.

When sampling water for later analyses, caution must be taken to prevent contamination of the sample with foreign material. To maintain the stability and integrity of a water sample collected for Hg determination, a number of factors must be considered. These include: the type of bottle material; the cleaning and pretreatment of all sampling devices; the redox conditions and chemistry of the sample; as well as those reagents used in the preservation of Hg in the sample (Leermakers *et al.* 1990, cited in Hall *et al.* 2002). Therefore, the same strict procedure was carried out at each of the five streams. Handling of all equipment was done using nitrile gloves. The samples were collected using 60-mL acid-washed, high-density polyethylene containers. To condition each bottle, the containers were rinsed on-site with the water that was to be sampled. One or more 0.45 μm Sterivax© capsule filters were used at each site for the collection of filtered water samples.

At each site, five 60-mL water samples were collected. This batch included two filtered and two unfiltered water samples, used for cation and Hg analyses, with one filtered sample used for the determination of anions, dissolved organic carbon (DOC), and alkalinity. Once collected, preservation of the samples was necessary to stabilize cations and Hg for later analyses. Those samples collected for Hg analysis were preserved using bromine monochloride (2 vol.%); ultrapure nitric acid (1 vol.%) was used in the preservation of those samples for the analysis of cations. Once removed from the field, the samples were stored 4°C, and then shipped to the Analytical Method Development labs at GSC-Ottawa, Ontario for analysis.

3.3 Marine Fieldwork

Marine sediment samples were collected from 23 different localities within Wine Harbour (Fig. 3.1). The sampling area encompasses much of the harbour, although access to some areas was restricted by shallow water depths (Fig 3.2). Sample sites were located just offshore, close to known on-land tailings deposits, as well as around a mussel aquaculture site currently in operation towards the western end of the harbour. Marine sediment samples included 16 grab samples and six gravity cores.

During sampling, an initial grab sample was taken to determine if the harbour floor was suitable for collection of a gravity core (Fig. 3.3). If the seafloor was easily penetrated and a fine-grained sediment recovered, sampling proceeded with a gravity

Figure 3.2 Boston Whaler used in the collection of grab and core samples at Wine Harbour (Photo taken by M. Parsons, 2005).

Figure 3.3 Gravity corer used for the collection of sediment cores in Wine Harbour (Photo taken by M. Parsons, 2004).

core, in addition to the grab. A 50 lb gravity corer was used for the collection of the cores. A core catcher was not used in any of the sampling at Wine Harbour to minimize sediment disturbance in the core. Sediment cores recovered ranged in length from 42 to 56 cm.

3.4 Laboratory Analyses

Bulk chemical compositions were determined for all of the tailings samples, while X-ray diffraction (XRD) and an electron microprobe were used to characterize the mineralogy and mineral chemistry of a select portion of the tailings samples. Chemical analyses carried out on both the tailings and marine sediment subsamples were done at ACME Analytical Labs in Vancouver, British Columbia. Mineralogical analyses of the tailings samples using XRD and electron microprobe were completed at the Geological Survey of Canada (Atlantic) and Dalhousie University, respectively. Chemical analyses of the water samples included measurements for cations, anions, Hg, dissolved organic carbon, and alkalinity, all carried out at the Analytical Method Development labs at GSC-Ottawa. Radiometric dating of marine sediment cores (^{210}Pb, ^{137}Cs) was also completed at Fisheries and Oceans Canada, but is outside the scope of this thesis.

3.4.1 Tailings composition and mineralogy

All of the tailings samples collected were sub-sampled and freeze-dried at GSC-Atlantic before being sent to ACME Analytical Laboratories, where the bulk chemical analyses were carried out. At ACME, a 1 g portion of each subsample was digested in 6 mL of a 2:2:2 solution of nitric acid, hydrochloric acid and water at 95°C for one hour

(Package IF-MS). Using inductively coupled plasma – mass spectrometry (ICP-MS), each sample was then analyzed for 53 elements. This method uses high-temperature plasma discharge to generate positively charged ions, which represent the elemental composition of a sample (Thomas 2001). Certified reference materials, CANMET STSDs 2-4 (Lynch 1990) and NIST 1646 (National Bureau of Standards 1982), and duplicate samples were submitted to test the accuracy and precision of the analytical procedures, respectively. Organic carbon analyses were completed at GSC-Atlantic, with assistance from the author, using a high-temperature combustion method.

To gain a general understanding of the main minerals present in the tailings, all 14 bulk samples were analyzed using X-ray diffraction (XRD). The XRD method records the angular positions of diffracted beams off planes of atoms in the various minerals to determine the spacing between atomic planes, and the identity of the mineral (Allaby & Allaby 2003). X- ray diffraction does not have the capability to detect those minerals with concentrations below 1-2%; therefore, trace quantities of particular minerals are unidentifiable using this method (Mosher 2004).

A more detailed look at the mineralogy and mineral chemistry of a selected group of samples was done using the electron microprobe at Dalhousie University. Six tailings samples were chosen based on their composition and locality, making sure to include tailings from both the terrestrial and marine settings. The main goal of the electron microprobe analyses was to clarify the composition of the sulphides and any secondary phases present in each of the samples, as the focus of this study is on potential sources of As and Hg. Signs of alteration (e.g reaction rims) around the grains, were also noted as they provide evidence of the types of processes the source rock underwent during gold extraction or subsequent weathering. Grain mounts were analyzed by way of wavelength dispersive spectrometry (WDS) on the JEOL 8200 microanalyzer at Dalhousie University. The analyzer was operated at 15keV, with a focused beam current (minimum spot size) of 20 nA. Calibration standards included cinnabar (Hg), sanidine (K), apatite (Ca) and arsenopyrite (As, S, Fe), which was also used as an analytical control.

3.4.2 Marine sediment geochemistry

All sediment core and grab samples were sub-sampled at GSC-Atlantic before being sent for bulk chemical analysis at ACME Analytical Laboratories. The sediment cores were vertically extruded and sub-sampled at 1 cm intervals to a depth of 30 cm. Below 30 cm, the sampling interval was increased to every 2 cm (Figs. 3.4a & 3.4b). The grabs were sub-sampled directly in the field. Most times the sub-sample was taken from the surface of the grab sample; however, if multiple layers were evident, a sample was taken from both the bottom (~10 cm) and top (0-1 cm) of the grab. All sub-samples were freeze-dried prior to shipment to ACME. Chemical and organic carbon analyses of the marine sediments followed the same procedures as those for the analysis of terrestrial tailings samples.

3.4.3 Water chemistry

All stream water samples were sent to the Analytical Method Development labs at GSC-Ottawa for analyses, which included measurements of cations, anions, Hg and DOC concentrations. Inductively coupled plasma-atomic emission spectrometry (ICP-AES) was used to determine all major element concentrations in the waters. Minor and trace

Figure 3.4a Vertical extrusion and subsampling of gravity cores at GSC-Atlantic (Photo taken by M. Parsons, 2005).

Figure 3.4b One-centimeter thick slices of sediment were taken from the top 30 cm of each core; sampling below 30 cm was carried out at 2 cm intervals (Photo taken by M. Parsons, 2005).

elements were measured using ICP-MS. Detection of Hg concentrations with values less than 10 ng/L (parts-per-trillion) was carried out using a Tekran Hg analyzer, which has a detection limit of 0.5 ng/L. Determination of anion concentrations was done using a Dionex ion chromatograph. Dissolved organic carbon measurements required the use of a high-temperature combustion method. This was done after all inorganic carbon was removed using phosphoric acid. Alkalinity measurements of the water were completed using automated Gran titrations.

3.5 GIS data compilation

All sample locations and descriptions were compiled into a GIS project, completed at the Geological Survey of Canada (Atlantic). Detailed information for each sample locality was entered into a database and linked to a specific location on a series of maps (e.g. Fig. 3.1). Base layers from the Nova Scotia Topographic Database included shorelines, roads, rivers, gold districts, and air photos for the Wine Harbour area, at a scale of 1:50,000.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter provides a summary of field observations, chemical and mineralogical analyses of tailings and marine sediments, and measurements of the chemical composition of stream water samples. The results define the geochemical nature of the tailings, marine sediments, and waters in the Wine Harbour Gold District, and provide evidence for the main processes controlling the release, transport, and fate of As and Hg, as will be discussed in Chapter 5. Field observations clarified the spatial distribution of tailings throughout the Wine Harbour area, and helped to determine those areas that were appropriate for more detailed study.

4.2 Locations of Tailings Deposits

On July 12, 2005, an initial reconnaissance visit to Wine Harbour was carried out to gain a general understanding of the distribution of gold mine tailings in the area. An historical map of Wine Harbour (Faribault, 1905), displaying the distribution of mill sites (Fig. 2.4), was used to help locate the areas of possible tailings deposits. Those on-land tailings deposits verified in this study are shown on a map in Figure 4.1.

At present, the tailings are highly overgrown with vegetation. This makes it difficult to ascertain their full spatial extent on land. The general location of tailings is down-gradient of old stamp mill sites, which are currently evidenced by concrete/stone foundations, timber remnants, and scrap material. All verified on-land tailings deposits are located in the northeastern section of Wine Harbour. Two separate deposits were

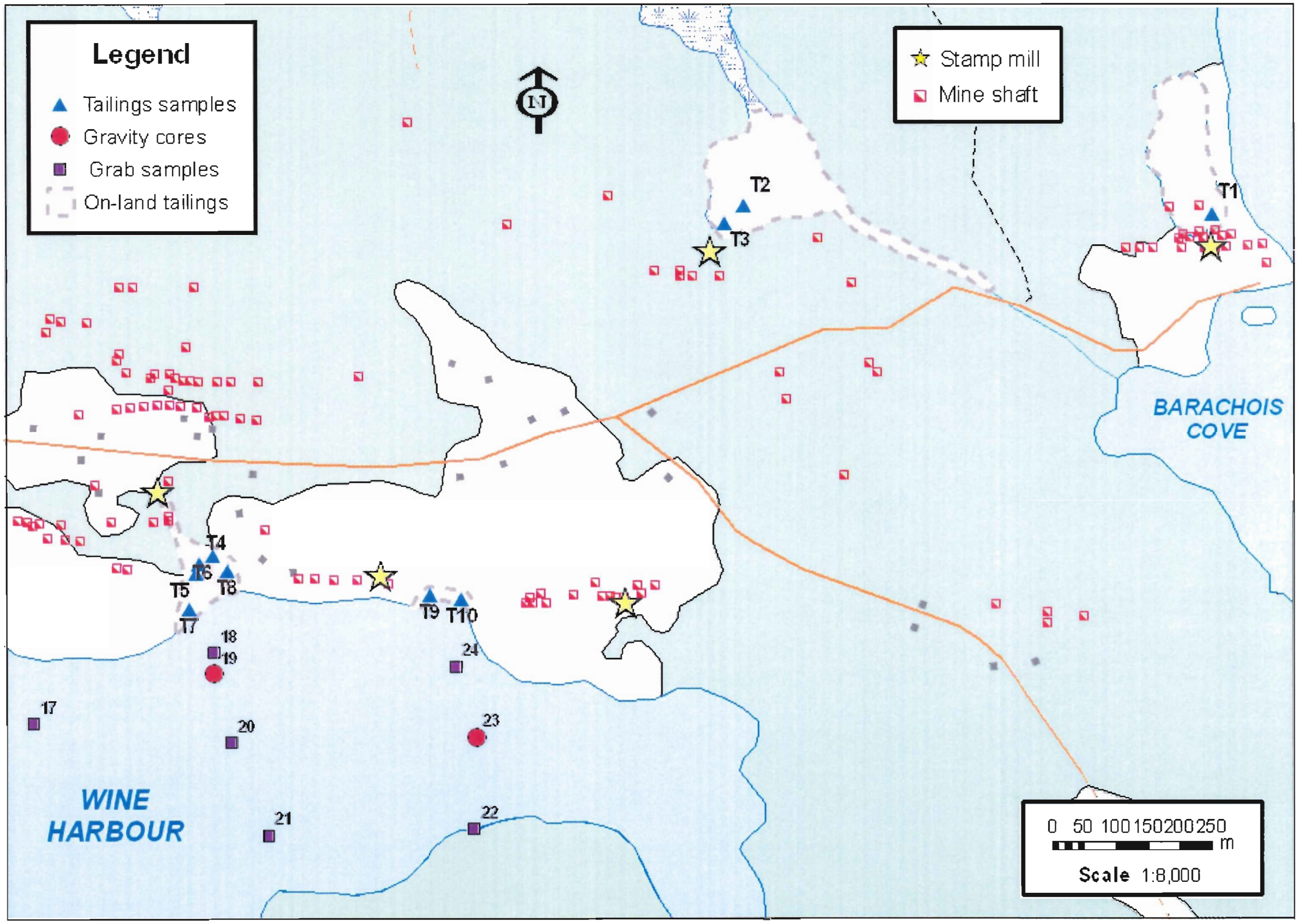


Figure 4.1 Spatial extent of on-land tailings deposits and sample locations in the Wine Harbour Gold District.

found along the shore (Fig. 4.1), just downslope from two mill sites, the Plough Lead Co's and Old Provincial Co's Mills (Figs. 2.4). Old remnants of the Plough Lead Co's Mill were located, but no remnants could be found for the Old Provincial Co's Mill. Northeast of these deposits and further inland, a third tailings area was located (Fig. 4.1) in the vicinity of the old Eureka Mill (Figs. 2.4). Timbers and a foundation from the mill structure were also found at this site. A fourth, and final site was found further east, in a swampy area along Barachois Cove.

In most areas, the Wine Harbour tailings commonly display a vertical stratigraphy (Fig. 4.2a) composed of a top-most layer of organic-rich soil, overlying rusty-brown, oxidized tailings, over light to dark grey, unoxidized tailings. At one location (T5, Fig. 4.1), a sulphide-rich lens was located within this stratigraphic sequence. Figure 4.2b shows the close vicinity of some on-land tailings deposits to the harbour itself, and rusty brown Fe-oxyhydroxide coatings are seen in Figure 4.3a. In water-logged areas, oxidized layers are often absent and only grey, unoxidized tailings are present (Fig. 4.3b). Recognition of the tailings is based on both their stratigraphy and fine-grained nature.

4.3 Tailings Chemistry and Mineralogy

Bulk chemical analyses completed on the tailings samples using ICP-ES/MS show very high concentrations of both As (200 to 200,000 ppm) and Hg (4,900 to 320,000 ppb). Additional ICP-ES/MS results from a selected group of elements are reported in Table 4.1. Graphs in Figures 4.4 and 4.5 illustrate the distribution of the As

Figure 4.2a On-land tailings stratigraphy (T5) composed of a brown, oxidized layer, overlying a dark grey, sulphide-rich lens, followed by a light grey, oxidized layer (Photo taken by M. Parsons, 2005).

Figure 4.2b Sample site T4, in close proximity to Wine Harbour, seen here in the distance (Photo taken by M. Parsons, 2005).

Figure 4.3a A groundwater outlet from underground mine workings, which runs into Wine Harbour. Iron-staining of the sediments imparts a rusty-brown colour, typical of sediments in the intertidal zone (Photo taken by M. Parsons, 2005).

Figure 4.3b Tailings sample site T9, in the intertidal zone. The tailings here are unoxidized, giving them a characteristic dark grey colour (Photo taken by M. Parsons, 2005).

Table 4.1
Concentrations of a selected group of elements in the tailings, analyzed using ICP-ES/MS

Element		Avg. Sed. Depth (cm)	Ag (ppb)	As (ppm)	Au (ppb)	B (ppm)	Cr (ppm)	Hg (ppb)	Mn (ppm)	Na (ppm)	Ni (ppm)	Pb (ppm)	S (ppm)	Sb (ppm)	V (ppm)	Zn (ppm)
Terrestrial Tailings	T1A	7.5	104	2460	701	1	8.5	10900	96	310	13	34	1400	8.0	5	49
	T2A	7.5	136	3420	220	<1	7.1	7450	599	10	23	26	2100	4.7	3	51
	T3A	20	174	13100	537	<1	6.6	11900	567	20	14	56	1000	10	2	49
	T3B	35	105	4600	274	<1	6.3	16200	391	10	33	30	2500	9.3	3	59
	T4A	20	384	7690	3760	<1	4.4	15800	58	20	13	79	6200	20	2	24
	T4B	40	161	4690	1990	<1	4.9	7130	95	10	16	34	4300	9.6	<2	21
	T5A	12	368	8100	1720	1	6.3	11800	69	30	20	103	7500	28	3	56
	T5B	27	6060	196000	29800	<1	2.6	320000	27	10	109	2090	92000	472	<2	64
	T6A	8	100	200	762	<1	6.2	4930	53	20	4.1	70	100	4.0	4	24
	T6B	25	408	5070	3700	<1	3.9	7750	83	30	6.5	65	100	11	3	22
Intertidal Tailings	T7A	5	97	185	33	9	26	600	394	2420	19	18	1900	0.60	22	49
	T8A	2.5	63	511	199	7	28	1240	382	3280	13	15	300	0.57	21	37
	T9A	2.5	149	1550	1210	2	20	9510	332	1170	17	55	3000	3.6	10	71
	T10A	2.5	13	86	30	1	4.8	444	70	1270	3.7	2	1000	0.16	3	14

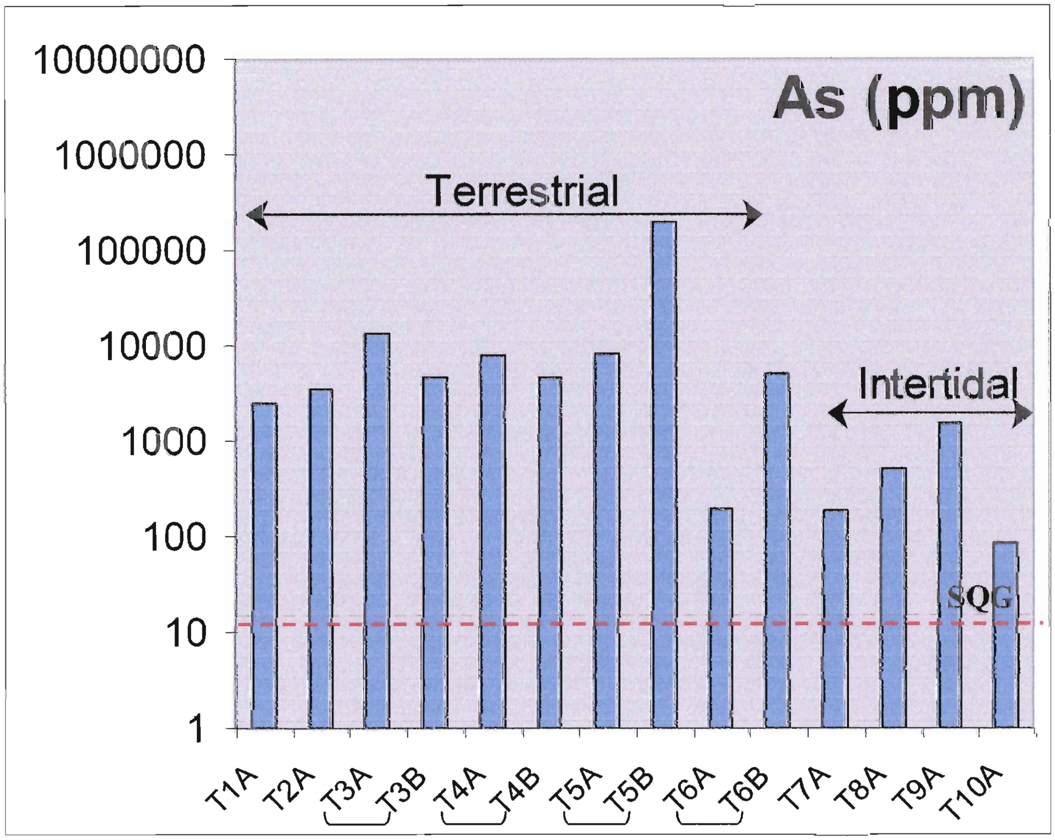


Figure 4.4 Distribution of arsenic concentrations (ppm) found in on-land tailings samples. The red horizontal dashed line shows the Canadian soil quality guideline (SQG) for arsenic in residential/parkland soils (Canadian Council of Ministers of the Environment 2004).

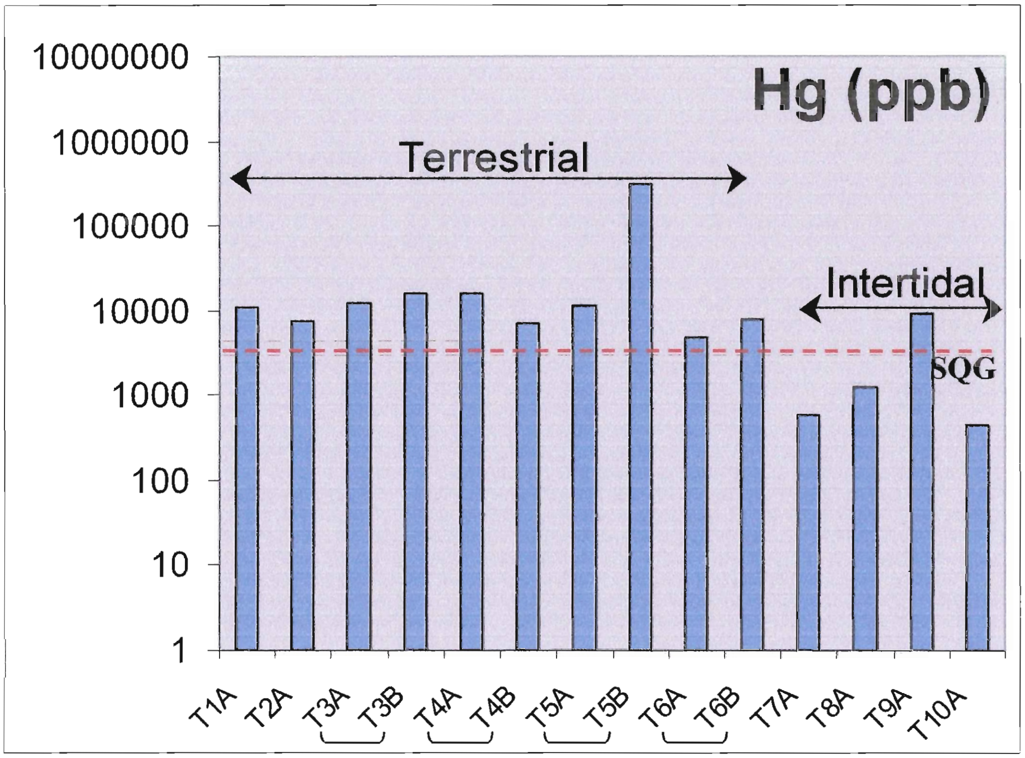


Figure 4.5 Distribution of mercury concentrations (ppb) found in on-land tailings samples. The red horizontal dashed line shows the Canadian soil quality guideline (SQG) for mercury in residential/parkland soils (Canadian Council of Ministers of the Environment 2004).

and Hg concentrations amongst the on-land tailings samples. The Canadian Council of Ministers of the Environment (CCME) has established environmental quality guidelines for As and Hg in residential/park soils at 12 ppm and 6.6 ppm, respectively (Canadian Council of Ministers of the Environment 2004), levels far lower than those found in the on-land tailings at Wine Harbour. Mean background levels for As and Hg in C-horizon till, measured at a series of gold mine districts throughout mainland Nova Scotia are 109 ppm and 86 ppb, respectively (Smith *et al.* 2005). Tailings in some areas of Wine Harbour contain levels well in excess of these numbers. The highest concentrations of As and Hg were both found in sample T5B (a sulphide-rich lens within tailings) (Fig. 4.2a), located down-gradient of the Plough Lead Co's Mill.

X-ray diffraction results indicate that the primary mineralogy of the tailings consists of quartz, chlorite, graphite, albite and muscovite, with Fe-oxyhydroxides dominating the secondary mineral phases. Smaller amounts of scorodite ($FeAsO_4{\bullet}2H_2O$) and possibly goethite were also evident in some spectra. Quartz, muscovite and graphite were found in similar quantities throughout all tailings samples. Slight variations in peak heights are evident, most prominent in those peaks corresponding to the mineral quartz. With the exception of these variations in peak heights, the patterns are relatively consistent from one sample to the next. X-ray diffraction spectra for all samples can be found in Appendix B.

In addition to X-ray diffraction, electron microprobe analyses were also carried out on grain mounts of selected tailings samples. Qualitative energy-dispersive spectrometry (EDS) analyses from the microprobe indicate the presence of accessory phases such as arsenopyrite, pyrite, pyrrhotite, ilmenite, zircon and gold. A summary of the quantitative (i.e. wavelength-dispersive) microprobe results is given in Table 4.2. The table highlights only sulphides, including arsenopyrite, pyrite and pyrrhotite in order confirm the assumption that arsenopyrite was the main host for As to Wine Harbour. In addition to the tailings samples analyzed using the electron microprobe, a sample of material panned from the Plough Lead Co's Mill foundation was also included. This sample included small grey magnetic spheres, visible gold, and Fe-stained, sand-sized material (Fig. 4.6a). Electron microprobe analyses also revealed an area of elemental mercury (Fig. 4.6b) within the same sample, which was likely derived from Hg loss during the amalgamation process. Additional EDS analyses on the Plough Lead Co's Mill spillage sample showed that the grey spheres were largely composed of iron (Fig. 4.7a & 4.7b) indicating the spheres may actually be magnetite (Fe_3O_4). The electron microprobe results for this sample (Appendix C) show low elemental totals, as it was not analyzed for oxygen. The remaining samples analyzed using the electron microprobe included four tailings samples collected on-land, in addition to two other tailing samples from the intertidal zone. The electron microprobe verified assumptions that most of these samples contained sulphides (Figs. 4.8a & 4.8b), with the exception of the intertidal marine samples (Fig. 4.9). Reaction rims were scarce around sulphides such as arsenopyrite, with most grains appearing relatively unaltered and smooth. Chemical maps, Figures 4.10a and 4.10b, of selected sulphide grains show the distribution of elements including arsenic (As), mercury (Hg), sulphur (S), iron (Fe), calcium (Ca) and silicon (Si), within the grain. The maps show the center of the grain in Figure 4.10a enriched in As and a rind of decreased As concentration around the outside of the grain.

Table 4.2

Summary of quantitative microprobe results (Mass %) for a selected group of on-land tailings samples

Element	Arsenopyrite (*n* =22)[a]			Pyrite (*n* =9)[a]			Pyrrhotite (*n* =4)[a]		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
As[b]	39	45	42	<0.02	0.1	0.08	<0.02	<0.02	<0.02
Ca[b]	<0.009	0.04	0.02	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
Fe	33	35	40	44	45	44	56	57	57
Hg[b]	<0.04	0.1	0.06	<0.04	0.08	0.06	<0.04	<0.04	<0.04
S	20	24	22	52	54	53	38	40	39

[a] n = number of analyses

[b] element present at concentrations below the detection limit

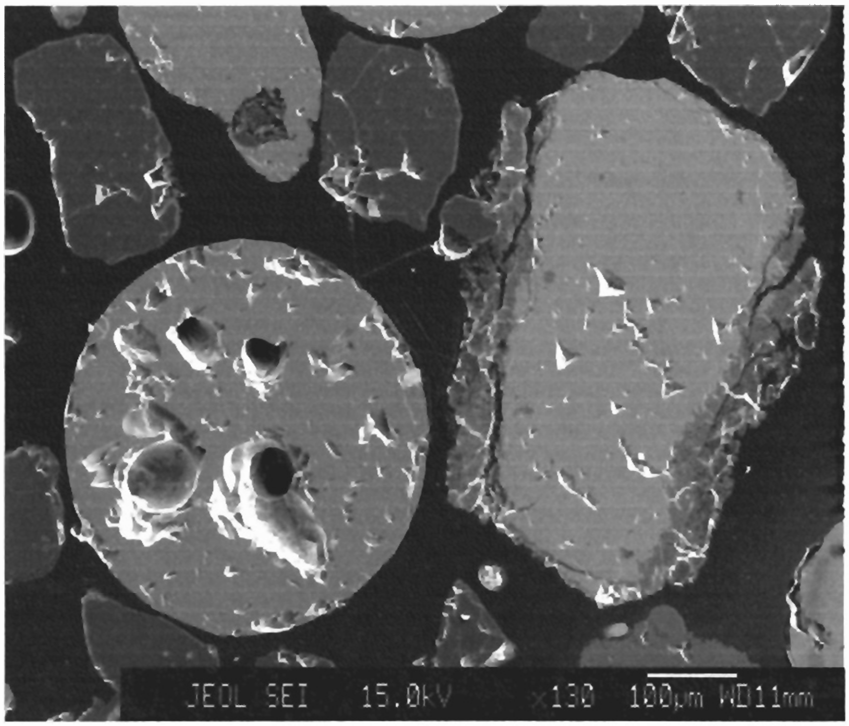


Figure 4.6a Secondary electron image of an Fe-rich sphere (left) and an arsenopyrite grain with a scorodite reaction rim (right) found in the Plough Mill spillage sample.

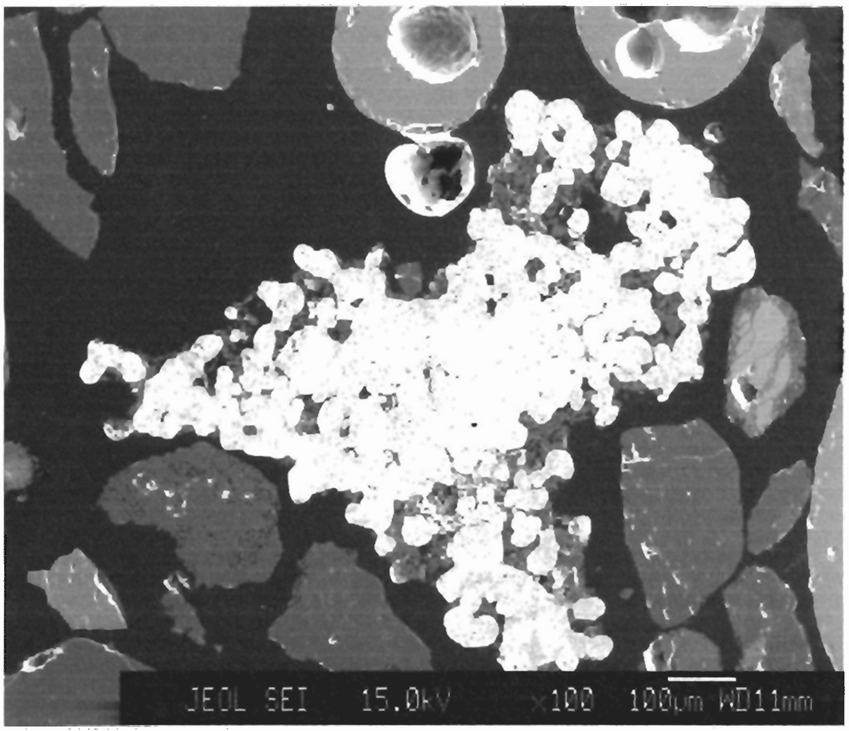


Figure 4.6b Secondary electron image of elemental Hg (white area) in the Plough Mill spillage sample.

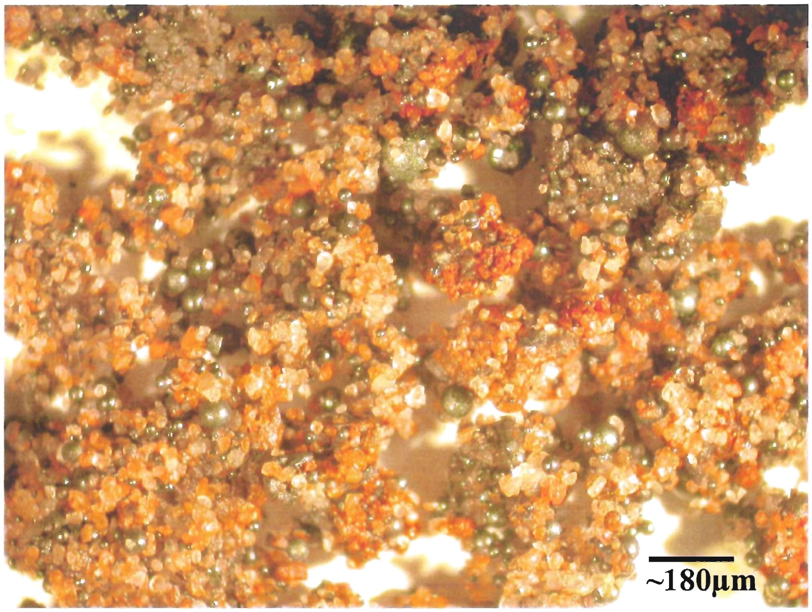


Figure 4.7a Plough Mill spillage sample showing an abundance of dark grey, Fe-rich spheres.

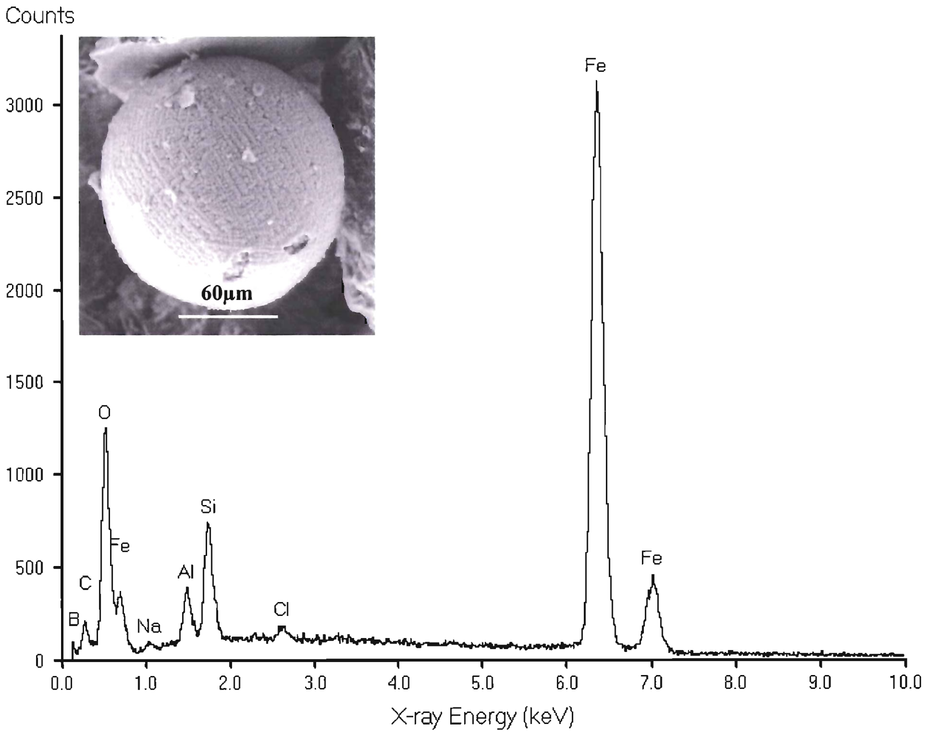


Figure 4.7b EDS spectra and SEM photo of an Fe-rich sphere from the Plough Mill spillage sample.

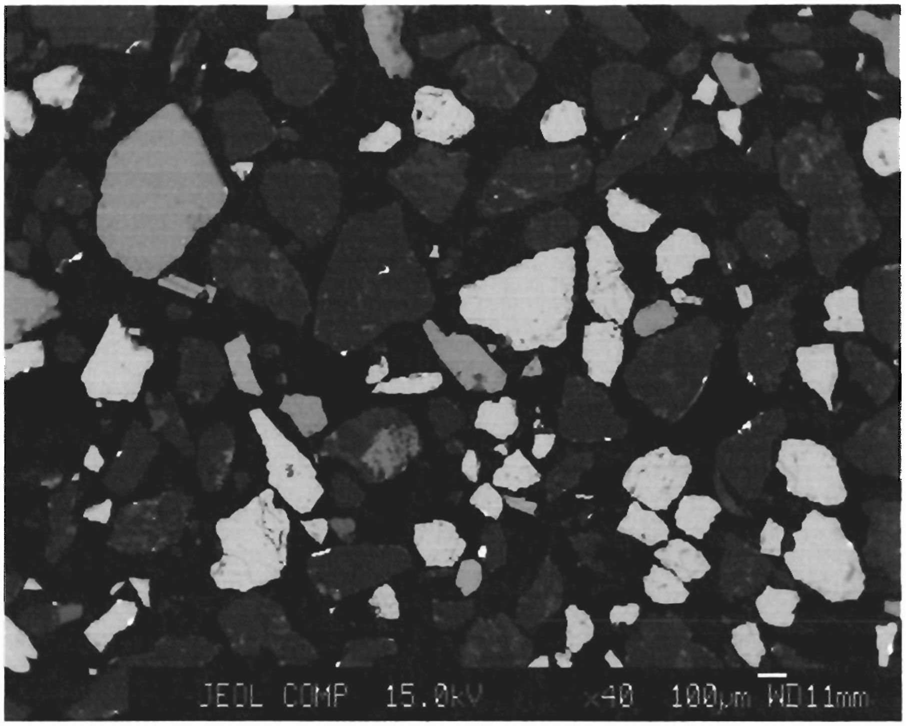


Figure 4.8a Secondary electron image of the sulphide-rich tailings sample, T5B. Sulphides show up as the lighter grains in the back-scatter images.

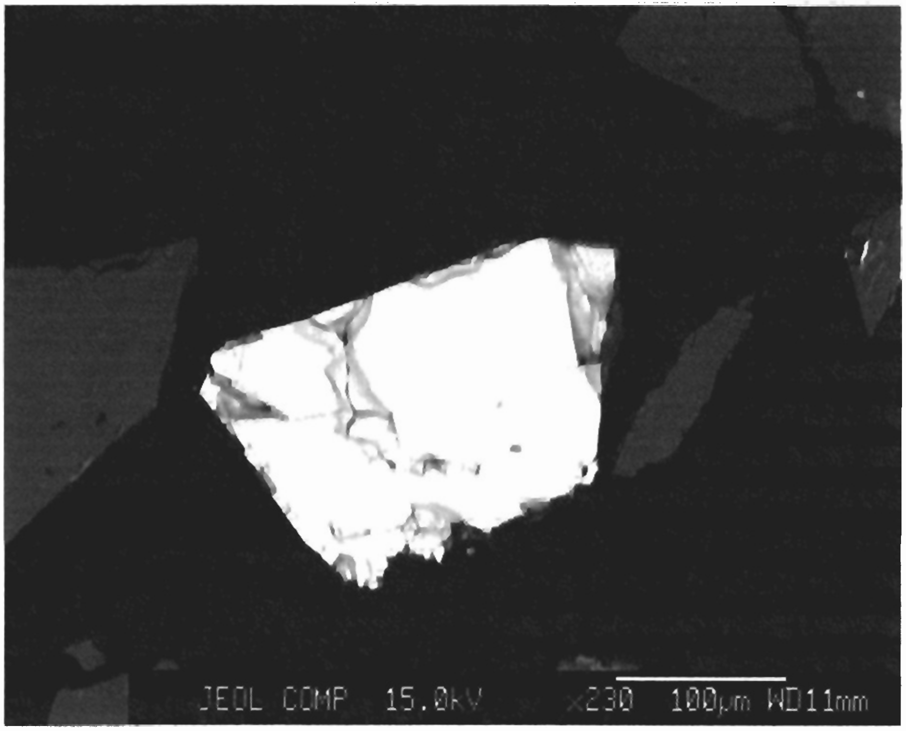


Figure 4.8b Secondary electron image of a pyrite grain in tailings sample T4B.

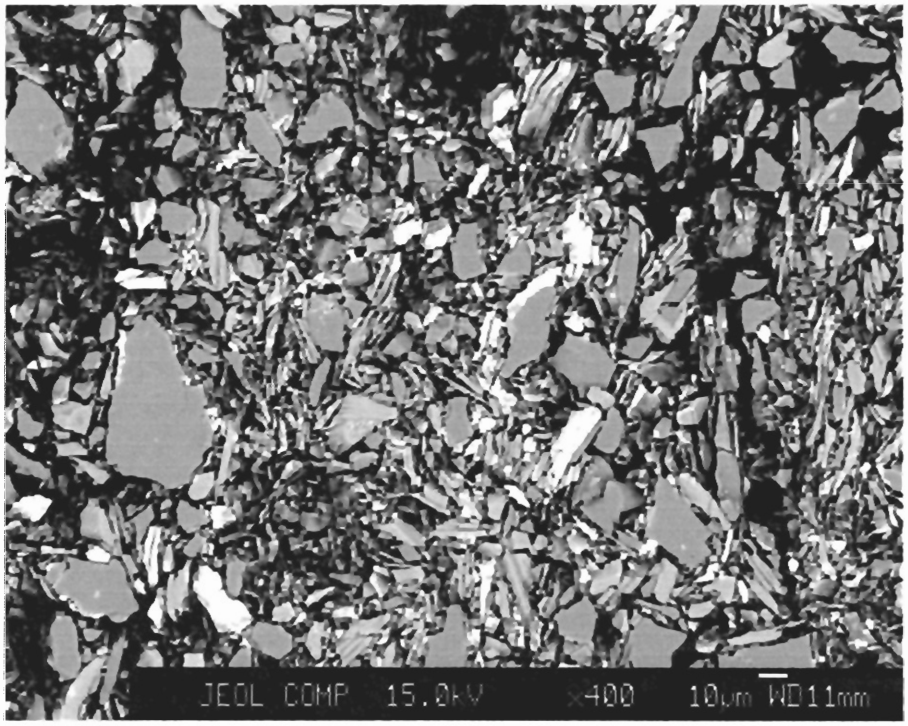


Figure 4.9 Secondary electron image of the marine sample T9A. This sample is very fine-grained, containing no sulphide grains. The white areas are Pb, used in the preparation of the grain mounts.

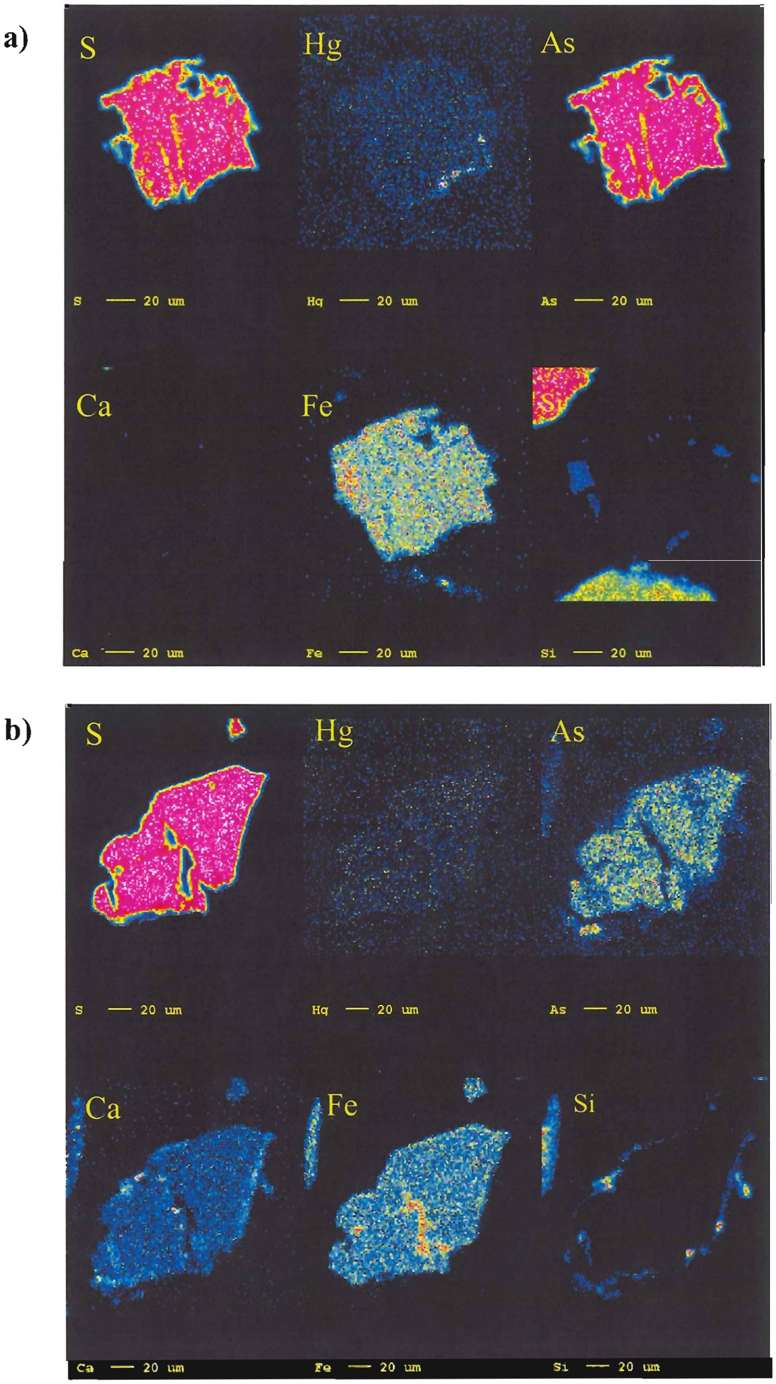


Figure 4.10 Chemical maps of a) an arsenopyrite grain from sample T4A and; b) a pyrite grain from sample T5A. The colours indicate the number of counts for that element in a particular location of the grain, where bright pink represents the highest count and blue, the lowest.

Also seen on this grain, is a small area of increased Hg concentration on the bottom right corner. Chemical maps for the remainder of the samples can be found in Appendix G.

4.4 Marine Sediment Composition

Bulk compositional analyses completed on grab samples of marine sediments and the top 15 cm of gravity cores also show very high concentrations of both As (4 to 1550 ppm) and Hg (5 to 9500 ppb). The spatial distribution of these two elements throughout the harbour is shown in Figures 4.11 and 4.12. These maps illustrate the average As and Hg concentrations in grab samples and the top 15 cm of gravity cores because of the ecological importance of this layer. Studies suggest that the zone of active bioturbation in most marine sediments occurs only to a depth of approximately 15 cm (Boudreau 1998). The maps show elevated concentrations of both As and Hg occurring in the same three locations, along the shoreline of Wine Harbour. In the eastern end of the harbour, the highest metal(loid) concentrations are located down-gradient of the Plough Lead Co's Mill and Provincial Mill sites (Fig. 2.4). The very high As and Hg levels in sediments from the small inlet at the western end of Wine Harbour were unexpected, as historical maps do not show this area. Malcolm (1976) does refer to a cyanide plant built Coopers Brook in 1899, however no remains were found. The overgrown vegetation in these areas presents the possibility that additional mill structures remain undiscovered. Another important feature to note is a mussel aquaculture operation located within this small inlet, which extends into the main part of the harbour (Figs. 4.11-12). Table 4.3 summarizes the concentrations of selected elements in the marine sediment subsamples. This table does not include those samples collected within the intertidal zone.

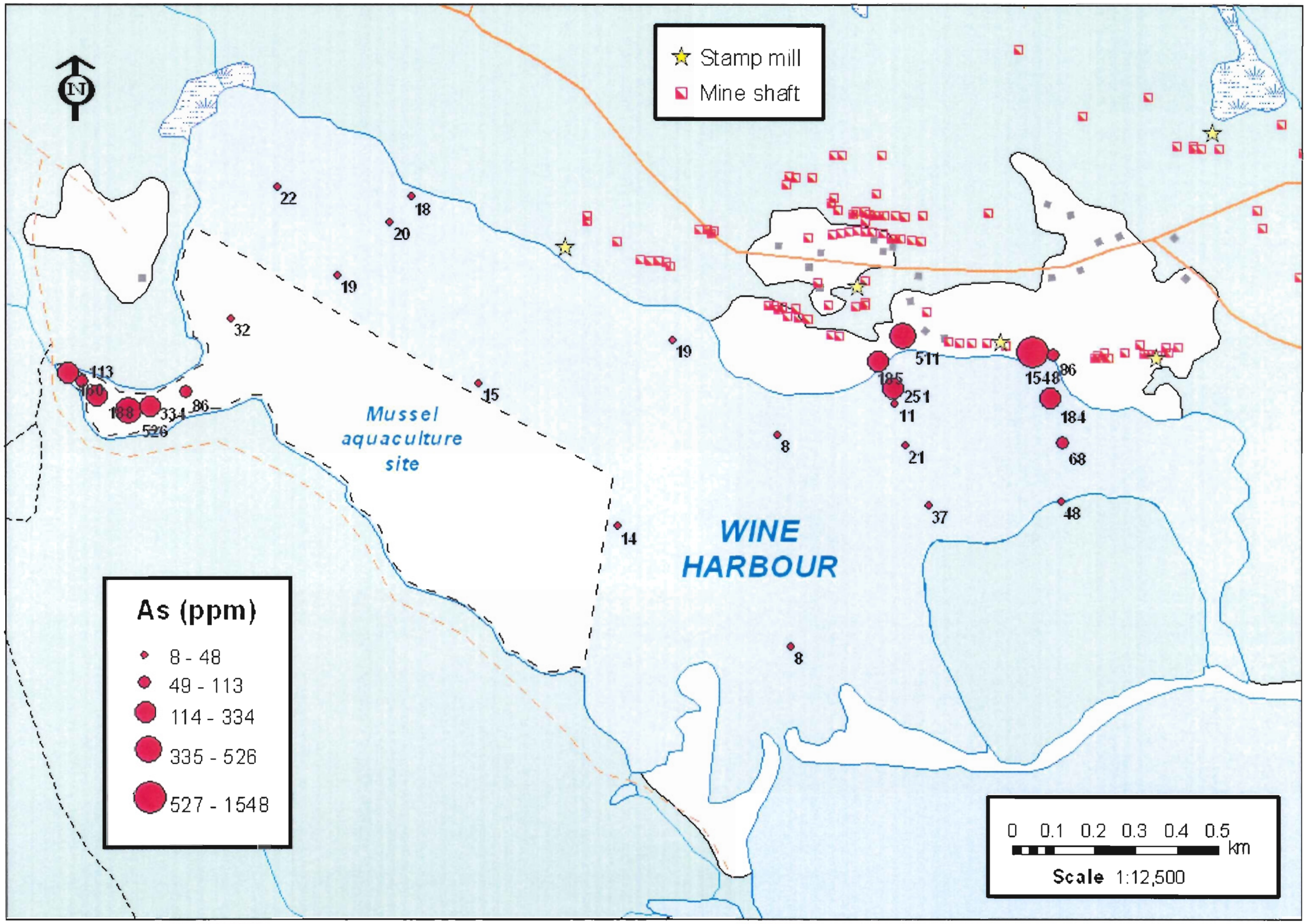


Figure 4.11 Arsenic concentrations (ppm) in marine sediments in Wine Harbour. Mean concentrations are shown for grab samples and the top 15 cm of gravity cores.

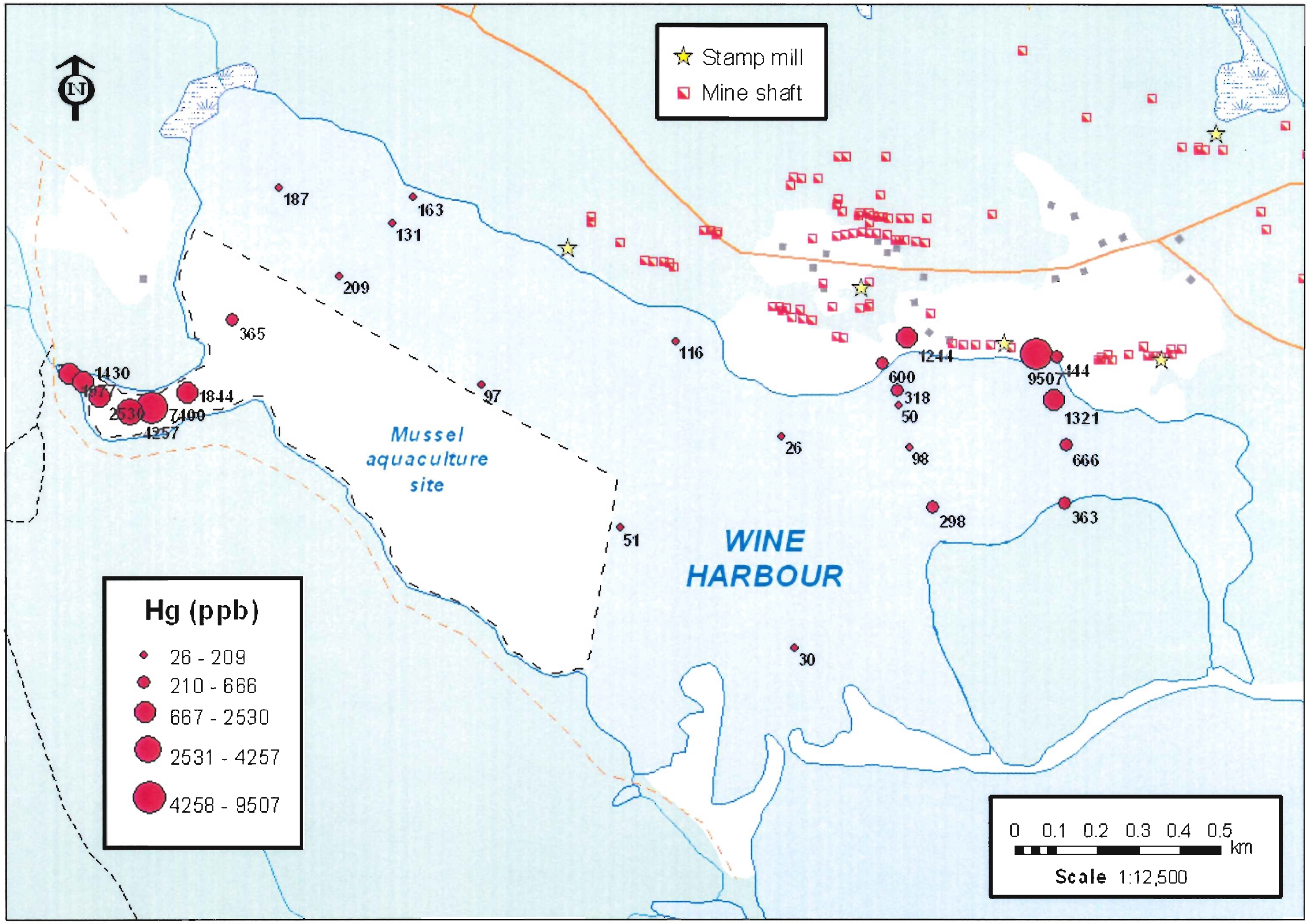


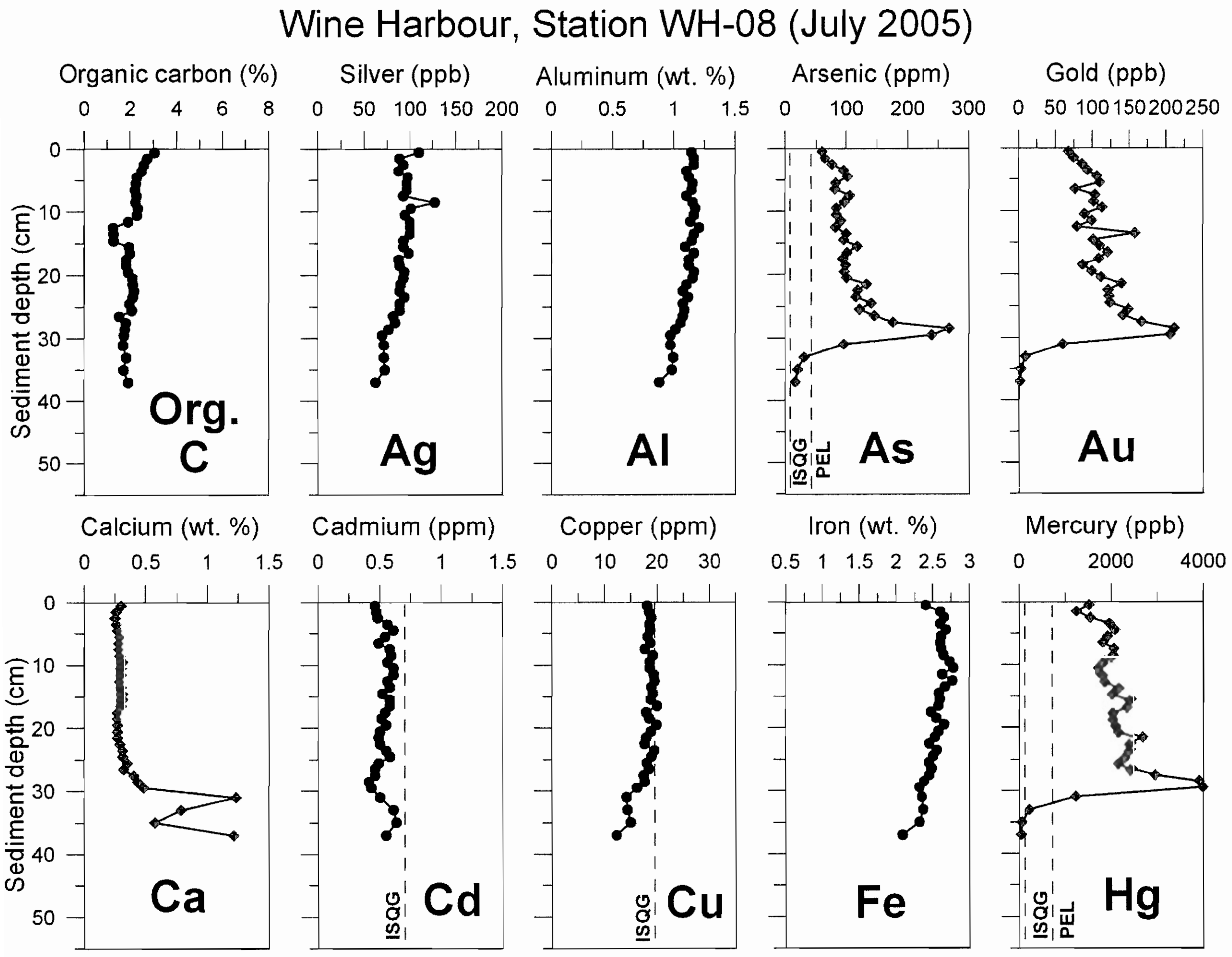
Figure 4.12 Mercury concentrations (ppb) in marine sediments in Wine Harbour. Mean concentrations are shown for grab samples and the top 15 cm of gravity cores.

Table 4.3
Summary of selected marine sediment chemistry results

Element	As ppm	Cd ppm	Cu ppm	Fe % dry wt.	Hg ppb	Mn ppm	Ni ppm	Pb ppm	Zn ppm
Minimum	4	0.09	6.8	1.27	5	290	11	5.4	26
Maximum	570	0.91	30	3.69	7400	970	26	53	78
Average	66	0.39	16	2.21	810	420	20	16	52
n[a]	229	229	229	229	229	229	229	229	229

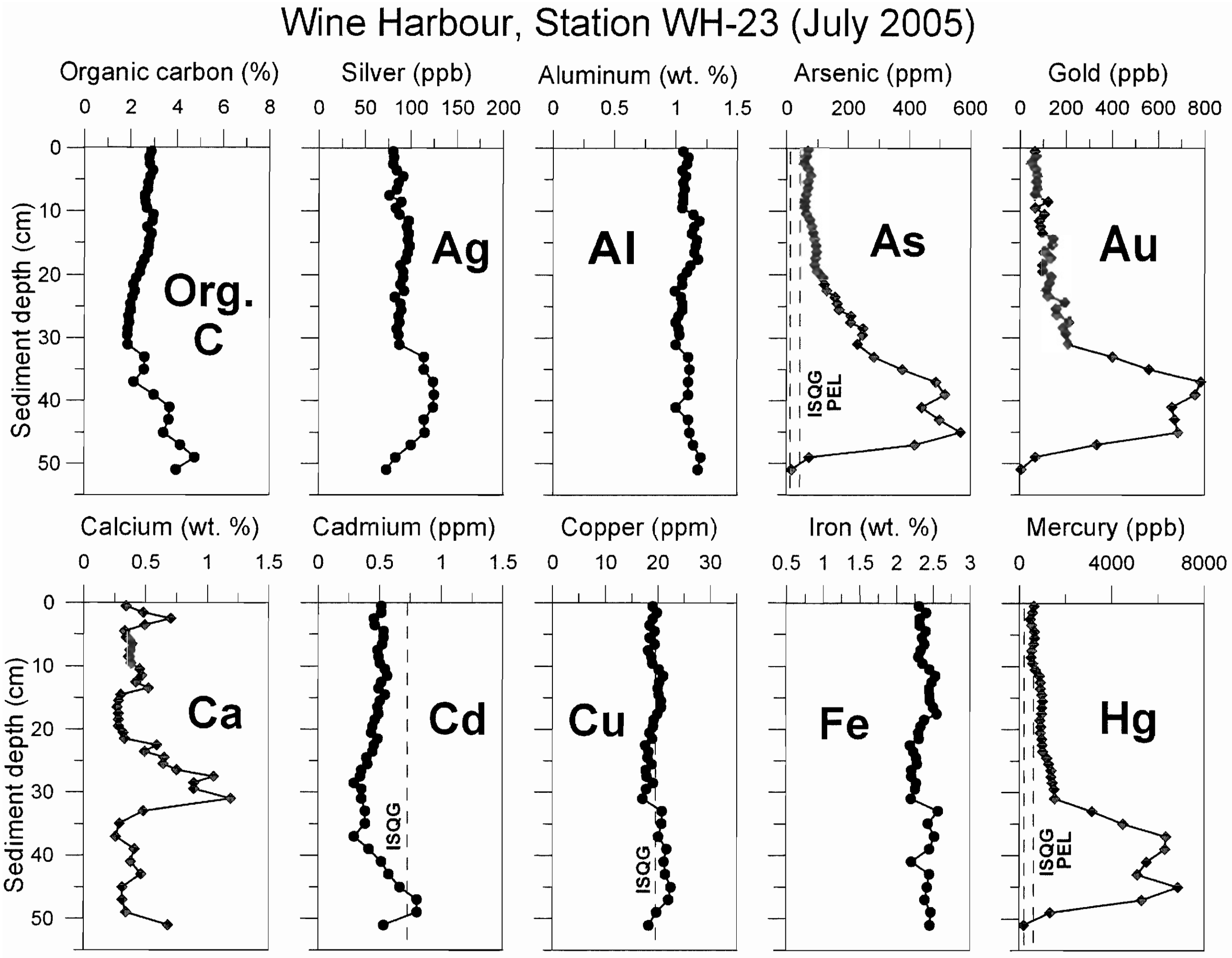
[a] n = number of analyses

Vertical core profiles produced for each of the six gravity cores illustrate the distribution of As, Hg, and other elements with depth. The concentrations of Ag, Al, Au, Ca, Cd, Cu, Fe, Li, Mn, Mo, Ni, Pb, S, Sb, Tl, V and Zn, as well as organic carbon were also plotted for correlation purposes. Core WH-08, in Figure 4.13a shows anomalously high levels of As (60 ppm) and Hg (1510 ppb) at the surface of the core, with an overall continuous increase in concentrations observed down to a depth of ~30 cm. At the 30 cm depth, both As and Hg reach their peak concentrations, at 267 ppm and 3980 ppb, respectively. Below these peaks, there is a noticeable decrease in As and Hg concentrations, to minimums of 16 ppm and 40 ppb respectively. A strong correlation can be seen between As, Hg, Au and Sb, all reaching peak concentrations at the same depths in the core. Calcium shows the opposite pattern; at 30 cm its profile shows a large decrease in concentration. The geochemical data for WH-23, Figure 4.13b, also shows elevated As (67 ppm) and Hg (622 ppb) at the surface. Two large pulses in As (516 & 568 ppm) and Hg (6340 & 6860 ppb) concentrations occur at depths of approximately 39 and 45 centimeters, and then decrease steadily towards the sediment-water interface, indicating that the tailings are overlain by a cleaner layer of sediments, thereby removing the main source of contamination from the biologically active surface layer. Similar to core WH-08, at depths below the As and Hg peaks, concentrations decrease to a minimum of 15 ppm As, and 189 ppb Hg. Gold shows the same pattern, reaching concentrations up to 783 ppb. There are two main guidelines plotted on some of the core profiles, the Canadian interim sediment quality guideline (ISQG) and the probable effect level (PEL). The guidelines, established by the CCME, provide a rough indication of the level of contamination in the bottom sediments of Wine Harbour (Canadian Council of



Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Figure 4.13a. Geochemical data showing element concentrations vs. depth for Core WH-08, collected in the western end of Wine Harbour. PEL = probable effect level, ISQG = interim sediment quality guideline.



Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Figure 4.13b. Geochemical data showing element concentrations vs. depth for Core WH-23, collected in the eastern end of Wine Harbour. PEL = probable effect level, ISQG = interim sediment quality guideline.

Ministers of the Environment 2002). The ISQG and PEL define three ranges of total concentration for a given element, including: those concentrations that are rarely (<ISQG), occasionally (>ISQG and <PEL), and frequently (>PEL) associated with adverse biological effects on the most sensitive receptor (Canadian Council of Ministers of the Environment 2002). In this case, the ISQG/PEL guidelines for As and Hg in marine sediments are 7.24/41.6 ppm and 130/700 ppb respectively. Core profiles for the remainder of the cores can be found in Appendix H.

Various processes can control the shape of core profiles, including sediment grain size variation. Figure 4.14a shows the concentrations of nickel (Ni) versus lithium (Li) for all marine sediment subsamples. For the purposes of this study, Li is used as a proxy for sediment grain size variations. The strong correlation of Ni with Li seen in this graph indicates that the predominant control on Ni concentration is changes in the sediment grain size. In contrast, plots for As and Hg versus Li, in Figures 4.14b and 4.14c, show no correlation between the two elements and Li. This lack of correlation indicates that the As and Hg concentrations in the marine sediments are largely controlled by an external source, in this case, the tailings.

4.4 Water Chemistry

Stream water samples collected around Wine Harbour show relatively little contamination from previous gold mining operations. Table 4.4 shows selected water-quality data collected from the five sites labeled in Figure 3.1. The results represent water compositions during a single sampling event on July 20, 2005. For each of the five sites sampled, the pH remained relatively constant, with a narrow range between 5.4-5.8.

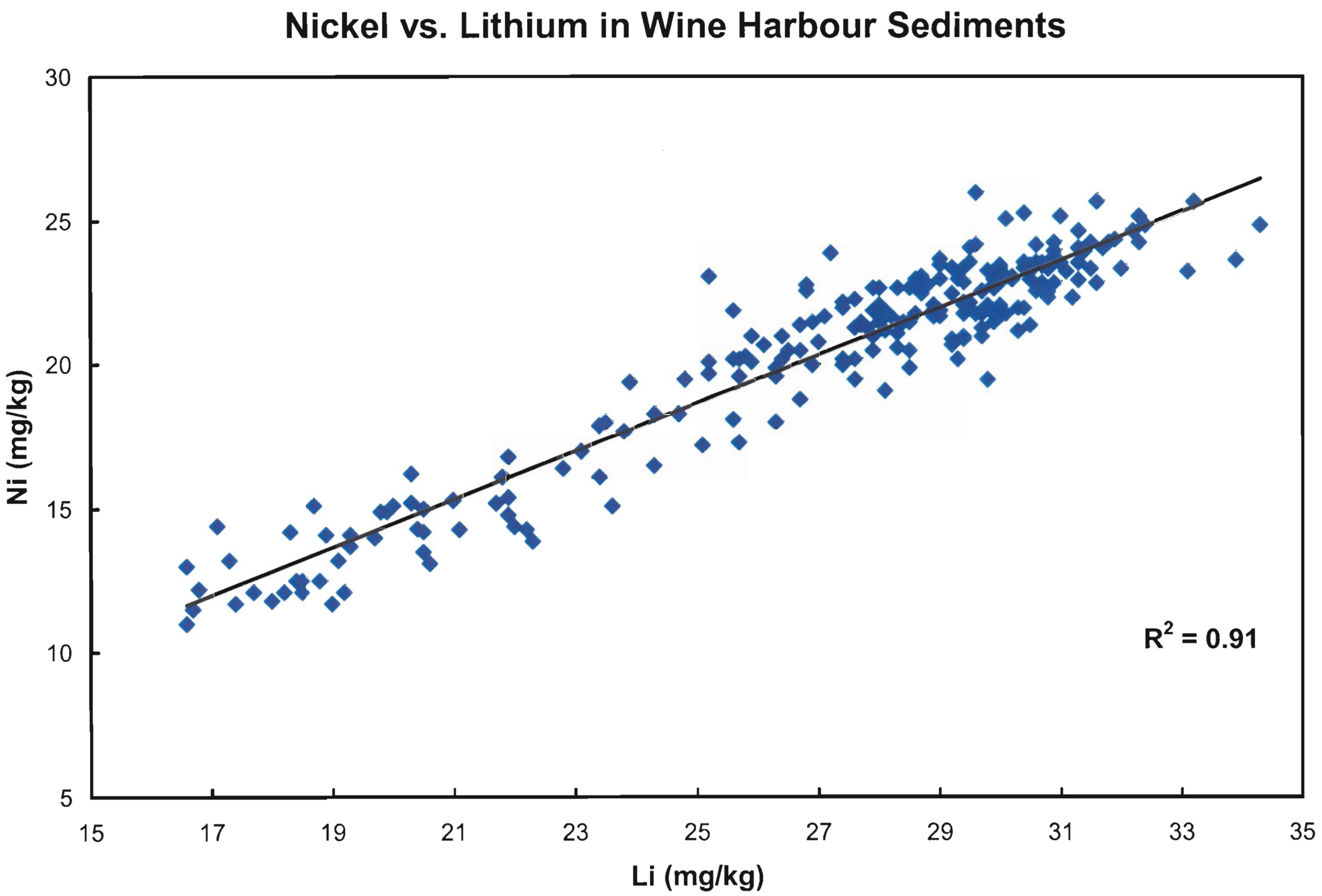


Figure 4.14a Concentrations of Ni versus Li in marine sediments from Wine Harbour. See text for further explanation.

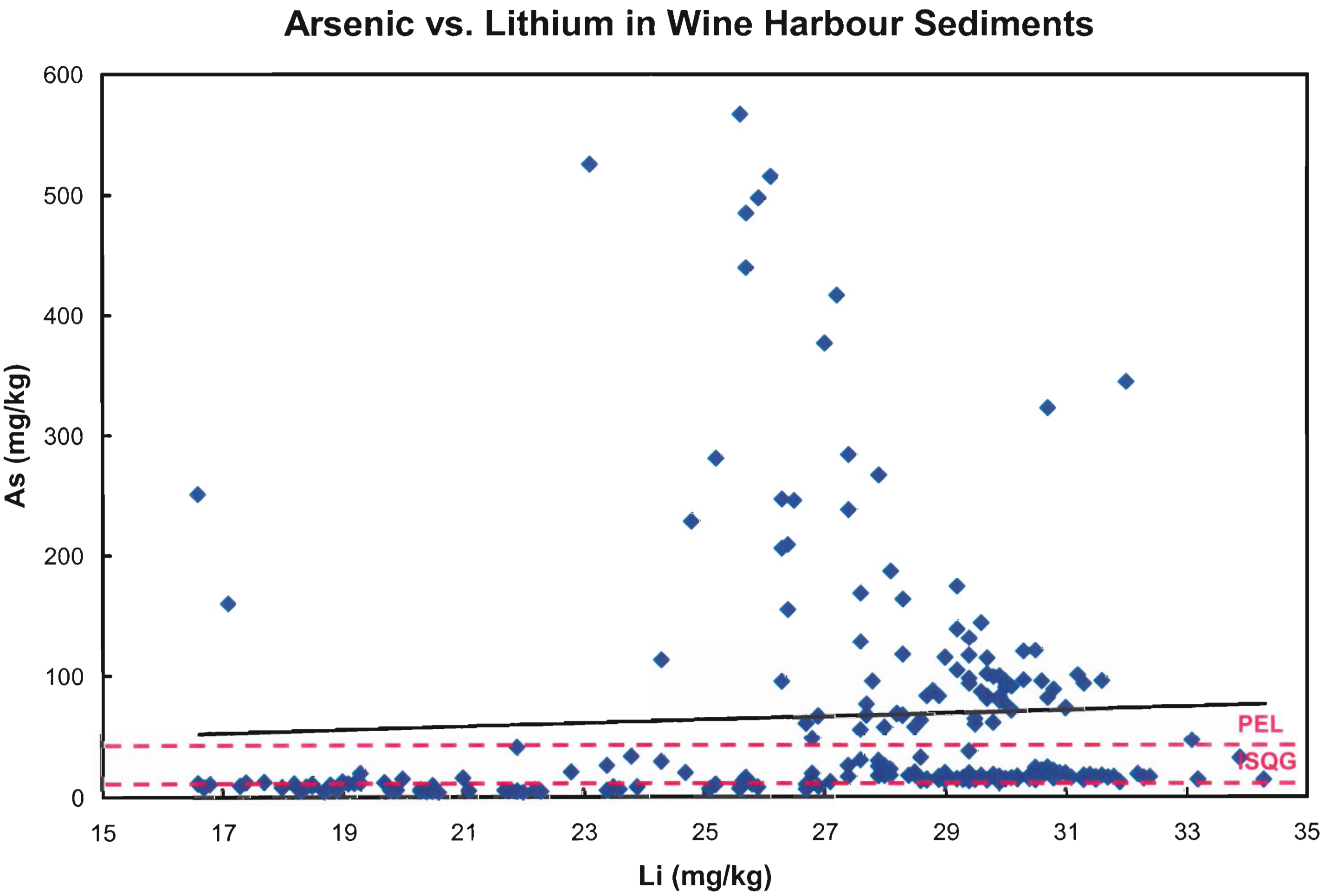


Figure 4.14b Concentrations of As versus Li in marine sediments from Wine Harbour. See text for further explanation.

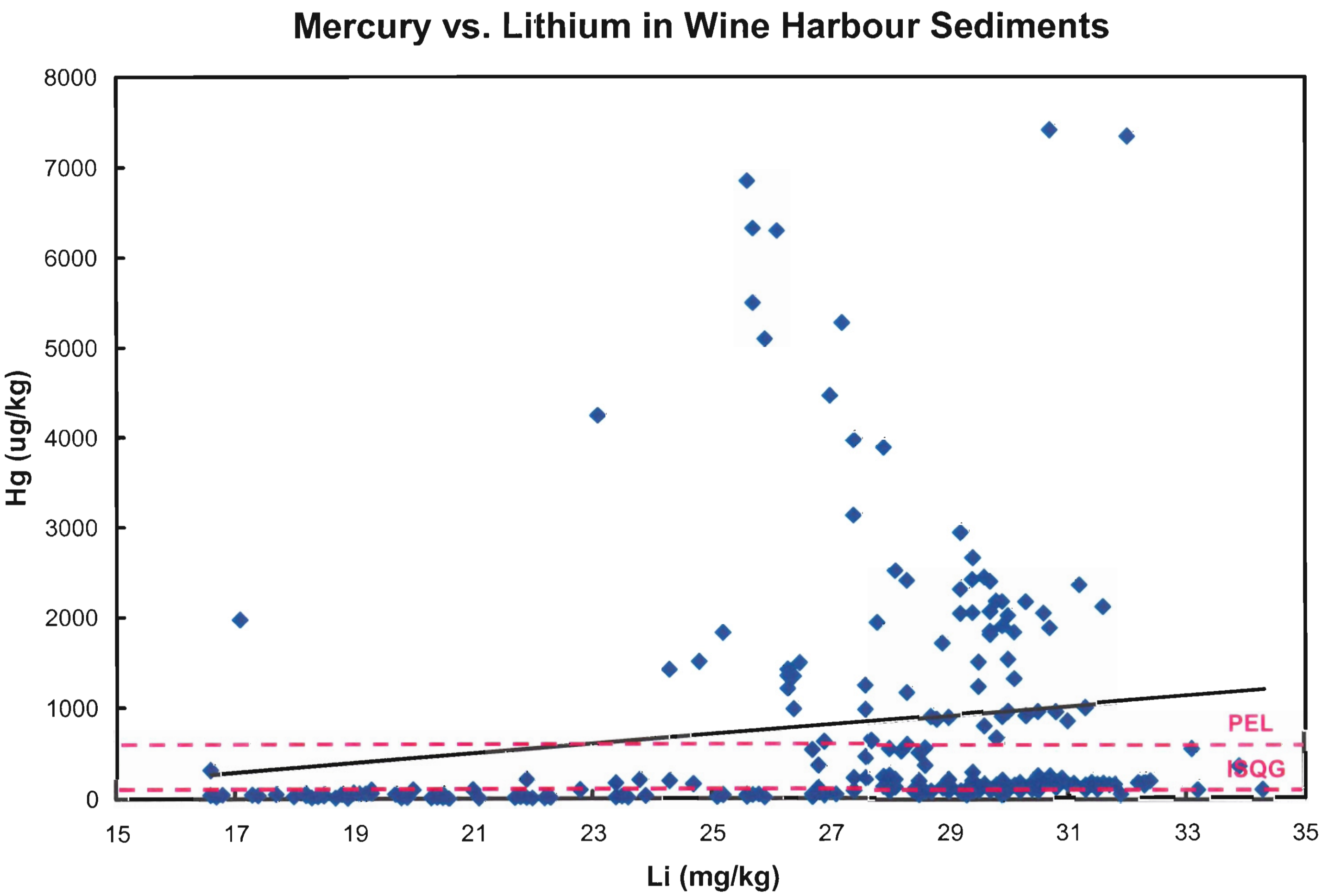


Figure 4.14c Concentrations of Hg versus Li in marine sediments from Wine Harbour. See text for further explanation.

Table 4.4
Selected water chemistry results

		W1		W2		W3		W4		W5				
Constituent	Units	Coopers Brook		Drainage through Eldorado Mill tailings		Brook at western end of Wine Harbour		Barachois Brook		Stream draining from shaft near Eldorado Mill		Field blanks		
pH	Standard units	5.40		5.51		5.49		5.75		5.44				
Temp	°C	19.5		8.6		18.0		18.6		6.9				
Conductivity	μS/cm	42		120		47		58		128				
Alkalinity	ppm	<1		30		3		3		31				
		Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	Filtered	Unfiltered	TB AUG C	AB AUG C	SB AUG C
DOC[a]	ppm	12	na	3	na	15	na	16	na	2	na	na	na	na
Al	ppb	140	160	11	15	190	200	150	170	9	82	< 2	< 2	< 2
As	ppb	1	1.5	35	40	1.7	2.2	17	23	23	140	< 0.1	< 0.1	< 0.1
Ca	ppm	1.3	1.3	10.9	11	1.5	1.5	1.8	1.8	11	11	0.29	0.26	0.26
Cl	ppm	7.4	na	12.4	na	9	na	11	na	12	na	na	na	na
Fe	ppm	0.64	1	0.18	0.26	0.51	0.69	0.84	1.3	0.12	1.9	< 0.005	< 0.005	< 0.005
Hg	ppt	4.4	5.6	6.9	11	6.4	6.9	7.5	10	3.1	25	< 0.5	0.7	< 0.5
Mn	ppb	140	150	480	480	44	52	210	220	100	590	< 0.1	0.3	0.3
Ni	ppb	0.3	0.5	0.3	0.4	0.3	0.3	0.4	0.4	0.3	0.8	< 0.2	< 0.2	< 0.2
Pb	ppb	0.26	0.39	0.08	0.11	0.14	0.33	0.23	0.4	0.05	0.38	< 0.01	< 0.01	< 0.01
SO_4	ppm	2.3	na	4.8	na	2	na	1.7	na	5	na	na	na	na
Zn	ppb	1.2	1.2	1.2	1.2	1	0.9	1.3	1.3	1.3	3.3	7.5	41.9	40.6

[a] DOC = dissolved organic carbon
na = not analyzed

At site W2, located directly in the Plough Lead Co's Mill tailings, the mildly acidic pH value suggests that acid released during the oxidation of sulphide minerals has been buffered by reaction with other minerals present in the tailings (Mosher, 2004). The range of water temperatures in July at Wine Harbour was 6.9-19.5 °C, with an average of 14.3 °C. The low of 6.9 °C was measured at site W5, which likely represents a groundwater sample. The stream here is located in a steep-walled channel in the bedrock, and drains directly from an infilled shaft adjacent to the Plough Lead Co.'s Mill. This channel appears to be lined with timbers, and is thought to be an old tailings sluice, used to conduct tailings toward Wine Harbour. The conductivity of all stream waters ranged from 42.6-129 μS/cm.

Filtered and unfiltered water samples were collected from all sites and analyzed for dissolved (<0.45 μm) and total concentration of cations and Hg. This type of analysis indicates the dominant form of the element, occurring as a dissolved species or as a component in the suspended sediment. Results show dissolved Hg concentrations ranging from 3.1-7.5 ppt and dissolved As ranging from 1.0-35 ppb. Total Hg concentrations have a range of 5.6-25 ppt and total As, a range of 1.5-140 ppb. The relative percentages of the dissolved and suspended fractions are approximately 65 and 35 % As, compared to 64 and 36 % Hg. These percentages indicate that the majority of the As and Hg entering the harbour from freshwater sources is in the dissolved phase.

Health Canada (2004) has established a guideline for Canadian drinking water quality at a limit of 25 ppb for As and 1 ppb for Hg. Arsenic concentrations in two streams cutting through the Plough Lead Co's tailings area (Fig. 4.15) are above the

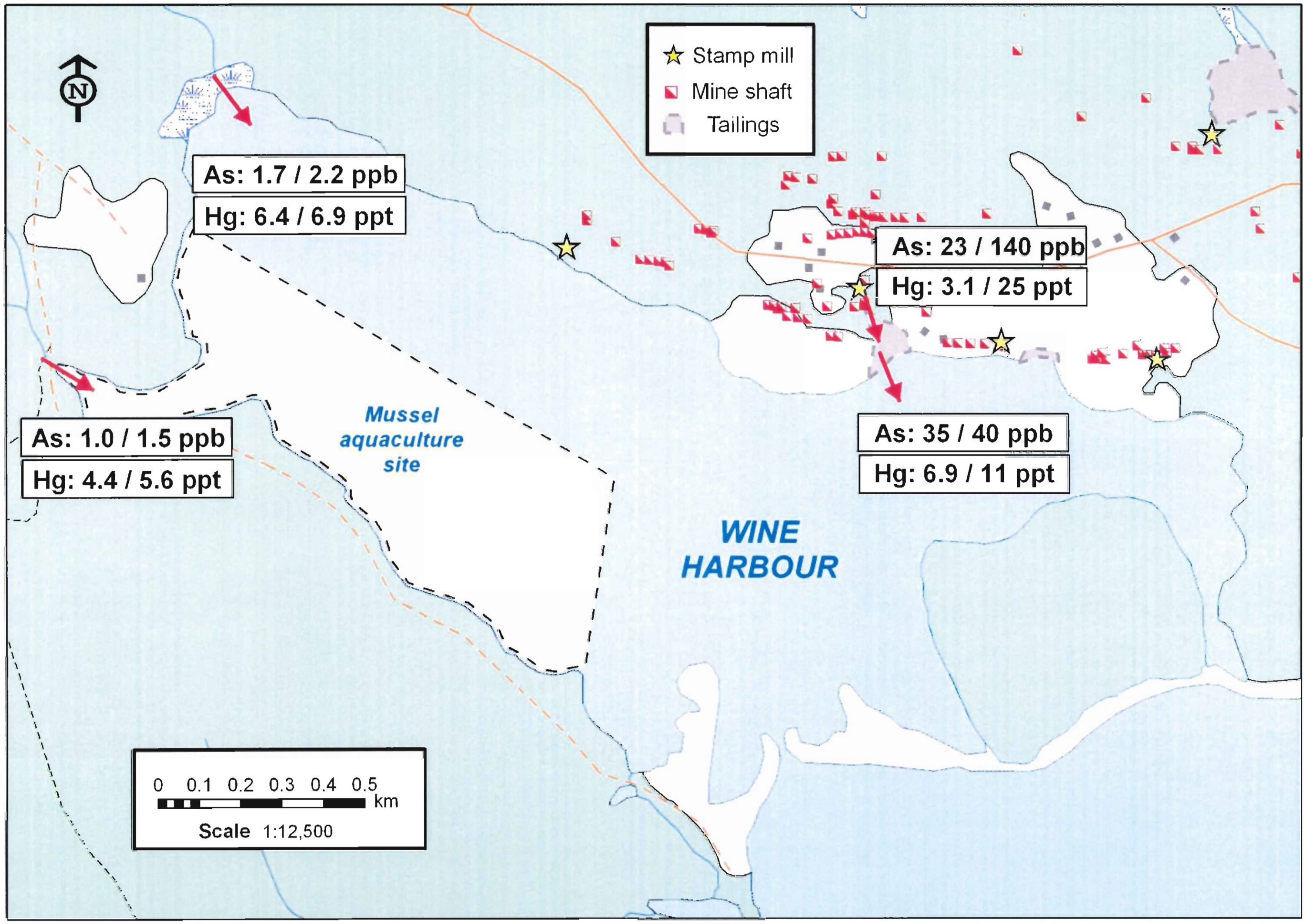


Figure 4.15 Arsenic (ppb) and mercury (ppt) concentrations (<0.45μm/total) in freshwater streams draining into Wine Harbour.

above this guideline. In contrast, Hg does not exceed this guideline in any of the streams draining into Wine Harbour.

4.6 Summary

The Wine Harbour tailings deposits are located within the vicinity of old stamp mill sites, inland and along the shores of the harbour. The stratigraphy of the tailings varies between a combination of red-oxidized and light grey-unoxidized tailings found inland, and the dark grey to black tailings found in water-saturated areas such as the intertidal zone. The primary mineralogy of the tailings includes quartz, muscovite and chlorite, with accessory phases including, arsenopyrite, pyrite, ilmenite, zircon and gold. iron-oxyhydroxides are the dominant secondary minerals, with lesser quantities of scorodite also present. Electron microprobe analyses indicate that the majority of sulphide grains are arsenopyrite. The concentrations of As and Hg in the tailings ranged from 200 to 200,000 ppm As and 4900 to 320,000 ppb Hg. Marine sediment (including the intertidal zone) concentrations of As and Hg were 4-1550 ppm and 5-9500 ppb respectively. The highest concentrations of As and Hg in the marine sediments are found along the shores of Wine Harbour and within a small inlet at the western end of the harbour. Geochemical data from a core collected within the small inlet show elevated As (67 ppm) and Hg (622 ppb) concentrations even at the top of the core. A second core from the harbour's eastern end shows the highest concentrations of As (568 ppm) and Hg (6863 ppb) at approximately 40 cm depth. The stream waters at Wine Harbour were slightly acidic and had a relatively stable pH (6.9-19.5). The dissolved concentration of mercury ranged between 3.1 and 7.5 ppt, with an arsenic range between 1.0 and 35 ppb.

Total mercury concentrations ranged between 5.6 and 25 ppt, with arsenic ranging between 1.5 and 135 ppb. These results show that the disposal of tailings at Wine Harbour has had a large impact on the marine sediments, while the stream waters show little contamination.

CHAPTER 5: DISCUSSION

5.1 Introduction

Gold mining and milling practices at Wine Harbour have left a noticeable impact on both the terrestrial and marine environments. On-land tailings and marine sediments reveal As and Hg levels that are commonly well in excess of the Canadian Council of Ministers of the Environment (CCME) environmental quality guidelines, raising concern about the potential for adverse impacts on both ecosystem and human health. Geochemical studies have verified the distribution of tailings deposits near historical mine workings, and also the extent of mine tailings in the adjacent marine environment. The majority of the tailings deposits are located in areas previously mapped (Glover *et al.* 1983), with one exception located at the western end of the harbour. The geoscience data presented in this thesis can be used to support ongoing risk assessment activities related to elevated As and Hg levels in the Wine Harbour area. Additional studies in complementary disciplines must be conducted before an accurate assessment of As and Hg bioavailability can be made. This chapter provides further interpretation of the results presented in Chapter 4, and a brief discussion of the factors controlling the cycling and bioavailability of As and Hg at Wine Harbour.

5.2 Tailings Distribution in the Wine Harbour Gold District

A combination of field observation and geochemical analyses have confirmed the presence of four main tailings deposits, down-gradient of known historical stamp mill structures in the Wine Harbour Gold District (Fig. 4.1). Their occurrence is consistent with the distribution of mill sites on the historical map for this gold district (Fig. 2.4). There is one exception, however, in a shallow inlet at the western end of the district, where Coopers Brook (sample site W1 on Fig. 3.1) drains into Wine Harbour (Figs. 4.11-12). The on-land tailings are overgrown with vegetation making the determination of their spatial extent difficult. The extent of oxidation in these tailings is highly variable, producing a vertical stratigraphy consisting of a top-most organic-rich soil, overlying a layer of rusty-brown oxidized tailings which transition into grey, unoxidized tailings at greater depths. In water-logged areas, the composition of the tailings deposits is less variable; the tailings have a characteristic light to dark grey colour due to reduced oxygen penetration in these saturated environments.

Mineralogical analyses of the on-land tailings samples using the electron microprobe and X-ray diffraction revealed arsenopyrite as the dominant sulphide phase in the tailings and it is, the main host for As. At deeper levels in the tailings, and under reduced conditions, sulphides such as arsenopyrite are stable and remain unaltered. In contrast, the sulphides in well-drained areas are variably oxidized, producing secondary phases such as Fe-oxides and Ca-Fe arsenates. The decrease in As concentrations away from the center of the grain shown in Figure 4.10a, indicates oxidation of the arsenopyrite, and the subsequent formation of secondary phases. This oxidation of sulphide grains leads to the release of As and S into the surrounding environment (Nriagu 1994). Loading of As and Hg into freshwater streams around Wine Harbour as a result of this process is evident at water sample sites W5 and W2 (Fig. 3.1), where dissolved/total As and Hg concentrations reach maximum levels of 35/140 ppb and 6.9/25 ppt, respectively (Fig. 4.15). In contrast, the high levels of Hg in the tailings are not naturally occurring, but are associated with Hg loss during the amalgamation process. This was confirmed by the discovery of elemental Hg in the Plough Lead Co's Mill spillage sample (Fig. 4.6b), as well as a small area of increased Hg concentration, which appears to be adsorbed or wetting the surface of the arsenopyrite grain seen in Figure 4.10a.

Very high levels of As and Hg (up to 200,000 ppm and 320,000 ppb, respectively) were recorded in most tailings samples, the highest of which were in the on-land deposits. Historical documentation indicates that the bulk of stamp-milling operations at Wine Harbour were situated in the eastern portion of the district; as a result, the majority of tailings deposits are confined to this area.

Elevated levels of As and Hg found in the marine sediments along the shores of Wine Harbour suggest that the tailings have been transported to the ocean (Figs. 4.11-12). Geochemical data suggest that there are three separate deposits of this nature. Two sites in the eastern end of the harbour, showing elevated As and Hg, are located down-gradient of known stamp mill sites (Fig. 4.1). Based on these findings, it can be inferred, that the As and Hg levels found in the marine sediments at these localities originated from the same source as those tailings deposits mapped on-land. These marine tailings could be the product of direct slurrying into the harbour, and/or direct precipitation of As- and Hg-enriched sediments from the contaminated effluent. At the third site, located in the small inlet at the western end of Wine Harbour, As and Hg levels found in the bottom sediments suggest an additional tailings deposit. With the lack of historical documentation on mill construction at this end of Wine Harbour, it is difficult to ascertain the source of this particular tailings deposit; therefore, further studies must be conducted to confirm its source. The lower levels of As and Hg found in the marine environment result from the increased dilution and sediment settling that occurs as the tailings are transported farther from their source.

Electron microprobe analyses revealed a distinct compositional difference between the on-land tailings deposits and those from within the intertidal zone. Samples recovered from the intertidal zone contained very few to no sulphide grains, indicating the dilution of tailings upon entry into the harbour, and sulphide oxidation in the shallow marine sediments. Additionally, bulk chemical analyses also reveal this compositional difference in tailings at the two sites. Table 4.1 shows much higher Na and B contents in the intertidal samples than those in the on-land samples.

Analyses of vertical metal profiles (maximum depth = 50 cm) in gravity cores give an idea of the tailings distribution in the deeper waters. The cores show peak concentrations of As and Hg at similar depths, followed by decreasing concentrations towards the sediment-water interface (Fig. 4.13a & 4.13b; Appendix H). This mid-depth enrichment of As and Hg suggests that the tailings were deposited during a single event. Preliminary ^{210}Pb and ^{137}Cs data show that these peaks are the result of deposition during periods of known milling (1862-1939) (J. Smith, DFO pers. comm., 2006). The strong correlation of peaks seen in As, Hg and Au concentrations indicates that the anomalously high levels of As and Hg can be attributed to the historical gold mining and milling practices. In contrast, Ca concentrations, such as those observed in core WH-08 (Fig. 4.13a), drop significantly with the addition of large quantities of As and Hg to the marine sediments. Shells are abundant in this area of the harbour, and are likely the dominant source of Ca in the sediments, with lesser quantities resulting from carbonates found in the tailings themselves. A large influx of As and Hg could effectively smother existing shellfish, explaining the sharp decrease in Ca. Additionally, organic carbon does not show a strong correlation with other metal(loid)s in the sediments, indicating that organic matter has little control on the shape of these vertical profiles. Overall, the core profiles show peak concentrations of As and Hg above background levels, typically at mid-depth (20 cm – 45 cm) in the cores, with a decrease in concentration towards the core surface, reflecting the end of milling operations in the late 1930s. A combination of active bioturbation and the deposition of cleaner sediments on top of these layers of maximum concentration can likely explain the gradual, and often, uniform decrease in As and Hg concentrations towards the core surface. Mixing of marine sediments through bioturbation processes can be seen in core WH-08 (Fig. 4.13a), evidenced by the jagged profile shown in As and Hg concentrations with decreasing depth towards the sediment-water interface. The most pronounced peaks of As and Hg are found along the shores of Wine Harbour, in cores WH-08, 19 and 23, closer to the point sources of contamination. In summary, three distinct ranges in As and Hg concentrations are evident in some of the cores (e.g. WH-23 in Fig. 4.13b), each representative of a specific period in time. The lowest concentrations found in the deepest sediments, represent the pre-industrial period. Immediately above this layer, peak concentrations in both As and Hg are indicative of the active gold mining period between 1862 and 1939, while the decrease in As and Hg concentrations towards the sediment-water interface are interpreted as post-mining sediments (1939 to present day).

A comparison of the geochemical data from marine sediments in a series of Nova Scotia inlets, including Wine Harbour, and unpublished data for neighboring gold districts, Isaacs and Seal Harbour, further confirms that the As and Hg levels found in the marine sediments at Wine Harbour are anomalously high (Fig. 5.1). The As levels present in the marine sediments of Wine Harbour are within the same range as those recovered Isaacs and Seal Harbours. Mercury on the other hand shows a different pattern; the Hg levels found in Wine Harbour represent the highest concentrations recovered among the inlets, with the exception of Halifax Harbour. The high levels of Hg in the Wine Harbour sediments are attributed to the mercury amalgamation process, which was the principle method of extraction used during the period of gold production (1862-1939). In contrast, neighboring Seal Harbour, with relatively low Hg levels, used cyanidation as its principle extraction method. The high concentrations of Hg found in Halifax Harbour sediments occur in samples collected from areas contaminated by raw sewage and industrial activities.

Overall, the on-land tailings show substantially higher levels of As and Hg than the marine environment, suggesting the dilution of tailings upon introduction into the aquatic environment. The streams surrounding Wine Harbour remain relatively clean, showing little contamination with As and Hg.

5.3 Controls on the Cycling and Bioavailability of Arsenic and Mercury

Metal(loid)s are released to the environment through both natural and anthropogenic processes, often accumulating to high levels in sediments, and subsequently may be incorporated into the surrounding biota (Campbell *et al.* 1988). The elevated levels of As and Hg found in some areas of Wine Harbour do exceed the CCME PEL considerably, but this alone is not necessarily indicative of toxicity. However, results such as this do suggest that further studies should be carried out to rule out

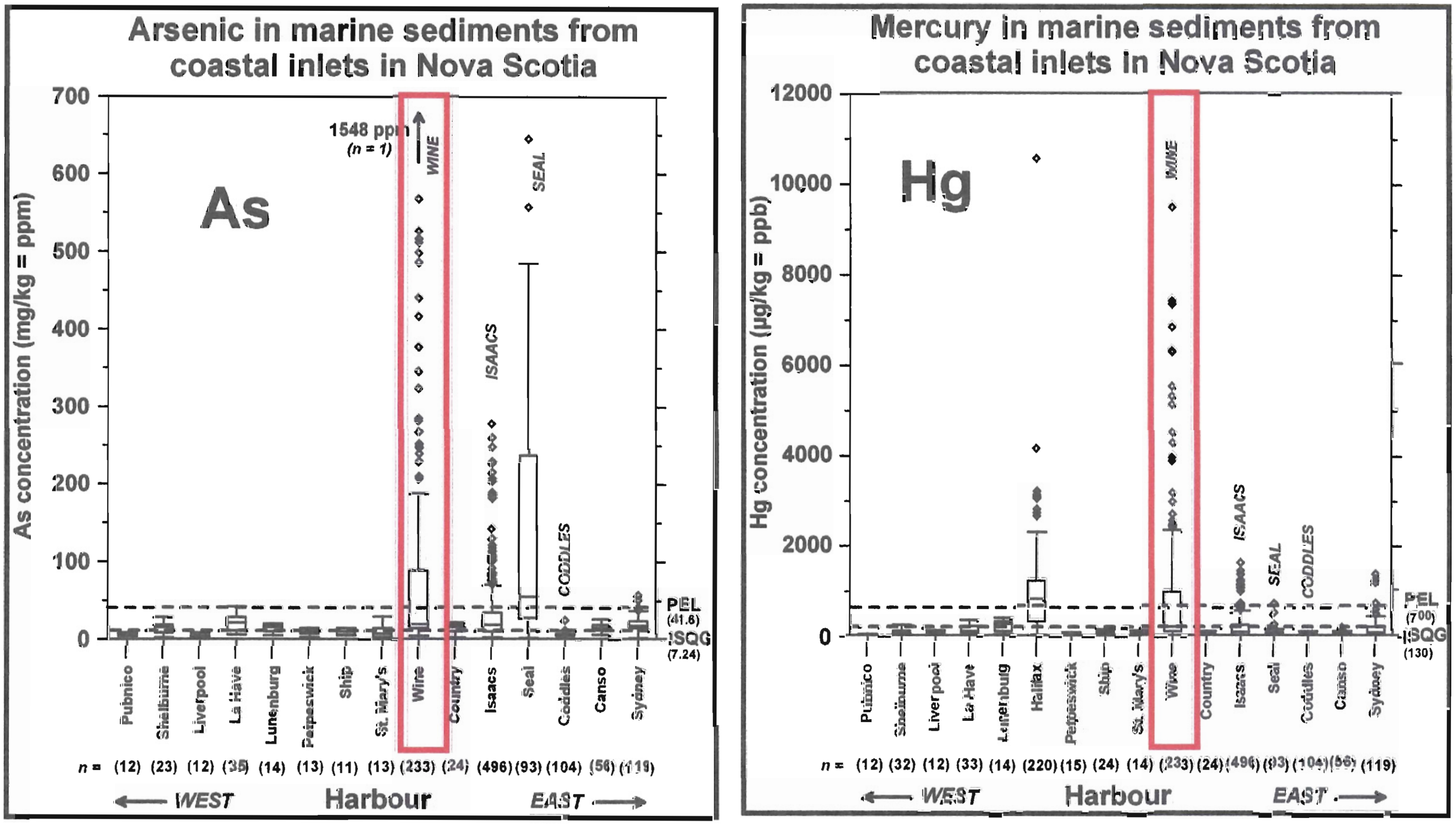


Figure 5.1 Arsenic (ppm) and mercury (ppb) concentrations in marine sediments in a series of coastal inlets in Nova Scotia (Diagrams compiled by M. Parsons 2005, from data in Winters *et al.* 1991; Loring *et al.* 1996; Stewart *et al.* 2001).

adverse biological impacts. Determination of the bioavailability of As and Hg is a complex task, requiring a multidisciplinary study, which is beyond the scope of this thesis. A number of parameters, such as the chemical, physical and biological properties of the organisms must be taken into account for an accurate evaluation of metal(loid) uptake.

The term "biological availability" refers to any metal(loid) which exists in a chemical state that can be taken up by an organism, and can subsequently react with its metabolic system (Campbell *et al.* 1988). Various factors can influence the bioavailability of metal(loid)s in marine sediments, including (1) the form and reactivity of the metal(loid); (2) the grain size and redox state of the sediments; (3) mobilization of sediments; (4) the ability of the metal(loid) to adsorb to other particulate matter, and; (5) the extent of bioturbation in the sediments.

In sedimentary environments, metal(loid)s such as As and Hg occur in both the dissolved and particulate phase, in a variety of chemical forms (Campbell *et al.* 1988). Measurements of the total metal(loid) concentration is, therefore, rarely useful in the determination of an elements biological availability. The thermodynamic and kinetic properties that control the bioavailabilty of a metal(loid) are dependent on the specific chemical species present in the water column or sediment.

The surface area of sediments has an effect on the number of surface-binding sites per unit mass of the particle (Luoma 1989). Coarser-grained, sandy sediments have a much smaller surface area per unit mass than do finer-grained, silty sediments. Sandy sediments therefore have a smaller number of binding surfaces in comparison to finer-grained sediments. This property causes differences in the bioavailability of metal(loid)s through the effects on their distribution between sediment and water (Luoma 1989).

The oxidation state of a metal(loid) often influences its bioavailability by altering its mobility in the environment (Campbell *et al.* 1988). Arsenic in particular, is more mobile and potentially more biologically available in its reduced state (Campbell *et al.* 1988); therefore, an understanding of the redox state of the element itself is an important factor to consider with respect to bioavailability.

The remobilization and subsequent redistribution of sediments in an aquatic environment has the potential to locally alter the bioavailability of As and Hg. Overall, Wine Harbour is a well-isolated body of water; however, comparison of airphotos spanning a number of years shows a noticeable shift in the barrier beach at the entrance to the harbour. Large storm events are likely along the shores of Nova Scotia, and are capable of reworking the bottom sediments. Entrainment of these sediments into the water column has the potential to both remobilize and/or bury the sediment-bound As and Hg.

Binding substrates in the sediments and/or water column are also important to take into consideration. Minerals such as Fe-oxyhydroxides and clays are effective binding substrates for As (Langston 1985), removing free As from the water column. At Wine Harbour, freshly precipitated Fe-oxyhydroxide coatings are found on surface marine sediments, and could be acting as a control on the distribution of As in the harbour. Although not as effective, organic material can also play a role in the partitioning of As (Langston 1985). In contrast, the distribution of Hg found in oxidized surface sediments is generally controlled by the content of organic matter (Langston

1985). These two factors could have a significant control on the bioavailability of As and Hg to those organisms living in Wine Harbour.

From a biological perspective, bioturbation in the top layer of sediments can result in the upward movement of metal(loid)s, and subsequently release them into the water column. Chemical reactions within the sediments can also be affected by bioturbation, indirectly impacting the fate of the metal(loid)s in the sediment.

At Wine Harbour, there remain a number of uncertainties, including those parameters above, which require further study before accurate predictions of the bioavailability of As and Hg can be made.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

The results obtained during this study show significant As and Hg contamination of both the terrestrial and marine environments at Wine Harbour. This is the direct result of historical gold mining and milling practices, which were active in the area between 1862 and 1939. Arsenic is concentrated in the sediments as a result of the weathering of arsenopyrite grains found in the waste rock and tailings piles, while the elevated Hg concentrations are attributed to losses from the amalgamation process used in the recovery of gold.

Tailings are dispersed throughout both the terrestrial and marine environments, with those on-land tailings located along the shores of Wine Harbour containing the highest concentrations of As and Hg. This study confirmed the spatial relationship between the on-land tailings and the location of historical mill structures shown on historical mining maps. A map showing the spatial distribution of the verified on-tailings deposits reveals that they are concentrated in the eastern end of Wine Harbour, where the majority of the stamp-milling operations were carried out.

The dispersal of tailings through slurrying and subsequent erosion has resulted in areas of elevated metal(loid) concentrations also occurring in the harbour. Vertical core profiles show that the highest levels of As and Hg in the marine sediments have been subsequently buried by a cleaner layer of sediment. However, levels are still very high at the sediment-water interface along the northeastern shoreline of Wine Harbour, down-gradient of known mill sites. Unexpectedly, the bottom sediments in a small inlet at the western end of the harbour contain the highest As and Hg levels measured at the sediment-water interface in Wine Harbour. Due to a lack of historical documentation for this portion of Wine Harbour, further studies are required to confirm the source of these high metal(loid) concentrations. Possible sources could include a documented cyanide plant on Coopers Brook, or additional mill sites which remain undiscovered.

The freshwater streams draining into Wine Harbour show little contamination with respect to As and Hg resulting from stamp-milling operations. The highest concentrations are found in a stream at the eastern end of the harbour, which cuts through a known tailings deposit. However, in comparison to the levels found in the marine and on-land tailings, contamination from freshwater input is minimal.

Results of this investigation can be used to help assess potential ecosystem and human health risks associated with the high levels of As and Hg recovered in the sediments of the historical Wine Harbour Gold District. It is not possible to ascertain the bioavailabilty of As and Hg from their total concentrations alone. Further multidisciplinary studies are suggested, incorporating data from chemical, physical and biological investigations. It is recommended that a sampling of mussels at the aquaculture site should be undertaken to ensure that these shellfish are not contaminated with As and Hg. Additional analyses should include determination of; (1) the speciation of As and Hg in sediments and water; (2) sediment pore water compositions; (3) the ability of metal(loid)s to adsorb to particulate matter; (4) the redox state of the sediments; (5) variations in grain size and redistribution of sediments; (6) the extent of bioturbation; and, (7) the feeding habits of resident biological organisms.

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APPENDIX A: SAMPLE SITE DESCRIPTIONS

APPENDIX A: SAMPLE SITE DESCRIPTIONS

T1

Tailings north of historical mill site, in a low, swampy area, next to Barachois Cove. One sample collected. In the ~30 cm hole, stratigraphy includes a 5 cm thick organic-rich soil layer overlying a 15 cm thick layer of light grey, unoxidized tailings, above a dark brown-black humus layer.

T2

Tailings approximately 75 m east of the remains of Eureka Mill, in a low-lying swampy area. The ground in this area is very saturated. One sample collected. In a hole ~20 cm deep, a 5 cm thick organic-rich layer overlays a 15 cm thick, layer of light-grey, unoxidized tailings.

T3

Tailings ~30 m west of site T2, back towards Eureka Mill. Two samples collected, T3A-B. Stratigraphy includes a 2 cm organic-rich soil layer overlying a 20 cm thick layer of red, oxidized tailings, beneath which there is a transition into light-grey, unoxidized tailings. The samples were taken at approximate depths of 20 cm (T3A) and 35 cm (T3B).

T4

Tailings just downhill of Plough Lead Co's Mill, on the shoreline, just off the road in a low lying area. Two samples collected, T4A-B. Stratigraphy includes a 5 cm organic-rich soil layer overlying a 30 cm thick layer of light grey, unoxidized layer with small red, oxidized patches and dark grey mottles beneath which is a layer of black, unoxidized tailings (colouring is likely due to bacteria in the tailings). The samples were taken at approximate depths of 20 cm (T4A) and 40 cm (T4B).

T5

Tailings ~ 10 m SW of site T4 in low lying, grassy area, approximately 20 m from shoreline. Two samples collected, T5A-B. Stratigraphy includes an 8 cm thick, organic-rich soil, overlying a 10 cm thick mixed layer of red, oxidized and grey unoxidized tailings, a 7 cm thick olive coloured layer above a 5 cm thick sulphide-rich black layer with high grading, beneath which is a light grey, unoxidized tailings layer. The sample were taken at approximate depths of 12 cm (T5A) and 27 cm (T5B).

T6

Tailings ~ 10 m NE of site T4, downhill from Plough Lead Co's Mill. Two samples collected, T6A-B. Stratigraphy includes a 3 cm thick organic-rich soil layer, overlying 12 cm thick, mixed layer of light grey, unoxidized, tailings with a dark grey layer running through the middle, beneath which is a mixed, light-grey, unoxidized layer with red oxidized lenses. The samples were taken at approximate depths of 8 cm (T6A) and 25 cm (T6B).

T7

Tailings immediately west of site T6, just on the beach shoreline. One sample was collected just below the water level (T7A). There is evidence of clams at this site and snails are very active. Stratigraphy includes a 5 cm thick red-brown sand, overlying a dark black, fine to silty, unoxidized sand. The sample was taken at an approximate depth of 5 cm.

T8

Tailings in a culvert immediately south of T6. Iron staining of sand is evident, likely due to groundwater outlet into the ocean from a nearby cottage. One sample was collected just below sea level, T8A. Stratigraphy includes a 5 cm coarse, poorly-sorted red sand, grading into dominantly grey mixture. The sample was taken at a depth of less than 5 cm.

T9

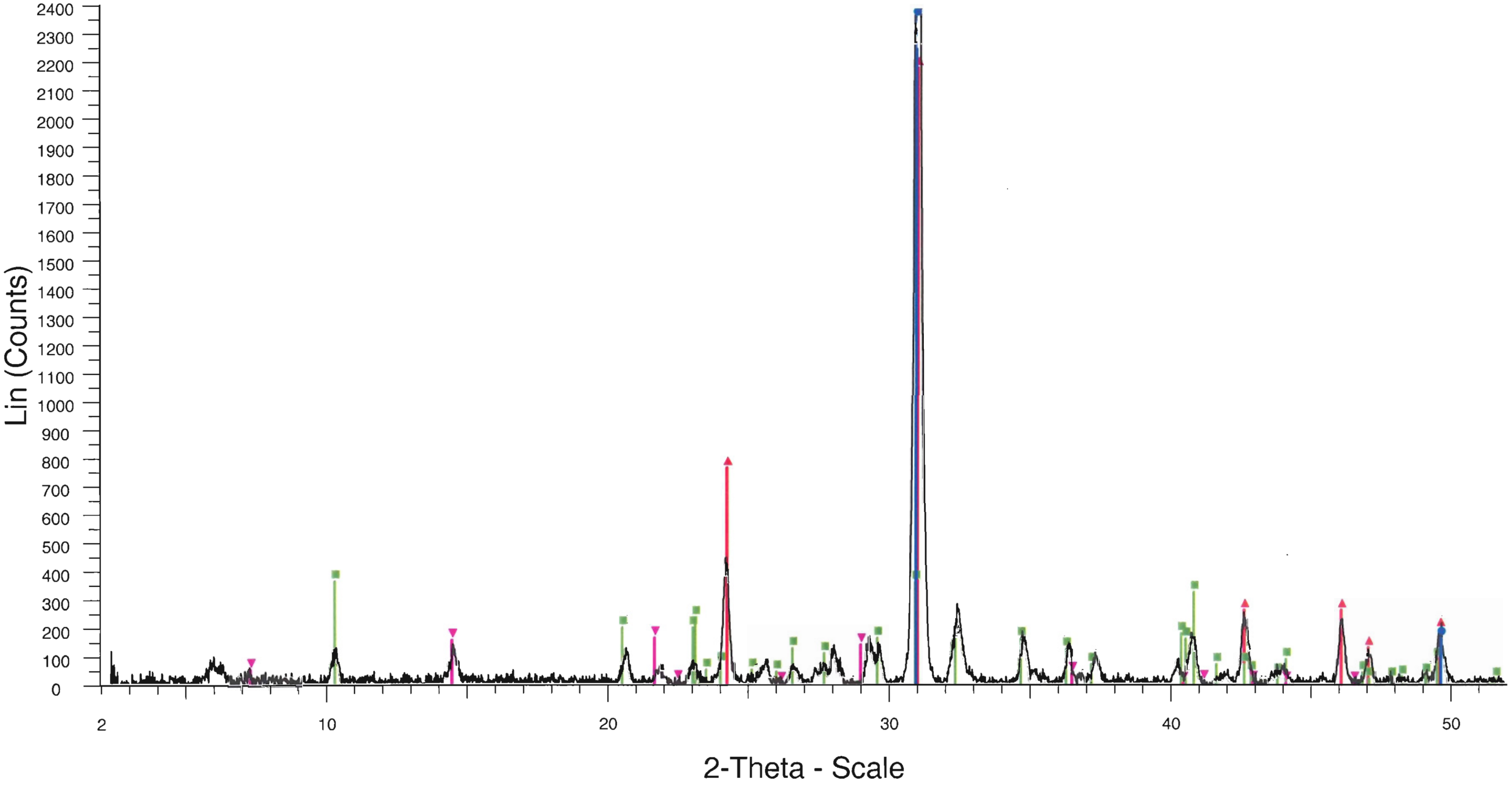
Tailings east of Plough Lead Co's tailings area (T6), along the shoreline, just south of previous site of the Old Provincial Co's Mill. One sample collected (T9A) on the shoreline flats during low tide. Snail activity is abundant in the area. Sample is composed of a cohesive, dark grey, clay and organic rich tailings.

T10

Tailings ~ 20 m west of site T9 on sandy beach just SW of Old Provincial Co's Mill site. One surface sample collected, T10A. Stratigraphy includes a very thin oxidized layer (~3 mm), overlying a black, unoxidized, fine-grained layer.

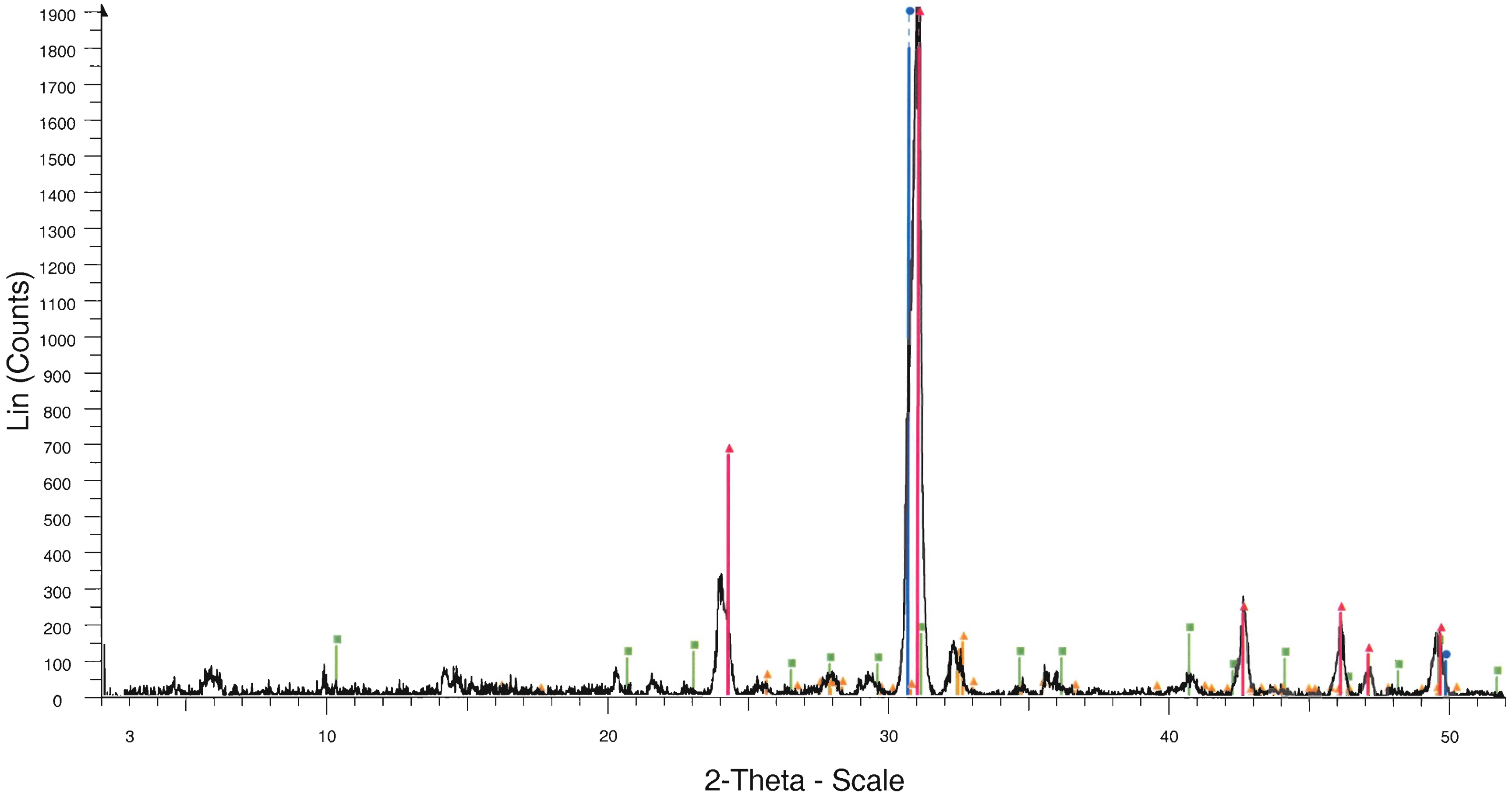
APPENDIX B : X-RAY DIFFRACTION RESULTS

Wine Harbour 2005 T1A



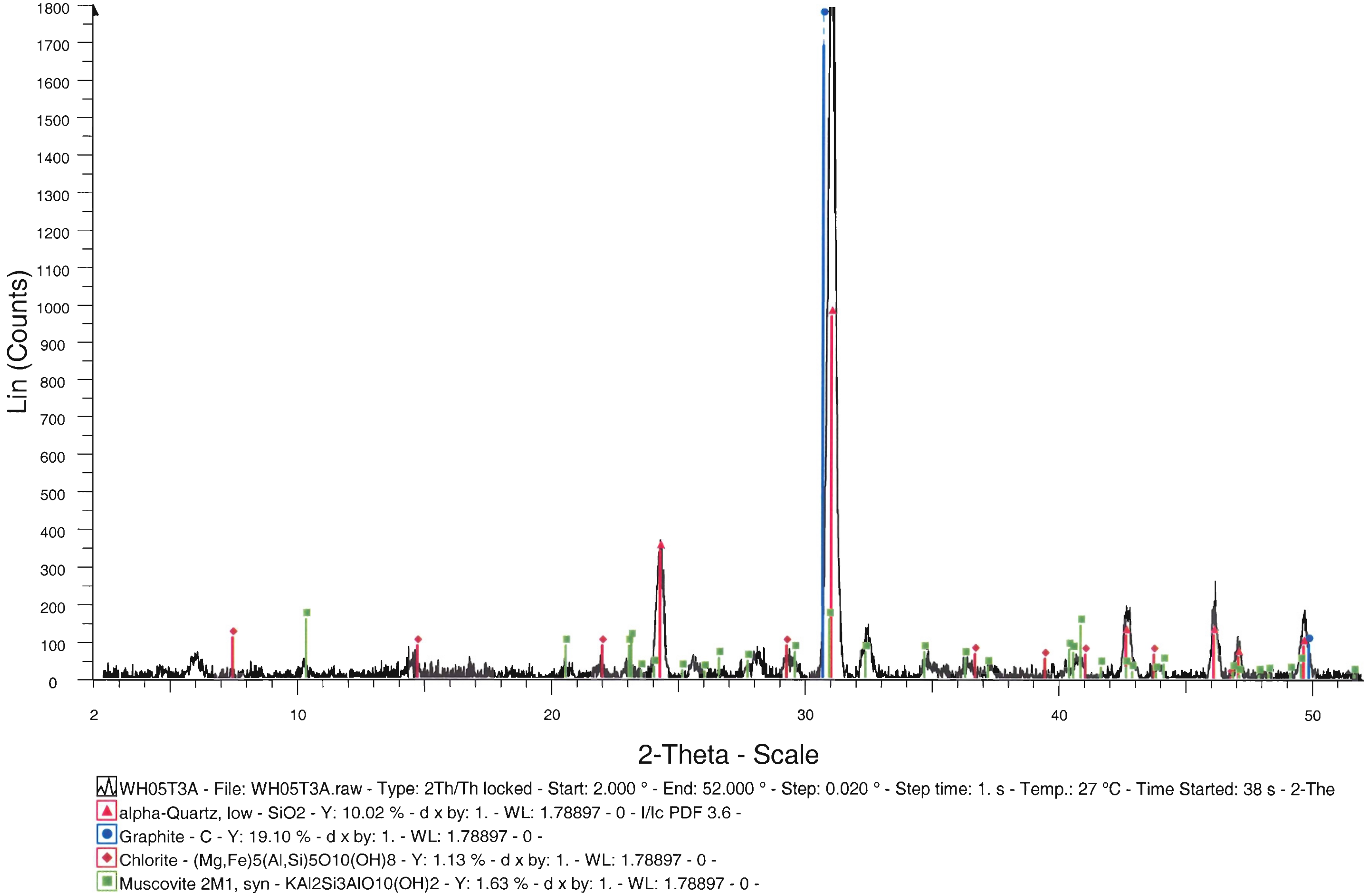
WH05T1A - File: WH05T1A.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 52.000 ° - Step: 0.020 ° - Step time: 1. s - Temp.: 27 °C - Time Started: 38 s - 2-Theta: 2.000 °
Operations: X Offset 0.200 | X Offset 0.175 | Background 1.000,1.000 | Import
▲ alpha-Quartz, low - SiO_2 - Y: 22.56 % - d x by: 1. - WL: 1.78897 - 0 - I/Ic PDF 3.6 -
● Graphite, syn - C - Y: 56.38 % - d x by: 1. - WL: 1.78897 - 0 -
🟩 Muscovite 2M1, syn - $KAl_2Si_3AlO_{10}(OH)_2$ - Y: 3.73 % - d x by: 1. - WL: 1.78897 - 0 -
▼ Clinochlore - $(Mg,Fe,Al)_6(Si,Cr)_4O_{10}(OH)_8$ - Y: 1.68 % - d x by: 1. - WL: 1.78897 - 0 -

Wine Harbour 2005 T2A

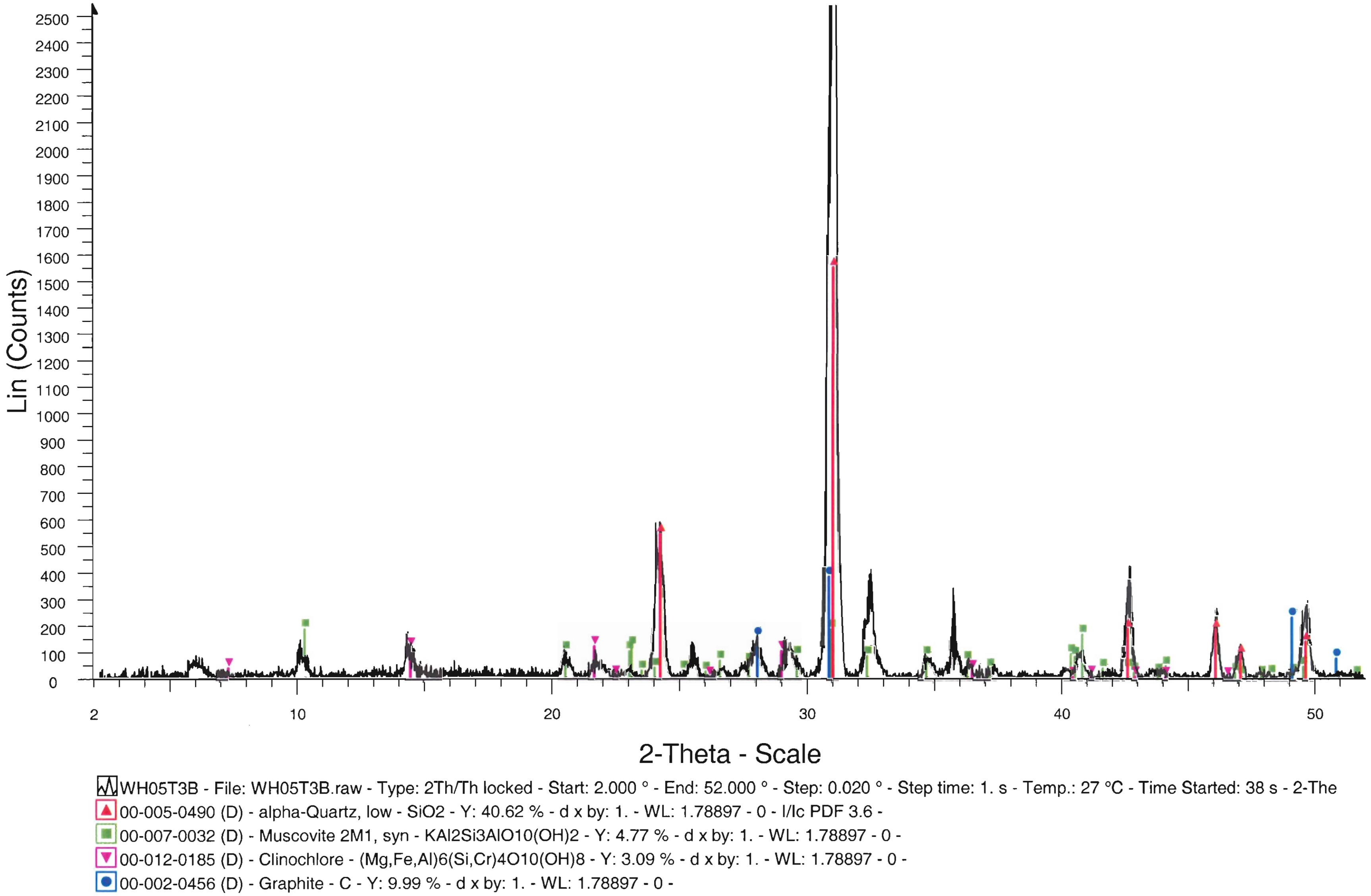


WH05T2A - File: WH05T2A.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 52.000 ° - Step: 0.020 ° - Step time: 1. s - Temp.: 27 °C - Time Started: 38 s - 2-Theta: 2.000 °
Operations: Background 1.000,1.000 | Import
▲ alpha-Quartz, low - SiO_2 - Y: 50.00 % - d x by: 1. - WL: 1.78897 - 0 - I/Ic PDF 3.6 - 00-005-0490 (D)
■ Muscovite - $KAl_2(Si_3Al)O_{10}(OH,F)_2$ - Y: 4.45 % - d x by: 1. - WL: 1.78897 - 0 - 00-002-0467 (D)
● Graphite - C - Y: 50.00 % - d x by: 1. - WL: 1.78897 - 0 - 00-001-0640 (D)
▲ Albite, calcian, ordered - $(Na,Ca)Al(Si,Al)_3O_8$ - Y: 3.83 % - d x by: 1. - WL: 1.78897 - 0 - I/Ic PDF 1.1 - 00-041-1480 (I)

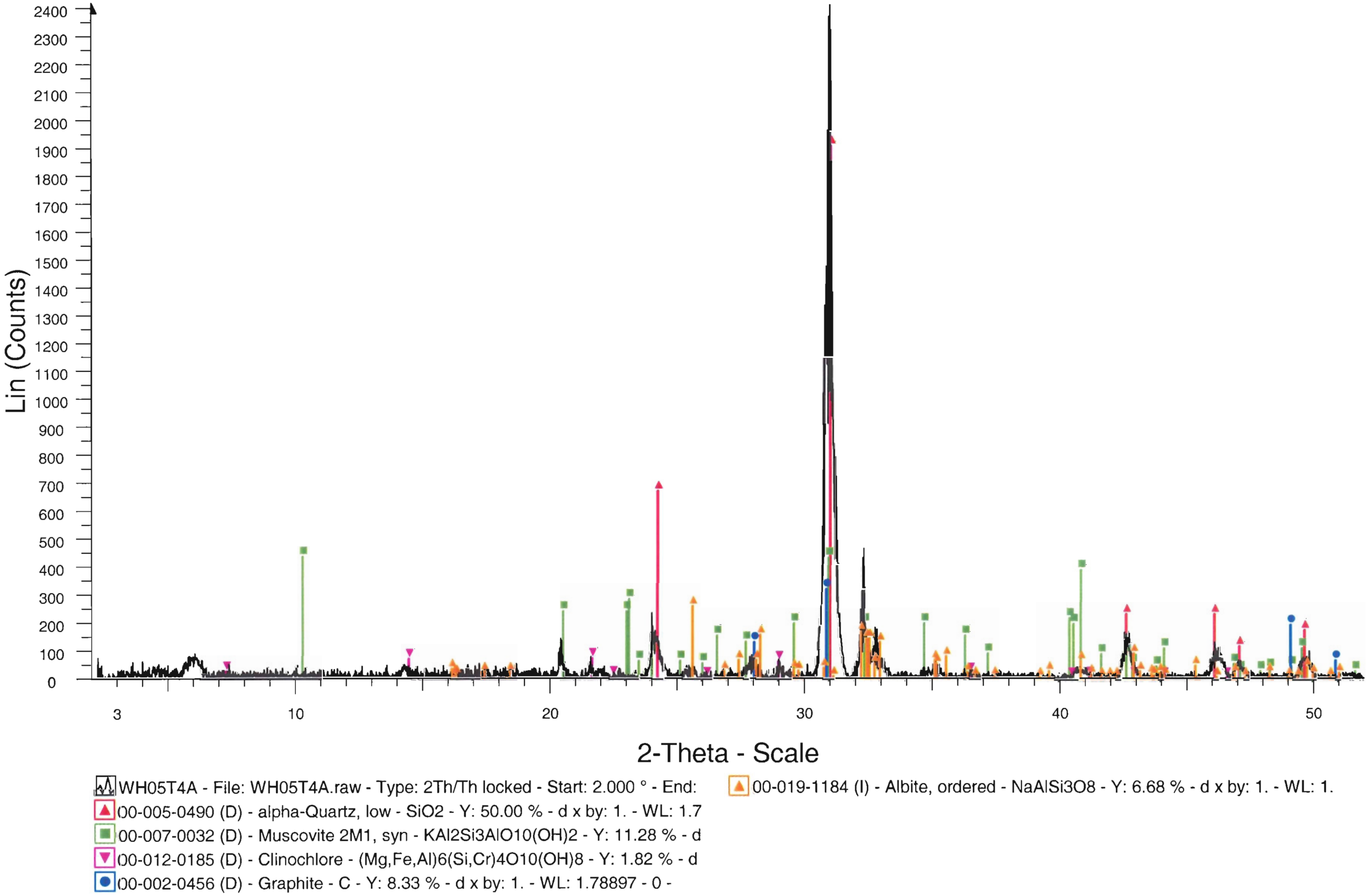
Wine Harbour 2005 T3A



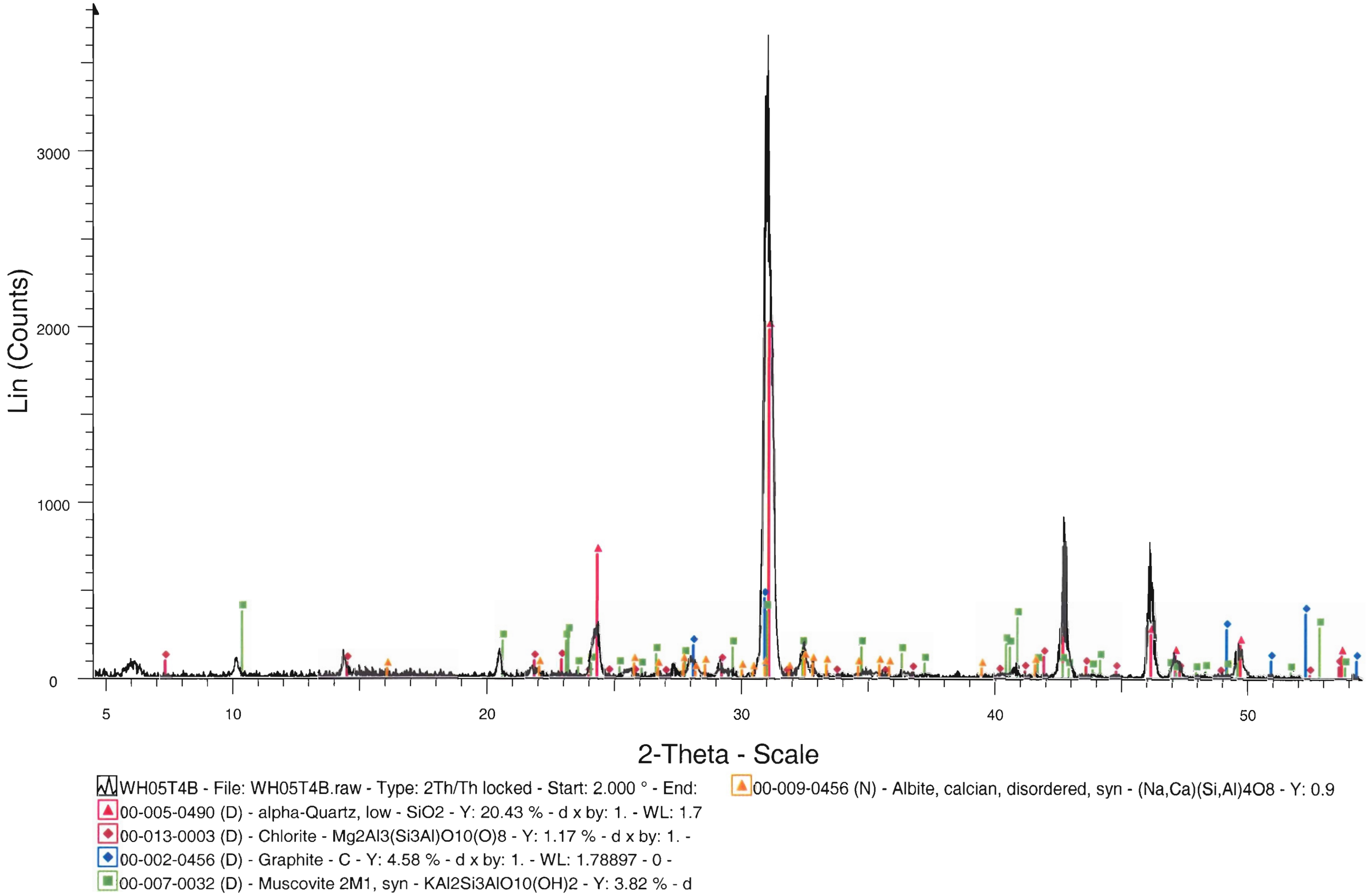
Wine Harbour 2005 T3B



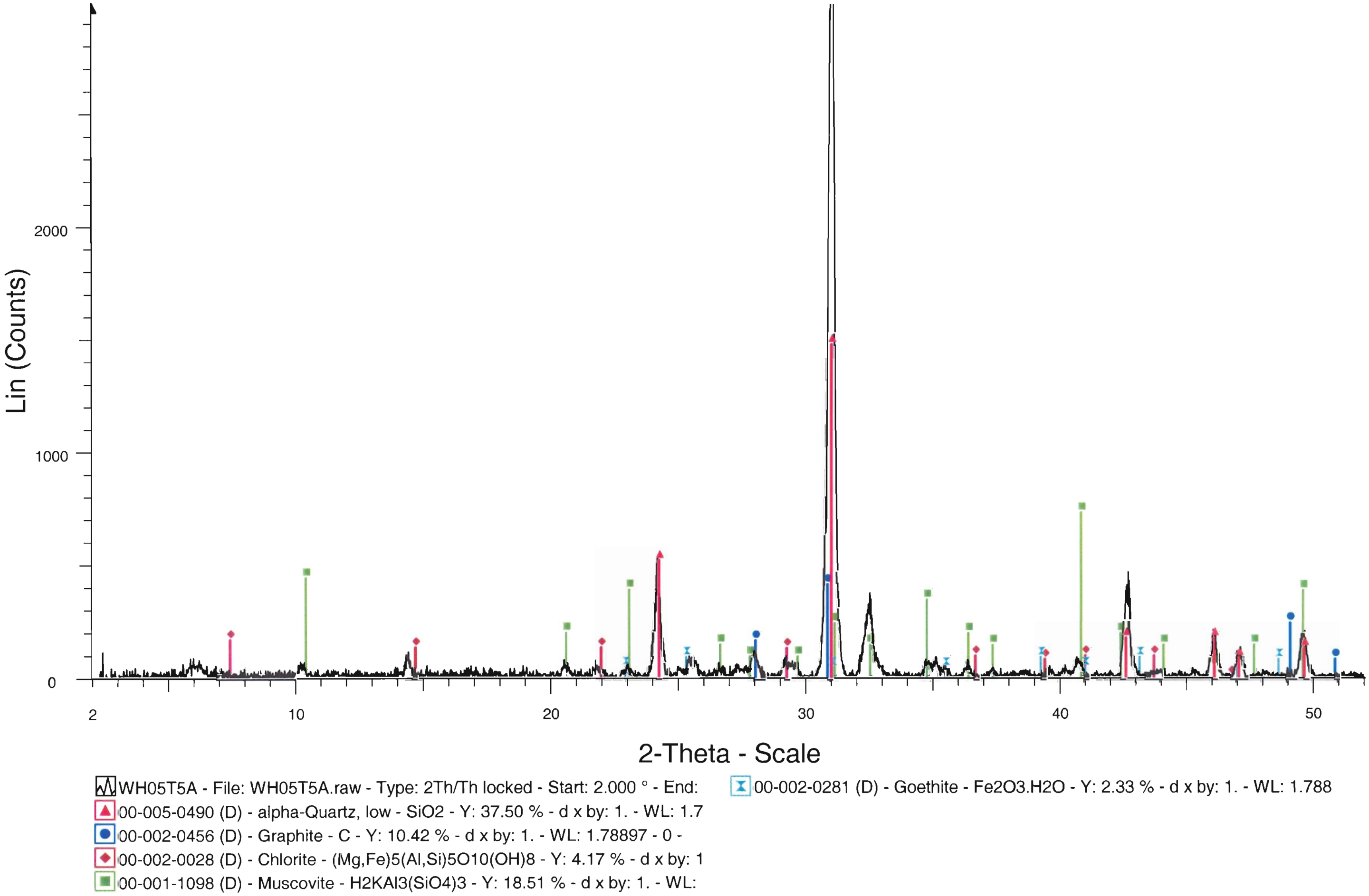
Wine Harbour 2005 T4A



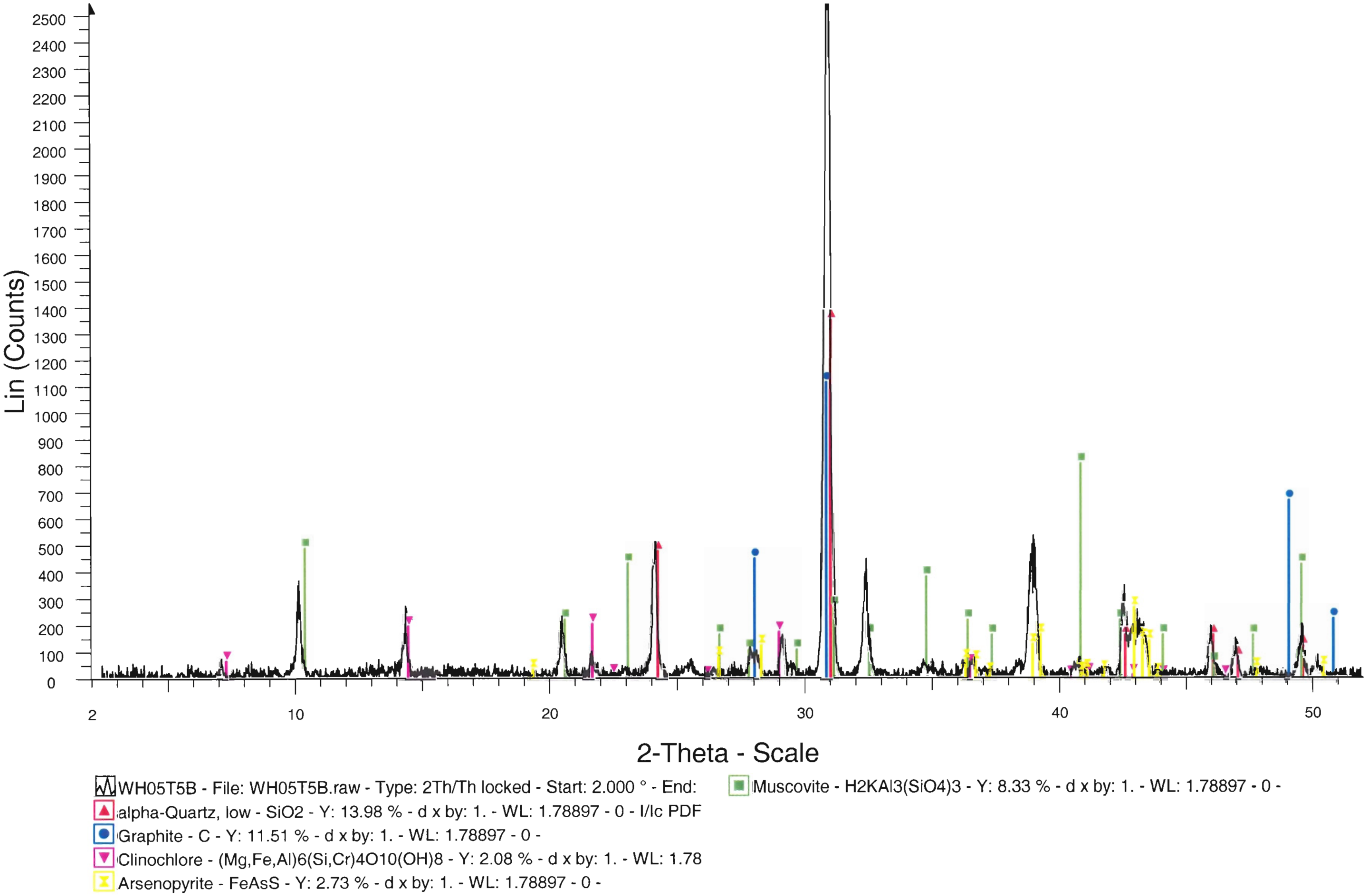
Wine Harbour 2005 T4B



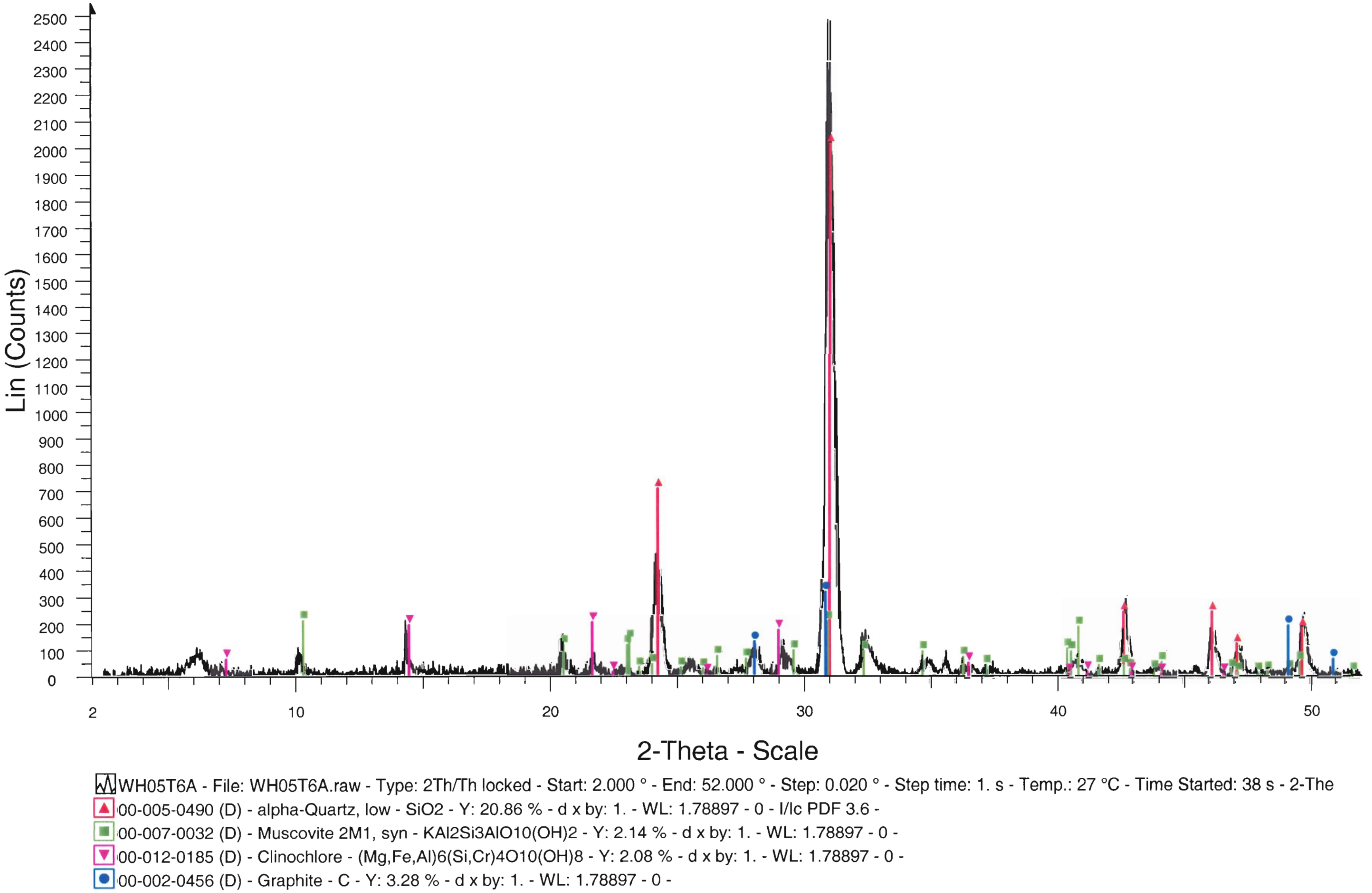
Wine Harbour 2005 T5A



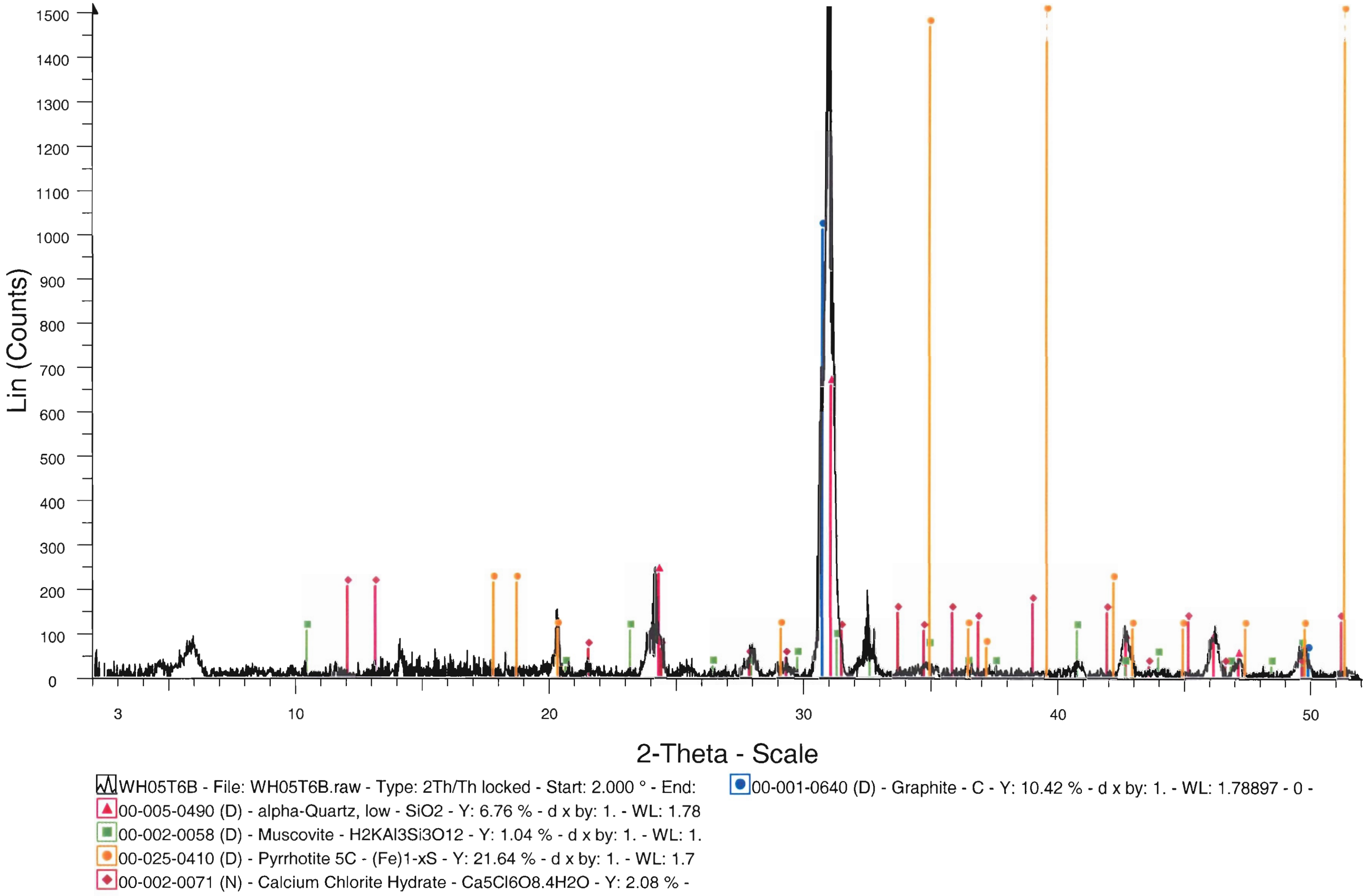
Wine Harbour 2005 T5B



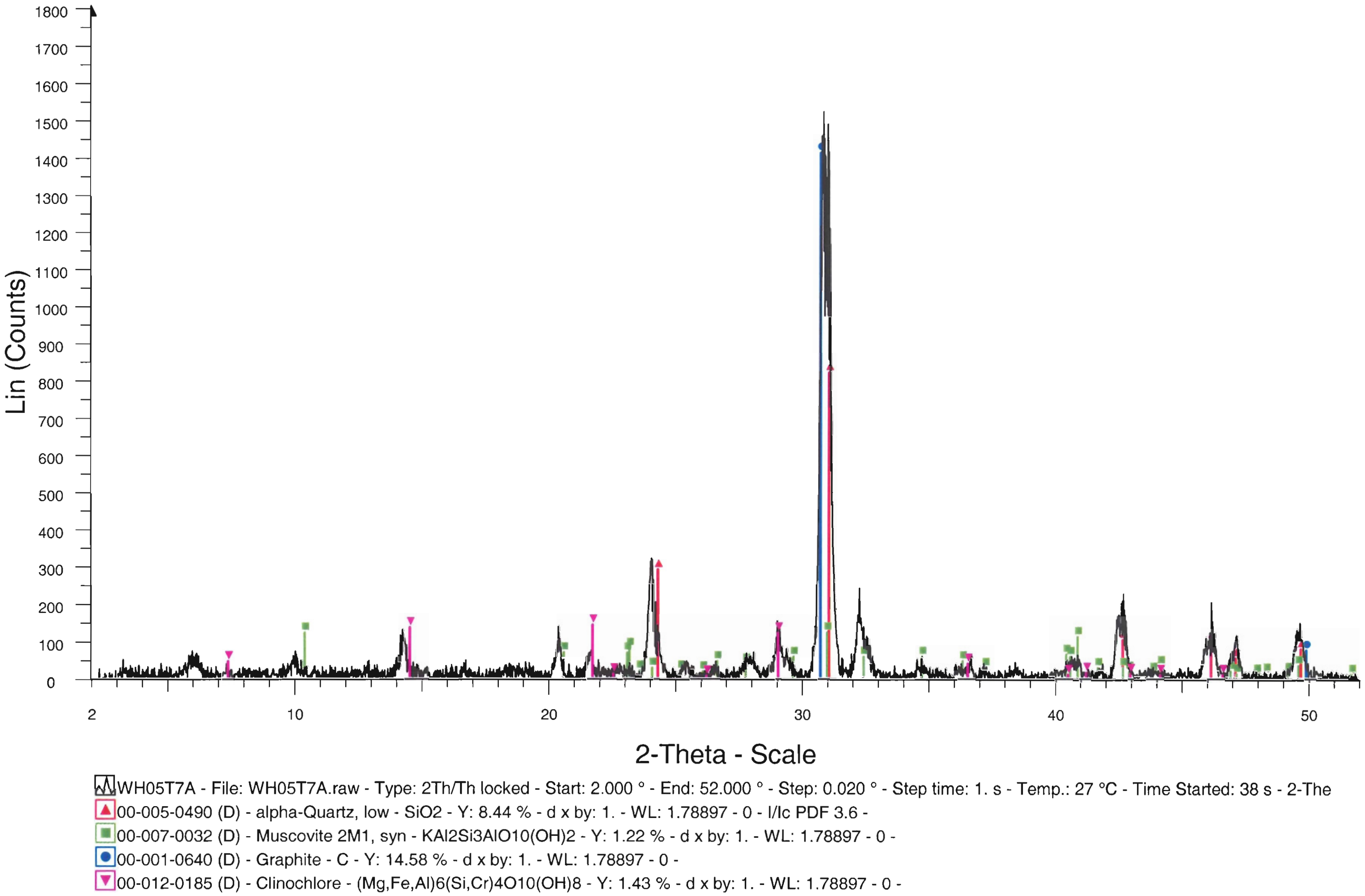
Wine Harbour 2005 T6A



Wine Harbour 2005 T6B



Wine Harbour 2005 T7A



WH05T7A - File: WH05T7A.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 52.000 ° - Step: 0.020 ° - Step time: 1. s - Temp.: 27 °C - Time Started: 38 s - 2-The

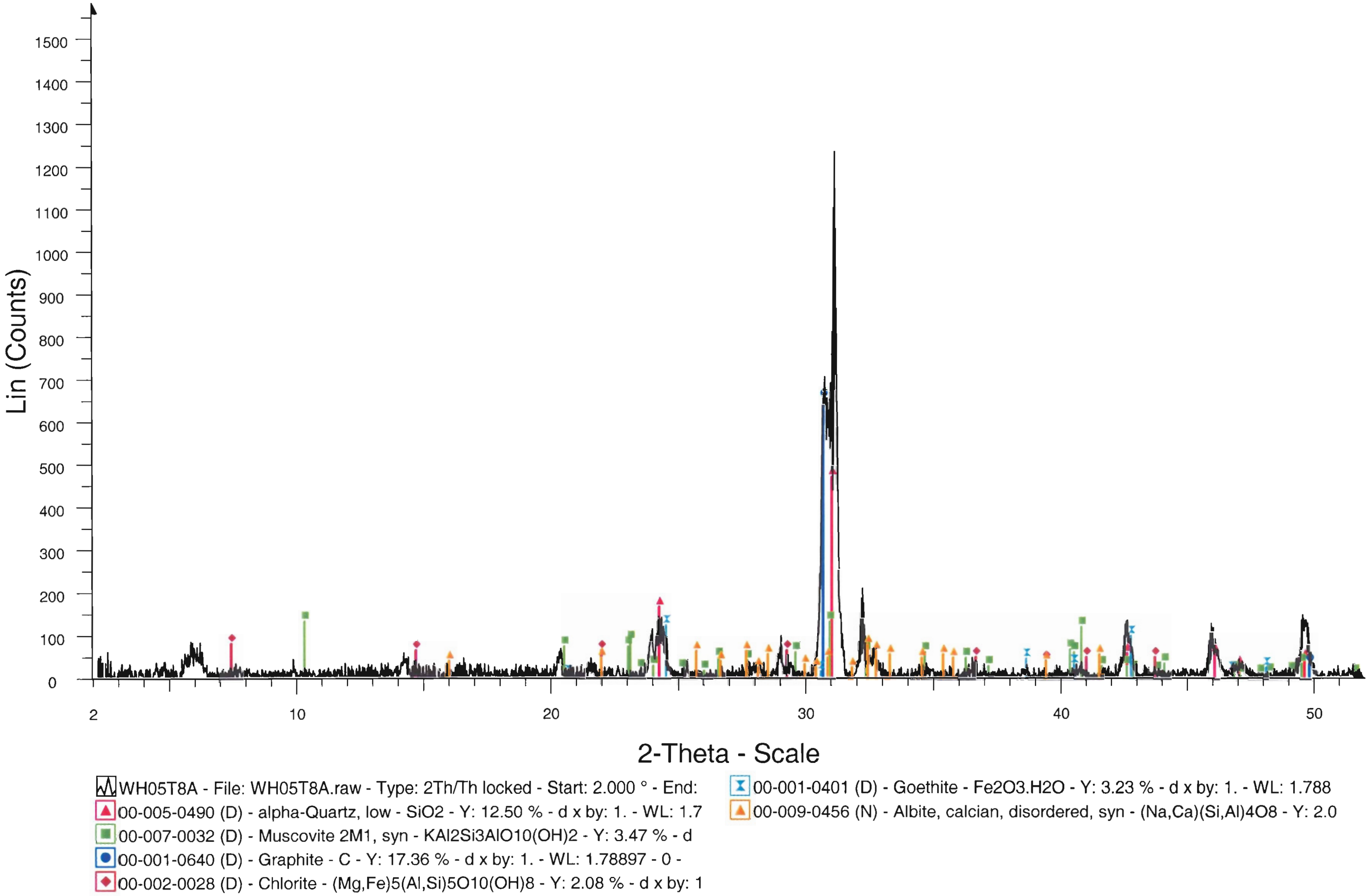
🟥 00-005-0490 (D) - alpha-Quartz, low - SiO_2 - Y: 8.44 % - d x by: 1. - WL: 1.78897 - 0 - I/Ic PDF 3.6 -

🟩 00-007-0032 (D) - Muscovite 2M1, syn - $KAl_2Si_3AlO_{10}(OH)_2$ - Y: 1.22 % - d x by: 1. - WL: 1.78897 - 0 -

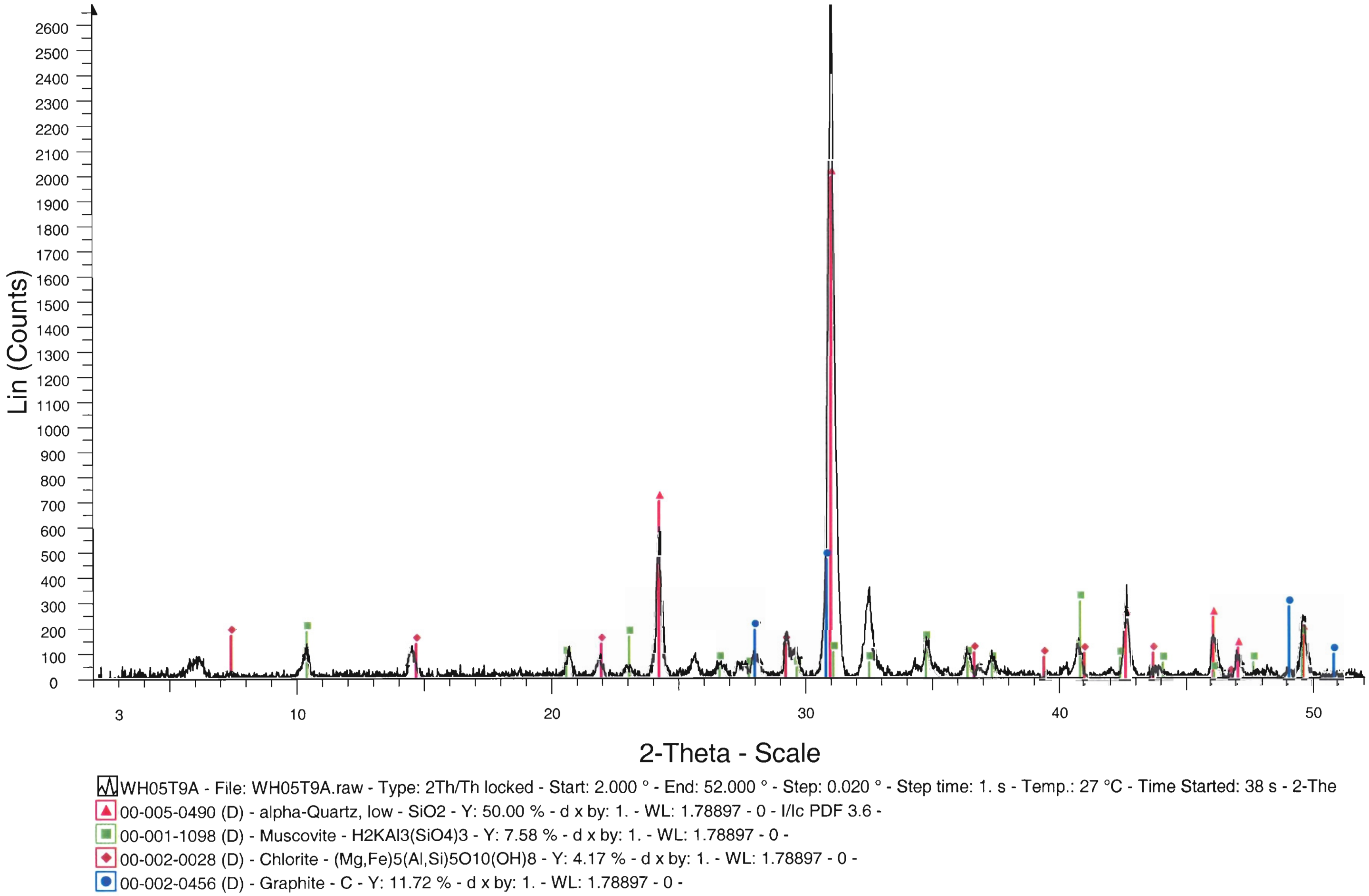
● 00-001-0640 (D) - Graphite - C - Y: 14.58 % - d x by: 1. - WL: 1.78897 - 0 -

▼ 00-012-0185 (D) - Clinochlore - $(Mg,Fe,Al)_6(Si,Cr)_4O_{10}(OH)_8$ - Y: 1.43 % - d x by: 1. - WL: 1.78897 - 0 -

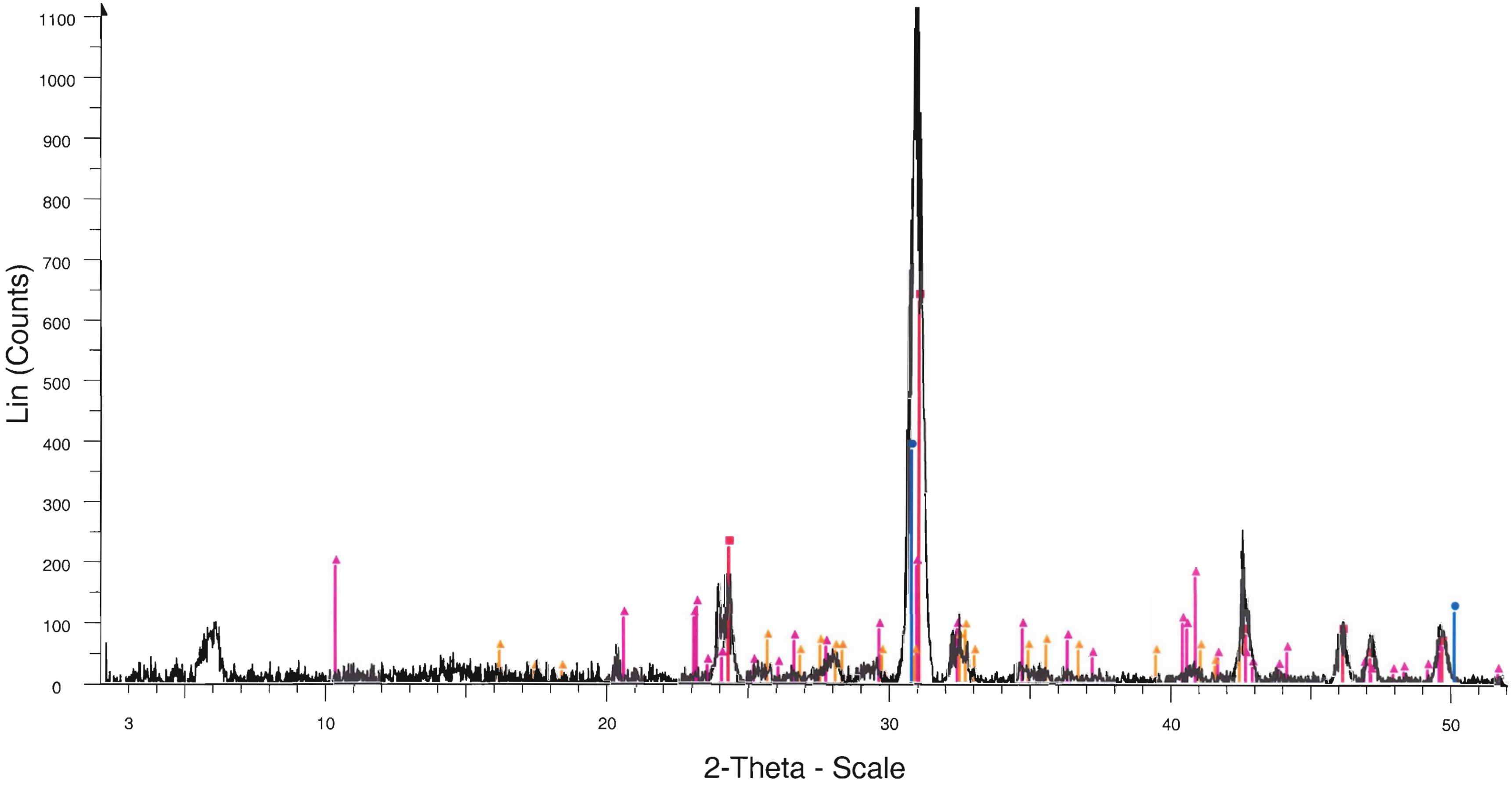
Wine Harbour 2005 T8A



Wine Harbour 2005 T9A

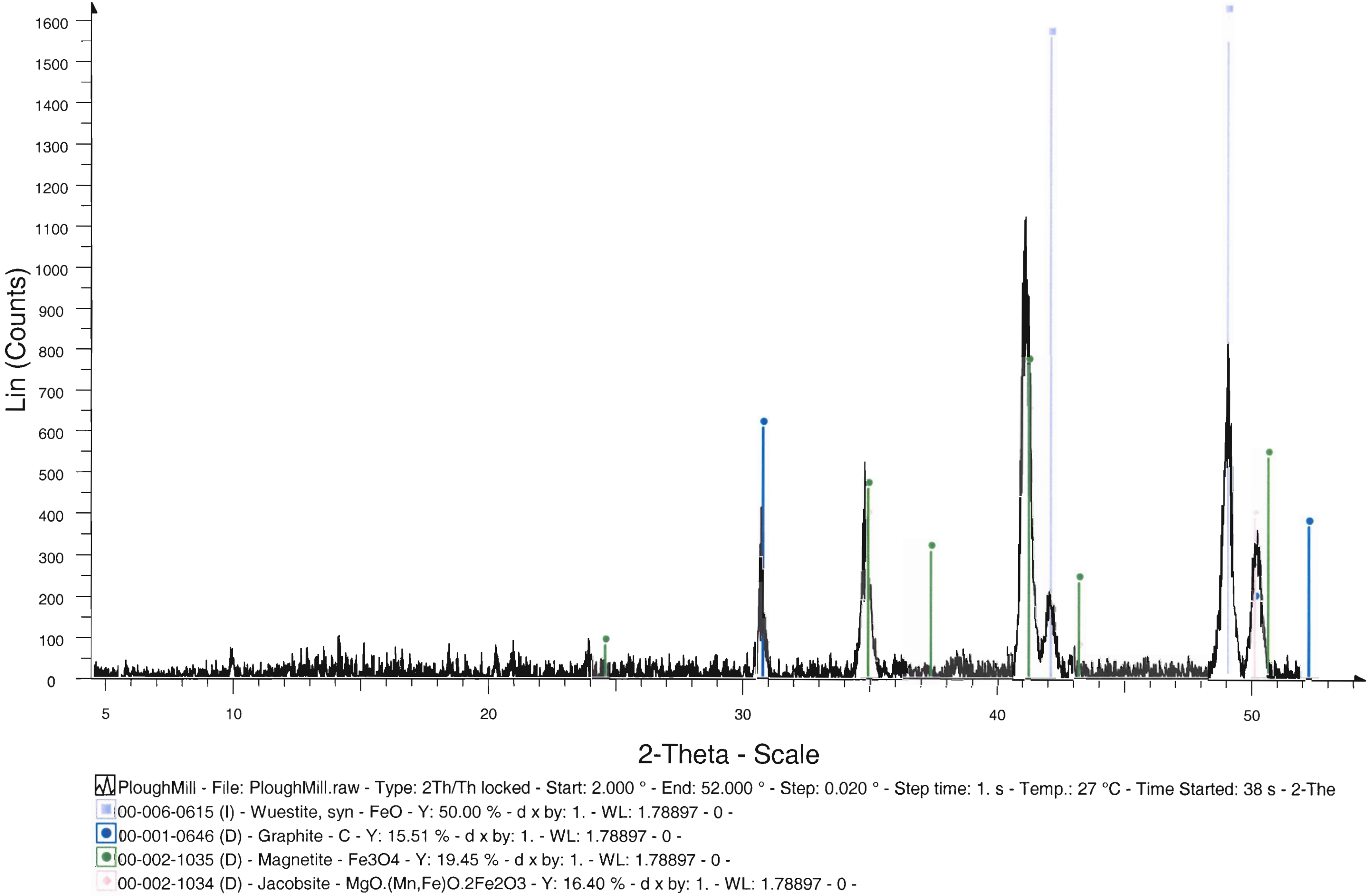


Wine Harbour 2005 T10A



WH05T10A - File: WH05T10A.raw - Type: 2Th/Th locked - Start: 2.000 ° - End: 52.000 ° - Step: 0.020 ° - Step time: 1. s - Temp.: 27 °C - Time Started: 38 s - 2-Theta: 2.00
Operations: X Offset 0.058 | Background 1.000,1.000 | Import
■ 00-005-0490 (D) - alpha-Quartz, low - SiO2 - Y: 6.51 % - d x by: 1. - WL: 1.78897 - 0 - I/Ic PDF 3.6 -
▲ 00-007-0032 (D) - Muscovite 2M1, syn - KAl2Si3AlO10(OH)2 - Y: 1.96 % - d x by: 1. - WL: 1.78897 - 0 -
▲ 00-009-0457 (D) - Albite, calcian, ordered - (Na,Ca)(Si,Al)4O8 - Y: 0.87 % - d x by: 1. - WL: 1.78897 - 0 -
● 00-001-0646 (D) - Graphite - C - Y: 3.94 % - d x by: 1. - WL: 1.78897 - 0 -

Wine Harbour 2005 Ploughmans Mill



APPENDIX C: MICROPROBE DATA (RAW)

Mass percent

No.	S	Hg	As	Fe	K	Ca	Total	Comment
20	21.111	0	44.19	34.133	0	0.0198	99.454	arsenopyrite control4
21	21.625	0	44.197	33.419	0	0.0168	99.258	arsenopyrite control5
22	0	0	0	64.345	0	0	64.345	Plough mill 1
23	23.163	0.0069	42.827	34.603	0	0	100.6	Plough mill 2
24	0.2759	0	13.451	26.815	0.1223	0.9373	41.602	Plough mill 3
25	0.081	28.124	0.0092	0.7438	0	0.1218	29.08	Plough mill 4
26	0.0855	43.265	0.1471	0.371	0.0018	0.1024	43.973	Plough mill 5
27	53.547	0.0406	0.1778	44.454	0	0	98.219	Plough mill 6
28	1.0777	0	0	50.473	0	0.0413	51.592	Plough mill 7
29	22.176	0	44.196	34	0	0	100.37	wh_t4a 1
30	21.992	0	42.198	33.446	0	0.0119	97.647	wh_t4a 2
31	22.7	0	43.42	34.329	0	0.0221	100.47	wh_t4a 3
32	54.398	0	0	44.354	0	0	98.752	wh_t4a 4
33	54.281	0	0	44.759	0	0	99.04	wh_t4a 5
34	39.978	0	0	57.11	0	0.0036	97.092	wh_t4a 6
35	40.053	0.0025	0	56.968	0	0	97.023	wh_t4a 7
36	23.136	0	43.097	34.194	0	0.0102	100.44	wh_t4a 8
37	14.423	0.0597	26.99	22.925	0	0.0375	64.435	wh_t4a 9
38	23.16	0.0557	43.274	34.157	0	0	100.65	wh_t4a 10
39	2.0599	0	5.0927	3.7708	0	0.0333	10.957	wh_t4a 11
41	19.873	0.1179	39.04	33.17	0	0.0396	92.24	wh_t4b 1
42	22.165	0.049	44.074	33.581	0	0	99.869	wh_t4b 2
43	21.873	0	44.425	34.057	0	0	100.35	wh_t4b 3
44	21.756	0.0736	45.17	34.004	0	0.0048	101.01	wh_t4b 4
45	22.264	0.1061	44.242	33.866	0	0.0031	100.48	wh_t4b 5
46	33.904	0.1051	0	38.769	1.317	0.0055	74.101	wh_t4b 6
47	22.09	0.0245	45.089	34.302	0	0	101.5	wh_t4b 7
48	21.632	0.0327	45.311	33.677	0	0.0062	100.66	wh_t4b 8
49	39.847	0.0283	0	56.349	0	0	96.224	wh_t4b 9
50	23.467	0	42.579	34.048	0	0.0102	100.1	wh_t4b 10
51	54.087	0.0796	0.0933	43.746	0	0	98.005	wh_t4b 11
52	2.2463	0	21.201	15.146	0.0913	0.0806	38.766	wh_t4a 12
53	21.668	0.0409	44.161	32.744	0	0	98.614	Arsenopyrite control5
54	21.996	0.0902	44.046	32.844	0	0	98.976	Arsenopyrite control6
Minimum	0	0	0	0.371	0	0	10.957	
Maximum	54.398	43.265	45.311	64.345	1.317	0.9373	101.5	
Average	23.182	2.1265	25.079	34.696	0.0451	0.0444	85.174	
Sigma	15.945	8.7198	20.829	14.431	0.2262	0.1606	25.495	
No. of data 34								

Atomic ratio

No.	S	Hg	As	Fe	K	Ca	Total	Comment
20	35.403	0	31.712	32.858	0	0.0266	100	arsenopyrite control4
21	36.202	0	31.662	32.115	0	0.0225	100	arsenopyrite control5
22	0	0	0	100	0	0	100	Plough mill 1
23	37.753	0.0018	29.87	32.375	0	0	100	Plough mill 2
24	1.2387	0	25.841	69.104	0.45	3.366	100	Plough mill 3
25	1.5875	88.061	0.0774	8.3646	0	1.909	100	Plough mill 4
26	1.1623	93.957	0.8554	2.8934	0.0196	1.1124	100	Plough mill 5
27	67.654	0.0082	0.0961	32.241	0	0	100	Plough mill 6
28	3.5823	0	0	96.308	0	0.1099	100	Plough mill 7
29	36.59	0	31.206	32.204	0	0	100	wh_t4a 1
30	37.112	0	30.472	32.4	0	0.0161	100	wh_t4a 2
31	37.21	0	30.458	32.303	0	0.029	100	wh_t4a 3
32	68.118	0	0	31.882	0	0	100	wh_t4a 4
33	67.873	0	0	32.127	0	0	100	wh_t4a 5
34	54.942	0	0	45.054	0	0.004	100	wh_t4a 6
35	55.052	0.0005	0	44.948	0	0	100	wh_t4a 7
36	37.795	0	30.127	32.065	0	0.0133	100	wh_t4a 8
37	36.819	0.0244	29.485	33.595	0	0.0766	100	wh_t4a 9
38	37.785	0.0145	30.212	31.989	0	0	100	wh_t4a 10
39	32.034	0	33.89	33.661	0	0.4143	100	wh_t4a 11
41	35.698	0.0339	30.009	34.203	0	0.057	100	wh_t4b 1
42	36.752	0.013	31.272	31.963	0	0	100	wh_t4b 2
43	36.193	0	31.457	32.35	0	0	100	wh_t4b 3
44	35.889	0.0194	31.885	32.2	0	0.0064	100	wh_t4b 4
45	36.705	0.028	31.213	32.05	0	0.0041	100	wh_t4b 5
46	59.211	0.0293	0	38.867	1.8859	0.0078	100	wh_t4b 6
47	36.166	0.0064	31.589	32.238	0	0	100	wh_t4b 7
48	35.836	0.0087	32.121	32.026	0	0.0082	100	wh_t4b 8
49	55.191	0.0063	0	44.803	0	0	100	wh_t4b 9
50	38.319	0	29.753	31.915	0	0.0133	100	wh_t4b 10
51	68.247	0.0161	0.0504	31.686	0	0	100	wh_t4b 11
52	11.146	0	45.019	43.143	0.3715	0.32	100	wh_t4a 12
53	36.498	0.011	31.83	31.66	0	0	100	Arsenopyrite control5
54	36.837	0.0241	31.565	31.574	0	0	100	Arsenopyrite control6

Minimum		0	0	0	2.8934	0	0	100
Maximum		68.247	93.957	45.019	100	1.8859	3.366	100
Average		36.606	5.3607	20.404	37.328	0.0802	0.2211	100
Sigma		19.317	21.746	15.465	18.474	0.3339	0.6708	0.0001
No. of data	**34**							

Mass percent

No.	S	Hg	As	Fe	Ca	Total	Comment
1	21.022	0.0196	44.415	34.005	0	99.462	arsenopyrite control1
2	21.135	0	44.311	33.917	0	99.364	arsenopyrite control2
3	14.565	0.2674	0.0711	0.3936	0.0635	15.361	wh_t5b 1
4	51.984	0	0	44.716	0	96.7	wh_t5b 2
5	38.28	0.017	0	57.131	0	95.428	wh_t5b 3
6	21.597	0	43.607	34.539	0	99.742	wh_t5b 4
7	21.858	0	43.627	34.453	0	99.938	wh_t5b 5
8	21.584	0	43.828	34.145	0	99.558	wh_t5b 6
9	21.426	0	44.536	34.532	0	100.49	wh_t5b 7
10	51.796	0	0	44.678	0	96.475	wh_t5b 8
11	22.405	0	42.858	34.581	0	99.843	wh_t5b 9
12	52.413	0	0.02	44.914	0	97.348	wh_t5b 10
13	52.568	0.0014	0.1293	44.507	0	97.206	wh_t5b 11
14	22.009	0	43.679	34.521	0	100.21	wh_t5b 12
15	21.493	0.0179	44.296	34.232	0	100.04	wh_t5b 13
16	21.78	0	44.53	34.322	0	100.63	wh_t5b 14
17	21.928	0	44.088	34.275	0	100.29	wh_t5b 15
18	52.319	0.0048	0.0363	44.559	0	96.919	wh_t5b 16
Minimum	14.565	0	0	0.3936	0	15.361	
Maximum	52.568	0.2674	44.536	57.131	0.0635	100.63	
Average	30.676	0.0182	26.891	36.579	0.0035	94.167	
Sigma	14.418	0.0626	22.047	11.157	0.015	19.736	
No. of data 18							

Atomic ratio

No.	S	Hg	As	Fe	Ca	Total	Comment
1	35.3	0.0053	31.916	32.779	0	100	arsenopyrite control1
2	35.481	0	31.833	32.686	0	100	arsenopyrite control2
3	97.654	0.2865	0.2041	1.5148	0.3404	100	wh_t5b 1
4	66.944	0	0	33.056	0	100	wh_t5b 2
5	53.856	0.0038	0	46.14	0	100	wh_t5b 3
6	35.945	0	31.057	32.998	0	100	wh_t5b 4
7	36.246	0	30.958	32.796	0	100	wh_t5b 5
8	36.01	0	31.29	32.701	0	100	wh_t5b 6
9	35.528	0	31.602	32.87	0	100	wh_t5b 7
10	66.883	0	0	33.117	0	100	wh_t5b 8
11	36.975	0	30.266	32.759	0	100	wh_t5b 9
12	67.021	0	0.0109	32.968	0	100	wh_t5b 10
13	67.246	0.0003	0.0708	32.683	0	100	wh_t5b 11
14	36.369	0	30.886	32.745	0	100	wh_t5b 12
15	35.761	0.0047	31.539	32.696	0	100	wh_t5b 13
16	35.978	0	31.477	32.545	0	100	wh_t5b 14
17	36.263	0	31.2	32.537	0	100	wh_t5b 15
18	67.15	0.001	0.02	32.829	0	100	wh_t5b 16
Minimum	35.3	0	0	1.5148	0	100	
Maximum	97.654	0.2865	31.916	46.14	0.3404	100	
Average	49.034	0.0168	19.129	31.801	0.0189	100	
Sigma	18.605	0.0673	15.671	8.186	0.0802	0.0001	
No. of data 18							

APPENDIX D : TAILINGS CHEMISTRY

Stn		WH 05 T1A	WH 05 T2A	WH 05 T3A	WH 05 T3B	WH 05 T4A	WH 05 T4B	WH 05 T5A	WH 05 T5B	WH 05 T6A	WH 05 T6B	WH 05 T7A	WH 05 T8A	WH 05 T9A	WH 05 T10A
Sed. Depth 1 (cm)		5	5	19	34	19	39	11	26	7	24	4	2	2	2
Sed. Depth 2 (cm)		10	10	21	36	21	41	13	28	9	26	6	3	3	3
Avg. Depth	(cm)	7.5	7.5	20.0	35.0	20.0	40.0	12.0	27.0	8.0	25.0	5.0	2.5	2.5	2.5
Total Carbon	(% dry wt.)	0.74	0.58	0.08	0.41	0.07	0.06	0.83	0.09	0.85	0.07	0.20	1.63	0.32	0.22
Organic Carbon	(% dry wt.)	0.74	0.07	0.08	0.06	0.07	0.05	0.83	0.09	0.85	0.05	0.19	0.35	0.11	0.22
Inorganic Carbon	(% dry wt.)	0.00	0.51	0.00	0.35	0.00	0.01	0.00	0.00	0.00	0.02	0.01	1.28	0.21	0.00
Ag	ppb	104	136	174	105	384	161	368	6058	100	408	97	63	149	13
Al	(% dry wt.)	0.51	0.42	0.4	0.39	0.25	0.26	0.36	0.18	0.33	0.31	1.45	1.36	0.86	0.26
As	ppm	2459	3419	13100	4598	7692	4694	8100	195700	200	5072	185	511	1548	86
Au	ppb	700.6	220.2	536.9	273.9	3759.1	1992.1	1718.4	29833.9	762	3696.9	33.3	198.6	1213.5	30
B	ppm	1	<1	<1	<1	<1	<1	1	<1	<1	<1	9	7	2	1
Ba	ppm	11.8	6.3	4.7	4.5	4	4.2	7	4.4	10.6	16.7	105.5	129.9	28.2	2.7
Be	ppm	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<.1	0.1	0.1	0.6	0.5	0.2	0.1
Bi	ppm	0.58	0.39	0.88	0.45	1.19	0.5	1.24	21.94	0.35	0.78	0.1	0.1	0.56	0.04
Ca	(% dry wt.)	0.11	1.03	0.26	0.67	0.08	0.15	0.1	0.06	0.1	0.09	0.37	0.14	0.84	0.05
Cd	ppm	0.19	0.11	0.14	0.12	0.1	0.07	0.16	0.31	0.04	0.23	0.07	0.05	0.09	0.02
Ce	ppm	18	19.9	16	16.3	17.9	18.6	23.4	11.7	26.6	27.2	29.1	22.3	78.2	15.7
Co	ppm	2.5	11.6	4.4	13.2	6.7	7.3	10.5	76.5	1.1	2.7	8.1	4.3	7.5	1
Cr	ppm	8.5	7.1	6.6	6.3	4.4	4.9	6.3	2.6	6.2	3.9	26.2	28.3	20.3	4.8
Cs	ppm	0.79	0.2	0.12	0.18	0.17	0.2	0.27	0.14	0.22	0.19	1.07	0.93	0.56	0.1
Cu	ppm	18.01	18.93	33.71	20.9	24.33	8.41	19.9	354.8	8.48	7.86	23.59	13.46	18.89	20.54
Fe	(% dry wt.)	1.32	1.75	2.85	1.57	1.38	1.23	1.57	16.76	0.65	1.63	2.87	3.46	2.06	0.59
Ga	ppm	1.6	1.3	1.2	1.1	0.9	0.9	1.2	0.6	1.1	1	4.8	4.5	2.9	0.9
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.12	0.1	0.1	0.1	0.1	<.02	0.07	<.02	0.08	0.3	0.28	0.26	0.03
Hg	ppb	10873	7452	11923	16219	15801	7127	11825	320000	4927	7745	600	1244	9507	444
In	ppm	<.02	<.02	0.02	<.02	<.02	<.02	<.02	0.17	<.02	<.02	0.02	<.02	<.02	<.02
K	(% dry wt.)	0.04	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.02	0.02	0.5	0.56	0.13	0.02
La	ppm	10.1	11.2	8.8	9	9.8	10.5	13.5	6.7	14.7	14.1	14.4	11.8	42.2	8.6
Li	ppm	9.7	8.7	7.7	7.5	4.9	4.2	6.4	2.8	6	5.1	25.8	13.6	11.1	4
Mg	(% dry wt.)	0.34	0.54	0.25	0.43	0.16	0.17	0.2	0.1	0.17	0.17	0.4	0.3	0.52	0.18
Mn	ppm	96	599	567	391	58	95	69	27	53	83	394	382	332	70
Mo	ppm	0.08	0.11	0.14	0.12	0.26	0.15	0.31	2.02	0.11	0.25	1.65	2.02	0.83	0.19
Na	(% dry wt.)	0.031	0.001	0.002	0.001	0.002	0.001	0.003	0.001	0.002	0.003	0.242	0.328	0.117	0.127
Nb	ppm	0.35	0.05	0.07	0.05	0.32	0.28	0.42	0.5	0.22	0.23	0.15	0.29	0.35	0.24
Ni	ppm	13.1	23.4	13.8	33.3	12.9	15.5	20.4	109.2	4.1	6.5	18.8	12.6	17.2	3.7
P	(% dry wt.)	0.046	0.052	0.045	0.046	0.044	0.042	0.053	0.028	0.058	0.046	0.031	0.051	0.059	0.026
Pb	ppm	34.14	25.78	56.43	30.13	78.94	34.26	103	2090	69.49	64.57	18.2	15.3	54.49	2
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	3	4	<2	<2	<2	<2	<2
Rb	ppm	3.4	1.2	0.8	1	0.8	0.9	1.7	0.7	1.7	1.2	22.8	22.9	5	0.7
Re	ppb	<1	<1	<1	<1	<1	<1	<1	3	<1	<1	1	1	<1	1
S	(% dry wt.)	0.14	0.21	0.1	0.25	0.62	0.43	0.75	9.02	0.01	0.01	0.19	0.03	0.3	0.1
Sb	ppm	8.03	4.67	10.05	9.31	19.75	9.64	28.16	472.44	3.96	10.85	0.6	0.57	3.55	0.16
Sc	ppm	0.8	0.8	0.7	0.6	0.3	0.3	0.4	0.3	0.4	0.3	2.5	2.3	1	0.2
Se	ppm	0.4	0.1	0.2	0.1	1	0.3	1.3	18.7	0.3	0.7	0.2	0.2	0.3	0.2
Sn	ppm	0.4	<.1	<.1	<.1	<.1	<.1	0.4	0.1	0.7	<.1	3.7	1.7	0.3	<.1
Sr	ppm	18.6	167.8	87.7	109.8	9	20.9	10.8	8.2	11.2	15	29.7	27.7	106.7	6.4
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.12	0.05	0.2	0.05	1.31	0.53	1.18	20.54	0.15	1.06	0.05	0.03	0.19	<.02
Th	ppm	2.4	2.7	2.1	2.3	3.8	2.5	4.9	2	2.2	3.1	3.8	3	11.2	2
Ti	(% dry wt.)	0.007	0.003	0.002	0.003	0.003	0.003	0.004	0.001	0.003	0.003	0.041	0.041	0.01	0.005
Tl	ppm	0.04	<.02	<.02	<.02	<.02	<.02	0.04	0.14	0.05	0.04	0.13	0.11	0.04	<.02
U	ppm	0.3	0.3	0.2	0.2	0.6	0.4	0.9	0.4	0.4	0.5	1	0.8	1.7	0.3
V	ppm	5	3	2	3	2	<2	3	<2	4	3	22	21	10	3
W	ppm	1.1	0.5	2.3	0.4	0.1	0.2	0.4	<.1	0.3	<.1	0.2	0.3	0.4	<.1
Y	ppm	2.66	3.19	2.97	2.78	2.92	3.24	3.68	1.91	3.49	4.44	6.38	4.62	8.55	1.85
Zn	ppm	48.8	51.2	49.1	59	24.2	20.8	55.5	63.5	23.7	21.7	48.7	37.2	71.3	14.3
Zr	ppm	4	4.4	3.5	3.7	3.4	3.1	1	3.3	0.4	3.5	15	15	11	1.8

APPENDIX E : MARINE SEDIMENT CHEMISTRY

Grab samples

Stn			WH 03	WH 05	WH 06	WH 07	WH 09	WH 09	WH 10	WH 11	WH 12	WH 13	WH 15	WH 16	WH 17	WH 18	WH 20	WH 21	WH 22
Sed. Depth 1 (cm)			0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Sed. Depth 2 (cm)			2	1	1	1	1	11	1	1	1	1	1	1	1	1	1	1	1
Avg.	Sed.	Depth	1.0	0.5	0.5	0.5	0.5	10.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	Carbon	(% dry wt.)	2.73	2.56	2.65	3.12	4.11	4.44	3.03	6.11	6.65	13.20	2.74	3.59	0.93	0.83	2.00	2.90	2.97
Organic	Carbon	(% dry wt.)	2.52	2.46	2.56	2.96	4.11	4.38	2.94	5.97	6.65	13.20	2.60	2.98	0.64	0.76	1.65	2.70	2.80
Inorganic	Carbon	(% dry wt.)	0.21	0.10	0.09	0.16	0.00	0.06	0.09	0.14	0.00	0.00	0.14	0.61	0.29	0.07	0.35	0.20	0.17
Ag		ppb	73	80	65	96	113	123	76	94	68	89	78	75	22	35	42	83	77
Al		(% dry wt.)	1.03	1.09	1.04	1.18	1.1	1.16	0.88	1.02	0.87	0.76	1.14	0.99	0.57	0.61	0.77	1.04	1.04
As		ppm	14	20	18	32	324	345	526	188	113	160	22	19	8	251	21	37	48
Au		ppb	4.5	9.4	10.7	22.6	357.5	389.5	137.8	108.4	57.3	57.3	8.3	9.4	1.9	21.7	8.6	31.9	44.4
B		ppm	38	37	59	56	70	70	50	81	80	154	43	121	18	21	42	53	49
Ba		ppm	28.9	30.8	24.9	31	28.1	24.9	18.1	20.5	17.9	18.7	31.9	26.4	10.7	13.8	21.5	31.3	31.2
Be		ppm	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.5	0.4	0.4	0.5	0.2	0.2	0.3	0.5	0.4
Bi		ppm	0.19	0.2	0.17	0.23	0.3	0.31	0.2	0.24	0.25	0.24	0.2	0.18	0.06	0.09	0.11	0.2	0.19
Ca		(% dry wt.)	1.66	0.36	2.1	0.29	0.35	0.33	0.25	0.38	0.53	0.74	0.35	0.46	1.05	0.39	1.18	0.4	0.34
Cd		ppm	0.36	0.4	0.23	0.53	0.57	0.62	0.3	0.48	0.47	0.47	0.26	0.5	0.11	0.21	0.26	0.49	0.4
Ce		ppm	23.9	27.3	24.7	31	32.4	34.6	24.6	30.5	28.9	31.2	31	26.8	15.9	21.3	20.5	27.2	25.7
Co		ppm	8.5	9.2	8.1	9.5	9.6	10.1	7.4	12.2	14.3	25.5	9.8	9.2	5.3	5.5	7.3	9.1	9.1
Cr		ppm	21.2	24.5	22.7	27.5	25.1	26.7	17.6	21.3	18	16.5	26.5	24.2	11.8	13.1	17.3	25.5	24.9
Cs		ppm	1.12	1.24	1.12	1.36	1.23	1.32	0.92	1.21	1.06	0.97	1.36	1.17	0.6	0.63	0.9	1.23	1.18
Cu		ppm	16.48	17.77	14.13	19.03	21.12	21.34	14.85	16.32	15.86	14.84	17.36	18.87	6.81	8.41	11.76	18.21	17.44
Fe		(% dry wt.)	2.16	2.43	2.22	2.61	2.68	2.87	2.09	2.97	2.69	3.69	2.4	2.34	1.27	1.36	1.72	2.33	2.26
Ga		ppm	3	3.4	3.1	3.6	3.3	3.5	2.6	3.1	2.5	2.2	3.7	3.1	1.9	1.9	2.4	3.1	3.2
Ge		ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf		ppm	0.06	0.07	0.07	0.08	0.08	0.09	0.05	0.06	0.07	0.04	0.08	0.09	0.06	0.06	0.06	0.07	0.08
Hg		ppb	51	131	163	365	7435	7365	4257	2530	1430	1977	187	116	26	318	98	298	363
In		ppm	0.02	0.02	0.02	0.03	0.02	0.02	<.02	0.02	0.03	0.02	0.02	0.02	<.02	<.02	<.02	0.02	0.02
K		(% dry wt.)	0.21	0.25	0.21	0.26	0.23	0.23	0.18	0.26	0.21	0.3	0.25	0.23	0.09	0.1	0.14	0.22	0.23
La		ppm	12.5	14.4	13	16.2	17.2	18.3	13.3	16.8	15.6	17.3	16.8	14.7	8.8	11.7	11.3	15.3	14.5
Li		ppm	29.3	30.8	29.8	33.9	30.7	32	23.1	28.1	24.3	17.1	30.6	26.8	18	16.6	22.8	29.4	26.8
Mg		(% dry wt.)	0.7	0.76	0.72	0.83	0.82	0.82	0.65	0.85	0.73	1.04	0.79	0.77	0.37	0.39	0.53	0.72	0.76
Mn		ppm	438	463	370	444	434	426	316	458	514	970	410	445	324	294	401	438	442
Mo		ppm	1.95	1.53	2.31	2.43	2.08	3.48	3.29	6.35	3.48	3.55	2.52	3.63	1.28	2.41	1.69	1.9	2.36
Na		(% dry wt.)	1.392	1.536	1.468	1.791	1.698	1.635	1.459	2.606	2.144	4.1	1.754	1.965	0.437	0.48	0.866	1.366	1.712
Nb		ppm	0.75	0.87	0.73	0.95	0.99	1.1	0.68	1.17	1.13	1.11	0.86	1.05	0.51	0.43	0.77	0.9	0.81
Ni		ppm	20.2	22.6	19.5	23.7	22.9	23.4	17	19.1	16.5	14.4	24.2	22.8	11.8	13	16.4	22.9	22.6
P		(% dry wt.)	0.072	0.081	0.075	0.074	0.074	0.073	0.066	0.098	0.082	0.113	0.096	0.063	0.031	0.04	0.053	0.074	0.076
Pb		ppm	15.08	15.37	14.95	18.53	24.02	25.8	20.11	30.27	26.53	37.93	18.1	17.85	5.43	9.23	10.36	17.83	16.74
Pd		ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt		ppb	<2	<2	<2	<2	<2	<2	<2	<2	3	2	2	<2	<2	<2	<2	<2	<2
Rb		ppm	10	11.3	9.9	11.9	10.1	10.4	7.5	10.1	8.1	6.9	11.8	10.9	5.2	5.4	7.8	10.9	10.4
Re		ppb	1	2	4	2	5	6	2	5	3	3	3	3	1	1	1	2	1
S		(% dry wt.)	0.66	0.85	0.85	1.23	1.41	1.62	0.98	2.07	1.44	1.92	0.84	1.2	0.26	0.41	0.53	0.95	0.8
Sb		ppm	0.17	0.19	0.18	0.21	0.81	0.9	1.28	0.61	0.49	0.91	0.23	0.22	0.09	0.7	0.15	0.21	0.27
Sc		ppm	1.8	2	1.7	2.1	1.9	2	1.3	1.6	1.4	1.2	2	1.9	1	1	1.4	2	1.9
Se		ppm	1.2	1.2	1.1	1.4	1.6	1.7	1.1	1.8	1.6	2.6	1.2	1.5	0.3	0.4	0.7	1.4	1.3
Sn		ppm	0.6	0.6	0.5	0.6	0.7	0.7	0.6	1.2	0.9	1	0.6	0.6	0.2	0.3	0.4	0.7	0.6
Sr		ppm	76.6	39.2	91.2	37.5	51.4	46.1	39.8	59	66.1	112.7	40.6	46.4	47.8	27.5	62.5	36.7	36.1
Ta		ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te		ppm	0.02	0.02	<.02	0.02	0.07	0.08	0.06	0.04	0.03	0.04	<.02	<.02	<.02	0.04	0.02	0.02	<.02
Th		ppm	2.9	3.6	2.9	3.8	3.7	3.9	2.5	2.6	2.3	1.8	3.6	3.3	1.9	3	2.5	3.3	3.1
Ti		(% dry wt.)	0.025	0.028	0.023	0.03	0.028	0.028	0.019	0.026	0.025	0.021	0.027	0.032	0.024	0.019	0.026	0.029	0.027
Tl		ppm	0.15	0.17	0.12	0.22	0.2	0.23	0.11	0.16	0.18	0.2	0.14	0.19	0.08	0.07	0.13	0.21	0.17
U		ppm	0.8	0.8	1	1	1.1	1.6	1.4	2.3	2	1.9	1.3	1.1	0.5	0.9	0.7	0.8	0.9
V		ppm	29	28	29	33	31	38	29	47	44	55	34	35	13	15	20	28	28
W		ppm	<.1	<.1	<.1	0.1	0.1	0.1	<.1	0.1	0.1	0.2	0.1	0.2	<.1	<.1	<.1	<.1	<.1
Y		ppm	6.33	7.15	6.41	7.82	7.95	8.32	5.52	7.9	7.16	7.34	8.07	7.82	3.7	4.47	5.35	7.22	6.81
Zn		ppm	52.2	57.8	49.6	60.4	63.6	62.9	47.9	60.9	51.6	50.3	58.8	54.5	27.9	40.6	40.4	55.7	51.7
Zr		ppm	2.8	3.5	2.7	3.9	3.9	4.3	2	2.5	2.6	2.1	3	4.4	2.5	2.4	2.8	3.4	2.9

Gravity cores

Stn		WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01
Sed. Depth 1 (cm)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sed. Depth 2 (cm)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
Total Carbon	(% dry wt.)	3.47	3.77	3.42	2.56	2.50	2.47	2.52	2.59	2.55	2.40	2.34	2.07	1.93	2.05	2.05	2.00	1.98
Organic Carbon	(% dry wt.)	3.04	2.72	2.58	2.48	2.28	2.23	2.19	2.25	2.22	2.32	2.27	1.89	1.26	1.28	1.28	1.93	1.98
Inorganic Carbon	(% dry wt.)	0.43	1.05	0.84	0.08	0.22	0.24	0.33	0.34	0.33	0.08	0.07	0.18	0.67	0.77	0.77	0.07	0.00
Ag	ppb	79	71	78	71	71	74	75	74	72	79	82	78	75	120	83	81	82
Al	(% dry wt.)	1.06	1.02	1.05	1	1.03	1.08	1.09	1.08	1.11	1.23	1.19	1.14	1.07	1.09	1.11	1.11	1.13
As	ppm	17	17	18	14	14	15	15	15	14	14	14	13	13	15	14	14	14
Au	ppb	7.8	5.1	5.5	22.6	12.1	4.6	5.4	4.6	5.3	4	4.6	5.9	33.7	5.2	5	4.4	5
B	ppm	48	37	44	40	36	37	37	41	39	36	35	31	27	26	28	28	28
Ba	ppm	30	28.3	28.3	27.2	27.6	28.4	29.4	29.1	29.2	30.8	30	29.7	27.9	28.6	29.7	30.6	29.9
Be	ppm	0.4	0.4	0.5	0.6	0.5	0.5	0.4	0.4	0.4	0.6	0.5	0.4	0.4	0.4	0.7	0.5	0.5
Bi	ppm	0.19	0.17	0.19	0.17	0.18	0.18	0.18	0.18	0.18	0.21	0.2	0.18	0.18	0.19	0.2	0.2	0.19
Ca	(% dry wt.)	0.65	0.39	0.34	0.33	0.41	0.44	0.69	0.66	0.36	0.28	0.27	0.27	0.28	0.48	0.58	0.59	0.78
Cd	ppm	0.43	0.38	0.41	0.41	0.42	0.41	0.37	0.42	0.39	0.39	0.41	0.37	0.34	0.36	0.36	0.39	0.38
Ce	ppm	24.5	24.7	25.8	24.8	25.5	25.3	25.9	25.5	26.5	27.9	27.6	27	25.9	26.6	26.9	27.3	27.2
Co	ppm	9	8.6	8.5	8.5	8.9	9.1	8.9	8.8	9.3	9.9	10.2	9.2	8.6	9.2	9.3	9.2	8.8
Cr	ppm	21.6	20.9	22	20.6	22.2	23.2	23.1	22.7	22.8	25.5	24.9	23.1	22	22.7	23.7	24.3	23.6
Cs	ppm	1.18	1.12	1.2	1.13	1.17	1.2	1.22	1.22	1.22	1.33	1.31	1.3	1.22	1.23	1.24	1.25	1.23
Cu	ppm	18.43	17.86	17.71	16.79	18.06	18.4	18.42	18.5	18.66	19.88	21.02	18.44	17.11	18.3	19.08	18.87	19.14
Fe	(% dry wt.)	2.2	2.16	2.24	2.13	2.18	2.23	2.36	2.27	2.31	2.57	2.52	2.43	2.33	2.37	2.39	2.42	2.42
Ga	ppm	3.4	3.2	3.3	3.3	3.4	3.5	3.6	3.5	3.7	3.9	3.8	3.6	3.5	3.4	3.6	3.6	3.6
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.09	0.09	0.08	0.08	0.08	0.1	0.1	0.11	0.11	0.09	0.1	0.1	0.1	0.11	0.1	0.1
Hg	ppb	97	88	102	96	93	94	87	101	101	112	108	96	92	90	99	101	104
In	ppm	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.02
K	(% dry wt.)	0.24	0.22	0.23	0.21	0.21	0.21	0.21	0.22	0.23	0.25	0.24	0.22	0.21	0.21	0.22	0.22	0.21
La	ppm	13.3	13.3	14.1	13.5	13.7	13.8	14	14.2	14.3	15.6	14.9	14.5	13.9	14.4	14.7	14.8	14.4
Li	ppm	28	27.4	28.4	29	28.7	29.2	29.2	30.2	30.5	34.3	33.2	29.4	28.6	28.7	30.5	29.5	29.7
Mg	(% dry wt.)	0.77	0.68	0.71	0.65	0.67	0.68	0.68	0.7	0.69	0.76	0.72	0.7	0.67	0.68	0.69	0.71	0.69
Mn	ppm	438	414	426	419	436	446	465	463	451	468	461	462	454	487	496	500	504
Mo	ppm	2.43	2.49	2.66	2.93	3.02	3.17	2.95	3.07	3.96	5.5	4.83	3.66	2.79	2.52	2.4	2.21	2.37
Na	(% dry wt.)	2.048	1.428	1.569	1.293	1.21	1.297	1.335	1.44	1.305	1.325	1.202	1.094	1.032	1.002	1.068	1.075	1.08
Nb	ppm	0.86	0.83	0.89	0.85	0.83	0.84	0.82	0.86	0.92	0.89	0.85	0.86	0.81	0.84	0.83	0.86	0.89
Ni	ppm	22.1	22	21.5	21.7	22.5	23.4	22.5	23	23.5	24.9	25.7	23.4	21.8	23.1	23.4	23.6	22.6
P	(% dry wt.)	0.071	0.064	0.065	0.06	0.059	0.06	0.058	0.06	0.059	0.058	0.059	0.056	0.054	0.053	0.053	0.054	0.055
Pb	ppm	15.27	14.84	16.04	15.04	15.8	16.14	16.83	16.32	16.65	19.02	19.31	16.71	16.16	17.44	18.59	18.86	18.39
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	10.6	10.4	10.5	10.6	10.7	10.8	11.3	11	11.5	11.9	12	11.7	11	11.3	11.3	11.7	11.7
Re	ppb	2	2	1	2	2	1	2	1	4	2	3	4	4	3	3	2	3
S	(% dry wt.)	0.93	0.83	0.94	0.86	0.88	0.9	1.01	0.99	0.97	1.03	1.04	0.99	0.99	1.01	0.99	0.99	0.97
Sb	ppm	0.2	0.19	0.21	0.2	0.22	0.2	0.22	0.22	0.19	0.23	0.24	0.23	0.21	0.22	0.2	0.2	0.19
Sc	ppm	1.9	1.8	1.9	1.9	2	2	2	2	2.1	2.3	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Se	ppm	1	1	0.9	0.9	1	0.9	0.9	0.9	0.9	1	0.9	0.8	0.8	0.8	0.9	0.9	0.8
Sn	ppm	0.5	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.6	0.7	0.7	0.7
Sr	ppm	54.4	38.8	34.9	31.2	32.4	33.3	42.3	42.5	31.3	30.6	29.7	29.2	27.7	33.2	37.4	38.8	44.9
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	<.02	0.02	<.02	0.02	<.02	<.02	0.02	<.02	<.02	<.02	0.02	<.02	<.02	0.02	0.03	0.03	0.02
Th	ppm	3.2	3	3.2	3.2	3.4	3.4	3.4	3.4	3.4	3.8	3.7	3.5	3.5	3.6	3.5	3.6	3.5
Ti	(% dry wt.)	0.026	0.025	0.027	0.027	0.028	0.028	0.028	0.028	0.03	0.029	0.028	0.031	0.03	0.03	0.03	0.031	0.03
Tl	ppm	0.17	0.17	0.18	0.18	0.19	0.19	0.17	0.18	0.18	0.2	0.2	0.19	0.19	0.19	0.2	0.2	0.19
U	ppm	1	0.9	1	1.1	1.2	1.2	1.2	1.1	1.4	1.8	1.6	1.4	1.2	1.1	1.1	1	1
V	ppm	30	29	31	29	29	30	31	32	33	39	37	33	30	30	30	31	30
W	ppm	<.1	0.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	0.1	<.1	<.1	0.1	0.1	<.1
Y	ppm	6.72	6.65	7	6.79	6.98	7.08	7.17	7.08	7.51	7.77	7.56	7.33	6.96	7.24	7.41	7.44	7.29
Zn	ppm	54.3	53.6	51.4	50.8	53.5	56.8	57.3	54.7	58.1	60.7	61.5	59.5	54.4	55.9	57.9	60.3	58.4
Zr	ppm	3.6	3.3	3.5	3.5	3.5	3.8	3.7	3.9	4.5	4.4	4.2	3.8	3.7	4.1	4	4.1	4.1

Stn		WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01	WH 01
Sed. Depth 1 (cm)		17	18	19	20	21	22	23	24	25	26	27	28	29	30	32	34	36
Sed. Depth 2 (cm)		18	19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38
Avg. Depth	(cm)	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0	33.0	35.0	37.0
Total Carbon	(% dry wt.)	1.94	2.00	2.22	2.16	2.24	2.28	2.40	2.32	2.24	1.52	2.06	2.06	1.90	2.21	2.12	1.97	2.11
Organic Carbon	(% dry wt.)	1.82	1.81	1.89	2.07	2.09	2.16	2.09	1.96	2.06	1.52	1.79	1.75	1.72	1.67	1.82	1.70	1.89
Inorganic Carbon	(% dry wt.)	0.12	0.19	0.33	0.09	0.15	0.12	0.31	0.36	0.18	0.00	0.27	0.31	0.18	0.54	0.30	0.27	0.22
Ag	ppb	84	89	88	86	85	86	79	77	77	77	73	68	70	63	62	70	59
Al	(% dry wt.)	1.14	1.12	1.14	1.14	1.14	1.1	1.11	1.04	1.09	1.15	1.08	1.08	1.06	1.01	1.08	1.07	1.05
As	ppm	14	14	14	15	16	15	15	14	18	18	22	17	18	18	17	16	18
Au	ppb	5.9	4.8	4.6	4	5.9	6.5	7	7.6	5.8	8.6	7	6.3	7.7	9.8	7.8	5.6	8.6
B	ppm	30	32	37	33	36	33	33	34	32	31	32	30	31	29	36	33	44
Ba	ppm	30.5	31.2	30.8	31.5	31.8	30.7	31.6	32.7	31.7	33.4	33.1	32	31.9	30.2	30.7	31.7	29.8
Be	ppm	0.5	0.6	0.5	0.4	0.6	0.4	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4
Bi	ppm	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.19	0.19	0.2	0.19	0.19	0.18	0.17	0.18	0.18	0.19
Ca	(% dry wt.)	0.6	0.57	0.56	0.62	0.65	0.68	0.72	0.92	0.64	0.68	0.79	0.73	0.83	0.92	1.32	0.91	0.83
Cd	ppm	0.39	0.41	0.4	0.39	0.38	0.36	0.38	0.35	0.34	0.36	0.37	0.33	0.34	0.28	0.28	0.31	0.33
Ce	ppm	28.1	27.6	28.2	28.3	28.2	26.9	26.5	26	27.7	28.7	28.2	27.3	27.1	26.1	26.1	27	26.2
Co	ppm	9.3	9.4	8.8	9.2	9.2	8.9	9.3	8.5	8.8	9.3	9	8.5	8.4	8.1	8.5	8.9	9
Cr	ppm	24.6	25.2	24.6	24.2	24	24.1	24.2	23.5	23.1	23.7	23.8	22.5	22.1	20.3	21.6	22.1	22
Cs	ppm	1.27	1.29	1.26	1.27	1.29	1.25	1.28	1.29	1.26	1.31	1.28	1.23	1.22	1.15	1.2	1.24	1.21
Cu	ppm	19.65	19.52	19.33	19.01	18.93	18.58	18.93	17.98	18.74	18.65	18.16	17.48	17.77	16.37	16.67	18.09	16.44
Fe	(% dry wt.)	2.5	2.47	2.48	2.5	2.44	2.36	2.35	2.27	2.3	2.41	2.27	2.26	2.25	2.14	2.29	2.31	2.37
Ga	ppm	3.6	3.7	3.7	3.7	3.7	3.6	3.6	3.4	3.6	3.7	3.6	3.5	3.4	3.1	3.4	3.5	3.4
Ge	ppm	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.1	0.1	0.09	0.09	0.08	0.1	0.09	0.1
Hg	ppb	109	110	114	106	123	115	132	130	125	150	143	145	140	140	149	112	167
In	ppm	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K	(% dry wt.)	0.22	0.22	0.23	0.23	0.23	0.22	0.23	0.22	0.22	0.23	0.23	0.23	0.22	0.2	0.21	0.22	0.2
La	ppm	15	14.9	15	15.2	15.3	14.9	15	15.1	14.9	15.8	15.6	15	15.2	14	14.3	15.1	14.3
Li	ppm	29.5	31.3	31.5	30	30.4	30.4	30	28.9	29	31.3	30.8	28.9	28.1	28.5	27.9	29.3	28
Mg	(% dry wt.)	0.71	0.71	0.71	0.72	0.72	0.7	0.69	0.66	0.69	0.71	0.68	0.67	0.67	0.63	0.66	0.66	0.64
Mn	ppm	505	505	493	499	495	484	480	465	464	483	458	455	455	443	486	477	452
Mo	ppm	2.42	2.61	2.6	2.61	2.32	2.19	2.39	2.44	2.55	2.77	2.54	2.56	2.61	2.07	1.69	2.33	3.99
Na	(% dry wt.)	1.116	1.156	1.238	1.156	1.195	1.115	1.113	1.039	1.082	1.114	1.062	1.05	1.04	0.972	0.995	0.943	0.857
Nb	ppm	0.84	0.85	0.85	0.91	0.91	0.87	0.88	0.86	0.88	0.87	0.85	0.85	0.83	0.8	0.88	0.85	0.85
Ni	ppm	24.1	24.7	23.4	23.5	23.4	23.6	23.4	21.9	23.5	23.6	22.4	22.1	21.9	20.5	21.9	23	22.7
P	(% dry wt.)	0.054	0.055	0.054	0.055	0.054	0.055	0.055	0.052	0.055	0.059	0.055	0.056	0.057	0.054	0.055	0.055	0.055
Pb	ppm	19.06	19.21	19.42	18.87	19.01	18.84	18.18	17.27	17.53	18.93	17.29	17.25	16.75	14.95	14.69	15.39	13.96
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	11.5	11.6	11.5	11.5	12	11.2	11.2	10.9	11.4	11.7	11.2	11	11.2	10	10.7	11.4	10.6
Re	ppb	2	4	3	4	3	2	3	2	3	2	2	2	2	3	2	2	2
S	(% dry wt.)	1	1.03	1.03	1.04	1.03	1	0.98	0.94	0.93	1	0.96	0.93	0.93	0.92	1.04	1.02	1.15
Sb	ppm	0.2	0.19	0.19	0.18	0.19	0.21	0.2	0.2	0.21	0.22	0.22	0.19	0.21	0.2	0.23	0.21	0.22
Sc	ppm	2.1	2.2	2.2	2.3	2.2	2.2	2.2	2.1	2.2	2.2	2.1	2.1	2	1.9	2	2.1	2
Se	ppm	0.9	0.8	0.9	0.9	1	0.9	1	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.8	0.9	0.9
Sn	ppm	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6
Sr	ppm	38.7	37.7	38.1	40.3	41	41.6	43.1	50.7	40.5	41.7	45.4	42.1	47.5	49.9	69.3	49.5	50.1
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	0.03	0.02	0.02	<.02	0.03	0.02	0.02	0.02	0.02	<.02	<.02	0.02	<.02	<.02	0.02	<.02
Th	ppm	3.6	3.7	3.7	3.6	3.7	3.6	3.4	3.3	3.4	3.6	3.7	3.5	3.3	3.1	3.2	3.7	3.3
Ti	(% dry wt.)	0.03	0.031	0.031	0.032	0.033	0.031	0.031	0.032	0.031	0.031	0.03	0.03	0.03	0.029	0.029	0.032	0.03
Tl	ppm	0.21	0.2	0.21	0.2	0.2	0.2	0.18	0.17	0.18	0.19	0.17	0.17	0.16	0.15	0.14	0.15	0.16
U	ppm	1	1	1.1	1	1.1	1	1	1	1.1	1.1	1.1	1.1	1	1	1.1	1.1	1.3
V	ppm	31	31	31	31	32	31	32	31	31	32	30	30	30	27	29	29	29
W	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Y	ppm	7.45	7.54	7.35	7.56	7.57	7.56	7.42	7.17	7.35	7.58	7.4	7.32	7.29	6.59	7.03	7.48	7.14
Zn	ppm	60.4	61.6	57.9	60.3	59.6	58.8	57.8	55.6	59.7	60.4	59.6	55.9	57.2	51.5	53.1	56.2	52.5
Zr	ppm	4	4.1	4	4.2	4	3.9	3.6	3.4	3.9	3.9	3.8	3.7	3.6	3.2	3.9	4	3.9

Stn		WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02
Sed. Depth 1 (cm)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sed. Depth 2 (cm)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
Total Carbon	(% dry wt.)	2.39	1.97	2.19	2.31	2.13	2.13	1.98	1.84	1.83	1.72	1.98	3.08	2.22	3.72	2.92	2.27	2.17	1.42	1.23
Organic Carbon	(% dry wt.)	2.25	1.86	2.01	2.21	2.06	1.96	1.79	1.63	1.54	1.46	1.63	2.37	1.70	2.21	2.25	1.48	1.46	0.93	0.83
Inorganic Carbon	(% dry wt.)	0.14	0.11	0.18	0.10	0.07	0.17	0.19	0.21	0.29	0.26	0.35	0.71	0.52	1.51	0.67	0.79	0.71	0.49	0.40
Ag	ppb	68	56	60	67	58	59	52	53	51	52	69	49	62	70	77	55	50	34	35
Al	(% dry wt.)	0.93	0.88	0.94	1	0.96	0.94	0.87	0.93	0.85	0.89	0.89	0.69	0.75	0.81	0.88	0.75	0.73	0.72	0.71
As	ppm	10	10	11	12	10	10	8	9	8	8	6	5	5	7	7	5	6	4	6
Au	ppb	1.9	2.1	2.9	2.2	2	2.4	1.7	2	1.2	1	2.3	1.5	1.2	2.4	1	0.8	0.5	0.4	1.7
B	ppm	40	33	34	40	43	44	36	30	22	22	26	38	32	40	30	21	19	13	11
Ba	ppm	24.5	21.6	23.4	26.2	22.5	23.2	22.1	25.3	21.8	21.9	20.7	16.8	17.3	19	21.3	18.3	17.5	21.1	16.3
Be	ppm	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.3	0.3	0.4	0.4	0.1	0.3	0.2	0.3	0.2	0.2	0.2
Bi	ppm	0.15	0.14	0.15	0.17	0.15	0.15	0.14	0.17	0.13	0.13	0.13	0.11	0.11	0.13	0.14	0.11	0.11	0.08	0.12
Ca	(% dry wt.)	0.65	0.42	0.34	0.33	0.36	0.48	0.48	0.67	0.49	0.94	1.02	0.65	1.06	1.39	1.53	1.6	1.48	0.89	0.82
Cd	ppm	0.34	0.28	0.35	0.39	0.35	0.33	0.3	0.26	0.22	0.24	0.25	0.18	0.25	0.31	0.4	0.22	0.2	0.18	0.14
Ce	ppm	24.5	23.4	24.1	26.1	23.2	23.4	22.9	23.5	23.3	23.2	22.1	19	19.7	19.3	22.2	19.2	17.6	17.3	18
Co	ppm	8.5	7.9	8.2	8.8	8.2	8.5	8.2	8.2	7.6	8.2	7.6	6.9	7.3	7.3	8	6.9	6.5	6.5	6.7
Cr	ppm	18.7	17.1	18.9	19.4	18.9	18.5	17.4	17.9	16	17	17.3	14.6	15.4	16.7	18.5	15.5	15.3	14.3	14.5
Cs	ppm	1.1	1	1.07	1.19	1.05	1.07	1.01	1.08	0.95	1.03	0.96	0.81	0.8	0.84	0.93	0.82	0.76	0.67	0.71
Cu	ppm	15.83	14.98	15.57	17.29	15.72	15.81	14.44	15.52	13.23	14.7	15.57	11.98	11.81	13.95	15.9	12.48	12.03	9.76	9.69
Fe	(% dry wt.)	2.05	1.92	2.02	2.15	2.1	2.08	1.93	2.03	1.85	1.99	1.96	1.79	1.7	1.86	1.93	1.68	1.65	1.62	1.7
Ga	ppm	3	2.9	2.9	3.3	3	3	2.9	3	2.8	2.9	2.8	2.3	2.4	2.5	2.8	2.4	2.3	2.3	2.5
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.08	0.09	0.08	0.08	0.07	0.08	0.08	0.07	0.08	0.1	0.06	0.08	0.08	0.09	0.06	0.07	0.08	0.08
Hg	ppb	42	37	45	46	43	48	33	34	24	14	16	11	18	18	21	17	14	12	13
In	ppm	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	<.02	<.02	0.02	0.02	<.02	<.02	<.02	<.02
K	(% dry wt.)	0.19	0.16	0.17	0.19	0.18	0.19	0.16	0.18	0.15	0.16	0.16	0.14	0.14	0.16	0.18	0.14	0.14	0.11	0.11
La	ppm	13	12.6	12.9	14.3	12.7	12.9	12.2	12.6	12.7	12.4	12.2	10.2	10.8	11.1	12.3	10.7	10	9.4	10
Li	ppm	25.2	25.2	25.8	27.1	25.6	26.7	23.9	26.9	23.5	25.9	26.7	21.9	21.8	25.1	25.6	23.4	21.7	21.9	23.6
Mg	(% dry wt.)	0.59	0.54	0.58	0.61	0.59	0.58	0.54	0.56	0.51	0.55	0.54	0.49	0.48	0.55	0.6	0.49	0.48	0.44	0.44
Mn	ppm	440	415	412	425	432	442	410	450	443	473	472	368	397	438	453	400	381	407	466
Mo	ppm	1.99	2.35	2.75	3.82	4.09	3.6	2.99	2.73	3.09	4.99	5.82	6.74	6.41	6.82	2.5	2.6	2.27	1.74	1.85
Na	(% dry wt.)	0.873	0.741	0.797	0.9	0.879	0.874	0.739	0.777	0.643	0.712	0.731	0.624	0.725	1.014	1.027	0.717	0.694	0.47	0.449
Nb	ppm	0.86	0.75	0.77	0.89	0.76	0.78	0.75	0.74	0.69	0.73	0.72	0.65	0.68	0.75	0.82	0.66	0.63	0.53	0.52
Ni	ppm	20.1	19.7	20.3	21.7	20.2	20.5	19.4	20	18	20.1	18.8	16.8	16.1	17.2	18.1	16.1	15.2	14.8	15.1
P	(% dry wt.)	0.062	0.054	0.059	0.061	0.054	0.055	0.051	0.053	0.05	0.051	0.05	0.042	0.045	0.049	0.051	0.046	0.042	0.038	0.066
Pb	ppm	12.86	11.27	12.68	13.65	12.66	12.67	11.85	11.66	10.05	10.64	10.72	9.06	9.09	11.41	12.54	9.72	9.3	7.42	8.05
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2
Rb	ppm	9.9	8.9	9.2	10.4	9.2	9.5	9	9.2	8.2	9.2	9.2	7.4	7.5	8	8.7	7.6	7.3	6.3	6.6
Re	ppb	1	1	1	3	1	1	1	2	1	<1	1	1	<1	2	1	1	1	<1	1
S	(% dry wt.)	0.6	0.56	0.66	0.72	0.71	0.74	0.62	0.65	0.51	0.56	0.72	0.61	0.72	0.83	0.86	0.69	0.66	0.51	0.55
Sb	ppm	0.16	0.16	0.28	0.22	0.18	0.18	0.17	0.18	0.14	0.15	0.13	0.11	0.11	0.13	0.13	0.11	0.11	0.09	0.11
Sc	ppm	1.7	1.6	1.7	1.8	1.7	1.7	1.5	1.8	1.5	1.6	1.8	1.4	1.4	1.5	1.7	1.3	1.4	1.3	1.3
Se	ppm	0.8	0.7	0.8	0.9	0.8	0.8	0.6	0.7	0.4	0.5	0.7	0.6	0.6	0.8	1	0.7	0.7	0.5	0.5
Sn	ppm	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.5	0.3	0.3	0.2	0.3
Sr	ppm	41.2	29.8	28.4	30.4	29.8	32.9	32	39.3	29.9	48.3	52.4	39.2	53.4	71.5	84.5	81.9	75.5	42.8	38.7
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	<.02	<.02	<.02	<.02	<.02	<.02	0.02	0.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Th	ppm	2.8	2.8	2.9	3.1	2.8	2.9	2.8	2.9	2.8	2.7	2.9	2.5	2.4	2.6	2.9	2.6	2.4	2.2	2.4
Ti	(% dry wt.)	0.029	0.026	0.026	0.029	0.027	0.027	0.027	0.028	0.027	0.027	0.029	0.024	0.025	0.025	0.027	0.026	0.025	0.027	0.026
Tl	ppm	0.14	0.13	0.14	0.16	0.14	0.14	0.13	0.12	0.1	0.11	0.12	0.1	0.11	0.13	0.15	0.1	0.09	0.07	0.08
U	ppm	0.7	0.8	1	1.3	1.2	1.1	1	0.9	0.8	1.1	1.3	1.3	1.3	1.5	1	0.9	0.9	0.7	0.8
V	ppm	27	24	26	28	27	26	24	25	22	23	22	20	20	23	27	20	19	16	18
W	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	0.1
Y	ppm	6.4	5.87	6.14	6.62	6.01	6.17	5.74	6.14	5.54	5.85	6.13	5	5.13	5.54	6.27	5.47	5.02	4.55	5.53
Zn	ppm	48.8	45.8	48.5	54.5	48.9	48.1	47.9	47.9	41.9	45.9	45.8	38.9	41	42.3	48.1	40.5	39.7	35.7	35.8
Zr	ppm	3.4	3.2	3.2	3.4	3.1	3.3	3.1	3.3	3.2	3.6	3.5	3	3	3.3	3.8	3.1	2.9	3.1	3.2

Stn		WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02	WH 02
Sed. Depth 1 (cm)		19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38
Sed. Depth 2 (cm)		20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40
Avg. Depth	(cm)	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0	33.0	35.0	37.0	39.0
Total Carbon	(% dry wt.)	1.32	0.41	0.43	0.51	0.40	0.93	2.83	2.95	4.43	2.82	4.10	1.40	2.95	1.73	1.48	2.25
Organic Carbon	(% dry wt.)	0.86	0.33	0.21	0.32	0.34	0.62	1.64	1.92	4.43	1.90	2.48	0.91	2.10	1.73	1.48	1.77
Inorganic Carbon	(% dry wt.)	0.46	0.08	0.22	0.19	0.06	0.31	1.19	1.03	0.00	0.92	1.62	0.49	0.85	0.00	0.00	0.48
Ag	ppb	86	18	20	24	23	20	42	49	58	55	56	31	48	53	48	54
Al	(% dry wt.)	1.12	0.68	0.69	0.69	0.65	0.64	0.64	0.64	0.68	0.69	0.67	0.63	0.65	0.7	0.64	0.64
As	ppm	15	5	4	6	4	5	6	6	4	5	6	4	5	5	5	6
Au	ppb	8	0.5	0.2	0.2	<.2	0.7	0.8	0.6	1.6	1.2	0.9	0.5	1.1	1.2	0.8	1
B	ppm	33	9	8	12	10	11	24	23	21	23	33	13	25	25	22	22
Ba	ppm	30.5	11.7	18.5	10.9	10.2	11.4	12.8	14.1	15.7	15.5	15.5	14.6	14.9	16.3	14.5	14.1
Be	ppm	0.4	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.2	0.2
Bi	ppm	0.19	0.09	0.09	0.09	0.08	0.09	0.08	0.12	0.12	0.1	0.11	0.09	0.1	0.1	0.1	0.09
Ca	(% dry wt.)	0.28	0.45	0.65	0.4	0.4	0.8	1.03	1	0.91	0.97	0.98	0.57	0.78	0.83	1.13	0.89
Cd	ppm	0.42	0.09	0.11	0.1	0.1	0.11	0.21	0.2	0.22	0.24	0.33	0.17	0.26	0.38	0.25	0.35
Ce	ppm	26	14.8	14.1	13.9	14.3	14.1	13.4	14.5	18.4	17.5	16.7	17.1	16.8	17.9	17.1	17.3
Co	ppm	8.9	6.2	6.5	6	5.9	6.4	6	6.4	5.7	5.8	6.1	5.9	5.7	6.1	5.9	5.9
Cr	ppm	26.1	13.6	13.6	13	12.9	13.8	14	15.3	13.1	13.7	14.1	12.2	13.4	13.8	13.2	12.8
Cs	ppm	1.25	0.57	0.61	0.57	0.54	0.59	0.64	0.72	0.73	0.71	0.72	0.68	0.68	0.77	0.74	0.74
Cu	ppm	18.73	7.31	7.42	8.91	7.04	8.72	8.98	9.9	10.27	10.71	11.14	8.47	9.81	10.97	9.99	10.83
Fe	(% dry wt.)	2.38	1.66	1.73	1.73	1.62	1.62	1.52	1.48	1.56	1.59	1.57	1.41	1.5	1.53	1.47	1.42
Ga	ppm	3.4	2.4	2.3	2.3	2.3	2.2	2.1	2.1	2.2	2.1	2.2	2.1	2.2	2.3	2.2	2.2
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.07	0.07	0.08	0.1	0.08	0.09	0.07	0.06	0.06	0.06	0.08	0.07	0.07	0.08	0.07	0.08
Hg	ppb	159	12	5	9	<5	8	9	11	17	10	11	10	13	15	10	13
In	ppm	0.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	0.02	<.02	<.02	<.02	<.02	0.02	<.02	<.02
K	(% dry wt.)	0.23	0.09	0.09	0.09	0.08	0.09	0.11	0.12	0.13	0.13	0.13	0.11	0.12	0.13	0.12	0.12
La	ppm	14.4	8.1	7.5	7.7	8.5	8.3	8.2	8.8	10.2	9.6	9.2	9.1	9.4	10	9.6	9.5
Li	ppm	31.3	22.3	22	22.2	20.6	21.1	18.9	19.8	20.4	18.7	20.3	20.5	18.3	20.5	20.3	19.9
Mg	(% dry wt.)	0.69	0.42	0.42	0.42	0.4	0.4	0.42	0.42	0.45	0.46	0.46	0.39	0.43	0.46	0.42	0.41
Mn	ppm	419	394	454	424	455	407	389	351	356	358	356	345	337	349	329	336
Mo	ppm	2.27	2.02	2.55	2.33	2.1	2.05	3.37	5.57	5.23	4.46	6.91	2.85	8.13	5.95	4.66	5.65
Na	(% dry wt.)	1.364	0.339	0.331	0.322	0.299	0.367	0.541	0.593	0.67	0.68	0.703	0.465	0.656	0.716	0.587	0.613
Nb	ppm	0.77	0.33	0.31	0.37	0.34	0.4	0.63	0.74	0.69	0.63	0.74	0.56	0.7	0.73	0.65	0.76
Ni	ppm	23	13.9	14.4	14.3	13.1	14.3	14.1	14.9	14.3	15.1	16.2	13.5	14.2	15	15.2	14.9
P	(% dry wt.)	0.064	0.036	0.038	0.038	0.039	0.041	0.039	0.041	0.043	0.043	0.042	0.036	0.042	0.043	0.041	0.045
Pb	ppm	17.34	5.65	5.63	6.13	5.52	5.97	7.06	7.88	8.78	9.56	9.16	7.46	8.78	9.6	9.4	8.67
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	2	2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	11.4	4.9	4.9	5.4	4.5	5.4	6	6.5	6.8	6.8	6.6	6.5	6.6	7.2	6.7	6.9
Re	ppb	1	<1	<1	<1	<1	1	<1	<1	1	<1	1	<1	1	1	<1	<1
S	(% dry wt.)	1.11	0.4	0.47	0.46	0.44	0.51	0.56	0.57	0.61	0.67	0.69	0.48	0.68	0.65	0.65	0.63
Sb	ppm	0.23	0.12	0.12	0.15	0.11	0.11	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.07	0.07
Sc	ppm	2	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.5	1.3	1.3	1.2	1.2	1.4	1.4	1.2
Se	ppm	1.1	0.3	0.3	0.3	0.3	0.4	0.5	0.7	0.6	0.7	0.8	0.4	0.7	0.7	0.7	0.6
Sn	ppm	0.6	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Sr	ppm	31.5	23.8	27	20.8	20.4	38	50.9	48.9	48.6	51.3	50.9	28.7	43.7	44.3	55.9	46.7
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Th	ppm	3.4	2.2	2.1	2.1	2.2	2.2	2.1	2	2.2	2.2	2.2	2.3	2.1	2.3	2.1	2.2
Ti	(% dry wt.)	0.027	0.024	0.023	0.024	0.023	0.023	0.022	0.023	0.024	0.023	0.024	0.025	0.024	0.025	0.024	0.024
Tl	ppm	0.2	0.05	0.05	0.05	0.05	0.05	0.09	0.1	0.1	0.09	0.12	0.08	0.11	0.13	0.1	0.13
U	ppm	1	0.7	0.7	0.7	0.7	0.8	0.9	1	1.1	1.1	1.2	0.8	1.4	1.3	1.2	1.2
V	ppm	33	16	17	17	16	16	18	19	19	20	21	16	20	20	18	18
W	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Y	ppm	7.16	3.95	4.19	4.06	4.13	4.25	4.12	4.39	4.8	4.77	4.95	4.46	4.66	4.83	4.67	4.67
Zn	ppm	58.1	32.8	33	32.8	32.9	33.1	33.1	35.6	39	37.1	38.3	35.3	35.6	41	37.2	39.2
Zr	ppm	3.3	3.1	3.1	3.3	3	2.8	2.6	2.6	2.9	2.6	3.1	2.9	2.9	3.1	2.9	3.1

Stn		WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04
Sed. Depth 1	(cm)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sed. Depth 2	(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
Total Carbon	(% dry wt.)	2.41	2.49	2.71	2.77	2.58	2.63	2.66	2.38	2.46	2.76	2.74	2.49	2.24	2.16	2.28	2.18	2.03	2.04	1.74
Organic Carbon	(% dry wt.)	2.24	2.36	2.57	2.60	2.47	2.47	2.50	2.15	2.08	2.13	2.21	2.26	2.05	1.98	2.01	1.91	1.70	1.87	1.74
Inorganic Carbon	(% dry wt.)	0.17	0.13	0.14	0.17	0.11	0.16	0.16	0.23	0.38	0.63	0.53	0.23	0.19	0.18	0.27	0.27	0.33	0.17	0.00
Ag	ppb	158	87	82	87		78	86	83	84	87	86	88	85	84	85	83	79	79	83
Al	(% dry wt.)	1.22	1.23	1.18	1.23		1.22	1.26	1.22	1.14	1.21	1.22	1.28	1.2	1.15	1.17	1.16	1.13	1.19	1.18
As	ppm	47	19	20	18		17	16	16	17	18	15	18	18	17	16	17	16	16	15
Au	ppb	19.3	8.9	8.5	7		12.7	8.6	11.2	7.8	7.8	9.2	9	10.5	10.1	15.7	8.1	8.1	7.8	7.8
B	ppm	98	34	36	35		38	42	37	33	37	36	37	37	34	36	35	35	35	32
Ba	ppm	41	33.5	30.1	31.1		31.1	31.7	31.9	29.9	32.6	30.7	31.7	31.2	30.3	30.2	28.3	29.5	30.1	31.3
Be	ppm	0.5	0.6	0.5	0.5		0.5	0.6	0.6	0.4	0.5	0.3	0.4	0.4	0.4	0.4	0.5	0.3	0.4	0.5
Bi	ppm	0.26	0.21	0.2	0.21		0.2	0.21	0.21	0.2	0.2	0.21	0.21	0.22	0.2	0.22	0.2	0.19	0.2	0.2
Ca	(% dry wt.)	0.34	0.38	0.3	0.25		0.29	0.26	0.24	1.13	1.88	2.99	0.54	0.3	0.33	1.21	0.44	0.41	0.52	0.48
Cd	ppm	0.91	0.42	0.42	0.42		0.43	0.45	0.47	0.41	0.46	0.44	0.48	0.45	0.4	0.38	0.4	0.38	0.36	0.39
Ce	ppm	28.2	28.6	25.6	27.2		26.7	27.4	28	24	27.1	26.2	28.2	27.3	25.7	26	25.8	26.6	27	27.5
Co	ppm	7.2	9.8	9.4	10		9.5	10.2	10	8.9	9.5	9.9	10.1	9.5	9.3	9.1	9.3	8.4	9.5	9.4
Cr	ppm	31	25.7	23.8	25.4		24.9	25.1	26.1	24.9	25.3	23.7	24.8	24.8	25.3	23.9	24.6	23.3	24.9	25.3
Cs	ppm	1.5	1.35	1.22	1.29		1.35	1.35	1.37	1.27	1.33	1.31	1.33	1.31	1.31	1.28	1.26	1.23	1.3	1.33
Cu	ppm	30.33	20.05	19.08	20.57		19.73	20.46	20.05	18.97	19.03	18.83	20.12	18.54	18.5	18.6	18.94	17.33	19.27	18.74
Fe	(% dry wt.)	2.58	2.61	2.49	2.56		2.53	2.59	2.54	2.48	2.62	2.7	2.71	2.65	2.57	2.54	2.53	2.47	2.59	2.55
Ga	ppm	3.8	3.9	3.6	3.8		3.8	3.9	3.9	3.6	3.7	3.6	3.8	3.7	3.6	3.7	3.6	3.5	3.7	3.7
Ge	ppm	<.1	<.1	<.1	<.1		<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.08	0.12	0.07	0.11		0.1	0.1	0.1	0.09	0.1	0.11	0.11	0.09	0.11	0.1	0.1	0.09	0.1	0.09
Hg	ppb	556	188	172	176		169	193	206	215	173	163	180	189	187	165	170	159	165	160
In	ppm	0.02	0.03	0.02	0.03		0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03
K	(% dry wt.)	0.32	0.24	0.25	0.26		0.25	0.25	0.25	0.23	0.26	0.26	0.26	0.24	0.24	0.24	0.24	0.23	0.24	0.24
La	ppm	16.2	15.6	14.3	14.9		15	15.2	15.4	13.9	14.6	14.2	15.3	15.3	14.4	14	13.8	13.9	14.6	14.5
Li	ppm	33.1	32.2	31	31.6		31.8	32.3	32.4	29.9	29.6	29	30.4	31.4	30.2	30.6	31.5	30.1	31.7	32.3
Mg	(% dry wt.)	0.9	0.72	0.75	0.76		0.75	0.75	0.73	0.72	0.77	0.76	0.77	0.73	0.71	0.73	0.71	0.7	0.74	0.73
Mn	ppm	304	486	427	448		442	442	445	445	484	473	451	459	488	486	475	451	493	485
Mo	ppm	6.89	1.76	2.35	2.47		3.75	5.35	5.11	3.01	2.69	2.93	3.97	3.36	2.39	2.28	2.11	1.75	2.17	2.25
Na	(% dry wt.)	2.165	1.044	1.621	1.588		1.44	1.427	1.415	1.276	1.501	1.431	1.342	1.29	1.207	1.255	1.254	1.193	1.19	1.206
Nb	ppm	1.37	0.96	0.85	0.9		0.96	0.86	0.95	0.83	0.86	0.84	0.89	0.88	0.85	0.85	0.87	0.79	0.91	0.9
Ni	ppm	23.3	24.7	23.6	25.7		24.3	25.2	24.9	23	24.2	23	25.3	24	23.1	23.6	24.3	21.8	24.1	24.3
P	(% dry wt.)	0.07	0.069	0.078	0.075		0.065	0.064	0.062	0.054	0.058	0.054	0.059	0.058	0.054	0.055	0.056	0.057	0.056	0.053
Pb	ppm	36.03	19.09	17.2	18.83		18.05	18.9	18.77	17.94	18.56	19.1	18.72	18.03	17.51	18.37	17.65	17.74	18.16	18.33
Pd	ppb	<10	<10	<10	<10		<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2		<2	<2	<2	<2	<2	<2	<2	2	<2	2	2	<2	<2	<2
Rb	ppm	14.9	12.7	11.9	12.8		12.8	12.5	12.4	11.5	12.1	11.5	12.2	11.9	12.1	11.8	11.8	11.5	11.9	12.6
Re	ppb	5	4	4	2		2	3	3	3	3	3	4	3	1	2	3	3	3	4
S	(% dry wt.)	1.85	1.15	1.15	1.3		1.19	1.21	1.23	1.25	1.15	1.18	1.13	1.11	1.05	1.04	1.04	0.98	0.98	0.96
Sb	ppm	0.19	0.22	0.23	0.24		0.33	0.28	0.23	0.21	0.21	0.19	0.21	0.22	0.24	0.21	0.21	0.19	0.21	0.19
Sc	ppm	2.3	2.3	2.3	2.2		2.3	2.4	2.2	2.1	2.2	2.2	2.3	2.1	2.2	2.1	2.2	2.1	2.2	2.3
Se	ppm	2	1.1	1.1	1.2		1.1	1.2	1.1	1	1	1	1	1	1	0.9	0.9	1	1	0.9
Sn	ppm	6.4	0.7	0.6	0.6		0.6	0.7	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.7
Sr	ppm	48.7	34.4	36.2	33.3		33.6	33	31.1	51	74.2	98	39.9	32.9	31.7	53.5	35.6	34.4	41.1	36.5
Ta	ppm	<.05	<.05	<.05	<.05		<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	0.02	0.02	0.02		0.02	<.02	0.02	0.02	0.02	0.02	0.02	0.03	<.02	0.02	0.03	0.02	0.02	0.02
Th	ppm	3.2	3.7	3.3	3.5		3.4	3.6	3.6	3.4	3.6	3.6	3.9	3.8	3.7	3.7	3.8	3.7	3.9	3.8
Ti	(% dry wt.)	0.036	0.032	0.027	0.028		0.028	0.028	0.03	0.028	0.028	0.027	0.029	0.03	0.03	0.03	0.03	0.031	0.032	0.032
Tl	ppm	0.21	0.21	0.19	0.2		0.2	0.2	0.23	0.21	0.22	0.19	0.22	0.21	0.2	0.21	0.2	0.19	0.19	0.19
U	ppm	2.6	0.9	1.1	1.1		1.3	1.8	1.7	1.2	1.2	1.3	1.5	1.3	1.1	1.1	1	0.9	1	1.1
V	ppm	42	34	33	35		38	40	37	34	37	39	37	35	33	33	32	31	32	31
W	ppm	0.3	<.1	<.1	<.1		<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Y	ppm	7.75	7.98	7.22	7.68		7.75	7.62	7.95	7.29	7.54	7.52	7.71	7.57	7.53	7.44	7.17	6.96	7.28	7.69
Zn	ppm	77.6	64.2	57.3	65.3		64.3	63.8	65.1	59.3	60.5	62.2	63.5	61.8	58.3	58.3	60	58.9	60.2	61.2
Zr	ppm	3.4	4	3.4	3.8		3.9	3.8	4.3	4.1	3.6	3.5	3.7	3.8	3.5	3.7	3.6	3.6	3.7	3.9

Stn		WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04	WH 04
Sed. Depth 1 (cm)		19	20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42
Sed. Depth 2 (cm)		20	21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44
Avg. Depth	(cm)	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0	33.0	35.0	37.0	39.0	41.0	43.0
Total Carbon	(% dry wt.)	1.99	1.93	2.20	2.05	2.05	2.13	2.08	2.06	2.17	2.32	2.27	1.99	2.15	2.12	2.37	2.72	3.15	3.00
Organic Carbon	(% dry wt.)	1.81	1.77	1.97	1.94	2.03	2.13	2.07	2.06	2.17	2.32	2.27	1.73	1.89	1.80	2.02	2.24	2.62	2.44
Inorganic Carbon	(% dry wt.)	0.18	0.16	0.23	0.11	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.26	0.26	0.32	0.35	0.48	0.53	0.56
Ag	ppb	76	81	78	85	77	77	76	73	72	76	69	62	62	59	66	66	76	72
Al	(% dry wt.)	1.12	1.16	1.15	1.15	1.12	1.15	1.13	1.09	1.15	1.19	1.12	1.04	1.12	1.08	1.06	1.1	1.16	1.13
As	ppm	16	16	16	20	19	18	18	20	24	24	23	24	25	20	23	32	12	12
Au	ppb	8.5	8.6	8.4	10.1	11.5	12.4	10.5	10.6	13.1	19.3	17	17.5	15.6	11.2	13.9	25.7	2.8	2
B	ppm	33	34	36	40	38	39	38	37	43	46	44	40	38	34	37	41	47	41
Ba	ppm	30.4	30.7	28.7	30.8	30.8	30	30	29.9	31.8	31.6	31	29.1	31.2	29.5	29.8	32	33.6	31.6
Be	ppm	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.4	0.4	0.3	0.4	0.3	0.6	0.5	0.5	0.5
Bi	ppm	0.19	0.2	0.19	0.2	0.19	0.19	0.19	0.18	0.2	0.21	0.19	0.17	0.16	0.15	0.15	0.16	0.16	0.16
Ca	(% dry wt.)	0.65	0.47	0.39	0.5	0.51	0.58	0.61	0.63	0.58	0.65	0.51	0.47	0.35	0.54	0.71	0.65	0.58	0.84
Cd	ppm	0.37	0.36	0.39	0.42	0.37	0.37	0.38	0.33	0.35	0.39	0.37	0.3	0.26	0.25	0.43	0.44	0.51	0.49
Ce	ppm	25.9	27.7	27	27.9	27.2	27.2	26.8	26.5	27.8	27.8	27.3	26.4	26.7	24.8	25.3	26.2	28.1	26.7
Co	ppm	9.1	9.1	9.1	9.4	8.9	9.3	8.4	8.5	9.1	9.1	8.7	8.5	8.5	8	7.9	8.3	8.4	8.2
Cr	ppm	24.4	23.5	24.5	24.4	24	25.1	24.3	23.1	24.4	25.3	23.9	21.4	23.9	22.9	22.1	24.4	26.3	26
Cs	ppm	1.28	1.32	1.26	1.32	1.26	1.31	1.28	1.22	1.32	1.31	1.3	1.17	1.21	1.19	1.19	1.23	1.33	1.27
Cu	ppm	17.75	18.73	18.21	18.86	17.42	18.74	17.84	16.85	17.4	18.78	17.27	15.82	16.29	15.81	16.34	16.74	18.38	17.02
Fe	(% dry wt.)	2.45	2.52	2.45	2.51	2.43	2.49	2.45	2.4	2.58	2.63	2.44	2.29	2.37	2.45	2.3	2.34	2.51	2.5
Ga	ppm	3.6	3.8	3.6	3.8	3.5	3.8	3.7	3.5	3.6	3.8	3.6	3.4	3.4	3.3	3.3	3.4	3.6	3.6
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.1	0.1	0.1	0.1	0.09	0.11	0.11	0.1	0.11	0.11	0.11	0.1	0.1	0.1	0.09	0.08	0.11	0.11
Hg	ppb	164	178	182	226	232	211	188	209	237	258	262	269	256	207	224	375	60	44
In	ppm	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K	(% dry wt.)	0.23	0.24	0.24	0.23	0.23	0.22	0.24	0.22	0.24	0.25	0.23	0.22	0.23	0.23	0.23	0.24	0.25	0.24
La	ppm	14.3	14.9	14.3	15.1	14.7	14.7	14.3	14.1	15	15.2	14.8	14.1	14.4	13.5	13.9	14.4	15.7	15.1
Li	ppm	29.9	31.1	30.8	30.9	30.9	30.9	30.4	29.4	30.5	30.7	30.5	28	27.9	28.5	28.1	28.6	31.9	29.9
Mg	(% dry wt.)	0.7	0.71	0.71	0.71	0.7	0.7	0.71	0.68	0.71	0.73	0.71	0.65	0.69	0.67	0.67	0.7	0.74	0.7
Mn	ppm	471	474	468	475	454	472	458	448	474	490	462	444	458	465	470	424	441	450
Mo	ppm	1.84	1.73	1.8	2.09	1.95	2.37	1.99	1.88	2.58	3.01	2.51	2.21	2.22	2.05	2.18	2.89	2.54	1.89
Na	(% dry wt.)	1.14	1.16	1.172	1.151	1.166	0.974	1.26	1.103	1.158	1.226	1.179	0.985	1.043	0.959	1.055	1.31	1.316	1.068
Nb	ppm	0.85	0.9	0.9	0.92	0.91	0.91	0.92	0.87	0.95	0.97	1.01	0.91	0.9	0.9	0.88	0.92	1	1.05
Ni	ppm	22.7	23.3	23.4	24.3	22.9	24	22	22.2	23	23.6	23.3	21.5	22.7	21.5	21.2	22.8	24.4	22.8
P	(% dry wt.)	0.055	0.055	0.055	0.056	0.057	0.056	0.056	0.054	0.056	0.057	0.053	0.051	0.056	0.051	0.054	0.056	0.059	0.059
Pb	ppm	17.47	18.62	18.18	17.46	16.99	17.74	17.49	16.28	16.67	16.83	15.95	13.5	12.99	11.59	11.4	12.28	11.04	10.72
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	11.9	12.2	12	12.2	11.9	12.1	12.1	11.4	12.2	12.6	12	11.4	12.1	11.5	11.4	12	12.7	12.2
Re	ppb	3	5	1	3	3	2	4	3	3	2	2	2	2	1	1	2	3	2
S	(% dry wt.)	0.95	0.96	0.95	1.04	0.98	0.94	0.98	1	1.1	1.21	1.05	0.96	0.99	1.13	1.07	1.04	1.23	1.19
Sb	ppm	0.2	0.19	0.17	0.2	0.19	0.21	0.19	0.2	0.25	0.24	0.2	0.2	0.21	0.21	0.17	0.17	0.17	0.16
Sc	ppm	2.1	2.1	2.2	2.2	2	2.2	2.3	2	2.3	2.2	2.1	2	2.2	2.2	2	2.1	2.4	2.2
Se	ppm	0.9	0.9	1	1	1	1	1.1	0.9	1	1.2	1	1	1	1	1.1	1.2	1.4	1.3
Sn	ppm	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Sr	ppm	44	36.2	33.7	36.5	36.3	38.5	41.9	41.3	41.4	40.8	38.5	34.6	32.1	35.8	42.4	43.6	43.1	49.4
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	<.02	<.02	0.02	<.02	0.02	0.02	<.02	0.02	0.02	0.02	<.02	<.02	<.02	0.02	<.02	<.02	<.02
Th	ppm	3.7	3.8	3.8	3.8	3.8	3.6	3.8	3.6	3.8	3.9	3.7	3.6	3.5	3.4	3.4	3.4	3.6	3.5
Ti	(% dry wt.)	0.031	0.031	0.031	0.033	0.031	0.032	0.033	0.032	0.032	0.032	0.031	0.03	0.031	0.031	0.029	0.03	0.032	0.032
Tl	ppm	0.19	0.2	0.2	0.2	0.19	0.2	0.19	0.17	0.17	0.19	0.18	0.17	0.14	0.15	0.24	0.24	0.24	0.21
U	ppm	0.9	1	1	1	1	1	1	1	1.1	1.2	1.1	1	1.1	1	1.1	1.3	1.2	1
V	ppm	31	32	32	32	31	32	31	29	32	33	32	28	31	29	30	31	32	31
W	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	0.2	<.1
Y	ppm	7.25	7.43	7.32	7.6	7.33	7.38	7.35	7.08	7.41	7.7	7.41	6.93	7.46	6.96	7.06	7.3	7.49	7.87
Zn	ppm	57.4	61.3	58.2	61.4	56.6	61.4	58.2	55	55.8	60.9	55.2	45.8	51.5	48.7	49	50.5	53.3	52.4
Zr	ppm	3.6	3.9	3.8	3.9	3.7	3.7	3.7	3.6	3.8	4	3.9	3.6	3.5	3.5	3.3	3.2	3.4	3.6

Stn		WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08
Sed. Depth 1 (cm)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Sed. Depth 2 (cm)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5
Total Carbon	(% dry wt.)	3.75	3.67	3.66	4.05	3.91	4.00	4.15	3.89	3.98	4.00	3.66	3.81	3.74	3.63	3.43	3.72	3.55	3.08	3.02
Organic Carbon	(% dry wt.)	3.21	3.13	3.18	3.42	3.56	3.29	3.26	3.40	3.27	3.12	3.38	3.34	3.36	3.11	3.15	3.58	3.21	2.93	2.90
Inorganic Carbon	(% dry wt.)	0.54	0.54	0.48	0.63	0.35	0.71	0.89	0.49	0.71	0.88	0.28	0.47	0.38	0.52	0.28	0.14	0.34	0.15	0.12
Ag	ppb	110	88	92	87	97	96	96	92	127	101	94	99	100	99	92	92	98	87	88
Al	(% dry wt.)	1.14	1.16	1.16	1.1	1.12	1.15	1.14	1.1	1.15	1.17	1.16	1.13	1.2	1.16	1.14	1.09	1.16	1.12	1.12
As	ppm	60	65	77	96	102	83	81	105	96	83	83	91	82	99	96	117	101	94	98
Au	ppb	67.5	74.6	85.6	93.2	105.7	109.5	76.6	102.9	101.5	112.7	88.7	98.8	78.8	157.3	100.7	109.2	120.2	108.1	86.3
B	ppm	43	40	40	46	50	52	49	51	54	53	56	56	61	57	57	54	62	51	52
Ba	ppm	28.9	27.5	26.6	25.1	24.8	27.7	24.9	25.4	26.2	26.6	26.8	26.7	27.5	26.4	25.8	25.1	25.8	25.8	26.6
Be	ppm	0.5	0.5	0.4	0.4	0.4	0.5	0.5	0.4	0.3	0.4	0.5	0.4	0.5	0.3	0.5	0.5	0.4	0.5	0.3
Bi	ppm	0.2	0.21	0.22	0.25	0.24	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.24	0.23	0.22	0.23	0.23	0.22	0.22
Ca	(% dry wt.)	0.3	0.26	0.25	0.26	0.27	0.29	0.28	0.28	0.29	0.31	0.3	0.3	0.29	0.3	0.31	0.31	0.3	0.27	0.27
Cd	ppm	0.46	0.47	0.48	0.56	0.61	0.54	0.49	0.58	0.59	0.56	0.61	0.61	0.56	0.58	0.52	0.58	0.58	0.54	0.51
Ce	ppm	26.7	27.3	27.7	27.1	28	28.9	27.2	28.4	28.8	28.1	28	27.8	28.2	29.2	29.1	28.1	28.5	27.9	28.3
Co	ppm	8.8	9.1	8.9	8.9	8.8	8.8	8.6	8.4	9	9	8.8	9.1	9.1	9	8.8	8.6	8.7	8.7	8.7
Cr	ppm	24.7	24	23.5	23	23.8	24.2	22.8	24.1	23.7	24.3	22.5	23.6	25.2	24	23.9	22.8	24.4	23	24
Cs	ppm	1.26	1.26	1.26	1.2	1.23	1.29	1.22	1.21	1.23	1.3	1.27	1.26	1.25	1.26	1.27	1.2	1.23	1.22	1.23
Cu	ppm	18.06	18.48	18.87	18.58	18.72	18.21	18.68	17.63	19.13	18.65	18.66	19.29	19.51	18.85	19.14	18.81	19.96	17.97	18.46
Fe	(% dry wt.)	2.4	2.6	2.65	2.6	2.67	2.61	2.6	2.61	2.64	2.72	2.77	2.62	2.76	2.66	2.58	2.59	2.57	2.47	2.54
Ga	ppm	3.5	3.5	3.4	3.4	3.3	3.5	3.4	3.3	3.4	3.5	3.4	3.6	3.5	3.4	3.5	3.5	3.5	3.4	3.3
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.07	0.09	0.08	0.09	0.09	0.09	0.1	0.11	0.09	0.1	0.09	0.1	0.09	0.1	0.09	0.09	0.09	0.08	0.09
Hg	ppb	1511	1239	1540	1952	2074	1911	1815	2052	2027	1854	1720	1843	1891	2188	2054	2430	2370	2060	2060
In	ppm	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02
K	(% dry wt.)	0.27	0.24	0.24	0.23	0.23	0.24	0.24	0.23	0.23	0.24	0.24	0.24	0.24	0.23	0.23	0.22	0.23	0.22	0.22
La	ppm	14.2	14.6	14.8	15.1	15.2	15.6	14.9	15.4	15.5	15.4	15.3	15.3	15.3	15.8	15.9	15.4	15.5	15.2	15.6
Li	ppm	29.5	29.5	30	27.8	29.7	29.9	29.7	29.2	30	29.7	28.9	30.1	30.7	29.8	30.6	29.4	31.2	29.4	29.4
Mg	(% dry wt.)	0.85	0.75	0.74	0.72	0.74	0.75	0.74	0.71	0.73	0.74	0.74	0.74	0.76	0.75	0.72	0.71	0.73	0.7	0.71
Mn	ppm	411	365	399	398	418	408	404	396	411	426	426	403	423	427	410	397	416	405	402
Mo	ppm	2.15	4.39	3.92	3.02	2.42	2.62	3.2	2.95	3.13	3.49	4.52	3.64	4.54	2.98	2.55	2.68	2.24	2.18	2.65
Na	(% dry wt.)	2.463	1.835	1.632	1.619	1.62	1.744	1.709	1.467	1.517	1.548	1.576	1.569	1.601	1.485	1.381	1.303	1.38	1.201	1.256
Nb	ppm	0.95	0.98	1.03	1.12	1.12	1.05	1.08	1.11	1.14	1.02	1	1.06	1.07	1.13	1.08	1.17	1.12	1.02	1.11
Ni	ppm	22.2	22	22.1	21.3	21.3	21.8	21	20.7	21.7	21.9	21.7	21.8	23.5	22.1	22.6	22.1	22.4	21	21.8
P	(% dry wt.)	0.077	0.076	0.074	0.068	0.066	0.07	0.065	0.061	0.06	0.06	0.059	0.06	0.059	0.061	0.06	0.06	0.059	0.06	0.059
Pb	ppm	17.75	17.42	18.29	18.83	18.67	19.07	18.29	18.7	18.51	19.08	19.09	18.63	19.52	19.27	18.58	19.13	19.7	18.69	17.95
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	12.2	11.8	11.7	10.9	11	11.7	11.1	11	11.1	11.4	11.3	11.3	11.6	11.5	11.4	10.7	11.1	11	11.2
Re	ppb	2	4	5	5	3	3	5	6	5	6	6	3	4	5	4	8	3	5	5
S	(% dry wt.)	0.95	1.27	1.35	1.41	1.4	1.35	1.34	1.38	1.33	1.41	1.5	1.36	1.43	1.32	1.27	1.34	1.29	1.14	1.2
Sb	ppm	0.3	0.31	0.31	0.36	0.37	0.35	0.33	0.36	0.36	0.31	0.33	0.34	0.32	0.37	0.35	0.41	0.36	0.34	0.35
Sc	ppm	2	2	2	1.9	2	2	2	2	2	2	1.9	2	2	2	2.1	2	2	2	2
Se	ppm	1.4	1.4	1.3	1.4	1.4	1.4	1.2	1.3	1.3	1.3	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.2	1.3
Sn	ppm	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7
Sr	ppm	50.3	38.5	37.3	39	39.8	39.9	39.1	37.3	38.5	38.7	38.2	38.7	38.9	38.9	37.3	38.5	37.5	34.3	34.9
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	0.02	<.02	0.02	0.04	0.02	0.02	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Th	ppm	3.2	3.3	3.3	3.4	3.4	3.4	3.3	3.4	3.5	3.4	3.3	3.4	3.5	3.5	3.6	3.6	3.6	3.6	3.6
Ti	(% dry wt.)	0.026	0.026	0.027	0.027	0.028	0.028	0.027	0.029	0.028	0.027	0.026	0.028	0.027	0.029	0.03	0.03	0.03	0.029	0.031
Tl	ppm	0.18	0.22	0.21	0.23	0.23	0.23	0.21	0.24	0.23	0.22	0.21	0.23	0.22	0.23	0.22	0.24	0.24	0.22	0.21
U	ppm	1.2	1.7	1.5	1.3	1.2	1.2	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.4	1.3	1.4	1.3	1.2	1.3
V	ppm	33	34	33	35	35	35	36	35	36	39	43	39	43	37	34	34	35	32	33
W	ppm	<.1	0.1	<.1	<.1	<.1	0.1	<.1	0.1	<.1	<.1	0.1	0.1	0.1	0.1	<.1	<.1	0.1	<.1	<.1
Y	ppm	7.01	7.09	7.23	7.53	7.29	7.6	7.41	7.58	7.68	7.69	7.56	7.67	7.83	7.82	7.43	7.57	7.81	7.34	7.56
Zn	ppm	56.2	57	60.4	58.7	58	59.3	57.9	57	58.8	59.9	60.6	62.3	61.4	61.3	58.9	64.2	61.4	56.5	58
Zr	ppm	2.7	3.5	3.7	4	4.2	3.9	4.1	4.4	4.6	4.5	4.3	4.3	4.3	4.6	4.3	4.6	4.6	4.2	4.4

Stn		WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08	WH 08
Sed. Depth 1 (cm)		19	20	21	22	23	24	25	26	27	28	29	30	32	34	36
Sed. Depth 2 (cm)		20	21	22	23	24	25	26	27	28	29	30	32	34	36	38
Avg. Depth	(cm)	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0	33.0	35.0	37.0
Total Carbon	(% dry wt.)	3.23	3.16	3.31	3.27	3.39	3.31	3.33	3.33	3.32	3.40	3.48	4.27	4.54	4.26	4.58
Organic Carbon	(% dry wt.)	3.02	2.96	2.93	2.98	3.23	3.02	2.75	3.17	3.18	3.10	3.16	3.66	4.09	4.06	3.60
Inorganic Carbon	(% dry wt.)	0.21	0.20	0.38	0.29	0.16	0.29	0.58	0.16	0.14	0.30	0.32	0.61	0.45	0.20	0.98
Ag	ppb	93	92	89	88	93	88	88	81	83	76	69	71	71	72	62
Al	(% dry wt.)	1.16	1.15	1.1	1.07	1.11	1.07	1.08	1.07	1.05	1.01	0.97	0.97	0.99	0.98	0.88
As	ppm	**96**	**100**	**132**	**118**	**115**	**139**	**121**	**145**	**175**	**267**	**239**	**95**	**30**	**19**	**16**
Au	ppb	99.1	111.1	138.6	120.4	122.2	123	148	140.4	166.3	210.7	205.2	59.5	8.9	2.3	1.3
B	ppm	55	50	52	51	62	60	55	58	59	55	58	55	55	60	47
Ba	ppm	27.6	27.2	26.1	25.5	25.1	26	26.2	27	26.5	25.9	25.8	23.8	24.4	25.1	23.4
Be	ppm	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.5	0.5	0.4	0.4	0.4
Bi	ppm	0.22	0.23	0.21	0.23	0.23	0.22	0.21	0.22	0.21	0.21	0.19	0.17	0.16	0.17	0.14
Ca	(% dry wt.)	0.27	0.27	0.27	0.29	0.31	0.31	0.35	0.32	0.4	0.43	0.48	1.23	0.78	0.57	1.21
Cd	ppm	0.55	0.5	0.49	0.5	0.55	0.58	0.49	0.46	0.46	0.41	0.43	0.5	0.61	0.63	0.55
Ce	ppm	28.5	28.8	28	27.4	28.3	27.9	27.1	27.3	27.5	26.7	27.3	26.1	27.6	28	25.5
Co	ppm	9.1	8.7	8.5	7.9	9.3	8.4	8.7	8.8	8.3	7.8	7.5	7.2	7.8	7.8	7.4
Cr	ppm	24.1	23.9	23.8	22.6	24.5	24.5	24.1	22.7	22.2	21.6	22.9	21.7	22.4	22.8	19.9
Cs	ppm	1.25	1.23	1.17	1.19	1.18	1.21	1.19	1.19	1.18	1.12	1.1	1.05	1.11	1.12	1.03
Cu	ppm	19.87	18.78	17.97	17.62	19.4	18.85	18.02	18.39	17.36	17.57	16.14	14.2	14.33	14.91	12.27
Fe	(% dry wt.)	2.65	2.57	2.52	2.45	2.55	2.5	2.44	2.48	2.45	2.37	2.31	2.34	2.36	2.31	2.08
Ga	ppm	3.6	3.5	3.3	3.3	3.4	3.3	3.3	3.4	3.2	3.1	3.1	2.8	2.9	3	2.7
Ge	ppm	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.09	0.09	0.08	0.1	0.1	0.1	0.09	0.09	0.09	0.11	0.08	0.08	0.08	0.08
Hg	ppb	**2126**	**2185**	**2679**	**2419**	**2409**	**2321**	**2180**	**2455**	**2952**	**3903**	**3985**	**1221**	**224**	56	40
In	ppm	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K	(% dry wt.)	0.23	0.21	0.2	0.21	0.22	0.22	0.21	0.22	0.21	0.2	0.19	0.19	0.2	0.2	0.18
La	ppm	15.2	15.6	15.2	15.3	15.8	15.8	15.5	15.8	15.6	15.6	15.9	14.6	15.8	16.3	14.9
Li	ppm	31.6	29.9	29.4	28.3	29.7	29.2	30.3	29.6	29.2	27.9	27.4	26.3	27.6	28.5	25.7
Mg	(% dry wt.)	0.72	0.71	0.71	0.7	0.71	0.7	0.69	0.7	0.67	0.65	0.64	0.64	0.64	0.63	0.56
Mn	ppm	409	402	395	386	410	400	398	406	397	386	367	358	357	345	309
Mo	ppm	3.06	3.18	2.85	2.66	2.39	2.44	2.41	2.79	2.79	2.95	2.75	2.84	3.43	2.08	1.85
Na	(% dry wt.)	1.291	1.164	1.239	1.195	1.355	1.243	1.183	1.135	1.125	1.073	1.033	1.049	1.144	1.175	0.979
Nb	ppm	1.05	1.05	1.04	1.05	1.12	1.1	0.96	1	0.99	0.97	1.12	1.07	1.25	1.26	1.14
Ni	ppm	22.9	21.5	20.9	21.1	21.8	20.9	21.2	21.8	20.9	20.5	20	18	19.5	19.9	17.3
P	(% dry wt.)	0.061	0.06	0.06	0.058	0.06	0.059	0.058	0.057	0.057	0.058	0.057	0.054	0.053	0.057	0.054
Pb	ppm	18.91	19.05	18.25	18.24	18.94	18.29	17.45	17.32	16.88	15.22	13.45	10.86	10.34	10.31	8.73
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	<2
Rb	ppm	11.1	11	10.9	10.1	10.8	10.6	10.3	10.3	9.8	9	9.3	9.1	9.5	9.5	8.3
Re	ppb	4	7	6	7	4	6	3	4	4	5	5	5	7	7	7
S	(% dry wt.)	1.22	1.15	1.12	1.15	1.26	1.26	1.12	1.18	1.22	1.23	1.21	1.29	1.37	1.42	1.29
Sb	ppm	0.35	0.35	0.4	0.4	0.4	0.42	0.39	0.47	0.5	0.67	0.64	0.34	0.22	0.18	0.15
Sc	ppm	2	2	1.8	1.9	2	2	1.9	1.9	1.8	1.8	1.7	1.7	1.8	1.9	1.7
Se	ppm	1.2	1.3	1.2	1.2	1.4	1.4	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.2
Sn	ppm	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.3	0.3	0.3	0.3
Sr	ppm	36.3	34.6	35.3	36	38.2	36.8	36.7	36.1	39.2	40	42.4	80.8	55.4	46.6	71.1
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.02	0.02	0.03	0.03	0.03	0.04	0.02	0.03	0.04	0.05	0.03	0.02	0.02	<.02	<.02
Th	ppm	3.6	3.6	3.5	3.5	3.5	3.4	3.5	3.4	3.3	3.2	3.2	2.9	3	3.2	2.7
Ti	(% dry wt.)	0.029	0.028	0.028	0.029	0.031	0.031	0.03	0.029	0.027	0.027	0.027	0.028	0.032	0.033	0.03
Tl	ppm	0.22	0.21	0.21	0.21	0.22	0.22	0.2	0.18	0.18	0.17	0.16	0.18	0.19	0.19	0.18
U	ppm	1.4	1.4	1.3	1.3	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.3	1.4	1.2	1.1
V	ppm	34	32	33	32	35	34	32	33	32	30	31	30	30	29	25
W	ppm	<.1	<.1	<.1	0.1	0.1	0.1	<.1	0.1	<.1	0.1	0.1	0.1	<.1	<.1	<.1
Y	ppm	7.52	7.46	7.35	7.39	7.63	7.68	7.26	7.31	7.19	6.88	7.22	6.98	7.76	7.68	7.11
Zn	ppm	60.7	60.7	58.4	57	59.1	56.8	54.2	55.9	53.2	49.6	49.2	44.2	46.9	48.3	43.5
Zr	ppm	4.2	4.4	4.1	4.1	4.4	4.3	3.8	4.1	3.9	3.9	4	3.7	3.9	3.9	3.5

Stn		WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19
Sed. Depth 1	(cm)	0	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17
Sed. Depth 2	(cm)	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	13.5	14.5	15.5	16.5	17.5
Total Carbon	(% dry wt.)	1.98	1.28	1.22	2.14	1.35	2.03	2.23	1.33	1.13	1.18	1.56	2.02	1.34	1.69	2.97	2.40	2.63
Organic Carbon	(% dry wt.)	1.57	0.74	0.77	1.15	0.97	1.41	1.21	0.93	0.62	0.96	1.31	1.49	0.99	1.05	1.90	1.16	0.96
Inorganic Carbon	(% dry wt.)	0.41	0.54	0.45	0.99	0.38	0.62	1.02	0.40	0.51	0.22	0.25	0.53	0.35	0.64	1.07	1.24	1.67
Ag	ppb	42	24	23	28	28	38	31	33	27	34	34	42	29	27	37	31	27
Al	(% dry wt.)	0.72	0.61	0.57	0.6	0.61	0.67	0.64	0.62	0.6	0.64	0.69	0.72	0.64	0.59	0.63	0.64	0.61
As	ppm	15	11	11	13	11	12	11	12	12	10	12	10	8	8	9	9	11
Au	ppb	6.5	2.4	3	5.9	6.6	4.3	4.2	5.1	2.3	3.1	3.8	3.9	2.1	2.2	5.4	3.4	3.1
B	ppm	43	17	17	22	20	29	27	24	17	27	34	32	24	24	40	32	24
Ba	ppm	18.2	15.7	14.2	13.8	13.5	15.1	13.4	13.6	12.4	12.1	14.1	15.4	13	10.4	12.8	13.4	11.9
Be	ppm	0.2	0.2	0.2	0.1	0.2	0.2	0.3	0.3	0.1	0.3	0.2	0.3	0.4	0.2	0.3	0.3	0.2
Bi	ppm	0.11	0.08	0.09	0.07	0.08	0.15	0.09	0.08	0.08	0.09	0.1	0.1	0.09	0.07	0.35	0.09	0.07
Ca	(% dry wt.)	1.06	1.2	1.17	0.78	0.52	0.63	0.7	0.78	0.81	0.59	0.49	0.66	1.09	1.25	1.29	0.78	0.85
Cd	ppm	0.3	0.11	0.12	0.14	0.19	0.22	0.2	0.18	0.12	0.2	0.25	0.27	0.17	0.17	0.23	0.19	0.17
Ce	ppm	19.2	17.6	15.3	15.3	15.9	17.5	16.9	16.4	15.5	17.2	18.6	18.8	16	14	15.8	16.6	15.7
Co	ppm	6.4	5.5	4.8	5.3	5.4	6.1	5.6	5.5	5.2	5.3	6.3	6.5	5.9	5.4	5.7	5.6	5.7
Cr	ppm	14.4	11.2	10.2	11.3	12.2	12.1	11.6	11.4	10.5	11.2	13.8	14.2	12	11.1	12.3	11.9	11.3
Cs	ppm	0.83	0.71	0.63	0.63	0.68	0.72	0.68	0.64	0.64	0.68	0.76	0.78	0.66	0.57	0.67	0.68	0.6
Cu	ppm	11.08	7.77	6.83	7.65	8.02	9.16	8.42	8.02	7.04	9.17	10.07	10.27	8.1	6.91	8.87	8.4	7.34
Fe	(% dry wt.)	1.68	1.31	1.28	1.33	1.34	1.44	1.4	1.38	1.28	1.38	1.47	1.57	1.41	1.37	1.45	1.41	1.35
Ga	ppm	2.3	2	1.8	1.9	1.9	2.2	2	2	1.9	2	2.2	2.3	2.1	1.9	2	2	1.9
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.06	0.13	0.06
Hg	ppb	97	33	41	64	57	60	56	51	36	49	50	50	25	25	45	48	44
In	ppm	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
K	(% dry wt.)	0.14	0.11	0.1	0.1	0.11	0.12	0.11	0.11	0.1	0.11	0.13	0.14	0.11	0.1	0.11	0.11	0.1
La	ppm	10.3	9.1	8.3	8.4	8.8	9.4	8.8	8.8	8.4	9.2	9.9	9.9	8.5	7.6	8.4	8.9	8.5
Li	ppm	20	18.5	16.6	19	18.2	19.3	19.2	17.7	17.4	18.8	19.7	20.5	18.4	16.7	17.3	18.5	16.8
Mg	(% dry wt.)	0.48	0.38	0.38	0.39	0.39	0.43	0.41	0.4	0.37	0.4	0.43	0.45	0.4	0.4	0.43	0.41	0.4
Mn	ppm	385	354	315	326	318	323	334	317	314	324	333	349	329	313	321	341	321
Mo	ppm	1.65	0.8	0.9	1.15	1.44	1.84	1.57	1.53	1.22	2.21	2.1	2.4	1.8	2.01	2.13	1.58	1.49
Na	(% dry wt.)	0.711	0.402	0.423	0.473	0.444	0.578	0.549	0.484	0.433	0.525	0.566	0.603	0.493	0.483	0.63	0.521	0.509
Nb	ppm	0.75	0.53	0.5	0.56	0.58	0.64	0.6	0.54	0.5	0.59	0.71	0.68	0.58	0.65	0.67	0.59	0.55
Ni	ppm	15.1	12.1	11	11.7	12.1	13.7	12.1	12.1	11.7	12.5	14	14.2	12.5	11.5	13.2	12.5	12.2
P	(% dry wt.)	0.05	0.041	0.034	0.035	0.034	0.037	0.036	0.036	0.032	0.033	0.035	0.039	0.033	0.029	0.036	0.035	0.033
Pb	ppm	9.64	6.39	6.04	6.39	6.79	8.26	7.21	7.22	6.5	7.29	8.88	9.49	7.23	6.26	8.04	7.61	6.67
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	7.7	6.2	5.7	5.7	5.8	6.5	6.3	6	5.9	6.1	6.8	7.4	6	5.3	6	6	5.7
Re	ppb	1	1	<1	1	<1	2	<1	<1	<1	1	1	1	1	1	1	<1	<1
S	(% dry wt.)	0.51	0.26	0.27	0.35	0.39	0.48	0.4	0.39	0.32	0.41	0.46	0.51	0.41	0.42	0.5	0.43	0.38
Sb	ppm	0.13	0.12	0.1	0.1	0.09	0.12	0.13	0.1	0.09	0.1	0.12	0.12	0.11	0.09	0.12	0.09	0.09
Sc	ppm	1.3	1	0.9	1	1	1.1	1	1	1	1	1.2	1.2	1	0.9	1	1	0.9
Se	ppm	0.6	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.5	0.4	0.5	0.4	0.5
Sn	ppm	0.5	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Sr	ppm	55.1	59.2	57.1	38.8	27.1	33.1	36.6	39.1	38	30.3	28.2	33.5	51.8	58.8	63.6	40.7	42.5
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Th	ppm	2.3	2.1	1.9	2.2	1.9	2	2	1.9	1.8	2.3	2.1	2.5	1.9	1.7	1.9	2	1.8
Ti	(% dry wt.)	0.027	0.024	0.021	0.023	0.024	0.024	0.024	0.022	0.022	0.024	0.025	0.026	0.024	0.023	0.024	0.024	0.023
Tl	ppm	0.13	0.08	0.09	0.09	0.1	0.11	0.1	0.09	0.09	0.1	0.11	0.12	0.09	0.08	0.1	0.1	0.09
U	ppm	0.6	0.5	0.4	0.5	0.5	0.6	0.6	0.6	0.5	0.6	0.7	0.8	0.7	0.7	0.7	0.6	0.6
V	ppm	20	13	14	15	15	16	15	15	13	15	17	18	15	15	18	15	14
W	ppm	0.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1	<.1
Y	ppm	5.14	4.23	3.85	3.91	4.21	4.47	4.29	4.15	4.03	4.21	4.77	5.01	4.25	3.76	4.32	4.28	4.25
Zn	ppm	37.7	29.7	26.1	29.2	31	34.4	30.4	30	29.7	32.2	36.4	38.3	31.3	28.5	48.2	32.9	30.2
Zr	ppm	3.1	2.7	2.5	2.6	2.8	3.2	2.9	2.6	2.6	2.9	3.2	3.2	3	3.2	3.1	3	2.9

Stn		WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19	WH 19
Sed. Depth 1 (cm)		18	19	20	21	22	23	24	25	26	27	28	29	30
Sed. Depth 2 (cm)		19	20	21	22	23	24	25	26	27	28	29	30	32
Avg. Depth	(cm)	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0
Total Carbon	(% dry wt.)	3.34	2.49	3.45	2.47	3.04	3.06	3.05	2.77	2.86	1.93	1.74	1.81	1.67
Organic Carbon	(% dry wt.)	1.88	1.55	1.86	1.83	2.42	2.24	2.57	2.38	2.38	1.72	1.61	1.59	1.37
Inorganic Carbon	(% dry wt.)	1.46	0.94	1.59	0.64	0.62	0.82	0.48	0.39	0.48	0.21	0.13	0.22	0.30
Ag	ppb	28	32	34	40	53	68	75	87	80	56	58	59	45
Al	(% dry wt.)	0.63	0.65	0.68	0.73	0.86	1	1.08	1.11	1.02	0.88	0.87	0.87	0.75
As	ppm	**10**	**11**	**20**	**16**	**20**	**26**	**26**	**20**	**30**	**26**	**29**	**33**	**41**
Au	ppb	2.9	4.8	12.9	7.6	15.2	22.8	23.3	15.4	16.3	13.5	19.5	22	21.8
B	ppm	26	29	31	33	50	57	64	66	47	36	45	38	34
Ba	ppm	12.9	13.7	14.8	16.5	20	24.6	26.8	28.4	27.3	22.7	22.5	22.7	18.9
Be	ppm	0.3	0.3	0.3	0.5	0.5	0.4	0.5	0.4	0.3	0.3	0.3	0.2	0.3
Bi	ppm	0.08	0.09	0.09	0.11	0.14	0.16	0.18	0.2	0.18	0.14	0.15	0.15	0.12
Ca	(% dry wt.)	1	0.78	0.69	0.6	0.51	0.46	0.56	0.38	0.34	0.49	0.41	0.4	0.49
Cd	ppm	0.18	0.2	0.2	0.24	0.34	0.39	0.43	0.44	0.37	0.29	0.33	0.31	0.26
Ce	ppm	16.3	16.5	17.8	18.8	21.2	25	25.4	26.6	25.7	22.6	22.8	22.3	21.3
Co	ppm	5.6	5.6	6.1	6.6	7.4	8.8	9	9.5	9.2	7.5	7.5	7.4	6.5
Cr	ppm	11.8	13.1	12.6	14	17.3	19.9	21.2	22.7	20.7	18	17.9	17.4	15.3
Cs	ppm	0.66	0.68	0.75	0.79	0.93	1.12	1.17	1.23	1.17	0.99	0.98	0.95	0.86
Cu	ppm	7.88	8.8	9.16	10.48	13.86	15.89	17.61	19.16	16.96	14.52	14.03	13.41	11.64
Fe	(% dry wt.)	1.4	1.42	1.47	1.55	1.83	2.14	2.28	2.37	2.18	1.89	1.85	1.83	1.61
Ga	ppm	2	2.1	2.2	2.4	2.7	3.1	3.3	3.4	3.1	2.8	2.8	2.6	2.5
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.06	0.06	0.06	0.06	0.07	0.08	0.07	0.08	0.08	0.07	0.07	0.06	0.07
Hg	ppb	38	55	99	99	**160**	**224**	**243**	**221**	**250**	**173**	**195**	**206**	**212**
In	ppm	<.02	<.02	<.02	<.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
K	(% dry wt.)	0.11	0.11	0.12	0.13	0.16	0.2	0.22	0.22	0.2	0.17	0.17	0.17	0.14
La	ppm	8.7	8.7	9.5	10	11.3	13.2	13.5	14.4	14	12.4	12.5	12.1	11.6
Li	ppm	18.2	19.1	19.3	21	24.7	27.4	28	29	27.9	23.4	24.3	23.8	21.9
Mg	(% dry wt.)	0.41	0.42	0.43	0.45	0.54	0.63	0.68	0.7	0.64	0.55	0.54	0.54	0.47
Mn	ppm	323	330	345	346	384	412	425	468	438	394	384	376	348
Mo	ppm	1.61	1.76	1.98	1.99	2.97	4.12	5.64	7.28	6.13	3.4	3.01	2.77	2.72
Na	(% dry wt.)	0.518	0.551	0.566	0.631	0.84	1.041	1.212	1.202	0.981	0.764	0.83	0.702	0.595
Nb	ppm	0.58	0.6	0.59	0.58	0.77	0.86	0.87	0.98	0.87	0.8	0.8	0.7	0.66
Ni	ppm	12.1	13.2	14.1	15.3	18.3	20.2	21.7	23.7	21	17.9	18.3	17.7	15.4
P	(% dry wt.)	0.035	0.036	0.038	0.041	0.047	0.054	0.056	0.058	0.054	0.05	0.05	0.046	0.041
Pb	ppm	7.21	7.96	8.45	9.77	13.14	16.16	18.3	20.71	19.02	14.49	14.82	14.48	11.68
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	6.1	6.2	6.6	7	8.6	10.1	10.7	11.2	10.2	8.9	9	8.9	7.7
Re	ppb	1	1	1	2	1	3	3	2	2	2	2	2	2
S	(% dry wt.)	0.41	0.43	0.48	0.52	0.71	0.88	1	1.04	0.93	0.78	0.76	0.69	0.6
Sb	ppm	0.09	0.1	0.12	0.12	0.16	0.21	0.22	0.23	0.23	0.18	0.18	0.17	0.19
Sc	ppm	1	1.1	1.1	1.2	1.5	1.7	1.8	1.9	1.8	1.5	1.5	1.5	1.3
Se	ppm	0.5	0.4	0.5	0.6	0.8	1.1	1.1	1.2	1	0.8	0.8	0.8	0.6
Sn	ppm	0.3	0.3	0.3	0.4	0.5	0.6	0.7	0.7	0.7	0.6	0.6	0.6	0.6
Sr	ppm	50	40.2	36.9	34.4	35.9	37	40.7	35.7	31.6	34.2	31.2	29.9	29.7
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	<.02	<.02	<.02	<.02	<.02	0.02	<.02	0.02	0.02	<.02	<.02	<.02	<.02
Th	ppm	2	2	2.2	2.2	2.6	2.8	3	3.2	3	2.6	2.7	2.7	2.8
Ti	(% dry wt.)	0.024	0.023	0.023	0.025	0.027	0.028	0.028	0.031	0.029	0.027	0.026	0.026	0.026
Tl	ppm	0.1	0.1	0.1	0.11	0.14	0.16	0.16	0.16	0.16	0.14	0.14	0.14	0.12
U	ppm	0.6	0.6	0.7	0.8	1	1.3	1.7	1.9	1.6	1	1	1	1
V	ppm	15	16	16	18	24	28	32	34	30	24	24	23	20
W	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	0.1	<.1	<.1	<.1	<.1	<.1
Y	ppm	4.19	4.35	4.54	4.69	5.78	6.76	7.03	7.27	6.92	6.14	6.13	5.86	5.34
Zn	ppm	32.7	32.2	34.2	37.9	46.7	51	55.7	59.7	54.8	49.9	47.3	45.9	40.6
Zr	ppm	2.8	2.7	2.9	2.8	3.4	3.7	3.7	4	3.9	3.6	3.5	3.4	3.3

Stn		WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23
Sed. Depth 1 (cm)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sed. Depth 2 (cm)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Avg. Depth	(cm)	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5
Total Carbon	(% dry wt.	3.16	2.93	2.97	3.06	2.90	2.90	2.93	2.85	2.99	3.04	3.41	3.32	3.16	3.29	3.24	3.39	3.32	3.21	2.49	2.49	2.41
Organic Carbon	(% dry wt.	2.86	2.78	2.80	2.93	2.81	2.73	2.71	2.59	2.61	2.67	2.96	2.92	2.69	2.87	2.77	2.76	2.72	2.57	2.43	2.37	2.21
Inorganic Carbon	(% dry wt.	0.30	0.15	0.17	0.13	0.09	0.17	0.22	0.26	0.38	0.37	0.45	0.40	0.47	0.42	0.47	0.63	0.60	0.64	0.06	0.12	0.20
Ag	ppb	80	81	80	84	91	86	84	76	89	83	87	97	95	97	96	98	96	94	88	91	91
Al	(% dry wt.	1.06	1.1	1.09	1.05	1.08	1.06	1.07	1.06	1.06	1.05	1.14	1.19	1.15	1.13	1.17	1.16	1.15	1.18	1.12	1.09	1.05
As	ppm	67	63	55	69	76	67	67	61	58	58	62	73	79	83	89	94	94	91	88	97	115
Au	ppb	62	67	46.6	64.3	72.4	68.5	72.3	62.2	120	64.7	103.8	82.1	88.2	95.8	139.4	137.2	102.6	129.6	96.4	95.3	132.9
B	ppm	53	53	52	56	58	57	53	52	55	57	70	71	62	72	74	70	70	62	59	59	52
Ba	ppm	27.5	28.8	30	29.8	28.9	28	28.5	26.6	28.1	27	28.5	31.2	30.2	30	29.3	30.7	29.6	29.9	28.6	29	29.7
Be	ppm	0.3	0.5	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.5	0.5	0.5	0.4	0.3	0.4	0.5	0.4	0.4	0.4	0.4	0.3
Bi	ppm	0.2	0.21	0.19	0.2	0.22	0.21	0.21	0.2	0.2	0.2	0.23	0.24	0.23	0.23	0.25	0.24	0.23	0.23	0.22	0.21	0.23
Ca	(% dry wt.	0.34	0.48	0.7	0.49	0.33	0.34	0.39	0.37	0.36	0.38	0.45	0.47	0.42	0.52	0.3	0.28	0.27	0.28	0.28	0.28	0.32
Cd	ppm	0.51	0.51	0.45	0.46	0.53	0.53	0.52	0.48	0.49	0.5	0.54	0.56	0.51	0.49	0.54	0.5	0.48	0.49	0.46	0.44	0.43
Ce	ppm	25.8	26.7	25.8	25.9	27	26.6	26.9	25.6	26.8	25.9	27.1	30.7	28.8	29.1	29.7	29.8	28.9	28.1	27.7	27.7	27.5
Co	ppm	9	9.8	9.6	8.8	8.8	8.9	9.2	8.7	9	9	9.5	9.8	9.1	8.8	9.2	9.2	8.9	9.1	8.8	8.6	8.5
Cr	ppm	21.6	22.7	21.4	22.6	22.4	22.5	23.8	22.3	22.5	21.4	23.7	24.9	23.4	24.2	24.4	25.4	25.8	24.3	24.6	25.2	23.3
Cs	ppm	1.17	1.21	1.16	1.17	1.18	1.17	1.19	1.13	1.17	1.18	1.22	1.32	1.26	1.24	1.23	1.27	1.21	1.24	1.22	1.24	1.21
Cu	ppm	19.02	19.79	19.02	18.34	19.29	18.36	19.33	18.11	18.71	18.85	20.13	20.97	20.19	19.92	20.11	20.56	20.57	19.84	19.19	19.03	18.35
Fe	(% dry wt.	2.3	2.4	2.31	2.31	2.39	2.34	2.37	2.32	2.29	2.35	2.44	2.52	2.47	2.44	2.44	2.45	2.49	2.54	2.37	2.32	2.29
Ga	ppm	3.2	3.3	3.3	3.2	3.3	3.2	3.3	3.1	3.2	3.3	3.4	3.6	3.5	3.5	3.6	3.6	3.5	3.4	3.4	3.4	3.4
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.07	0.08	0.08	0.07	0.09	0.1	0.1	0.08	0.08	0.08	0.09	0.11	0.09	0.09	0.09	0.09	0.1	0.09	0.08	0.1	0.09
Hg	ppb	622	565	455	531	651	642	602	532	512	558	673	860	910	910	961	1004	965	964	880	918	900
In	ppm	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02
K	(% dry wt.	0.25	0.23	0.24	0.23	0.24	0.23	0.24	0.22	0.24	0.24	0.25	0.26	0.25	0.23	0.24	0.23	0.23	0.24	0.22	0.22	0.21
La	ppm	13.9	14.2	13.6	14.4	15	14.7	14.6	14.1	14.4	14.2	14.7	16.3	15.8	15.8	16	16.6	16.2	15.7	15.5	15.7	16
Li	ppm	26.9	28.6	27.6	28.2	27.7	27.7	28.3	26.7	28.5	28	29.8	31	29.9	28.7	30.8	31.3	30	30	28.8	30.3	29
Mg	(% dry wt.	0.74	0.71	0.72	0.71	0.73	0.72	0.74	0.71	0.7	0.71	0.77	0.79	0.76	0.75	0.74	0.75	0.73	0.74	0.69	0.69	0.67
Mn	ppm	417	448	457	415	423	418	428	420	412	413	449	459	449	436	439	423	415	436	417	420	425
Mo	ppm	1.94	1.99	1.95	2.35	2.51	2.06	2.09	2.29	2.66	2.61	3.42	3.36	2.79	2.59	2.72	2.9	2.88	2.96	2.63	3.1	3.01
Na	(% dry wt.	1.944	1.49	1.593	1.674	1.701	1.665	1.645	1.452	1.461	1.549	1.72	1.688	1.474	1.454	1.366	1.32	1.22	1.198	1.138	1.123	1.041
Nb	ppm	0.89	0.94	0.88	0.91	0.95	0.92	0.89	0.88	0.9	0.85	0.94	0.96	0.95	0.98	1	1	0.99	0.98	0.93	0.98	0.87
Ni	ppm	21.5	23	22.3	21.7	21.4	21.5	22.7	21.4	22.7	21.9	23.3	25.2	23.2	22.7	23.6	24.1	22.9	23.3	22.8	22	21.9
P	(% dry wt.	0.078	0.073	0.075	0.068	0.068	0.064	0.066	0.065	0.064	0.063	0.067	0.065	0.064	0.064	0.065	0.063	0.063	0.063	0.06	0.059	0.06
Pb	ppm	18.09	18.64	17.46	18.93	19.9	19.59	20.25	18.01	19.04	19.47	21.23	23.16	22.77	22.74	23.54	24.25	23.68	23.85	22.45	22.37	22.36
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	10.5	11.2	10.8	10.6	11.2	11	11.3	10.8	10.8	10.9	11.4	12.2	11.5	11.6	11.8	11.6	11.3	11.5	10.9	10.9	10.6
Re	ppb	3	3	2	1	3	1	1	2	3	3	3	3	3	3	4	4	4	4	5	3	2
S	(% dry wt.	0.96	1.01	0.89	0.97	1.06	1.02	1.04	0.95	0.96	1.04	1.11	1.11	1.09	1.05	1.06	1.03	1.07	1.15	1.07	1.03	1
Sb	ppm	0.29	0.3	0.29	0.33	0.39	0.33	0.32	0.3	0.3	0.32	0.35	0.36	0.38	0.38	0.38	0.39	0.37	0.38	0.37	0.4	0.45
Sc	ppm	1.8	1.9	1.8	1.8	2	1.9	1.9	1.8	2	1.9	1.9	2.1	2.1	2.1	2	2.1	2.1	2	1.9	1.9	1.9
Se	ppm	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.2	1.3	1.2	1.2	1.1	1.3	1.1	1.2	1.1	1.1	1.1
Sn	ppm	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1	1	0.9	0.9	0.9	0.9
Sr	ppm	40.6	42.4	53.4	44.9	39.2	37.5	39.2	37.9	37.1	39.5	44	44.5	41.5	45.2	36.3	35	34.5	33.6	32.3	31.3	32.7
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	<.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.03	0.04	0.03	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.03
Th	ppm	3	3	3.1	3.4	3.4	3.3	3.4	3.3	3.3	3.2	3.5	3.7	3.7	3.7	3.8	3.8	3.7	3.6	3.5	3.7	3.7
Ti	(% dry wt.	0.025	0.027	0.025	0.027	0.026	0.026	0.025	0.025	0.026	0.025	0.026	0.028	0.027	0.027	0.028	0.027	0.028	0.027	0.028	0.03	0.029
Tl	ppm	0.21	0.2	0.18	0.21	0.22	0.21	0.22	0.19	0.2	0.2	0.21	0.21	0.2	0.2	0.2	0.19	0.19	0.19	0.19	0.19	0.19
U	ppm	0.8	0.9	0.9	1	1	0.9	0.9	1	1.1	1.1	1.2	1.3	1.2	1.2	1.4	1.4	1.4	1.4	1.3	1.3	1.3
V	ppm	27	29	29	28	28	27	28	28	28	29	32	33	31	33	34	34	34	33	32	31	31
W	ppm	<.1	0.1	<.1	0.1	<.1	0.2	<.1	0.1	<.1	0.1	0.1	0.1	0.1	<.1	0.1	<.1	0.1	0.1	0.1	0.1	0.1
Y	ppm	6.95	7.32	7.26	7.01	7.25	6.85	7.22	6.82	7.15	7.02	7.07	7.67	7.36	7.62	7.58	7.79	7.58	7.42	7.28	7.32	7.35
Zn	ppm	56.9	56.6	56.2	56.5	56.9	57.1	57.3	56.2	57.7	57.7	60.1	64	61.2	61.7	62.8	63.8	61.4	61.3	59.5	59.9	58.2
Zr	ppm	3.5	3.8	3.5	3.8	3.9	3.9	3.9	3.6	3.7	3.7	3.8	4.1	4.1	4.1	4.3	4.3	4.2	4.3	4	4	4.1

Stn		WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23	WH 23
Sed. Depth 1 (cm)		21	22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50
Sed. Depth 2 (cm)		22	23	24	25	26	27	28	29	30	32	34	36	38	40	42	44	46	48	50	52
Avg. Depth	(cm)	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	31.0	33.0	35.0	37.0	39.0	41.0	43.0	45.0	47.0	49.0	51.0
Total Carbon	(% dry wt.)	2.30	2.38	2.28	2.39	2.31	2.33	2.36	2.21	2.43	2.25	2.89	2.78	2.29	3.13	3.97	3.99	5.46	4.36	5.10	4.52
Organic Carbon	(% dry wt.)	2.09	2.15	2.06	1.98	1.97	1.89	1.91	1.86	1.83	1.85	2.57	2.55	2.12	2.98	3.65	3.62	3.39	4.11	4.74	3.94
Inorganic Carbon	(% dry wt.)	0.21	0.23	0.22	0.41	0.34	0.44	0.45	0.35	0.60	0.40	0.32	0.23	0.17	0.15	0.32	0.37	2.07	0.25	0.36	0.58
Ag	ppb	88	92	82	88	89	86	87	84	86	87	114	114	124	125	124	114	115	100	83	73
Al	(% dry wt.)	1.05	0.99	1.04	1.05	1.05	1.02	1	1.02	1.03	1	1.1	1.11	1.1	1.1	1	1.1	1.11	1.14	1.2	1.18
As	ppm	121	129	156	164	169	209	207	247	246	229	284	377	486	516	440	498	568	417	72	15
Au	ppb	124.1	113.1	119	189.4	151.5	156.7	209.6	182.7	193.6	204.8	399.4	557.6	782.5	758.9	658.8	669.4	684	332.6	67.2	3.7
B	ppm	55	49	49	47	43	42	44	43	45	44	85	87	68	96	121	133	113	132	154	128
Ba	ppm	29.4	28.3	26.6	29.3	26.9	28.4	26.6	27.7	27.8	26.8	26.8	31.4	26	25.5	24.3	24.7	25.1	27.2	31	30.9
Be	ppm	0.3	0.4	0.3	0.4	0.4	0.3	0.3	0.6	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.3	0.4	0.3	0.4	0.5
Bi	ppm	0.22	0.22	0.21	0.23	0.23	0.23	0.24	0.23	0.24	0.22	0.31	0.33	0.34	0.33	0.32	0.31	0.33	0.27	0.17	0.17
Ca	(% dry wt.)	0.33	0.59	0.49	0.65	0.64	0.75	1.05	0.89	0.89	1.19	0.48	0.29	0.26	0.41	0.38	0.46	0.31	0.31	0.34	0.68
Cd	ppm	0.48	0.45	0.44	0.39	0.4	0.35	0.34	0.29	0.35	0.35	0.38	0.38	0.29	0.41	0.51	0.57	0.66	0.8	0.8	0.53
Ce	ppm	28.4	25.8	28	29.3	28.5	28.1	28.7	30.1	29.8	28.1	34.9	38.3	43.1	40.4	35.1	35.6	39.6	34.2	28.3	27.2
Co	ppm	8.6	8.1	8.5	8.1	8.1	8.5	8.1	8.4	8.2	7.6	8.4	8.2	7.3	8.1	7.4	8.1	8.5	8.7	8.9	8.2
Cr	ppm	24.5	23.4	20.6	22	22.9	20.9	20.3	20.8	20.7	20.1	23.2	23.5	22.1	21.9	20.7	21.8	22.8	23	26.8	26
Cs	ppm	1.21	1.13	1.08	1.15	1.12	1.12	1.1	1.1	1.1	1.07	1.11	1.04	0.99	0.97	0.99	0.97	0.99	1.11	1.27	1.3
Cu	ppm	18.85	17.57	18.18	18.01	18.82	17.66	17.85	19.03	17.72	17.08	20.74	20.68	20.02	21.56	21.08	21.34	22.37	21.94	19.68	18.18
Fe	(% dry wt.)	2.3	2.18	2.22	2.26	2.27	2.2	2.2	2.26	2.25	2.19	2.56	2.42	2.51	2.44	2.2	2.44	2.41	2.38	2.46	2.45
Ga	ppm	3.3	3.2	3.2	3.2	3.3	3.2	3.1	3.2	3.2	3.1	3.5	3.3	3.4	3.2	3	3.2	3.2	3.4	3.5	3.6
Ge	ppm	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Hf	ppm	0.09	0.08	0.09	0.08	0.09	0.08	0.08	0.08	0.09	0.09	0.1	0.1	0.1	0.09	0.1	0.09	0.09	0.09	0.09	0.09
Hg	ppb	962	991	1000	1173	1257	1355	1362	1432	1503	1518	3149	4482	6336	6311	5506	5106	6863	5291	1326	189
In	ppm	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	<.02	0.02	0.02	0.02	0.02
K	(% dry wt.)	0.21	0.19	0.2	0.21	0.2	0.2	0.19	0.19	0.2	0.19	0.22	0.2	0.19	0.2	0.21	0.21	0.21	0.24	0.28	0.26
La	ppm	16.3	14.9	15	15.8	15.4	15.5	14.9	16.4	16.1	15.2	18.2	20.3	22.9	21.7	18.4	19.5	21.5	18.8	15.8	15.8
Li	ppm	30.5	27.6	26.4	28.3	27.6	26.4	26.3	26.3	26.5	24.8	27.4	27	25.7	26.1	25.7	25.9	25.6	27.2	30.1	30.8
Mg	(% dry wt.)	0.67	0.64	0.66	0.67	0.67	0.65	0.64	0.66	0.66	0.64	0.7	0.7	0.71	0.72	0.69	0.74	0.73	0.76	0.82	0.76
Mn	ppm	432	416	414	435	424	426	424	429	430	408	397	372	340	370	331	321	308	318	367	409
Mo	ppm	2.89	2.69	2.56	2.78	2.78	2.61	2.43	2.28	2.74	1.78	2.42	2.91	3.1	3.41	3.72	5.75	6.25	7.08	9.27	3.49
Na	(% dry wt.)	1.042	0.988	1.01	0.992	1.03	0.982	0.958	0.933	0.978	0.958	1.063	0.985	0.859	1.083	1.248	1.391	1.366	1.504	1.741	1.373
Nb	ppm	0.92	0.89	0.87	0.82	0.81	0.77	0.74	0.79	0.77	0.73	0.93	0.89	0.85	0.85	0.82	0.81	0.86	0.86	0.99	1.09
Ni	ppm	21.4	20.2	21	20.6	21.3	20.2	19.9	19.6	20.5	19.5	22.2	20.8	19.6	20.7	20.2	21	21.9	23.9	25.1	23.5
P	(% dry wt.)	0.06	0.056	0.057	0.058	0.055	0.055	0.053	0.056	0.056	0.055	0.058	0.061	0.062	0.062	0.062	0.065	0.066	0.064	0.067	0.063
Pb	ppm	22.11	21.08	20.98	22.5	23.66	22.57	22.1	24.13	23.31	22.23	29.94	53.36	35.08	34.09	31.87	30.83	30.31	22.59	12.82	11.1
Pd	ppb	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Pt	ppb	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Rb	ppm	10.8	10	10.1	10.2	10.4	10.2	9.6	9.8	9.9	9.3	10.1	9	8.6	9.1	9.1	9	8.4	9.5	11.5	12
Re	ppb	2	4	3	4	3	3	1	2	3	2	2	3	3	2	3	2	1	4	4	6
S	(% dry wt.)	1	0.96	0.95	0.99	0.99	0.98	0.98	0.96	1.01	1	1.32	1.08	1.06	1.12	1.23	1.3	1.26	1.25	1.42	1.42
Sb	ppm	0.46	0.47	0.55	0.55	0.58	0.63	0.62	0.73	0.71	0.67	0.87	1.02	1.29	1.28	1.02	1.1	1.31	0.95	0.26	0.2
Sc	ppm	2	1.8	1.9	1.9	1.8	1.8	1.6	1.7	1.7	1.7	1.9	1.7	1.7	1.6	1.6	1.8	1.6	1.9	2.2	2.2
Se	ppm	1.1	1	1	0.9	1	0.9	1	0.9	0.8	0.8	1.1	1	0.9	1.1	1.3	1.2	1.2	1.5	1.7	1.5
Sn	ppm	1	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.1	1	0.8	0.8	0.8	0.7	0.7	0.6	0.5	0.4
Sr	ppm	32.5	41	37.8	43.1	42.9	46	58.9	54	54.9	66.1	43.3	35.3	34.8	48.7	48.4	51.8	43.2	43.5	47.4	55.6
Ta	ppm	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Te	ppm	0.03	0.03	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.04	0.04	0.08	0.07	0.09	0.06	0.06	0.07	0.06	<.02	<.02
Th	ppm	3.7	3.4	3.6	3.7	3.7	3.6	3.5	3.9	3.7	3.7	4.2	4.5	5.2	4.6	3.7	3.8	4.1	3.5	2.9	3.2
Ti	(% dry wt.)	0.03	0.027	0.027	0.026	0.026	0.026	0.024	0.025	0.025	0.024	0.023	0.02	0.018	0.017	0.017	0.018	0.017	0.019	0.024	0.029
Tl	ppm	0.19	0.19	0.19	0.19	0.19	0.16	0.15	0.14	0.14	0.14	0.13	0.12	0.11	0.13	0.14	0.17	0.21	0.27	0.3	0.21
U	ppm	1.2	1.1	1.2	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.3	1.5	1.5	1.6	1.7	2	2.1	2.2	2.6	1.5
V	ppm	30	28	28	28	28	27	27	27	27	26	30	29	27	30	31	32	30	32	36	33
W	ppm	0.1	<.1	0.1	<.1	<.1	0.1	<.1	<.1	<.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.1	0.1	<.1
Y	ppm	7.45	6.95	6.78	6.93	7.05	6.76	6.51	6.7	6.79	6.47	7.25	7.03	7.27	7.12	6.52	6.91	6.75	6.92	7.52	7.69
Zn	ppm	58.9	56.1	59	58.3	58.9	56.5	54.2	56.2	56.5	53.5	63	64.1	62.7	57.5	58	57.7	59.9	60	55	51.3
Zr	ppm	4	3.8	4	4.2	4.1	3.9	3.7	4	3.9	3.8	4.7	4.6	5.1	4.4	3.6	4	4.2	4.1	3.7	3.9

APPENDIX F : WATER CHEMISTRY

	pH	Temperature	Conductivity	Alkalinity PC-Titrate as CaCO3	DOC SHIMADZU DIRECT
	Standard units	°C	µS/cm	ppm	ppm
D.L.				1	1
WH 05 W1	5	20	42	< 1	12
WH 05 W2	6	9	120	30	3
WH 05 W3	5	18	47	3	15
WH 05 W4	6	19	58	3	16
WH 05 W5	5	7	128	31	2

Anions	F Dionex EG-40	Cl Dionex EG-40	SO4 Dionex EG-40	Br Dionex EG-40	NO3 Dionex EG-40	PO4 Dionex EG-40
	ppm	ppm	ppm	ppm	ppm	ppm
D.L.	0.01	0.01	0.02	0.02	0.02	0.02
WH 05 W1 FU A	0.05	7.38	2.25	0.06	0.35	< 0.02
WH 05 W2 FU A	0.05	12.44	4.83	0.07	1.01	< 0.02
WH 05 W3 FU A	0.05	9.01	1.96	0.07	0.07	< 0.02
WH 05 W4 FU A	0.05	11.26	1.72	0.13	0.22	< 0.02
WH 05 W5 FU A	0.05	12.15	4.95	0.07	1.14	< 0.02

	Ag ICP-MS DIRECT ppb	Al ICP-MS DIRECT ppb	As ICP-MS DIRECT ppb	B ICP-MS DIRECT ppb	Ba ICP-MS DIRECT ppb	Be ICP-MS DIRECT ppb	Ca ICP-ES DIRECT ppm	Cd ICP-MS DIRECT ppb
D.L.	0.005	2	0.1	0.5	0.2	0.005	0.02	0.02
WH 05 TB AUG C	< 0.005	< 2	< 0.1	56.2	4.8	< 0.005	0.29	< 0.02
WH 05 AB AUG C	< 0.005	< 2	< 0.1	52.2	38.8	< 0.005	0.26	< 0.02
WH 05 SB AUG C	< 0.005	< 2	< 0.1	53.2	37.5	< 0.005	0.26	< 0.02
WH 05 W1 FA C	< 0.005	136	1.0	5.2	2.9	0.014	1.28	< 0.02
WH 05 W2 FA C	< 0.005	11	34.9	9.1	3.8	0.006	10.92	< 0.02
WH 05 W3 FA C	< 0.005	188	1.7	6.5	2.4	< 0.005	1.45	< 0.02
WH 05 W4 FA C	< 0.005	148	17.2	6.2	1.9	0.010	1.82	< 0.02
WH 05 W5 FA C	< 0.005	9	22.6	8.8	3.6	< 0.005	11.35	< 0.02
WH 05 W1 UA C	< 0.005	159	1.5	5.5	3.1	0.014	1.29	< 0.02
WH 05 W2 UA C	< 0.005	15	39.8	9.1	3.8	< 0.005	10.75	< 0.02
WH 05 W3 UA C	< 0.005	202	2.2	6.4	2.6	< 0.005	1.46	< 0.02
WH 05 W4 UA C	< 0.005	174	22.6	6.6	2.1	0.008	1.84	< 0.02
WH 05 W5 UA C	< 0.005	82	135.1	8.4	6.3	0.011	11.35	0.02

	Ce ICP-MS DIRECT ppb	Co ICP-MS DIRECT ppb	Cr ICP-MS DIRECT ppb	Cs ICP-MS DIRECT ppb	Cu ICP-MS DIRECT ppb	Dy ICP-MS DIRECT ppb	Er ICP-MS DIRECT ppb	Eu ICP-MS DIRECT ppb
D.L.	0.01	0.05	0.1	0.01	0.1	0.005	0.005	0.005
WH 05 TB AUG C	< 0.01	< 0.05	< 0.1	< 0.01	< 0.1	< 0.005	< 0.005	< 0.005
WH 05 AB AUG C	< 0.01	< 0.05	< 0.1	< 0.01	< 0.1	< 0.005	< 0.005	< 0.005
WH 05 SB AUG C	< 0.01	< 0.05	< 0.1	< 0.01	< 0.1	< 0.005	< 0.005	< 0.005
WH 05 W1 FA C	0.46	0.21	0.1	0.02	0.3	0.037	0.020	0.010
WH 05 W2 FA C	0.15	0.21	< 0.1	0.01	0.3	0.008	0.005	< 0.005
WH 05 W3 FA C	0.56	0.16	0.2	< 0.01	0.3	0.046	0.022	0.015
WH 05 W4 FA C	0.27	0.43	0.2	< 0.01	0.3	0.028	0.015	0.007
WH 05 W5 FA C	0.17	0.14	< 0.1	0.01	0.4	0.009	< 0.005	0.005
WH 05 W1 UA C	0.56	0.26	0.2	0.02	0.3	0.038	0.020	0.011
WH 05 W2 UA C	0.19	0.23	< 0.1	0.01	0.3	0.008	< 0.005	< 0.005
WH 05 W3 UA C	0.60	0.19	0.3	< 0.01	0.3	0.046	0.022	0.015
WH 05 W4 UA C	0.32	0.46	0.2	< 0.01	0.3	0.027	0.015	0.011
WH 05 W5 UA C	1.72	1.50	0.1	0.02	0.8	0.053	0.024	0.029

	Fe	Ga	Gd	Ge	Hf	Hg	Ho	In
	ICP-ES	ICP-MS	ICP-MS	ICP-MS	ICP-MS	TEKRAN	ICP-MS	ICP-MS
	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT
	ppm	ppb	ppb	ppb	ppb	ppt	ppb	ppb
D.L.	0.005	0.01	0.005	0.02	0.01	0.5	0.005	0.01
WH 05 TB AUG C	< 0.005	< 0.01	< 0.005	< 0.02	< 0.01	< 0.5	< 0.005	< 0.01
WH 05 AB AUG C	< 0.005	< 0.01	< 0.005	< 0.02	< 0.01	0.7	< 0.005	< 0.01
WH 05 SB AUG C	< 0.005	< 0.01	< 0.005	< 0.02	< 0.01	< 0.5	< 0.005	< 0.01
WH 05 W1 FA C	0.642	0.01	0.048	< 0.02	0.01	4.4	0.008	< 0.01
WH 05 W2 FA C	0.179	< 0.01	0.015	< 0.02	< 0.01	6.9	< 0.005	< 0.01
WH 05 W3 FA C	0.509	< 0.01	0.053	< 0.02	0.02	6.4	0.008	< 0.01
WH 05 W4 FA C	0.835	0.01	0.037	< 0.02	0.01	7.5	< 0.005	< 0.01
WH 05 W5 FA C	0.116	< 0.01	0.016	< 0.02	< 0.01	3.1	< 0.005	< 0.01
WH 05 W1 UA C	1.021	0.02	0.057	< 0.02	< 0.01	5.6	0.008	< 0.01
WH 05 W2 UA C	0.264	< 0.01	0.014	< 0.02	< 0.01	11.2	< 0.005	< 0.01
WH 05 W3 UA C	0.690	< 0.01	0.054	< 0.02	0.03	6.9	0.008	< 0.01
WH 05 W4 UA C	1.265	0.02	0.041	< 0.02	0.02	10.3	0.005	< 0.01
WH 05 W5 UA C	1.873	< 0.01	0.101	< 0.02	< 0.01	25.1	0.010	< 0.01

	K	La	Li	Lu	Mg	Mn	Mo	Na
	ICP-ES	ICP-MS	ICP-MS	ICP-MS	ICP-ES	ICP-MS	ICP-MS	ICP-ES
	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT
	ppm	ppb	ppb	ppb	ppm	ppb	ppb	ppm
D.L.	0.05	0.01	0.02	0.005	0.005	0.1	0.05	0.05
WH 05 TB AUG C	< 0.05	< 0.01	0.03	< 0.005	< 0.005	< 0.1	< 0.05	0.19
WH 05 AB AUG C	< 0.05	< 0.01	0.02	< 0.005	< 0.005	0.3	< 0.05	0.14
WH 05 SB AUG C	< 0.05	< 0.01	0.04	< 0.005	< 0.005	0.3	< 0.05	0.15
WH 05 W1 FA C	0.34	0.35	0.55	< 0.005	0.646	141.2	0.20	4.60
WH 05 W2 FA C	0.75	0.06	0.55	< 0.005	2.380	476.1	0.16	7.22
WH 05 W3 FA C	0.35	0.31	0.52	< 0.005	0.754	43.7	< 0.05	5.48
WH 05 W4 FA C	0.36	0.16	0.55	< 0.005	1.125	212.2	< 0.05	6.96
WH 05 W5 FA C	0.71	0.08	0.67	< 0.005	2.522	103.4	0.09	7.16
WH 05 W1 UA C	0.33	0.41	0.56	< 0.005	0.639	153.6	< 0.05	4.57
WH 05 W2 UA C	0.77	0.08	0.56	< 0.005	2.329	481.7	0.11	7.19
WH 05 W3 UA C	0.39	0.34	0.51	< 0.005	0.756	51.9	< 0.05	5.45
WH 05 W4 UA C	0.39	0.19	0.54	< 0.005	1.123	221.3	< 0.05	6.91
WH 05 W5 UA C	0.74	0.80	0.59	0.006	2.504	585.9	0.09	6.96

	Nb	Nd	Ni	P	Pb	Pr	Rb	Re
	ICP-MS	ICP-MS	ICP-MS	ICP-ES	ICP-MS	ICP-MS	ICP-MS	ICP-MS
	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT
	ppb	ppb	ppb	ppm	ppb	ppb	ppb	ppb
D.L.	0.01	0.005	0.2	0.05	0.01	0.005	0.05	0.005
WH 05 TB AUG C	< 0.01	< 0.005	< 0.2	< 0.05	< 0.01	< 0.005	0.05	< 0.005
WH 05 AB AUG C	< 0.01	< 0.005	< 0.2	< 0.05	< 0.01	< 0.005	0.09	< 0.005
WH 05 SB AUG C	< 0.01	< 0.005	< 0.2	< 0.05	< 0.01	< 0.005	0.08	< 0.005
WH 05 W1 FA C	< 0.01	0.316	0.3	< 0.05	0.26	0.080	0.84	< 0.005
WH 05 W2 FA C	< 0.01	0.074	0.3	< 0.05	0.08	0.019	0.64	< 0.005
WH 05 W3 FA C	< 0.01	0.315	0.3	< 0.05	0.14	0.082	0.92	< 0.005
WH 05 W4 FA C	< 0.01	0.167	0.4	< 0.05	0.23	0.042	0.75	< 0.005
WH 05 W5 FA C	< 0.01	0.099	0.3	< 0.05	0.05	0.024	0.55	< 0.005
WH 05 W1 UA C	< 0.01	0.377	0.5	< 0.05	0.39	0.093	0.88	< 0.005
WH 05 W2 UA C	< 0.01	0.089	0.4	< 0.05	0.11	0.024	0.64	< 0.005
WH 05 W3 UA C	< 0.01	0.331	0.3	< 0.05	0.22	0.087	0.90	< 0.005
WH 05 W4 UA C	< 0.01	0.204	0.4	< 0.05	0.35	0.049	0.77	< 0.005
WH 05 W5 UA C	< 0.01	0.830	0.8	< 0.05	0.38	0.209	0.54	< 0.005

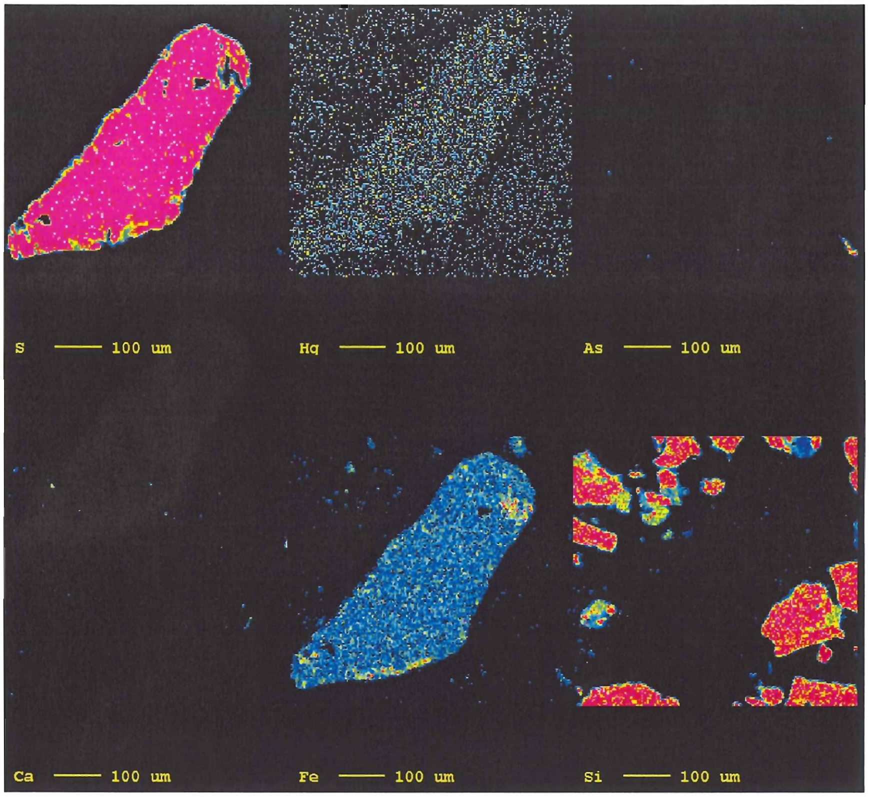
	S	Sb	Sc	Se	Si	Sm	Sn	Sr
	ICP-ES	ICP-MS	ICP-ES	ICP-MS	ICP-ES	ICP-MS	ICP-MS	ICP-MS
	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT	DIRECT
	ppm	ppb	ppm	ppb	ppm	ppb	ppb	ppb
D.L.	0.05	0.01	0.001	1	0.02	0.005	0.01	0.5
WH 05 TB AUG C	< 0.05	1.36	< 0.001	< 1	0.09	< 0.005	< 0.01	< 0.5
WH 05 AB AUG C	< 0.05	1.22	< 0.001	< 1	0.07	< 0.005	< 0.01	< 0.5
WH 05 SB AUG C	< 0.05	1.27	< 0.001	< 1	0.08	< 0.005	< 0.01	< 0.5
WH 05 W1 FA C	0.77	0.04	< 0.001	< 1	0.69	0.056	< 0.01	9.5
WH 05 W2 FA C	1.75	0.13	< 0.001	< 1	2.46	0.014	< 0.01	108.1
WH 05 W3 FA C	0.66	0.02	< 0.001	< 1	0.11	0.063	< 0.01	10.7
WH 05 W4 FA C	0.60	0.03	< 0.001	< 1	0.81	0.029	< 0.01	14.7
WH 05 W5 FA C	1.77	0.10	< 0.001	< 1	2.52	0.021	< 0.01	114.5
WH 05 W1 UA C	0.73	0.02	< 0.001	< 1	0.68	0.069	< 0.01	9.6
WH 05 W2 UA C	1.64	0.15	< 0.001	< 1	2.48	0.018	< 0.01	111.8
WH 05 W3 UA C	0.63	0.03	< 0.001	< 1	0.12	0.070	< 0.01	10.8
WH 05 W4 UA C	0.62	0.03	< 0.001	< 1	0.81	0.045	< 0.01	15.2
WH 05 W5 UA C	1.82	0.13	< 0.001	< 1	2.54	0.150	< 0.01	116.0

	Ta ICP-MS DIRECT ppb	Tb ICP-MS DIRECT ppb	Te ICP-MS DIRECT ppb	Ti ICP-MS DIRECT ppb	Tl ICP-MS DIRECT ppb	Tm ICP-MS DIRECT ppb	U ICP-MS DIRECT ppb	V ICP-MS DIRECT ppb
D.L.	0.01	0.005	0.02	0.5	0.005	0.005	0.005	0.1
WH 05 TB AUG C	< 0.01	< 0.005	< 0.02	< 0.5	< 0.005	< 0.005	< 0.005	< 0.1
WH 05 AB AUG C	< 0.01	< 0.005	< 0.02	< 0.5	< 0.005	< 0.005	< 0.005	< 0.1
WH 05 SB AUG C	< 0.01	< 0.005	< 0.02	< 0.5	< 0.005	< 0.005	< 0.005	< 0.1
WH 05 W1 FA C	< 0.01	0.007	< 0.02	1.8	0.007	< 0.005	0.016	0.2
WH 05 W2 FA C	< 0.01	< 0.005	< 0.02	< 0.5	< 0.005	< 0.005	0.045	< 0.1
WH 05 W3 FA C	< 0.01	0.008	< 0.02	2.2	< 0.005	< 0.005	0.012	0.2
WH 05 W4 FA C	< 0.01	0.005	< 0.02	1.5	< 0.005	< 0.005	0.006	0.2
WH 05 W5 FA C	< 0.01	< 0.005	< 0.02	< 0.5	< 0.005	< 0.005	0.072	< 0.1
WH 05 W1 UA C	< 0.01	0.008	< 0.02	2.5	< 0.005	< 0.005	0.012	0.3
WH 05 W2 UA C	< 0.01	< 0.005	< 0.02	0.5	< 0.005	< 0.005	0.049	< 0.1
WH 05 W3 UA C	< 0.01	0.009	< 0.02	2.7	< 0.005	< 0.005	0.016	0.3
WH 05 W4 UA C	< 0.01	0.005	< 0.02	2.2	< 0.005	< 0.005	0.009	0.4
WH 05 W5 UA C	< 0.01	0.012	< 0.02	1.3	< 0.005	< 0.005	0.208	0.2

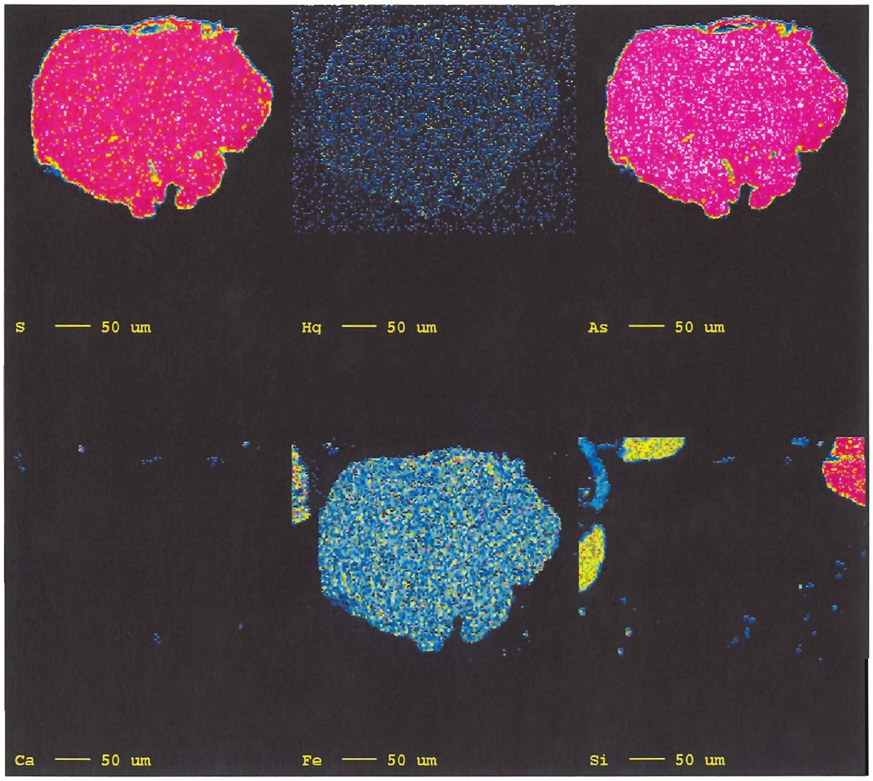
	W ICP-MS DIRECT ppb	Y ICP-MS DIRECT ppb	Yb ICP-MS DIRECT ppb	Zn ICP-MS DIRECT ppb	Zr ICP-MS DIRECT ppb
D.L.	0.02	0.01	0.005	0.5	0.05
WH 05 TB AUG C	< 0.02	< 0.01	< 0.005	7.5	< 0.05
WH 05 AB AUG C	< 0.02	< 0.01	< 0.005	41.9	< 0.05
WH 05 SB AUG C	< 0.02	< 0.01	< 0.005	40.6	< 0.05
WH 05 W1 FA C	< 0.02	0.20	0.013	1.2	< 0.05
WH 05 W2 FA C	< 0.02	0.05	0.005	1.2	< 0.05
WH 05 W3 FA C	< 0.02	0.21	0.016	1.0	0.10
WH 05 W4 FA C	< 0.02	0.15	0.014	1.3	0.09
WH 05 W5 FA C	< 0.02	0.05	0.007	1.3	< 0.05
WH 05 W1 UA C	< 0.02	0.23	0.015	1.2	0.06
WH 05 W2 UA C	< 0.02	0.05	0.007	1.2	< 0.05
WH 05 W3 UA C	< 0.02	0.24	0.022	0.9	0.13
WH 05 W4 UA C	< 0.02	0.17	0.013	1.3	0.09
WH 05 W5 UA C	< 0.02	0.28	0.027	3.3	< 0.05

APPENDIX G: CHEMICAL MAPS

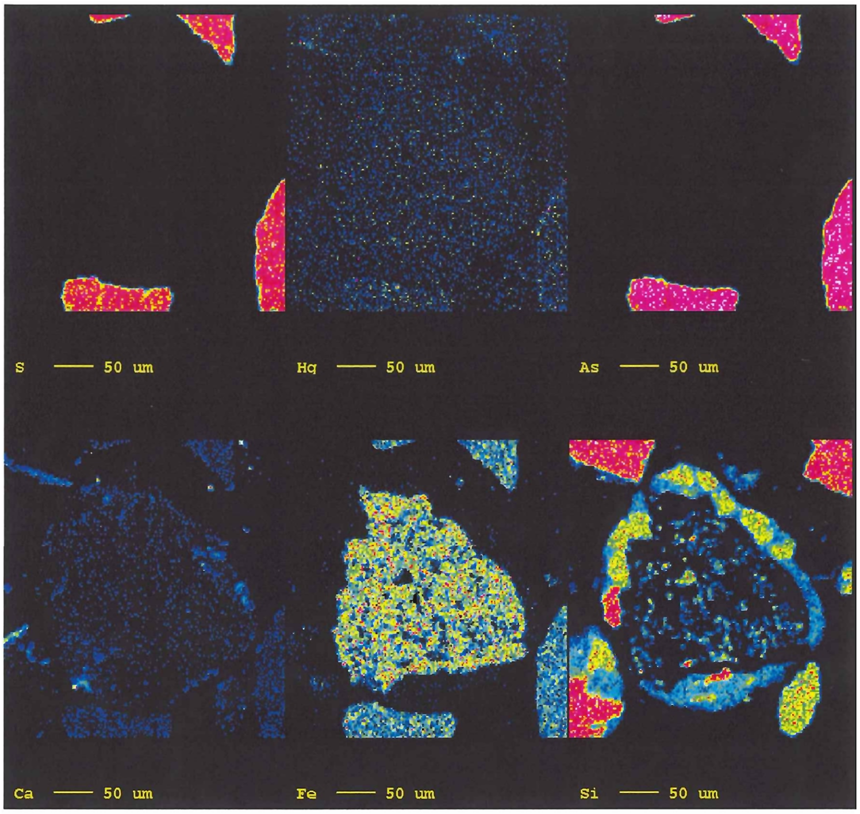
Tailings sample T4A



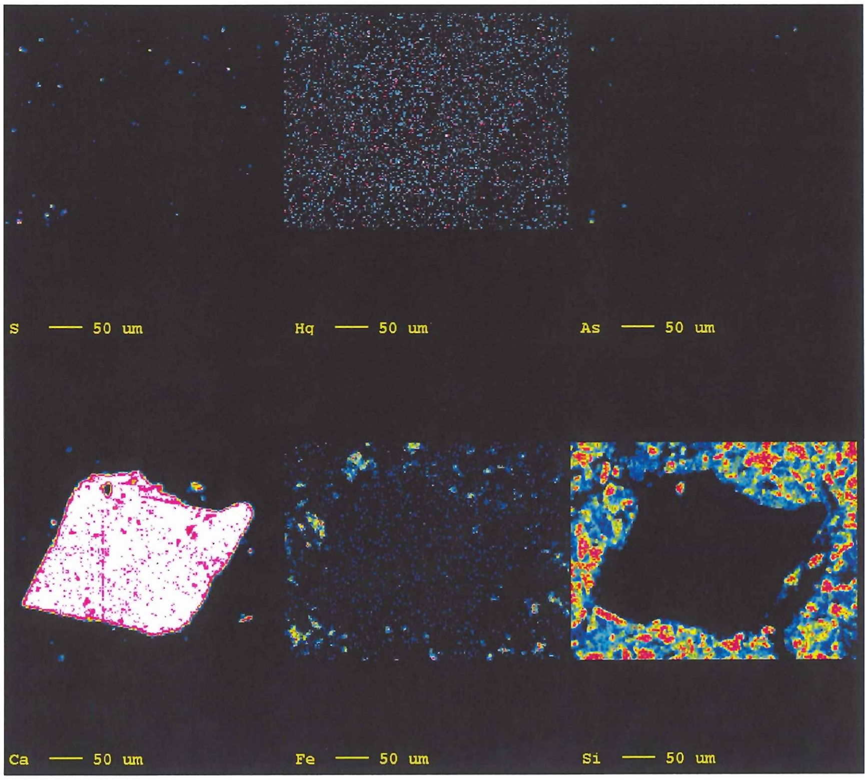
Tailings sample T5B



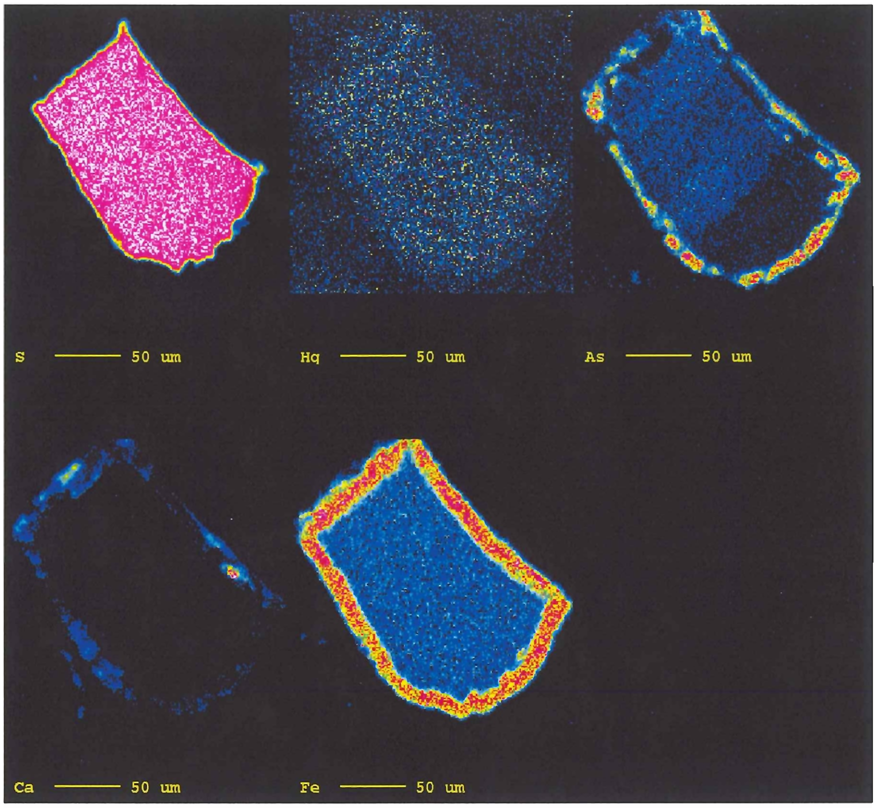
Tailings sample T5B



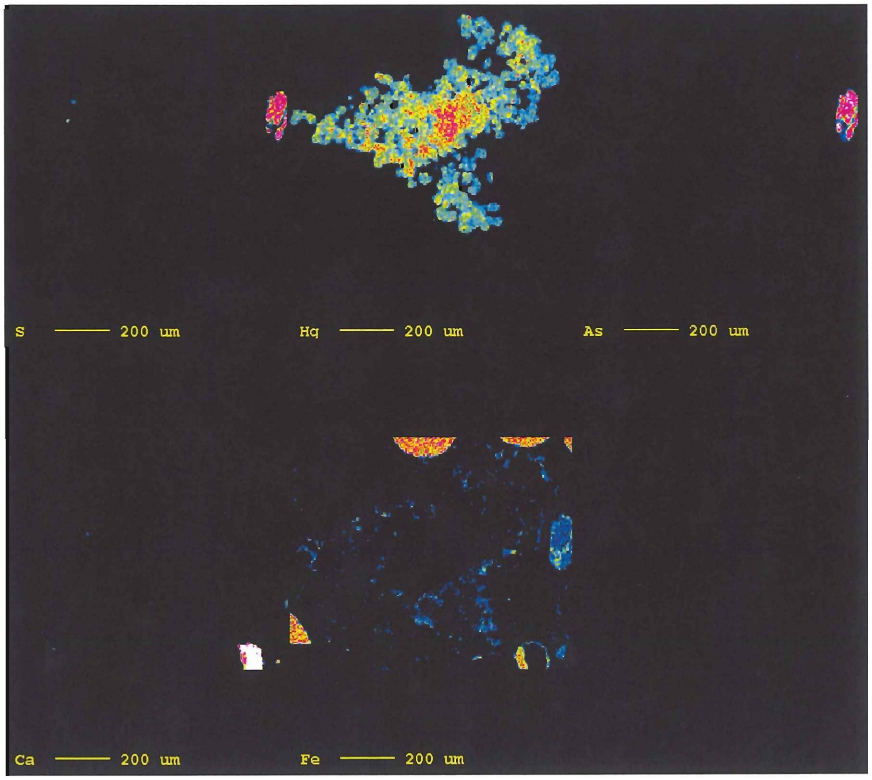
Tailings sample T9A



Plough Mill spillage sample

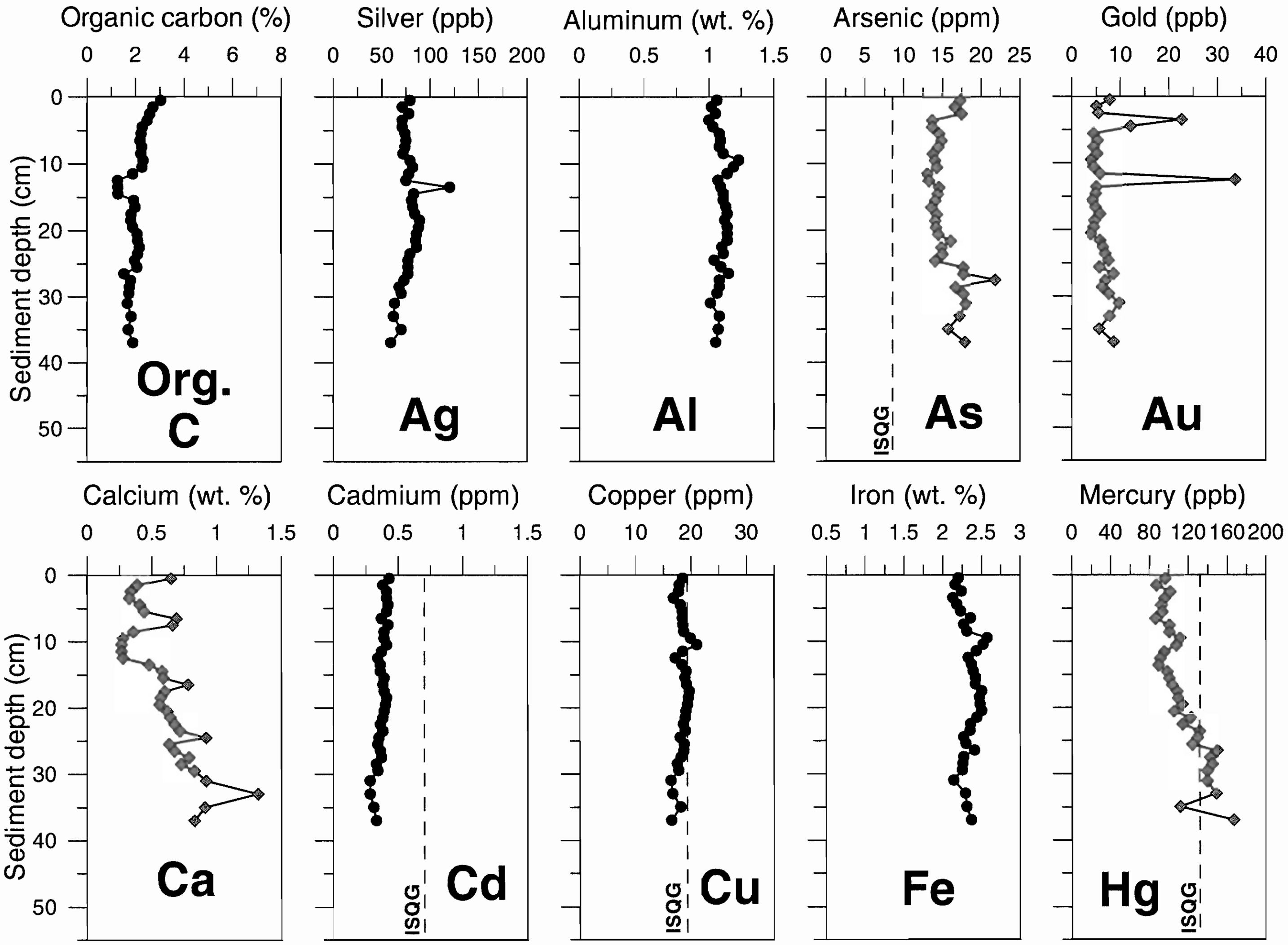


Plough Mill spillage sample



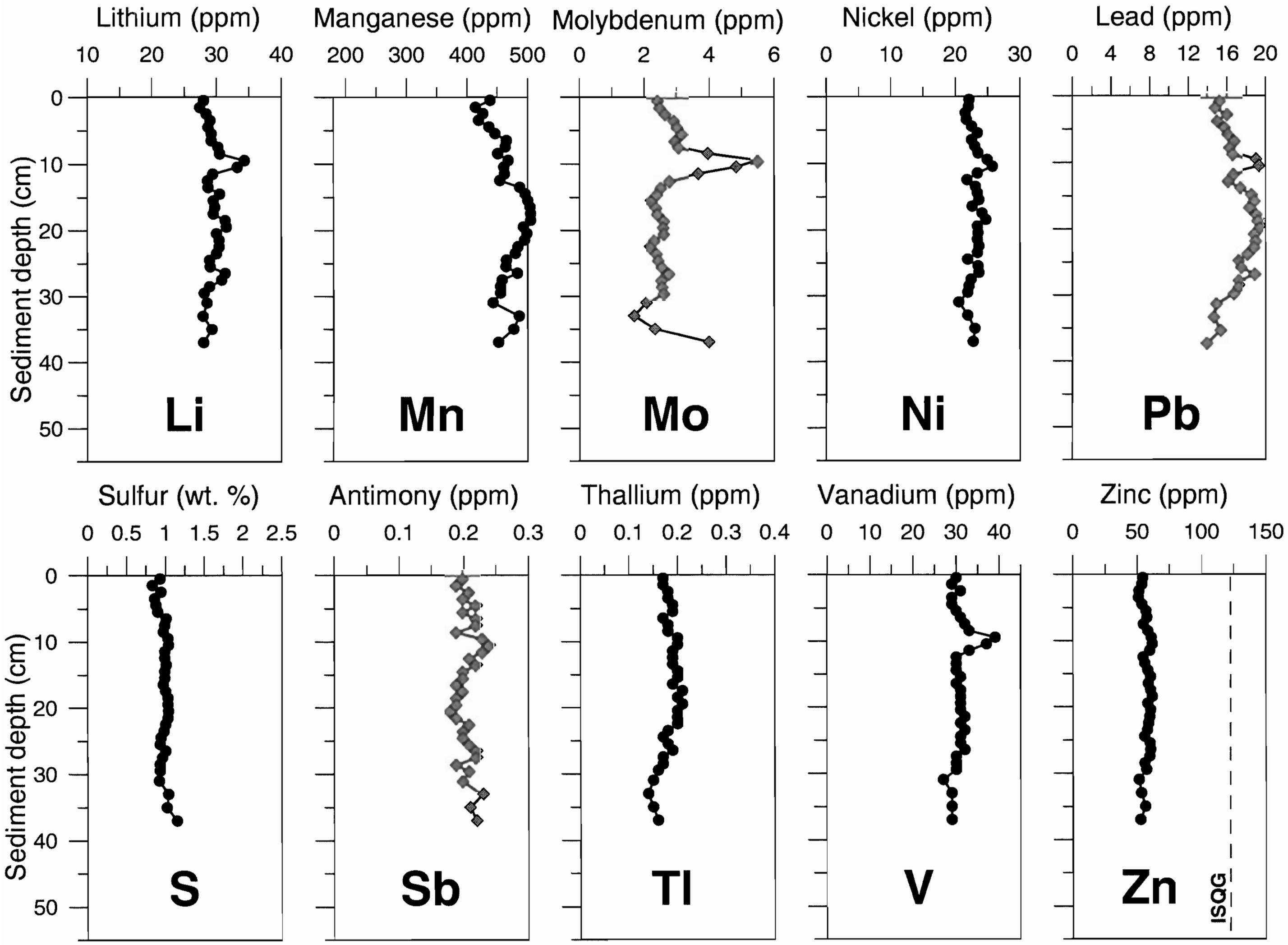
APPENDIX H: GRAVITY CORE PROFILES

Wine Harbour, Station WH-01 (July 2005)



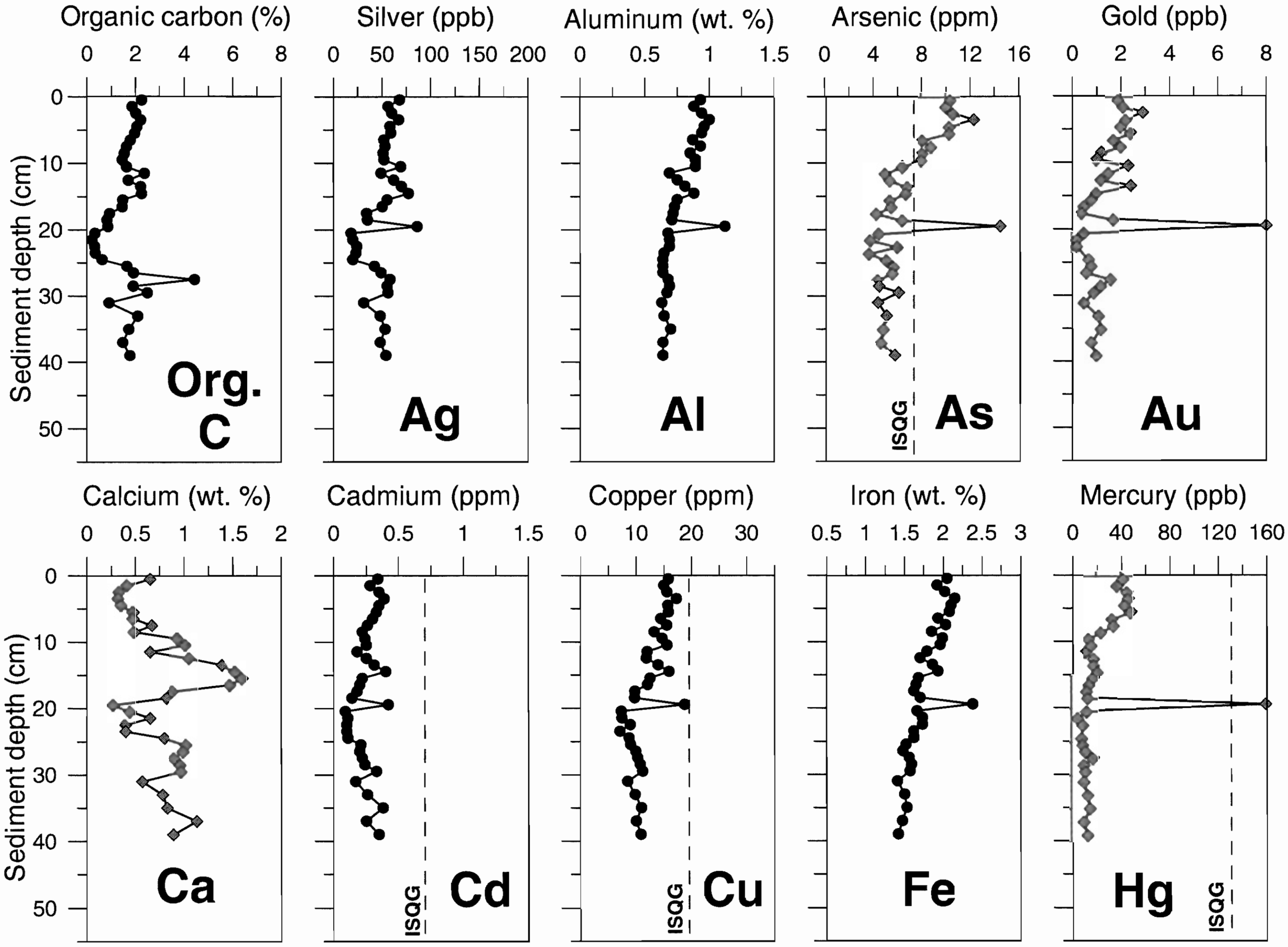
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-01 (July 2005) (cont'd)



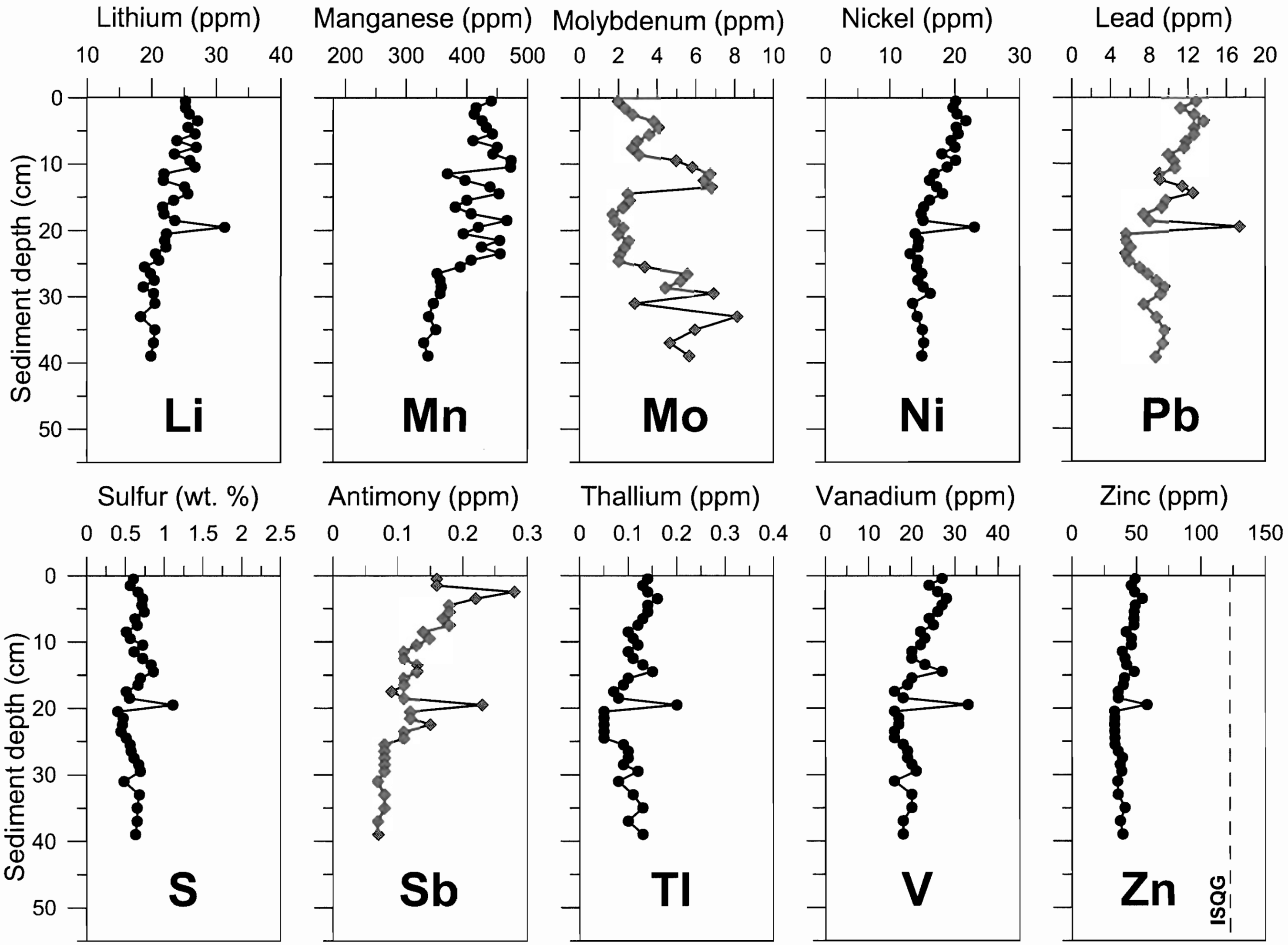
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-02 (July 2005)



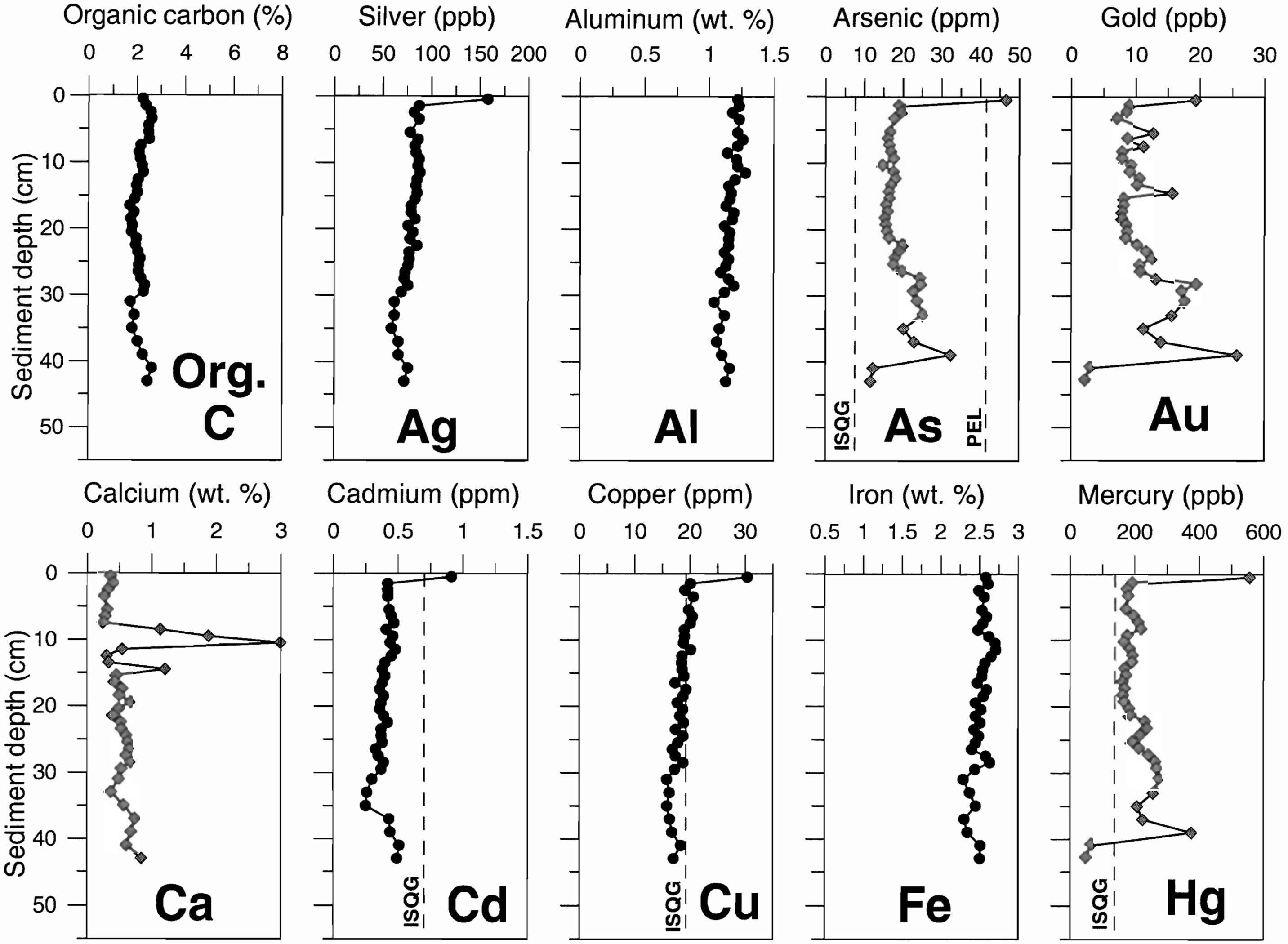
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-02 (July 2005) (cont'd)



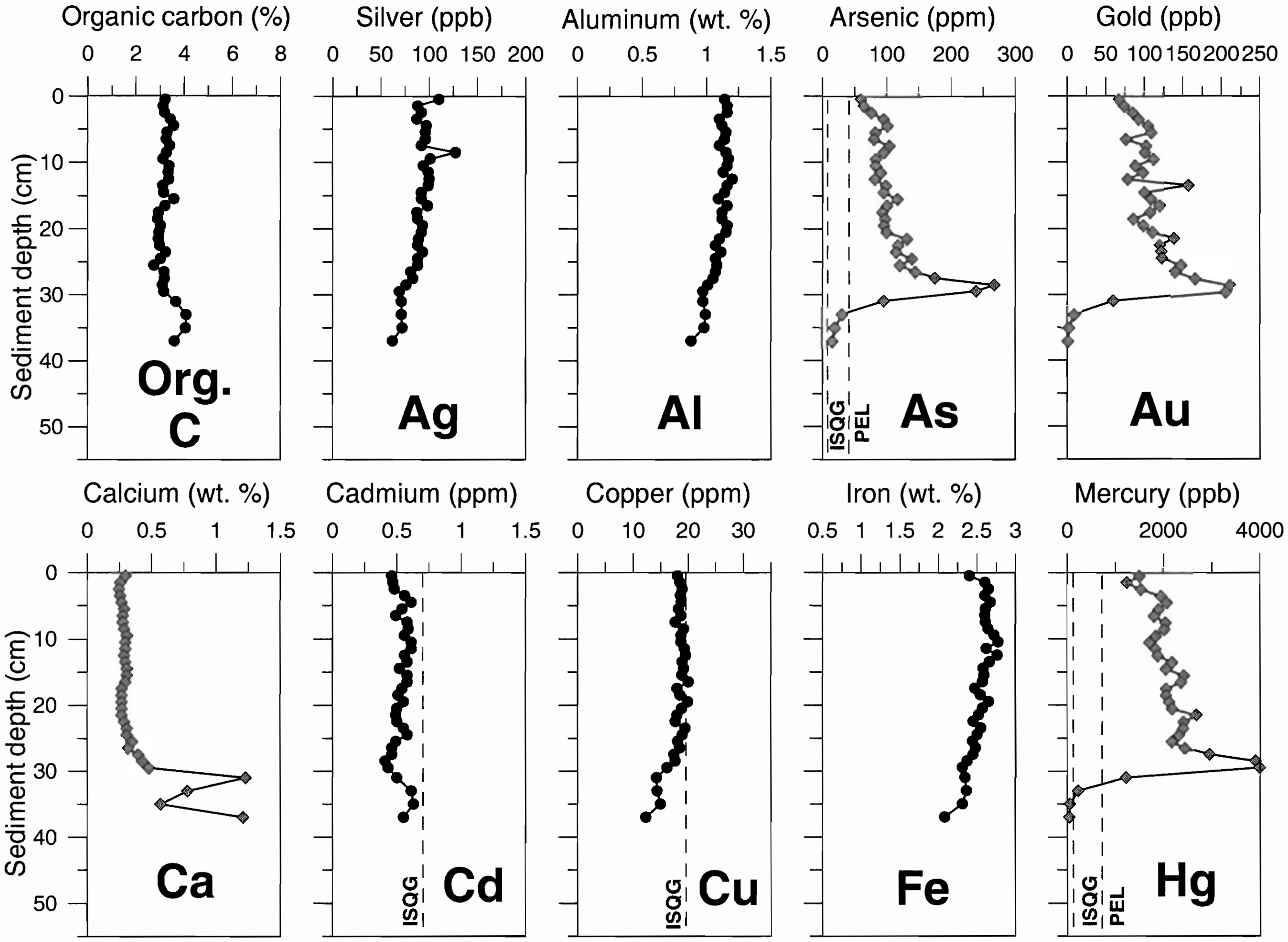
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-04 (July 2005)



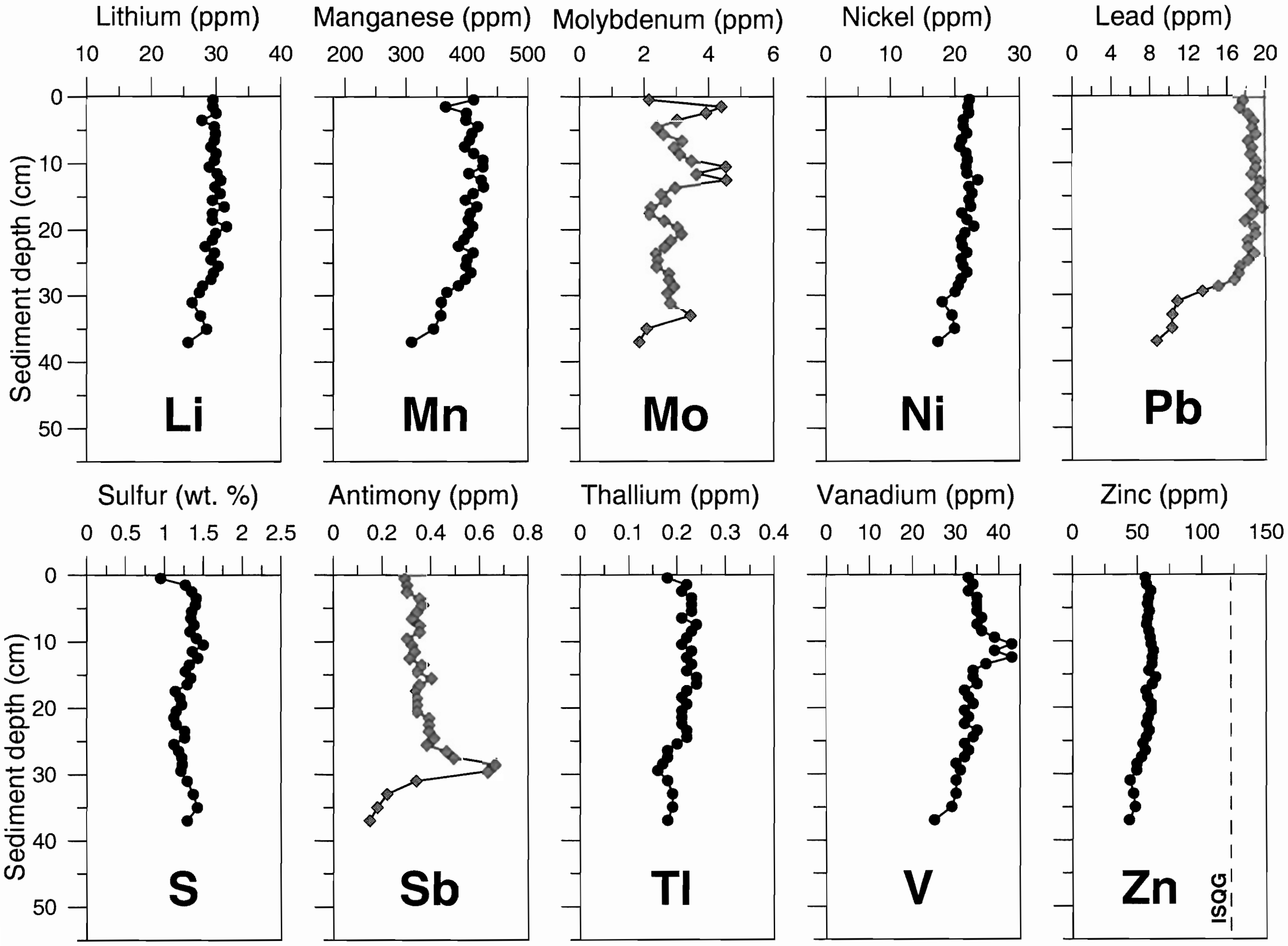
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-08 (July 2005)



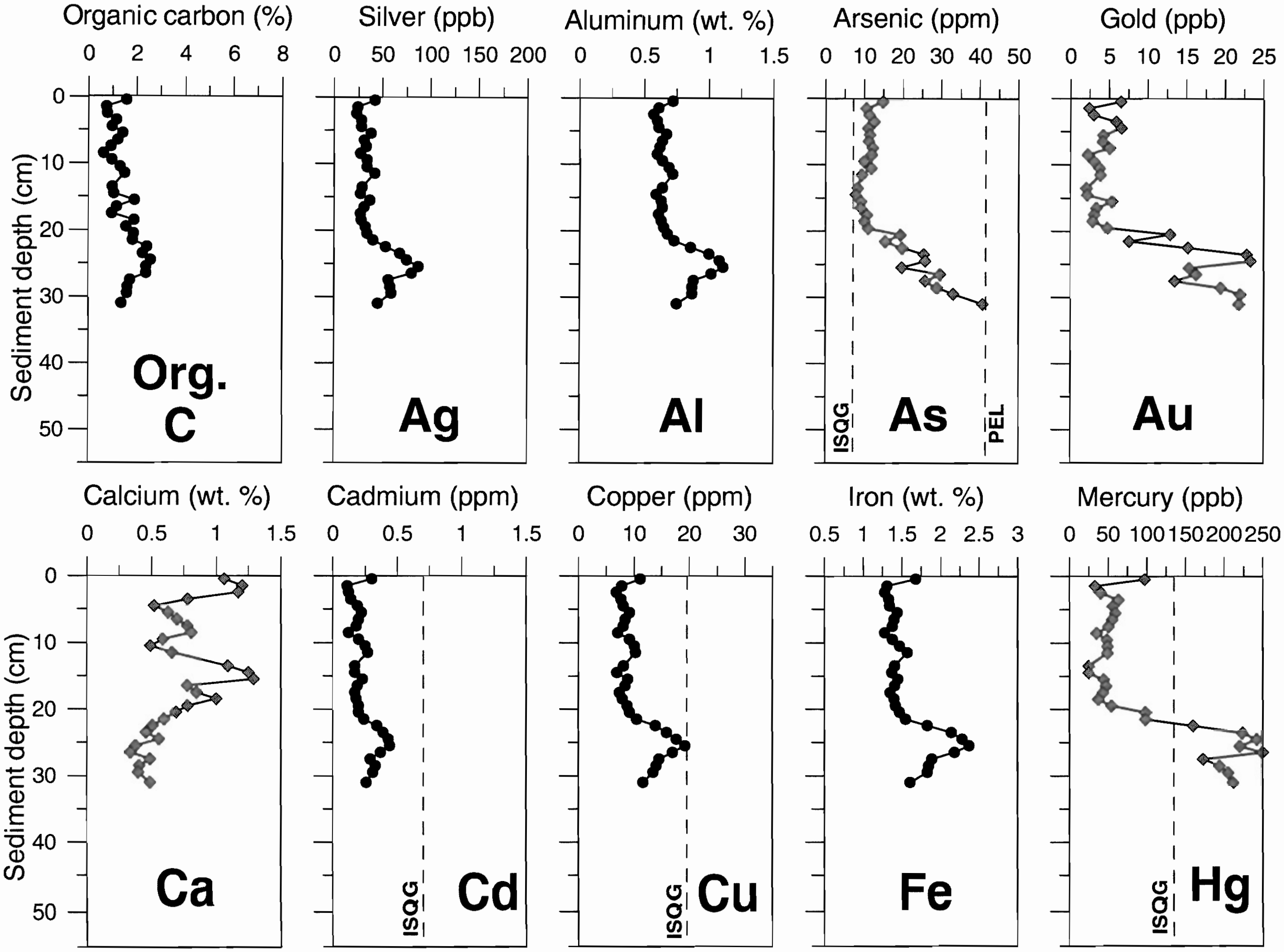
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-08 (July 2005) (cont'd)



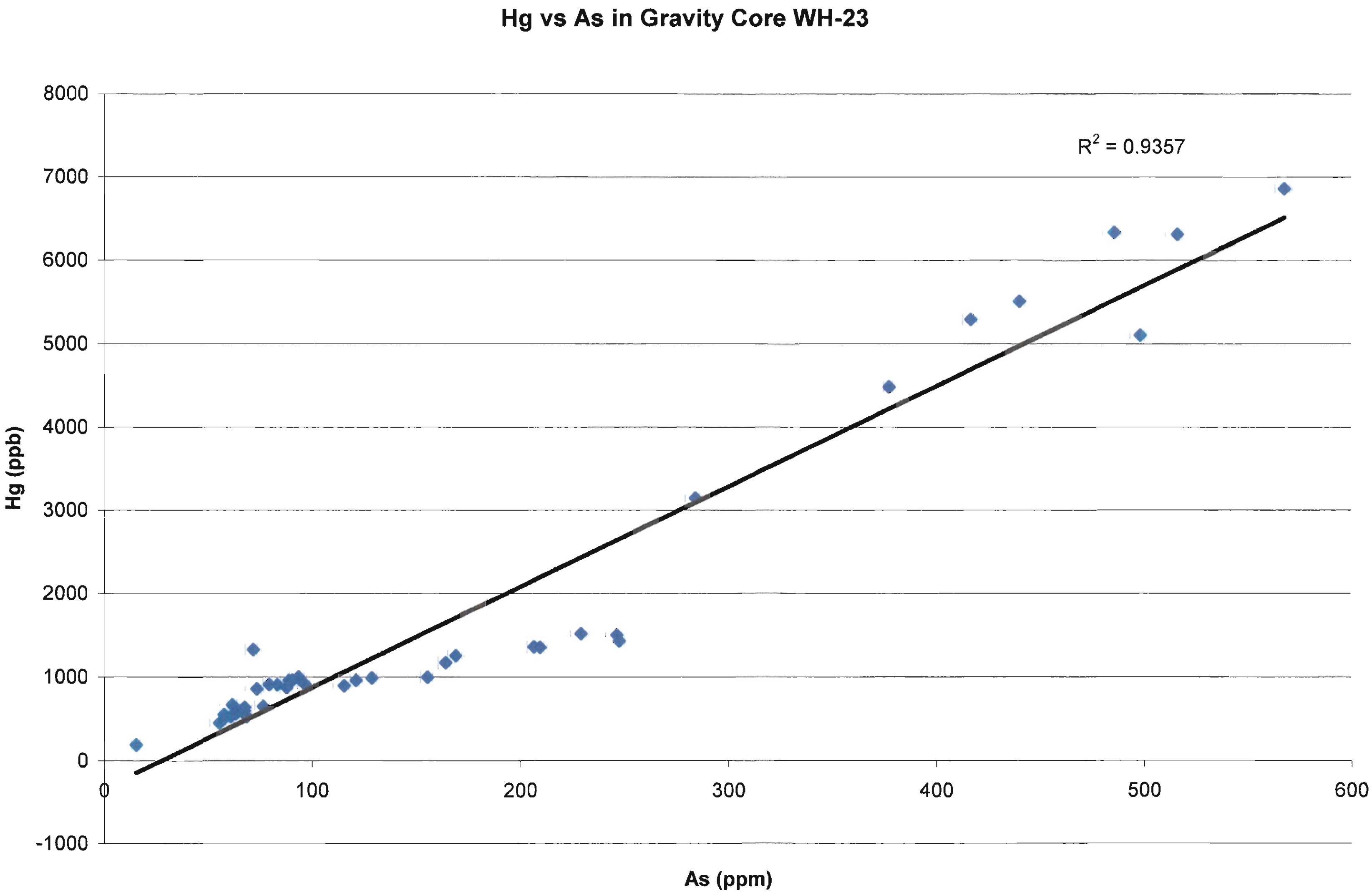
Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

Wine Harbour, Station WH-19 (July 2005)



Note: Horizontal scales for As, Au, Ca, Hg, Mo, Pb, and Sb vary between cores.

APPENDIX I : CORRELATION GRAPHS


Hg vs As in Gravity Core WH-23
R² = 0.9357
Hg (ppb)
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
100
200
300
400
500
600
As (ppm)