STABLE ISOTOPIC AND GEOCHEMICAL STUDIES OF LATE QUATERNARY STALAGMITES, SOUTH-CENTRAL APPALACHIAN MOUNTAINS, EASTERN NORTH AMERICA

by

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Abstract

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The University of Texas at Arlington, 2014

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A tripartite investigation was conducted utilizing speleothem geochemistry and modern cave environments: reconstruction of paleoclimate variability in southeastern West Virginia that spans the late Pleistocene to mid-Holocene, the development and optimization of Microbeam X-Ray Fluorescence analysis of speleothems, and high-frequency cave drip monitoring and cave environment study and implications for stalagmite paleoclimate studies.

Paleoclimate interpretations of stable isotopic and geochemical results from three coeval ^{230}Th-dated stalagmites provide insight into the timing, magnitude, and forcing mechanisms of past climate variability. Stable isotopic δ^{13}C and δ^{18}O and trace element (Sr) time series demonstrate variability between the coeval records, indicating different hydrologic histories of speleothem calcite. Many of the large-scale variations in the stalagmite record are shown to coincide with global climate events, especially the Younger Dryas, which is well-constrained as abrupt shifts in the proxy record. The stalagmite record displays clear linkages with SST and meltwater records from the GOM.

Trace metal abundances and ratios in speleothems are extensively used as indicators of the hydrogeochemical processes active in overlying epikarst and serve as

valuable proxies for precipitation amount and source, water residence time, and vegetation cover. Conventional methods of trace metal acquisition can be expensive, time-consuming and destructive. The use of microbeam XRF in measuring trace elements in speleothems has several advantages, as it is non-destructive, rapid, and is capable of providing high-quality data. A suite of test scans was performed using a Rh microfocus beam and a W collimator beam in order to define the appropriate methodology for the application of μ-XRF. Statistical simulations confirm that the data are governed by a Poisson distribution, through which statistical parameters may be calculated. While these data are typically reported as ratios to Ca, it is more appropriate for μ-XRF results to be reported as Sr counts, eliminating complications of differential surface and near-surface effects due to the more shallow penetration depth of the X-ray beam into the sample material for Ca. Calibration curves were created that convert the Sr counts to concentrations (ppm), allowing for the direct conversion to quantitative data.

Over a 2.5 year period, three caves in southeastern West Virginia were continuously monitored for temperature and relative humidity. Surface precipitation drip frequency loggers were deployed near each of the cave entrances and compared to six cave frequency loggers installed under active cave drips. The behavior of the cave drip frequency responses to meteoric precipitation events reveals insight into the flowpaths of the water through the epikarst. Hydrochemical analyses reveal a wide variety of behaviors, and the dilution of dripwaters during a period of increased precipitation is evidenced by the abrupt change in multiple parameters. Only half of the active stalagmites studied with the cave drip loggers were determined to be suitable for paleoclimate studies, which highlights the importance of cave monitoring prior to speleothem collection.

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Section I

Stable Isotopic and Geochemical Studies of Late Quaternary Stalagmites, South-Central Appalachian Mountains, Eastern North America

Chapter 1

Introduction

Research Objectives

The purpose of this study is to infer climate and environmental changes on both a regional and global scale using stable isotopic and trace geochemical records developed from stalagmites.

Numerous paleoclimate records have been developed with a high degree of spatial and temporal variability. Global climatic changes and events can be examined through comparisons of such records. Many of the longest and most continuous records are based on ice-cores and marine sediment cores. A dearth of high-resolution, long-term (10^3 years) continental paleoclimate records exists and speleothems, which are secondary calcite mineral precipitates formed in caves, may fill that gap by possibly providing information regarding not only global-scale climate changes but also may highlight regional continental climate and environmental conditions.

As a framework for this study, several questions were posed:

1) Can the geochemistry of speleothem calcite provide information about past climate events and conditions?
2) What were the environmental conditions of the study area from 27 – 4 kyr BP?
3) What were the timing, magnitude, and duration of climate changes in the study region during this period?
4) Were the climate changes evidenced by speleothem chronologies of global or regional extent?
5) What are the possible mechanisms responsible for regional-scale climate changes?

The remainder of the introduction will address 1) the global framework of paleoclimatology, with an emphasis on Quaternary climate records, and 2) the background section, which will address karst geomorphology and speleogenesis, as well as an in-depth discussion of the origins and evolution of each of the geochemical proxies utilized in speleothem paleoclimate studies.

The results and discussion sections will present the geochemical results and geological interpretations, respectively, of these records in order to answer the five research objectives outlined previously.

Global Paleoclimate Framework

The fundamental purpose of paleoclimatology is to reconstruct the climatic record of the Earth through time. Paleoclimatologists seek to understand not only how, when, and to what magnitude the climate has changed, but also seek to identify the mechanisms responsible for such changes, on both a regional and global scale. Paleoclimatology has become increasingly important, as recent anthropogenic climate change factors can only be understood after a thorough examination of natural climate variability (Crutzen and Steffen 2003). The inherent complexity of the global climate system, which includes numerous interactions and feedbacks between the biosphere, cryosphere, atmosphere, hydrosphere, geosphere, and more recently, anthroposphere, ultimately prohibits a complete understanding of climate systems, especially those that have operated in the remote past. However, evidence of past climates and environments can be found within the geologic record and, with proper age controls, may provide high-quality climate records.

An abundance of evidence, with a variety of spatial and temporal distributions, exists for the environmental and climatic conditions of the Quaternary Period. Ice cores (Dansgaard et al. 1969; Langway 1970; Johnsen et al. 1992; 1993; Petit et al. 1999; Thompson et al. 2000; Kobashi et al. 2007; Rasmussen et al. 2008) and marine sediment cores (F Ruddiman and McIntyre 1981; Labeyrie et al. 1987; Duplessy et al. 1988; Hughen et al. 1996; Haug et al. 2001) provide the longest and most continuous records, while those of, for example, tree rings (Briffa et al. 2004; McCarroll and Loader 2004), lake sediments and fossil pollen (Talbot 1990; Odgaard 1999; Huang et al. 2002; Torres et al. 2013), and speleothems (Dreybrodt 1996; Baker et al. 1997; McDermott 2004; Fairchild et al. 2006) often provide shorter records of continental climates and environments.

The chronologic framework for paleoclimate records is provided by the longest of the proxy records such as those from the Greenland Ice Sheet Project 2 (GISP-2) (Stuiver and Grootes 2000; Blunier and Brook 2001; Dawson et al. 2007), North Greenland Ice Core Project (N-GRIP) (Ruth et al. 2003; Mortensen et al. 2005), and European Project for Ice Coring in Antarctica (EPICA) (Delmonte et al. 2002; Lambert et al. 2008). Ice cores are valuable archives as they provide numerous proxies such as lamina thickness that correlates with precipitation amounts, dust/volcanic ash concentration that varies with atmospheric circulation intensity/volcanic activity (Cole□Dai et al. 2000; Oppenheimer 2003), CO_2 concentrations within trapped bubbles that allow direct measurement of past atmospheric concentrations (Indermühle et al. 2000; Neftel et al. 2011), and $\delta^{18}O$ values of the ice itself which have been directly related to temperature variability and ice volume (Stuiver and Grootes 2000; Johnsen et al. 2001). Figure 1-1 shows temperature variations in Greenland (GISP2) based on ice core $\delta^{18}O$ values (Alley 2004).

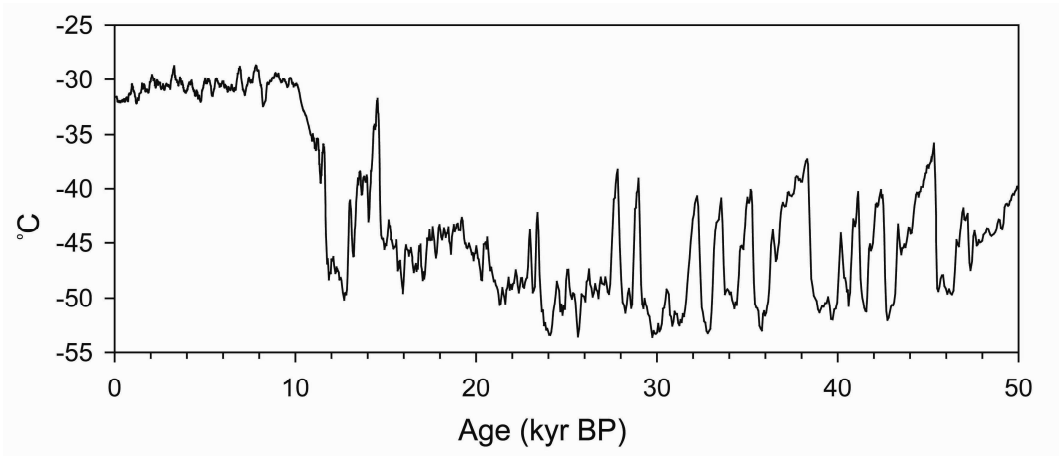

Figure 1-1 GISP2 temperature variations for the past 50 kyr

While much of the research into the Quaternary climate has concentrated on deep-water formation and thermohaline circulation in the North Atlantic (Bard et al. 2000; Bond et al. 1992; 1993; 1999; Broecker 1994; 1998), there are many high-quality records from various locales that represent multiple aspects of the global climate system.

Marine sediment cores have also been utilized as paleoarchives, as they contain multiple paleoclimate proxies and are often long, continuous records. The marine sediment core record from the Cariaco Basin, located off the north central coast of Venezuela, for example, is an excellent record of low-latitude paleoclimate change (Peterson et al. 1991; Lin et al. 1997; Haug et al. 2001; Hughen et al. 2004).

Speleothems have been utilized in paleoclimate studies and have the capability to provide evidence of climate changes with a wide range of spatial and temporal variability. The Hulu Cave speleothem record (Wang et al. 2001) from eastern China reflects the East Asian Monsoon (EAM) intensity throughout the late Quaternary.

The comparison of these long, continuous records of changing global climates to the record developed in this dissertation will allow examination of the extent to which climatic events are propagated, atmospheric processes facilitate climate change over

long time scales, and additionally, may reveal regional climatic mechanisms active in the study area.

Overview of Quaternary Climate

The Quaternary Period, encompassing the last 2.58 my, is characterized primarily by the establishment and subsequent growth and decay of large continental ice sheets (Raymo 1997). This entire period, including the present, is considered an 'ice age', as at least one large, year-round ice sheet has continuously been present on the Earth's surface. The equatorward expansion and retreat of large ephemeral ice sheets, such as the North American Laurentide Ice Sheet (LIS), define episodes known as 'glacials' and 'interglacials', respectively, all within the current ice age (Shackleton 2000). The current interglacial period began 11.65 kyr BP, and marks the transition from the Pleistocene Epoch to that of the current Holocene (Walker et al. 2009). The dynamic global climate of the last 30 ky is characterized by major climatic events, including the Last Glacial Maximum (LGM), which occurred from 26.5 to 19 kya BP (Clark et al. 2009). After the LGM, a period of warming known as the Bølling-Allerød interstadial occurred. This warming was interrupted by a rapid (but brief ~1.3 kyr) climate shift back into glacial conditions for the North Atlantic at approximately 12.8 kyr BP, an event known as the Younger Dryas. After the Younger Dryas occurred, the Holocene Climatic Optimum (HCO) began, which was a period of higher global temperatures that lasted from 9 – 5 kyr BP.

In addition to these major climatic events and trends, numerous short-lived events occurring during this time have been identified. These include the Heinrich events, which are characterized as pulses of cold, low salinity meltwater from the discharge and melting of icebergs (Broecker et al. 1992; MacAyeal 1993; Bard et al. 2000)º, Dansgaard-

Oeschger (D-O) events, and Bond events, which are a series of rapid warm-cold cycles during the late Pleistocene and Holocene, respectively (Bond et al. 1992; Bond et al. 1997). Throughout the Holocene, oscillatory climatic modes, such as the El Niño Southern Oscillation (ENSO) (Cobb et al. 2003), the Pacific Decadal Oscillation (PDO) (Schneider and Cornuelle 2005) and the North Atlantic Oscillation (NAO), have influenced climatic variability.

The effects of these glaciations on the Earth's climate has included lower sea levels, lower average global temperatures, higher albedo due to increased ice cover, changes in hydrologic and atmospheric processes, and the creation and development of glacial geomorphological features such as moraines and pluvial lakes (Clark et al. 1999). While considerable speculation has occurred as to the cause of glacial cycles, the widely-accepted driver of glacial cyclicity is the varying amount of insolation received on the Earth's surface due to its asymmetrical orbital geometry (Hays et al. 1976; Imbrie and Imbrie 1980). This 'orbital hypothesis' predicts that the controls on climate are the cycles of obliquity (~41 ky) and precession of the equinoxes (~21 ky) and possibly eccentricity (~100 ky) (Milankovitch 1941). While the proxy data rarely exhibit clear correspondence to the three primary orbital cycles, the orbital hypothesis provides a framework from which to consider the variation in insolation, a fundamental driver of atmospheric processes, over long periods of time.

The climatic processes and resulting environmental conditions throughout this time served as primary controls on the development of human civilization. The migration of humans from Africa to all corners of the globe, to the rise of agriculture, civilization, and modern societies, the Earth's climate has played a critical role. For example, the rise and fall of global sea level with the growth and decay of ice sheets has periodically exposed land bridges from one land mass to another, allowing for the migration of plant

and animal species, rainfall patterns have governed agricultural development, and directly impacted the development of human civilization.

Background

Karst Geomorphology and Speleogenesis

Karst landscapes are those that have been shaped by the dissolution of soluble bedrock, typically limestone or dolomite (Ford and Williams 1989). Speleothems are secondary calcite precipitates that form in caves, and encompass a wide variety of forms, including stalactites and stalagmites (Palmer 2007).

The processes of cave formation and speleogenesis have been extensively studied, e.g. (Ford and Williams 1989; Palmer 1991; Klimchouk et al. 2000; Ford and Williams 2007; Palmer 2007). The following sections will briefly discuss karst geomorphology and the chemical reactions that govern the processes of carbonate dissolution and precipitation.

The chemical evolution of water from the land surface into the cave occurs throughout the system and involves multiple chemical reactions that occur with a substantial degree of spatial and temporal variability. In order to fully describe these reactions, the karst geomorphological terminology must first be established. Figure 1-2, adapted from Fairchild et al. (2006) depicts a generalized representation of a karst system.

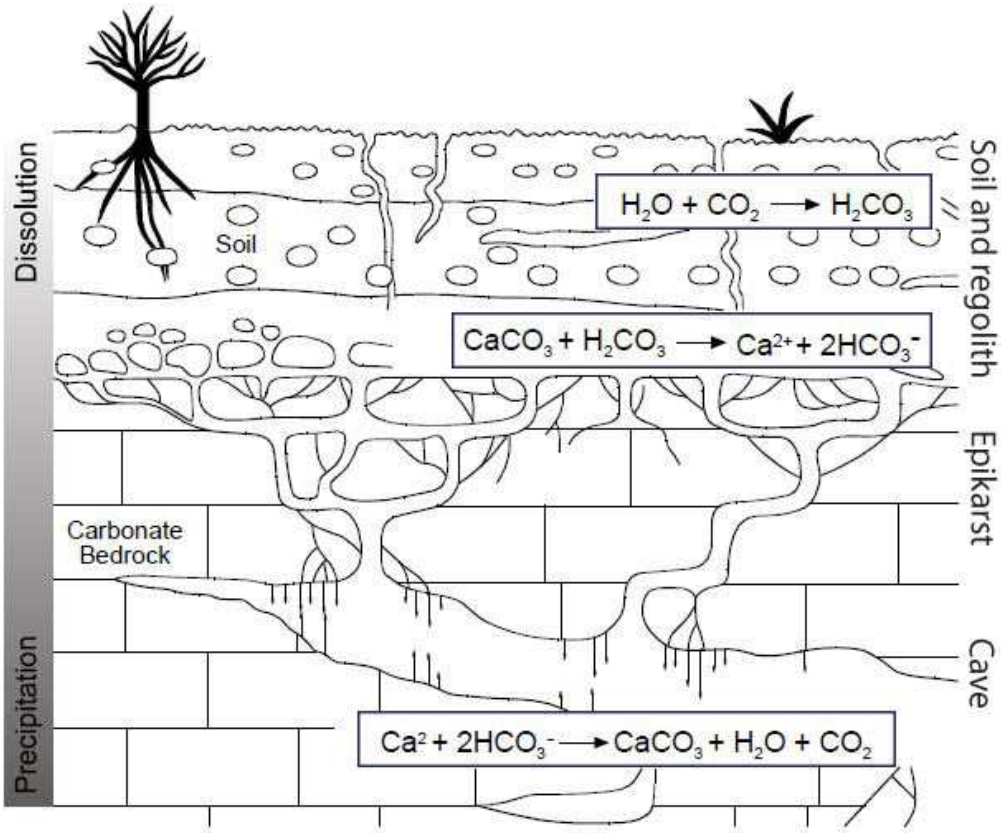

Figure 1-2 Generalized representation of a subsurface karst system and the dominant chemical reactions.

In the above figure, the karst system is characterized by a dissolution-precipitation gradient, where most of the dissolution reactions occur in the soil and regolith and upper epikarst zones while most of the precipitation reactions occur within the lower epikarst zone and the cave. In the soil and regolith, the primary reaction occurs, seen in Equation 1.

Equation 1. $H_2O + CO_2 \rightarrow H_2CO_3$

As meteoric waters seep into the soil, they are saturated with carbon dioxide, which is derived from a mixture of atmospheric (only significant near the surface) and plant and microbial respiration sources. These waters and carbon dioxide combine to form carbonic acid. The rapidity with which meteoric water penetrates into the zones above the cave also plays a role in the amount of carbon from an atmospheric component that is incorporated into speleothem calcite. Relatively shorter water residence times disallow complete equilibration between soil CO_2 and the water, of which an atmospheric component may be significant (Baker et al. 1997). The carbonic acid acts to dissolve the carbonate host rock and regolith *via* the reaction, given as Equation 2.

Equation 2. $CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$

Upon exposure to carbonic acid, H_2CO_3, the carbonate host will dissociate into Ca^{2+} cation and carbonate anion, CO_3^{2-} constituents, of which the latter then combines with hydrogen, with the resulting product being two bicarbonate anions, $2HCO_3^-$. This solution flows through the epikarst and eventually seeps into the cave. Under some circumstances, the calcite may precipitate in the epikarst prior to seepage into the cave, a process referred to as 'prior calcite precipitation' (PCP) (Fairchild et al. 2000), modifying the geochemical proxy evolution. The climatic implications and geochemical consequences of this process can be found in the discussion section. The calcite precipitation reaction, driven by the high-to-low pCO_2 (partial pressure of CO_2) gradient between that of the solution and that of the cave atmosphere, is given as Equation 3.

Equation 3. $Ca^{2+} + 2HCO_3^- \rightarrow CaCO_3 + H_2O + CO_2$

It is through this series of carbonate dissolution and precipitation reactions that solutional caves are formed within carbonate host rock, and speleothems, as secondary calcite precipitates, are formed within cave voids. These chemical reactions, occurring in a variety of microenvironments found in a karst system, govern the geochemical evolution of the stable isotopes and trace elements measured in speleothem calcite.

Speleothem Geochemistry

δ Notation

Stable isotope compositions are reported using the δ notation, in per mil or parts per thousand (‰). In order to have a standardized method of reporting isotopic values, the isotopic value of the sample is compared to that of a carbonate standard, the Vienna PeeDee Belemnite (VPDB). The standard for defining the isotopic composition of freshwater is Vienna Standard Mean Ocean Water (VSMOW). $\delta^{18}O$ and $\delta^{13}C$ for an unknown sample are calculated using the following equations.

$$\delta^{18}O = [((^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{standard}) / (^{18}O/^{16}O)_{standard}] * 1000$$

$$\delta^{13}O = [((^{13}C/^{12}C)_{sample} - (^{13}C/^{12}C)_{standard}) / (^{13}C/^{12}C)_{standard}] * 1000$$

The terms “enriched” and “depleted” are used in reference to the standard of the material for which one is referring. Positive (negative) values indicate that the material contains more of the heavy (light) isotopes than the standard.

$\delta^{18}O$ of Speleothem Calcite

This section will address the 1) origins of oxygen isotope signatures in speleothem calcite, 2) early and modern interpretations of $\delta^{18}O$ values from speleothem calcite, 3) external factors that affect the source oxygen isotope values, and 4) internal factors involving the dissolution and precipitation reactions that govern speleogenesis.

The oxygen isotope signatures preserved in speleothem calcite originate from those oxygen atoms entrained in water molecules having originated as meteoric precipitation on the surface. Equation 1 shows water and carbon dioxide combining to form carbonic acid, which reacts with the carbonate host rock to produce bicarbonate. Though it appears that the oxygen in speleothem calcite comes from three sources (meteoric precipitation, carbon dioxide in the soil, and carbonate host rock), nearly all of the oxygen is derived from meteoric precipitation. Bicarbonate is present only at a parts per thousand (ppt) level and relatively very few oxygen atoms released from the host carbonate (Dorale et al. 2002). Oxygen isotope values from speleothem calcite reflect that of meteoric precipitation (Hendy and Wilson 1968; Hendy 1971; Emiliani 1971).

Of the multiple climatic proxies contained within speleothem calcite, $\delta^{18}O$ is perhaps the most challenging to decipher. Hendy and Wilson (1968) first described the use of stable isotope values as paleoclimate proxies in speleothems. An early goal of paleoclimate studies utilizing speleothems was to use the $\delta^{18}O$ values as a paleothermometer (Gascoyne 1992; Talma and Vogel 1992; Lauritzen 1995) though these values have since been understood to be influenced by numerous factors in addition to atmospheric temperature, such as variations in the reservoir sourcing, variable seasonal meteoric precipitation contributions, the amount of rainfall during discrete events, and evaporative processes in the vadose zone (Dansgaard 1964; Bar-Matthews

et al. 1996; Bar-Matthews et al. 1997; McDermott 2004; Fairchild et al. 2006; Lachniet 2009).

The difficulty in discerning the controls on oxygen isotope variations in speleothems is due largely to the fact that there are numerous processes that can affect the isotopic composition of the meteoric precipitation, and the various processes operating within the subsurface. The following section will describe the various factors that influence $\delta^{18}O_{sc.}$ Figure 1-3, from Lachniet (2009), shows the various surface and subsurface processes that influence $\delta^{18}O_{sc}$ values.

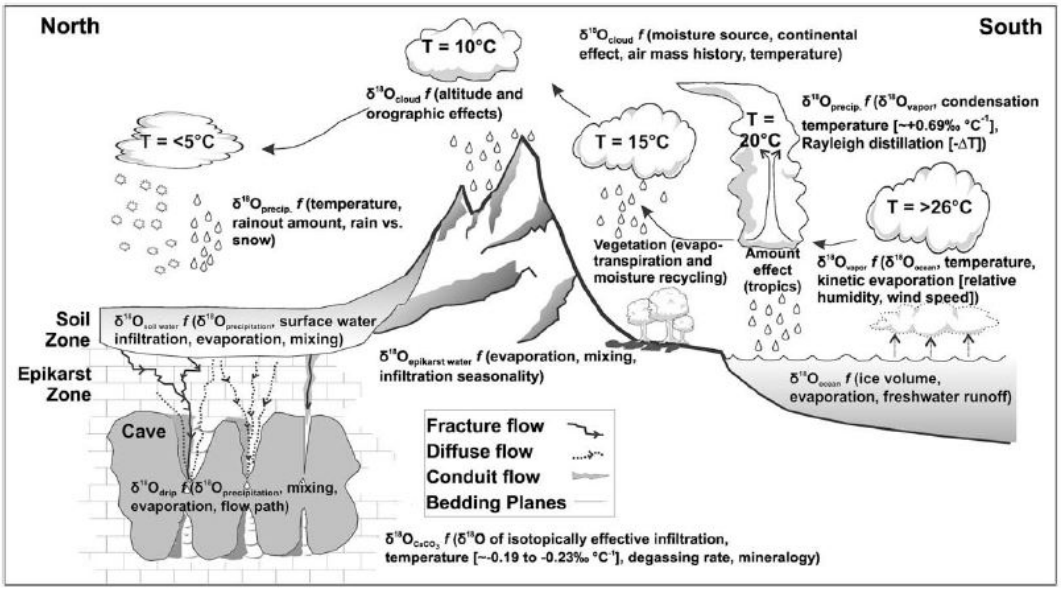

Figure 1-3 Schematic outlining the processes that influence $\delta^{18}O$ values of speleothem calcite.

The isotopic evolution of waters is complex, from the evaporation of water from reservoirs at low latitudes, to entrainment in cloud masses with variable northward trajectories, to meteoric precipitation over the landmass, infiltration into the subsurface, and ultimately to speleothem deposition. Any or all of the following primary factors may

influence the $\delta^{18}O_{sc}$: 1) atmospheric circulation, 2) source reservoir isotopic chemistry, 3) soil and upper epikarst processes, 4) lower epikarst and cave processes, and 5) diagenetic alteration (Fairchild et al. 2006).

The atmospheric processes that govern the spatial distribution of oxygen isotopes on the Earth's surface are well understood (Dansgaard 1964; Rozanski et al. 1982; Rozanski et al. 1993; Gat 1996; Dutton et al. 2005). The effects of temperature, evaporation, condensation, altitude, and continentality govern the distribution of oxygen isotopes. Surface temperatures and the isotopic composition of surface waters are strongly correlated (Sharp 2007). The kinetic fractionation of oxygen isotopes through the process of evaporation results in water vapor that has relatively less (depletion) of the heavy isotope, ^{18}O, and thus enriches the remaining liquid. While evaporation is a kinetic process, condensation is an equilibrium process and is dependent on temperature alone. $\delta^{18}O_{precip}$ is also influenced by an altitude effect, where isotopic values decrease with increasing altitude due to the occurrence of adiabatic cooling-induced condensation. As atmospheric masses move across land masses, the heavier isotope is preferentially removed due to the mass difference of the two isotopes. This process occurs in equilibrium and can be described in terms of Rayleigh fractionation. This ultimately leads to water mass residuals becoming progressively depleted landward as meteoric precipitation continues (Dutton et al. 2005).

Source reservoir isotopic chemistry can also play an important role in the $\delta^{18}O_{precip}$ and ultimately, that of speleothem calcite. The largest source of moisture for atmospheric masses is the oceans. Though this reservoir is extensive, it is not immutable in its oxygen isotopic signature. Ocean temperature affects the variation of $\delta^{18}O$ of ocean water over long time scales. During glacial periods, when large amounts of freshwater were stored in ice sheets and glaciers, the oceans were both more enriched in ^{18}O and

more saline than during interglacial periods. Thus, there is not only a spatial variation in $\delta^{18}O_{precip}$ but also temporal.

Oxygen isotopes may also be affected by processes that occur in the soil and epikarst zones, which are collectively referred to as the 'dissolution region'. This zone serves as storage for meteoric waters and, depending on soil and epikarst characteristics, can greatly reduce isotopic variability through the mixing of waters from different rainfall events. Because this region also serves as the land-atmosphere interface, evaporation and evapotranspiration processes have the potential to modify the isotopic composition of meteoric waters, with implications for seasonal $\delta^{18}O$ variation of cave dripwaters.

The lower epikarst and cave system environment may also affect $\delta^{18}O_{sc}$ due to the presence of highly-variable flow paths within the epikarst (Figure 1-2). Fracture networks with more direct flowpaths (i.e., less water-rock interaction time) would likely result in cave dripwaters whose isotopic values more closely resemble those isotopic characteristics of individual precipitation events. In contrast, small-scale fracture networks and/or a perched reservoir system may result in the 'muting' of individual precipitation event values, as mixing of waters from multiple events would occur prior to cave infiltration. Figure 1-4, after Fairchild and Baker (2012), illustrates possible flow paths through which dripwaters may infiltrate a cave system.

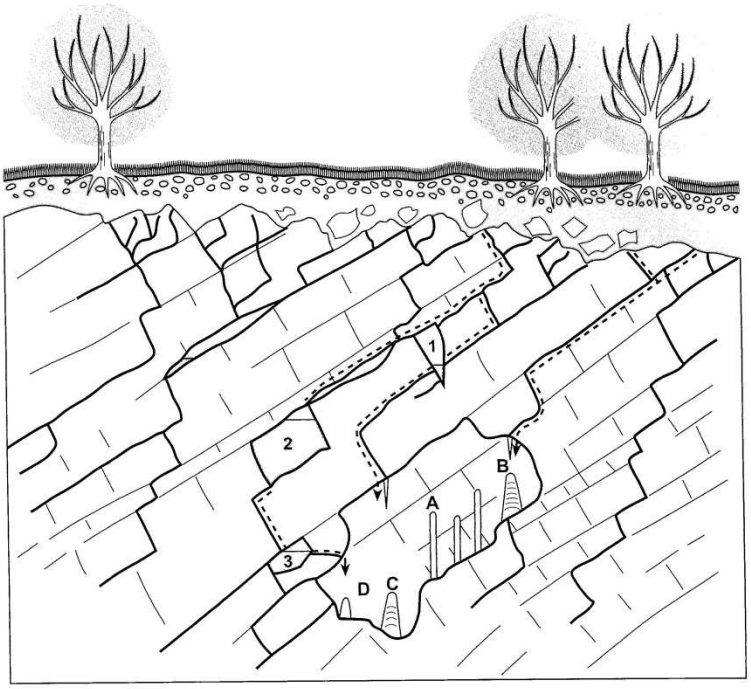

Figure 1-4 Schematic of hypothetical flowpaths of dripwater infiltration feeding stalagmite growth in a cave.

The cave features labelled with the numbers 1 – 3 highlight distinct perched water reservoirs of mixed event waters. Dashed lines indicate the various flowpaths through the epikarst. Stalagmite A is fed by diffuse flow through fine fractures or the limestone matrix. Stalagmite B, however, is fed through fracture flow, where there is a direct flow path along the limestone bedding plane from the surface. This flow path would be expected to exert a larger variability in drip frequency in response to meteoric precipitation events. Stalagmites C and D are both fed through perched reservoirs within the host rock, though C is fed through the process of ‘underflow’ behavior of reservoir 1 and D is fed through the process of ‘overflow’ behavior of reservoir 3, which only flows after a water-level threshold is reached. Figure 1-4, though much more simplistic than

real cave systems, illustrates the wide range of flow paths that cave dripwaters can take. Water flow paths have implications for dripwater frequency, geochemical evolution of dripwaters through the host rock, speleothem morphology and petrographic fabric, and, ultimately, the isotopic characteristics of the speleothems. The average $\delta^{18}O$ values of dripwaters, though they can vary depending on the flow path, are generally within 10-20% of the average annual $\delta^{18}O$ value of meteoric precipitation over the cave region (Jones et al. 2004).

Upon entry into the cave atmosphere, the contrast between pCO_2 of water and cave air drives the degassing of the supersaturated dripwaters. The rapidity of degassing is governed by the pCO_2 gradient between dripwaters and the cave atmosphere. Only drips that are slow enough to allow complete degassing are considered to have attained isotopic equilibrium between the gas and liquid phases. Coincident with degassing of the liquid, the precipitation of calcite is prompted (see Equation 3 on page 8).

One of the qualities that make speleothems valuable paleoclimate proxies is their preservation potential- diagenetic alteration is rare. Speleothem $CaCO_3$ is most commonly composed of either calcite or the metastable polymorph aragonite. At surface conditions, calcite is the most stable form and aragonite will diagenetically alter to calcite over time. Speleothems often contain varying amounts of both forms, and the distinction is important because aragonite, in comparison to primary calcite, may have slightly different isotopic characteristics (but larger differences in trace element concentrations, discussed in Trace Element Geochemistry). Secondary calcite, which results from the diagenetic alteration of aragonite, is unsuitable for paleoclimate studies as not only will isotopes and trace elements be disturbed, but those elements utilized in U-series dating as well (Fairchild and Baker 2012). A detailed petrographic analysis of the fabric of

speleothem laminae is not always feasible, however, as this requires the destruction of finite sample material.

$\delta^{13}C$ of Speleothem Calcite

This section addresses 1) the origins of the carbon in speleothem calcite, 2) the early and modern interpretations of $\delta^{13}C$ values from speleothem calcite, 3) the external factors that affect the source $\delta^{13}C$ values, and 4) internal factors involving the dissolution and precipitation reactions that govern speleogenesis.

Unlike $\delta^{18}O_{sc,}$ the carbon isotopic composition of the atmosphere has little effect on $\delta^{13}C_{sc}$. The air in soil voids, though it can have a significant atmospheric component near the surface, is dominated by CO_2 respired through plant and microbial activity (McDermott 2004). This CO_2 has carbon isotopic signatures reflective of the parent plant material.

Because speleothem carbon originates primarily from plant-respired CO_2, $\delta^{13}C_{sc}$ is reflective of the vegetation active above the cave. Early studies utilizing $\delta^{13}C_{sc}$ determined that the type of vegetation in the region is the dominant control, with those plants utilizing the C3 photosynthetic pathway having $\delta^{13}C$ values between -32 to -22‰ VPDB and for those using the C4 pathway having $\delta^{13}C$ values between -16 to -9‰ VPDB (Dorale et al. 1998). When CO_2 is dissolved into pore water, carbonic acid (Equation 1) is formed and acts to dissolve carbonate host rocks (Equation 2) (typically marine limestones) that have $\delta^{13}C$ values slightly above 0‰ VPDB (Keith and Weber 1964). The dissolution reactions occurring within the soil and epikarst have been modeled as an ‘open’ system, with an infinite supply of plant-respired CO_2 or as a ‘closed’ system, which has a finite amount (Hendy 1971). For C3 plant-dominated regions (like the current study area) under an open system, the $\delta^{13}C$ values of the dissolved inorganic carbon (DIC)

species are expected to be between -18 to -14‰ (Baker et al. 1997). Under closed system conditions, however, the finite reservoir of CO_2 would be consumed by the formation of carbonic acid; thus the dissolution of the carbonate regolith would be limited by the amount of CO_2 available, leading to a larger contribution of limestone DIC to the solution. This would result in more enriched $\delta^{13}C$ values of speleothem calcite. Whether the dissolution regions active in the past more closely resemble open or closed systems cannot be determined, though in natural systems, these regions are believed to be at least partially open (McDermott 2004).

In some regions, particularly arid to semi-arid areas, that may have experienced transitions between these two groups of plant species; $\delta^{13}C_{sc}$ values have been used, often alongside pollen records, as evidence that such vegetation transitions can be interpreted as indicating shifts in climate parameters (Dorale et al. 1992; Holmgren et al. 1995; Baker et al. 1996; Bar-Matthews et al. 1997; Holmgren et al. 2003).

For those areas having only deciduous C3 plants over the time of speleothem growth, shifts in $\delta^{13}C_{sc}$ values cannot be interpreted as indicative of large-scale vegetation C3/C4 shifts. Instead, the variation in $\delta^{13}C_{sc}$ values over time has been linked to processes independent of vegetation controls. Values of $\delta^{13}C_{sc}$ are often more enriched than those values expected (-18 to -14‰) for C3 plant-dominated areas. This enrichment is likely due to two main processes which occur in the vadose zone under dry conditions: increased water-rock interaction time and PCP (Fairchild et al. 2000).

Additionally, $\delta^{13}C$ enrichment of dripwaters can occur due to the amount of degassing that occurs upon infiltration of the dripwaters into the cave atmosphere (Fairchild and Baker 2012). The amount of cave pCO_2, which can vary seasonally (higher values expected during the summer months, as the relatively colder cave air remains in the topographic lows of the cave system) can affect $\delta^{13}C_{sc.}$ During periods of enhanced

ventilation (e.g., winter months), rapid degassing would result in ^{13}C enrichment of dripwaters as compared to the off-gassed CO_2. For those drips that do not undergo complete degassing, the lack of equilibration of carbon species in solution can lead to high-frequency variability in $\delta^{13}C_{sc.}$

The effect of diagenetic alteration of speleothems on $\delta^{13}C_{sc}$ is the same as that discussed for $\delta^{18}O_{sc}$ in the previous section.

Stable Isotope Fractionation

The fundamental assumption in the use of speleothem calcite as a paleoclimate archive is that the calcite was deposited in isotopic equilibrium with the cave drip-waters (Mickler et al. 2006). Stable isotope fractionation is defined as the partitioning of isotopes between two substances or two phases of the same substance with different isotope ratios. This occurs *via* isotopic exchange reactions through which equilibrium isotope distribution is maintained or through kinetic processes which drive disequilibria (Hoefs 2009).

Hendy (1971) outlined three primary modes of speleothem calcite deposition as 1) equilibrium-fractionated deposition, where CO_2 is degassed at a slow rate so as to allow isotopic equilibrium to be maintained between the carbon species in solution, 2) kinetically-fractionated deposition, where CO_2 is degassed at a relatively rapid rate that prevents equilibria, and 3) deposition through evaporation, where the precipitation of calcite occurs primarily through the removal of water in the evaporation process. For mid-latitude caves, including the study region, humidity is high (95 – 99% relative humidity) and evaporation is negligible, especially for those portions of the cave located far from entrances. Speleothem calcite deposited in these conditions is often very near isotopic equilibrium with its parent dripwater (McDermott 2004).

Various methods have been utilized in an attempt to identify the depositional modes and, if present, quantify the amount of isotopic disequilibrium. The type of fractionation was thought to be evidenced by the presence of covarying $\delta^{18}O_{sc}$ and $\delta^{13}C_{sc}$ values along laminae toward the flanks of the stalagmite (Hendy 1971). The 'Hendy test', involved measuring isotopic values along laminae in order to determine if disequilibrium fractionation had occurred at the growth surface. However, this test has since been discredited as being impractical and prone to producing invalid results due primarily to the difficulty in taking consistent and representative samples for isotopic analysis across flank-thinning laminae (Dorale and Liu 2009). The Hendy test for covariance was later applied to down-axis stable isotope values measured along the growth axis, which relies on the $\delta^{18}O_{sc}$ and $\delta^{13}C_{sc}$ values measured consistently at discrete intervals. Although it has since been demonstrated that certain instances of positive covariation in isotopes may have environmental causes unrelated to disequilibrium fractionation, such as those records from monsoonal regions, areas where soil water evaporation is a significant factor, or even from temperate regions, where increased temperatures may increase soil respiration rates (thereby creating a covariance between $\delta^{18}O_{sc}$ and $\delta^{13}C_{sc}$ (Mickler et al. 2006)), the correlation coefficient, r^2, values of speleothem time series can provide an estimate of the extent of disequilibrium in speleothems over time. The examination of covariance may also allow for the identification of periods of low *versus* high disequilibrium fractionation, which could lend further insight into climatic processes operating in the past.

Trace Element Geochemistry

Several trace elements in speleothem calcite have been utilized in climatic or environmental studies and many different techniques for measuring these values have been applied. A discussion of these various techniques is beyond the scope of this study.

However, a distinction will be made between these studies, as they fall into two main categories: those that primarily utilize the alkaline earth metals Mg, Sr, and/or Ba (e.g. (Roberts et al. 1998; Ayalon et al. 1999; Hellstrom and McCulloch 2000; Huang et al. 2001)), and those that utilize a suite of elements (e.g. (Fairchild et al. 2001; Treble et al. 2003; Frisia et al. 2005)). The former studies utilize these elements primarily as paleohydrological indicators on decadal and longer scales while the latter utilize a suite of various elements to determine annual variations in trace elemental concentrations in speleothem calcite, often with the goal of utilizing annual trace element cyclicity as a marker for annual lamina boundaries.

Because this study utilizes only Sr, only those factors affecting the incorporation of this element into speleothem calcite will be discussed further. Atmospheric circulation does not affect Sr in speleothem calcite as the Sr that is incorporated into speleothem calcite and aragonite lattices originates primarily from either the dissolution of carbonate regolith or through the decomposition of organic matter in the soil (Fairchild and Baker 2012). For either origin, the longer the pore water spends in contact with these materials, the more enriched in Sr will be the resulting dripwaters. During periods of high precipitation, pore water would be flushed relatively quickly through the karst system, as compared to that of drier periods, when water would remain in the pore spaces and in contact with Sr-rich materials, which is analogous to the enrichment of $\delta^{13}C_{sc}$ under dry conditions, as discussed in the previous section. It is by this mechanism that changes in Sr composition in speleothems are interpreted as changes in the meteoric precipitation and moisture availability over time.

Geologic Setting

Culverson Creek Cave (CCC) is located in Greenbrier County, in the Allegheny Mountains of south-eastern West Virginia. The Appalachian Mountains extend from the

island of Newfoundland, Canada, to the state of Alabama in the United States. The study area lies within the Valley and Ridge physiographic province, which trends northeast to southwest. Figure 1-5 shows the location of Culverson Creek Cave.

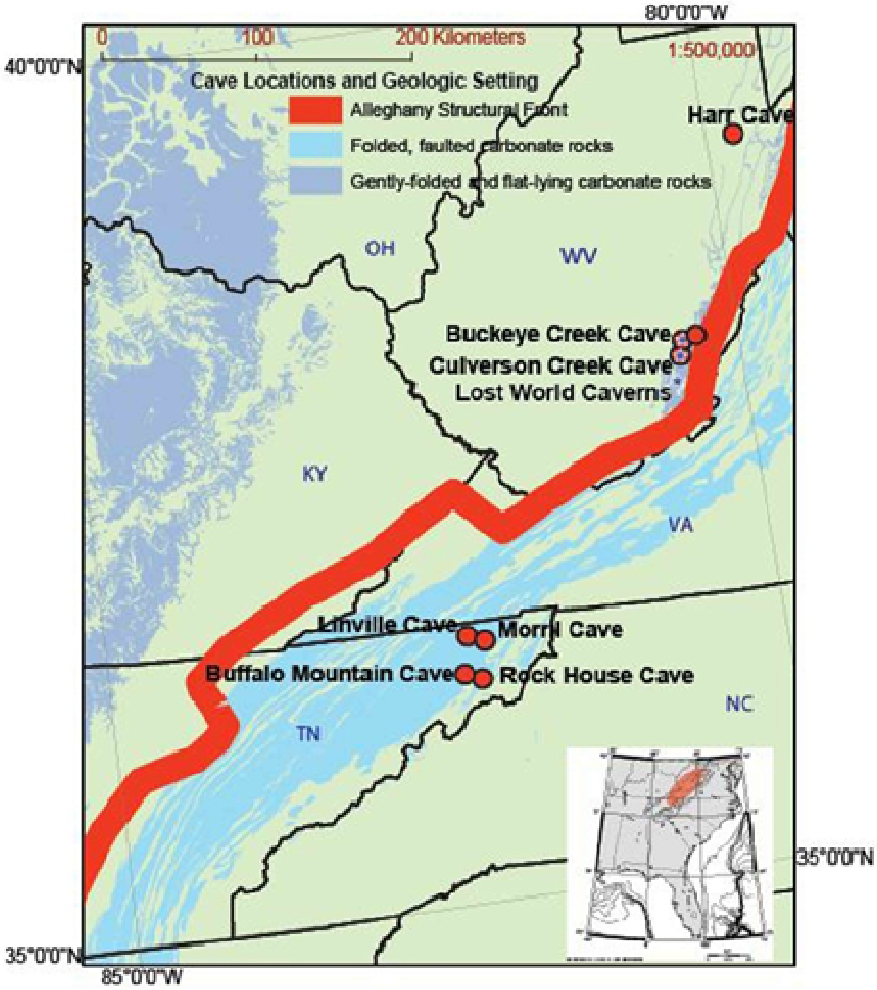

Figure 1-5 Regional Map showing the location of Culverson Creek Cave

This heavily-karstified region is an ideal location for a speleothem-based paleoclimate study because 1) there are over 1200 documented caves in Greenbrier County alone, with a wide variety of physical characteristics, 2) the region is in the mid-

latitudes, where the speleothems are more likely to be sensitive to climate change, yet remained exposed during the maximum southern extension of the North American Laurentide Ice Sheet during the Last Glacial Maximum (McDermott 2004), 3) the region is located in a temperate climatic zone, receiving abundant rainfall with seasonal variability, and 4) the three caves of this study are located in a rural area with few man-made landscape changes, which have the potential to disrupt the flow of water that feeds the stalactite drips.

The abundance of caves in the study region allows for a larger sampling pool from which to find suitable speleothems for analysis, as certain physical characteristics are required in order to utilize geochemical methods of study. In addition, the wide variety of cave dimensions, ages, and formation histories provides an ideal setting from which to examine the inherent intra- to inter-cave variability of dripwater in terms of chemistry, drip frequency, and flow-paths through the vadose zone.

Mid-to-high latitude speleothems are more likely to be sensitive to glacial to inter-glacial transitions than their tropical counterparts, as the most dramatic climate shifts generally occur in these regions (Giorgi 2006). According to the Regional Climate Change Index (RCCI), which is a comparative index designed to identify the regions that are the most responsive to global climate change (referred to as “Hot-Spots” by the author), Eastern North America is the prominent Hot-Spot in North America (Giorgi 2006). This index, shown graphically in Figure 1-6 on page 25, is based on the difference between numerous general circulation model (GCM) projections and an instrumental record (1960-1979) that is minimally affected by greenhouse gas forcing and utilizes four factors in the index calculation: the change in regional mean surface air temperature relative to the global average (also known as the Regional Warming Amplification Factor), change in regional mean precipitation, and the change in both regional surface

air temperature and precipitation interannual variability.

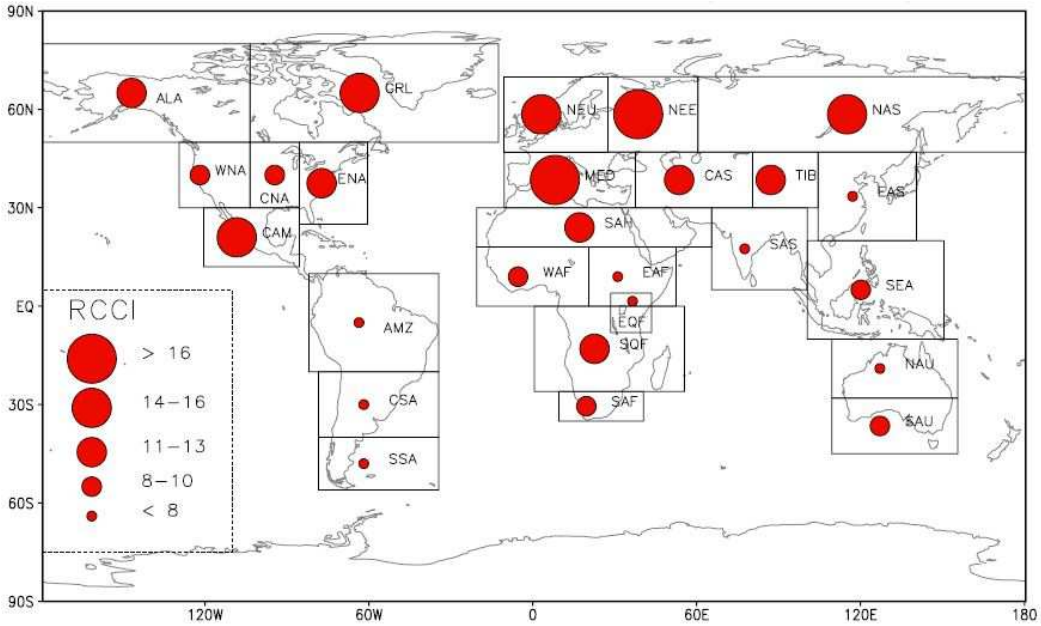

Figure 1-6 Regional Climate Change Index. After Giorgi 2006.

Though the RCCI is a comparative index based on GCM simulations, it does highlight the importance of certain regions for the identification of important regional climatic responses to global climate changes. In addition to Eastern North America being a more sensitive area to global climate changes, the proximity of the southern margin of the LIS to the study region is of note (~300 km), as the deposition of speleothem calcite has been shown to either decrease substantially or cease entirely when covered by glacial ice (McDermott 2004). During the LGM, model simulations reveal orographically-enhanced southerly low-level flow regimes which bring more precipitation to the region surrounding the ice sheet margin (Bromwich et al. 1995).

The modern temperate climate of the region is optimal for the study of the temporal and chemical variability of cave dripwaters, as abundant meteoric precipitation

and dense vegetation occur. The rainfall is not distributed evenly throughout the year. A slightly greater portion of the annual precipitation occurs in the spring and summer months as compared to the fall and winter. This seasonal variability allows for the examination of dripwater responses to rainfall minima and maxima. Additionally, the study region often receives summer rainstorms, which may result in a large pulse of water into the vadose zone. The variety of dripwater responses in terms of frequency and surface-to-cave lag-times to these pulses yield insight into the residence time of the waters as well as the types and variety of flow pathways by which the water travels from the surface into the cave, and ultimately to the stalagmite.

Brief Tectonic History of the Appalachians

The complex tectonic history of the Appalachian Mountains began approximately 750 mya, during the Neoproterozoic era, when it is believed that the supercontinent Rodinia began to rift apart. By 735 mya, failed rifting along (what would be) the central and southern portions of the Appalachians resulted in the formation of many volcanic rocks and plutonic structures that comprise modern topographic highs due to the relatively high degree of erosional resistance compared to other rock types (Hatcher 2005). By approximately 565 mya, rifting of this section resulted in the formation of a rift basin between the two landmasses. Over the next 85 million years, thin sequences of marine sedimentary strata were deposited in this basin. By 480 mya, during the middle Ordovician, this passive margin became an active subduction zone, as the western edge of northern Gondwana was drawn beneath the eastern edge of Laurentia. This episode, known as the Taconic Orogeny, resulted in folding, faulting, and uplift of this marginal crust. During the formation of the latest supercontinent Pangaea, at approximately 300 mya, the region underwent yet another orogeny, as the crust that would become North

America, and that of Africa, collided in an event known as the Alleghanian Orogeny. These repeated episodes of accordion-like rifting and convergence have produced the extensive deformation and prevalence of NE-SW trending thrust faults in this region. The young Appalachian Mountains likely resembled the modern Rocky Mountains of western North America but were extensively eroded until renewed uplift during the Cenozoic exposed what remains of the mountain range today (Hatcher 2005).

Culverson Creek Cave is formed within the Union Limestone Member of the Greenbrier Group, which is Mississippian in age and consists primarily of interbedded limestone, shales, and sandstone. The Union Limestone is composed of variable white-to-gray, massive limestone and contains chert and abundant marine fossils. The Greenbrier Group is relatively flat within the Greenbrier Valley, with a general dip and dip direction of 3^0W. The low dip angle has allowed for the development of an extensive karst landscape, and numerous cave pits are found at the Greenville Shale-Union Limestone contact. The relatively impermeable Greenville Shale, which overlies the Union Formation, serves as a caprock in this region (Dasher and Balfour 1994). Figure 1-7 shows a generalized stratigraphic column for the study area, adapted from Dasher and Balfour, 1994.

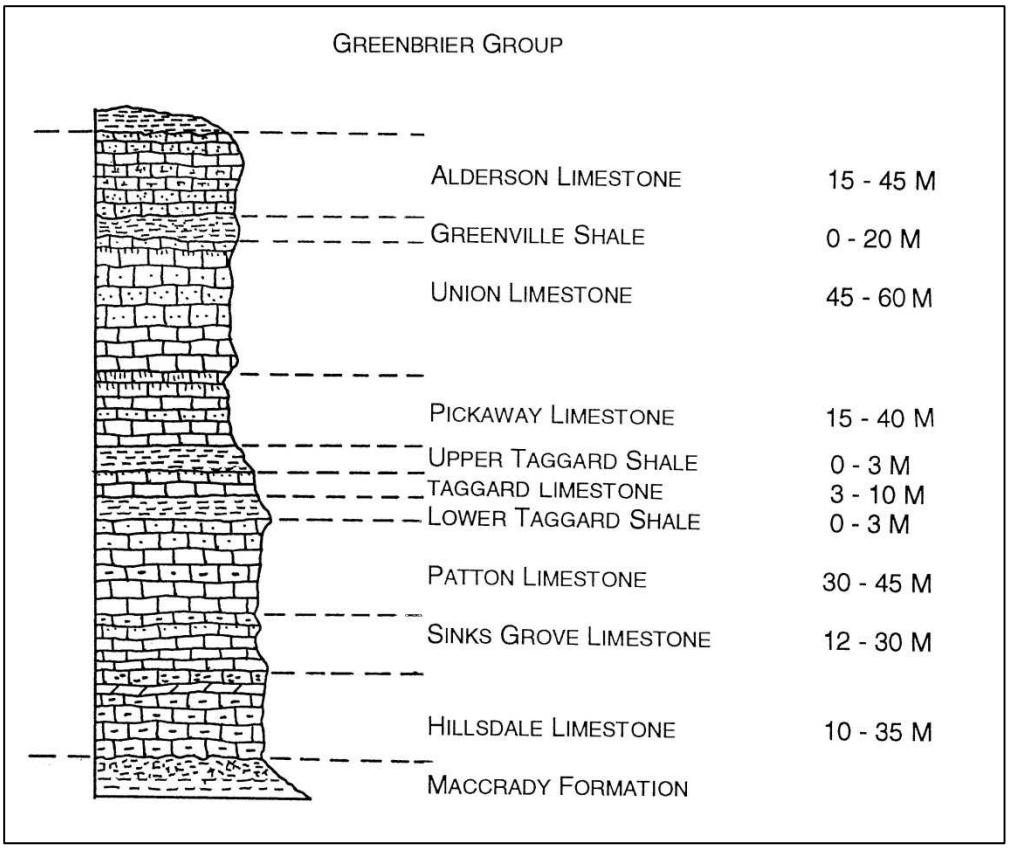

Figure 1-7 Generalized stratigraphic cross section for Greenbrier Valley, West Virginia

Late Quaternary Paleoclimate Record of the South-Central Appalachians

Pollen and Plant Macrofossil Records

The deglacial transition, from the late Pleistocene throughout the Holocene, brought about many changes in plant species as well as geomorphic changes to the landscape. Several paleoclimate studies have utilized pollen assemblages, paleosols, and geomorphic evidence from the study region, carried out in an effort to better understand the response of biota to dramatically changing landscapes and climatic conditions (Watts 1979; Peteet et al. 1993; Driese et al. 2005; Willard et al. 2005). This

section will briefly describe the most pertinent of these records. A more detailed analysis and comparison of these data are found in the Discussion section.

Driese et al. (2005) studied silt paleosols in fluviolacustrine sediment from cores obtained in southeastern West Virginia. These sediments were deposited during the latest Pleistocene to Holocene and record six main phases of climatic and environmental transition: 1) A cooler climate during the LGM with deposition of silt-rich sediment on a bedrock valley surface, 2) geomorphic stabilization and cool, wet climate, with the region biota being dominated by C3 plants, 3) a hiatus of approximately 15.5 kyr due to erosion, 4) aggradation by deposition of fluvial gravels prior to 6.36 kyr BP, 5) geomorphic stabilization with a warmer climate and a transition from C3 dominated plant populations to increasing amounts of C4 plants up to 3.83 kyr BP, and 6) a return to cooler, mesic conditions during the last 3-4 kyr.

Willard et al. (2005) analyzed Holocene-age pollen and plant macrofossil assemblages from Chesapeake Bay and constructed a record of the last 10.5 kyr BP % *Pinus* abundance. The occurrence of *Pinus* lends clues as to the climate changes that occurred during this time, as *Pinus* distribution is largely governed by winter temperatures (Willard et al. 2005). The most notable shift in the % *Pinus* record is the abrupt doubling of species abundance from 5.5 – 4.8 kyr BP, which is consequential to mid-Holocene warming and represents a change from deciduous to mixed deciduous-conifer forests of the region. This dramatic increase in *Pinus* is interpreted to be due to warmer winter temperatures due to increased winter insolation and greater precipitation during this time.

Of the several pollen records from this period from eastern North America, that of Watts (1979) is perhaps the most pertinent, as it utilizes pollen records from several locations in the Appalachians, including a record from Cranberry Glades, WV, which is located near the study area. These pollen records reveal major shifts in plant populations

and distributions throughout the mountainous Appalachian region, where topographic changes can pose unique challenges to plant migration (Watts 1979). Those plant species present in periglacial regions suggest a cold, dry, and windy environment. With climatic warming during the deglacial, warm-weather species increased in range and diversity northward and this record suggests that conditions were warmer and drier during this period than during modern times, but not as dry as that of the glaciation. Persistent tundra present at higher elevations in the central Appalachians served as a phytogeographical barrier until approximately 12.5 kyr BP. These changing plant populations and climatic conditions can be subdivided into three main phases:

1) 13 – 9 kyr BP; early Holocene plant migrations, where open spruce forest was invaded by conifer-hardwood forests and increased aquatic floral diversity. Tundra environment disappeared as an increase in annual temperature lengthened the growing season, enabling species such as white spruce to migrate northward.

2) 9 – 5 kyr BP; the “Hypsithermal”, also known as the HCO, where forest populations were stable and water tables were relatively low.

3) 5 – 0 kyr BP; wetter conditions, with water tables higher than that of the HCO.

Though the records of Driese et al. (2005), Willard et al. (2005), and Watts (1979) utilize proxies that vary in their temporal and spatial extent, their combination creates a broad framework for understanding the regional climate of southeastern West Virginia during the late Pleistocene and throughout the Holocene. The shifting populations of plant species during this period indicate changes in moisture and temperature conditions. Additionally, a thorough understanding of the dominant vegetation species present in the study area during speleothem formation may aid in the interpretation of $\delta^{13}C$, as the carbon present in speleothem calcite is derived primarily from plant-respired CO_2.

Speleothem Records from West Virginia

Speleothems from the Greenbrier Valley, West Virginia, have been utilized in numerous paleoclimate studies over the last 40 years (Thompson et al. 1974; Thompson et al. 1976; Springer et al. 2008; Springer et al. 2009; Hardt et al. 2010). A review of this literature provides not only a paleoclimate history of the study area, but also chronicles the evolution of the methods and interpretations of the geochemical proxies over the development of the discipline. This section will briefly discuss each of the five major publications of speleothem paleoclimate records from the study area, with an emphasis on the methodological developments of the early works and the climatic implications of the recent literature. A comparison of the Culverson Creek record with those studies mentioned below can be found in the Discussion section.

Thompson et al. (1974) presented a paleoclimate study utilizing multiple speleothems from Bone-Norman Cave and Grapevine Cave (now known as Lost World Caverns) in Greenbrier County, West Virginia, only tens of kilometers from Culverson Creek Cave. The authors compare a composite $\delta^{18}O_{sc}$ record to summer insolation curves and concluded that a positive correlation between the two was evidence for relatively cool summer temperatures controlling the accumulation of glacial ice. The authors also concluded that because none of the speleothem samples utilized in the study experienced deposition during 30 – 6 kyr BP, that this was evidence for another glacial advance. Though many of the methods and conclusions of this study have since been shown to be unfounded (e.g., non-deposition of speleothem calcite can result from mechanisms other than glacial ice cover), Thompson et al. (1974) was one of the first studies to utilize geochemical proxies of several speleothems to create a long, continuous paleoclimate record.

Thompson et al. (1976) expanded on their previous publication by utilizing those speleothems in a more in-depth study. Here, the authors state implicitly that the growth rates of speleothems (or cessation of growth), though often climatically-dependent, cannot alone be indicative of environmental conditions as numerous factors are involved in speleogenesis. Samples for stable isotope analysis were taken along the growth axis from randomly-selected laminae and age models using linear interpolation between radiometric ages (U-Th methods) were developed. The authors also utilized isotopic values of fluid inclusions within the calcite in an effort to calculate paleotemperatures. They concluded that the isotopic composition of the cave waters had changed very little over time and that variations in $\delta^{18}O_{sc}$ were controlled primarily by changes in the fractionation factor, $\alpha_{c\text{-}w}$. Although many conclusions of the study are unsupported (e.g., the use of $\delta^{18}O$ values as a "paleothermometer" and the variable fractionation factor), many of the same methods used in modern paleoclimate studies, such as the development of geochemical time-series, were pioneered in the study.

The recent publications of Springer et al. (2008; 2009) and Hardt et al. (2010) utilize speleothems from Buckeye Creek Cave (BCC), which is located approximately 10 km from Culverson Creek Cave. Springer et al. (2008) utilized stable isotope and trace element results from stalagmite BCC-002 to reconstruct a paleoclimate record of six major centennial-scale drought events. These droughts are thought to be the result of cooling of the North Atlantic and the Pacific Oceans and the subsequent decline of moisture transport from the Gulf of Mexico (GOM). These drought events are characterized by enriched $\delta^{13}C_{sc}$ and Sr/Ca values when the region was relatively dry due to the influence of moisture on plant-respired CO_2 in the soil and an increase in water residence time in the vadose zone, respectively.

Springer et al. (2009) used the paleoclimatic record of BCC-002, as reported previously, in combination with a slackwater stratigraphic record, to create a Holocene hydroclimatological record of the Greenbrier River catchment. These data provide insight into the effect of changing climate on river morphology, which is an increasingly important topic in terms of anthropogenic climate change. This record is characterized by three major phases: 1) the cold, dry conditions of the late Pleistocene and aggradation of the river channel, 2) the enriched $\delta^{13}C_{org}$ of the stratigraphic record, when paired with palynological records (Watts 1979; Willard et al. 2005; Driese et al. 2005), provides a history of the HCO, and 3) the increase in precipitation accompanied by incision of the Greenbrier River Valley down to the bedrock surface.

Hardt et al. (2010) utilized a composite $\delta^{18}O_{sc}$ record of the last 8 kyr from three speleothems from BCC, known as BCC-002 (the record reported in Springer et al. (2008; 2009)), BCC-004, and BCC-006. They compared modern $\delta^{18}O_w$ values of precipitation to the speleothem record and concluded that $\delta^{18}O_{sc}$ enrichment represents an increase in the relative contribution of summer precipitation, which itself is strongly influenced by the Bermuda High circulation in the GOM. Though the study region receives moisture from the Pacific teleconnection in addition to the GOM, this study demonstrated that much of the $\delta^{18}O_{sc}$ variability is related to atmospheric controls on moisture sourcing.

Chapter 2

Methods

Speleothem collection and processing

The speleothems utilized in the present study were collected from Culverson Creek Cave, in Greenbrier County, southeastern West Virginia. The three stalagmites are labeled CCC-001, CCC-003, and CCC-007, and have lengths of 573 mm, 425 mm, and 495 mm, respectively. The samples were collected from a shallow cave passage located >1 km from the nearest known entrance, in-situ, and were not active upon collection. CCC-001 was utilized in two previous publications (Gilbert 2010; Hardt 2010) and many of the same data are used in this study. Due to the use of different methods for age model construction for CCC-001, slightly different geochemical and trace element time series were constructed for this study as were reported elsewhere.

After collection, the stalagmites were cut in half perpendicular to the growth axes with a continuous-rimmed diamond blade affixed to a wet-saw and polished to a smooth, flat surface with a hand-held water-spray polisher. All of the stalagmites appear to be composed of dense, columnar calcite with no visible evidence (i.e. detrital clay inclusions within calcite laminae) of major hiatuses within the laminae.

Stable Isotopic Analysis

The stalagmites were sampled for stable isotopic analyses at 0.5 mm increments along the growth axes using a hand-held milling tool (Foredom model SR-2272) equipped with a dental burr (Brasseler USA, US#1/4). Samples were taken contiguously in order to reduce any aliasing effects that may result from taking samples at discrete intervals. After collection, the sample powders were stored in micro-centrifuge tubes.

Aliquots of sample powders were then weighed (range 200-250 µg) using a Sartorius CP microbalance and placed into individual reaction vials (LabCo Exetainer 12 ml borosilicate vials). The sealed vials were then purged with helium and acidified using pure orthophosphoric acid, and subsequently equilibrated at 50^0C for 13 hours. Stable isotopic analyses were performed at the University of Texas at Arlington using a GasBench-II coupled to a ThermoFinnigan DeltaV Isotope Ratio Mass Spectrometer and standardized to V-PDB using NBS-19. Totals of 992, 1,146 and 849 samples were obtained for CCC-001, -003, and -007, respectively. The average standard measurement precision was 0.1‰ for both $\delta^{18}O$ and $\delta^{13}C$.

Trace Element Analysis

A semi-portable microbeam x-ray fluorescence unit (Bruker ARTAX) was utilized to develop non-destructive down-axis geochemical transects of Ca and Sr for the speleothems.

The ARTAX system is comprised of a motor-driven, tripod-supported x-y-z axis with a spot size of 70-650 microns, and has interchangeable element tubes and a variety of filters. The sample is subjected to an X-ray beam that excites and subsequently emits characteristic X-rays along a spectrum of known wavelengths that allows for the identification and concentration of atoms present in the sample. Therefore, the terms “count” and “count time” refer to the number of atoms of a particular element detected and the amount of time an individual sample location was exposed to the incident beam.

The spatial sensitivity of the system yields a minimum step increment of 5 microns, ultimately allowing for resolution down to spot-size overlap. Because the beam is non-contact and non-destructive, scans can be performed at a variety of count-times and resolutions, thereby conserving speleothem materials for additional or future

analyses. The maximum long-axis range of an individual scan is 4 cm, requiring that long speleothem transects be pieced together. The ARTAX system is controlled by the Spectra software program in which the various machine settings and parameters are customizable. Once a scan is programmed and initiated, ARTAX is fully-automated and requires no further manipulation. Additionally, the mount is equipped with a camera that records pictures of measurement locations, which aids in connecting the transects.

^{230}Th Age Dating

^{230}Th age-dating of speleothem samples was performed by Dr. Y. Gao (et al.) at the University of Minnesota using a Finnigan-MAT Neptune Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICP-MS) with a single MasCom multiplier using the decay constants reported by (Cheng et al. 2000).

The samples for ^{230}Th age dating were drilled using 0.9 mm diameter tungsten carbide dental burrs. Sample powders were dissolved in nitric acid, then mixed with a ^{229}Th/^{233}U/^{236}U tracer and allowed to dry. An iron chloride solution was then added, and followed incrementally by ammonium hydroxide until the iron was precipitated. The supernatant was then decanted and columns of anion resin were used to separate the thorium and uranium. Hydrochloric acid was then added to elute the Th and water to elute the U. Each sample was then dried and dilute nitric acid was added.

Geochronology

The age and depth models to which the proxy values are plotted were constructed using the algorithm StalAge which was specifically designed to create speleothem age models with a 95% confidence interval (Scholz and Hoffmann 2011).

StalAge is written in the R programming language as open-source statistical software (Pinheiro et al. 2010).

For speleothems, there is no standard method for age model construction. The most straightforward method is through simple linear interpolation between age data points. Though simple to construct, and often used, this method has distinct disadvantages: 1) each section between age dates is treated as its own age model, with a linear relationship inferred for all values between adjacent age dates, meaning that each section relies only on two data points, 2) age inversions (that may occur due to analytical error or overlapping error bars) produce negative slopes and must be discarded, and 3) though it is possible to report the uncertainty associated with these models, it is often omitted (Scholz et al. 2012).

Numerous methods have been utilized in speleothem age model construction to varying degrees of success. These include the mixed effect regression model (Heegaard et al. 2005), smoothing cubic spline (Beck et al. 2001), finite positive growth rate model (Drysdale et al. 2004), and deposition models implemented in OxCal, which is a radiocarbon calibration and analysis program (Ramsey 2008). According to (Scholz et al. 2012), all of these methods have distinct advantages and disadvantages depending on a particular dataset. For complicated samples that have problematic sections, such as hiatuses and age reversals in the age dates, StalAge, OxCal, and the finite positive growth rate model perform the best, as they have the capability to deal with these non-standard age model factors. Many of these methods allow a moderate to high degree of customization in age model creation, but the “tuning” of these models can be argued as introducing subjectivity into model creation. Of the three methods of age modeling that can handle complicated sections, only StalAge is user-friendly and has no customizable

parameters aside from the options pertaining to outliers, thus making the results reproducible, non-subjective, and available to “non-expert” users.

StalAge is performed in a series of step-wise functions for each set of age and depth data. First, the data are screened for any major outliers. If any such values are detected, the user has the option of either enlarging the error bars iteratively by 10% until that data point is no longer an outlier or by omitting that point from the dataset. This is necessary because of the possibility of having samples that contain detrital (or unoriginal) thorium or analytical errors during sample processing. Data points must be in stratigraphic agreement (i.e., no reversals) with at least two other data points to not be considered outliers. Second, the data are screened for the presence of minor outliers, an operation which is performed by fitting error-weighted straight lines through all subsets consisting of three adjacent data points. Those points that do not pass this screening have their error bars increased iteratively by 10% until inclusion within the subset is achieved. Third, the age model is performed using the screened data. If all data points can now be fitted with an error-weighted straight line within the error bars, a Monte-Carlo simulation is performed on each of the subsets. Finally, the age model is tested for inversions, evidenced visually as a section of negative slope. If an inversion is detected, the age is replaced by what would be a maximum of the previous value.

Chapter 3

Results

^{230}Th Age Dates

For sample CCC-001, 42 ^{230}Th age dates were obtained, with 14% of the samples as duplicates. For CCC-003, 37 ^{230}Th age dates were obtained, with 8% as duplicate samples. For sample CCC-007, 16 ^{230}Th age dates were obtained, with 6% as duplicate samples. Table 3-1, shows the combined U/Th data and ^{230}Th age results for the study samples.

Table 3-1 U/Th data table and ^{230}Th ages for CCC-001, CCC-003, and CCC-007.

Sample ID	^{238}U (ppb)		^{232}Th (ppt)		δ^{234}U measured[a]		[^{230}Th/^{238}U] activity[c]		[^{230}Th/^{232}Th] ppm[d]		^{230}Th Age (yr BP) uncorrected		^{230}Th Age (yr BP) corrected [c,e]	
CCC1-3	419.6	±1.0	367.0	±8	658.0	±3.0	0.0819	±0.00030	1540	±30	5448	±22	**5432**	**±25**
CCC1T	382.5	±0.8	928	±4	648.4	±3.2	0.0838	±0.00132	570	±9	5678	±92	**5635**	**±97**
CCC1-46.5	541.7	±1.2	305	±6	706.0	±3.0	0.0912	±0.00030	2670	±60	5907	±23	**5898**	**±24**
CCC1-63	535.4	±1.0	172	±4	722.1	±2.9	0.0966	±0.00030	4950	±110	6214	±22	**6208**	**±22**
CCC1-90	487.6	±0.9	170	±1	724.1	±3.1	0.1014	±0.00142	4797	±75	6588	±96	**6583**	**±96**
CCC1-101	410.6	±0.6	376	±8	732.5	±2.8	0.1062	±0.00030	1910	±40	6808	±25	**6793**	**±28**
CCC1-123	495.1	±0.7	244	±5	739.8	±2.5	0.1122	±0.00040	3750	±80	7175	±27	**7167**	**±28**
CCC1-150	552.2	±0.8	250	±6	755.4	±2.4	0.1148	±0.00020	4170	±90	7280	±19	**7272**	**±20**
CCC1-166	634.8	±1.0	336	±7	748.4	±2.4	0.1204	±0.00030	3750	±80	7682	±21	**7674**	**±22**
CCC1-181	492.9	±1.0	243	±1	786.9	±3.0	0.1283	±0.00146	4293	±53	8093	±96	**8085**	**±96**
CCC1-187	429.5	±0.8	375	±1	777.0	±2.9	0.1301	±0.00119	2457	±24	8255	±79	**8241**	**±80**
CCC1-189B	463.5	±0.7	690	±14	764.4	±2.7	0.1308	±0.00030	1450	±30	8293	±24	**8268**	**±29**
CCC1-189A	459.3	±0.6	595	±12	770.1	±2.0	0.1316	±0.00040	1680	±30	8320	±27	**8300**	**±30**
CCC1-190.5	509.1	±1.0	175	±1	772.3	±3.0	0.1276	±0.00093	6125	±53	8118	±63	**8112**	**±63**
CCC1-212.5	414.9	±0.6	382	±8	802.6	±2.8	0.1713	±0.00040	3060	±60	10750	±30	**10730**	**±30**
CCC1-227	320.9	±0.4	271	±6	837.9	±2.7	0.1839	±0.00040	3590	±80	11350	±30	**11340**	**±30**
CCC1-242.5	544.1	±0.6	356	±7	826.3	±1.9	0.1928	±0.00040	4860	±100	12010	±30	**12000**	**±30**
CCC1-250	444.4	±0.8	169	±1	818.3	±3.1	0.1899	±0.00140	8246	±75	11948	±95	**11942**	**±95**
CCC1-260	438.0	±0.8	157	±1	808.4	±3.2	0.1975	±0.00163	9107	±94	12524	±111	**12518**	**±111**
CCC1-268	574.0	±0.7	69	±3	805.2	±2.0	0.1996	±0.00040	27300	±1000	12610	±30	**12610**	**±30**
CCC1-280A	434.8	±0.9	265	±1	833.5	±3.7	0.2050	±0.00206	5546	±59	12836	±138	**12826**	**±138**
CCC1-280B	459.9	±0.6	275	±6	829.7	±2.4	0.2062	±0.00070	5690	±120	12870	±50	**12860**	**±50**
CCC1-298	589.3	±0.9	38	±1	812.3	±2.4	0.2110	±0.00050	54000	±1300	13320	±40	**13320**	**±40**
CCC1-300.5	603.6	±1.2	27	±1	826.0	±3.2	0.2118	±0.00170	78630	±2913	13341	±115	**13340**	**±115**

Table 3-1—*Continued*

CCC1-330.5A	559.3	±1.1	122	±1	806.1	±3.1	0.2161	±0.00199	16328	±193	13784	±137	**13780**	**±137**
CCC1-330.5B	592.8	±1.0	132	±3	801.0	±2.7	0.2177	±0.00070	16100	±300	13860	±50	**13850**	**±50**
CCC1-340.5	574.6	±0.7	101	±2	761.2	±2.1	0.2137	±0.00050	20100	±400	13920	±40	**13920**	**±40**
CCC1-370.5	535.1	±0.7	47	±1	771.6	±1.9	0.2229	±0.00060	41000	±1000	14470	±40	**14470**	**±40**
CCC1-375A	508.1	±0.9	52	±1	746.4	±3.1	0.2245	±0.00259	36365	±728	14882	±185	**14881**	**±185**
CCC1-375B	537.0	±0.8	55	±1	741.0	±2.5	0.2285	±0.00100	36900	±900	15130	±70	**15130**	**±70**
CCC1-389	641.9	±1.1	79	±2	813.9	±2.7	0.2403	±0.00060	32200	±700	15280	±50	**15280**	**±50**
CCC1-404	664.6	±1.2	163	±3	809.1	±2.8	0.2433	±0.00070	16300	±300	15530	±50	**15520**	**±50**
CCC1-420.5	764.0	±1.3	47	±1	779.9	±2.5	0.241	±0.00060	65100	±1500	15640	±50	**15640**	**±50**
CCC1-430.75	960.1	±1.8	21	±1	764.9	±2.6	0.2396	±0.00070	184000	±6000	15690	±50	**15690**	**±50**
CCC1-455.75	760.1	±1.1	54	±1	760.1	±1.1	0.2548	±0.00050	59500	±1400	16110	±40	**16110**	**±40**
CCC1-465A	641.6	±1.3	58	±1	788.7	±3.2	0.2531	±0.00165	46522	±786	16476	±119	**16475**	**±119**
CCC1-465B	678.3	±1.1	62	±2	783.2	±2.6	0.2531	±0.00080	45300	±1100	16450	±60	**16450**	**±60**
CCC1-468.5A	510.1	±0.7	505	±10	807.4	±2.4	0.2603	±0.00060	4340	±90	16700	±50	**16690**	**±50**
CCC1-468.5B	510.0	±0.8	450	±9	805.9	±2.6	0.2584	±0.00060	4800	±100	16590	±50	**16570**	**±50**
CCC1-474	493.8	±0.8	772	±16	823.9	±2.6	0.2638	±0.00070	2780	±60	16780	±50	**16750**	**±50**
CCC1-483	414.1	±0.7	579	±12	787.1	±2.5	0.2932	±0.00070	3460	±70	19230	±60	**19210**	**±60**
CCC1-491	290.2	±0.4	2570	±50	755.1	±2.5	0.3021	±0.00080	561	±11	20260	±70	**20120**	**±120**
CCC3-29	737.7	±1.1	13435	±269	668.3	±1.8	0.1023	±0.0004	93	±2	6873	±28	**6497**	**±225**
CCC3-30	1091.1	±1.8	709	±15	704.8	±1.9	0.1312	±0.0004	3328	±69	8686	±31	**8614**	**±32**
CCC3-1	1143.8	±2.2	639	±13	694.8	±2.2	0.1647	±0.0005	4861	±99	11072	±35	**11003**	**±36**
CCC3-31	770.3	±1.1	357	±8	718.9	±1.8	0.1695	±0.0005	6032	±130	11240	±39	**11171**	**±40**
CCC3-32	783.6	±1.2	684	±14	725.2	±1.9	0.1733	±0.0005	3272	±68	11461	±40	**11385**	**±42**
CCC3-33	512.3	±0.7	103	±3	807.1	±1.8	0.1908	±0.0006	15672	±474	12071	±41	**12007**	**±41**
CCC3-34	1175.1	±2.1	111	±4	721.3	±2.0	0.1894	±0.0006	33017	±1107	12615	±42	**12552**	**±42**
CCC3-3	970.1	±1.5	237	±5	720.3	±1.8	0.1969	±0.0006	13278	±309	13145	±43	**13080**	**±43**
	1356.1	±2.2	34	±2	766.7	±2.1	0.2113	±0.0005	140717	±9030	13766	±39	**13705**	**±39**

Table 3-1—*Continued*

CCC3-4A														
CCC3-4B	1341.6	±2.4	36	±3	766.0	±2.0	0.2111	±0.0006	130734	±12107	13763	±47	**13701**	**±47**
CCC3-5	1211.3	±1.8	42	±2	837.1	±1.9	0.2256	±0.0005	107510	±6232	14153	±38	**14092**	**±38**
CCC3-6	942.8	±1.5	46	±3	903.5	±2.2	0.2402	±0.0007	81158	±4745	14561	±47	**14499**	**±47**
CCC3-7	894.9	±1.4	25	±3	944.2	±2.2	0.2521	±0.0007	149987	±15354	14983	±45	**14921**	**±45**
CCC3-8	702.3	±1.1	118	±4	973.0	±2.1	0.2627	±0.0007	25798	±805	15403	±48	**15340**	**±48**
CCC3-9	1057.9	±1.8	121	±4	966.4	±2.3	0.2667	±0.0007	38553	±1190	15712	±49	**15649**	**±49**
CCC3-10	857.6	±1.3	78	±3	954.7	±2.2	0.2699	±0.0007	49226	±1821	16013	±49	**15951**	**±49**
CCC3-11	1161.1	±2.0	19	±3	902.5	±2.3	0.2657	±0.0007	267668	±37148	16216	±51	**16155**	**±51**
CCC3-12	1252.8	±2.2	35	±3	893.1	±2.3	0.2663	±0.0007	155460	±11008	16342	±50	**16281**	**±50**
CCC3-13	797.8	±1.2	19	±3	960.4	±1.9	0.2782	±0.0008	197696	±29582	16487	±51	**16426**	**±51**
CCC3-14	1031.6	±1.6	40	±3	898.6	±1.8	0.2784	±0.0007	119590	±8265	17082	±52	**17020**	**±52**
CCC3-15	830.9	±1.3	81	±3	914.9	±2.3	0.2927	±0.0007	49304	±1752	17860	±52	**17798**	**±52**
CCC3-16	707.3	±1.1	170	±4	881.5	±2.2	0.2944	±0.0007	20224	±509	18318	±55	**18253**	**±55**
CCC3-17	570.8	±0.9	136	±4	896.5	±2.1	0.3037	±0.0008	21032	±608	18779	±61	**18714**	**±61**
CCC3-18	641.5	±1.0	46	±3	737.8	±1.9	0.2857	±0.0009	66367	±4402	19342	±67	**19280**	**±67**
CCC3-19	468.0	±0.7	51	±3	738.3	±2.2	0.2910	±0.0009	44387	±2586	19727	±74	**19664**	**±74**
CCC3-20	891.2	±1.3	199	±5	685.5	±1.8	0.2876	±0.0007	21190	±511	20151	±59	**20086**	**±59**
CCC3-21	798.5	±1.3	134	±4	668.7	±2.3	0.2992	±0.0008	29441	±809	21268	±72	**21204**	**±72**
CCC3-22A	771.9	±1.1	261	±6	635.5	±1.7	0.3106	±0.0008	15144	±344	22660	±70	**22593**	**±70**
CCC3-22B	595.6	±0.9	145	±4	641.7	±1.9	0.3119	±0.0009	21195	±600	22667	±75	**22602**	**±75**
CCC3-23	799.7	±1.3	581	±12	618.6	±1.9	0.3169	±0.0009	7193	±150	23432	±77	**23358**	**±77**
CCC3-24	785.9	±1.2	327	±7	669.6	±1.9	0.3418	±0.0010	13561	±296	24603	±84	**24535**	**±84**
CCC3-25A	876.6	±1.4	385	±8	653.6	±2.0	0.3470	±0.0009	13040	±277	25287	±80	**25219**	**±80**

Table 3-1—*Continued*

CCC3-25B	925.7	±1.6	382	±8	653.3	±2.2	0.3461	±0.0010	13822	±300	25220	±87	**25152**	**±87**
CCC3-26	745.5	±1.0	1693	±34	733.6	±1.8	0.3687	±0.0009	2677	±54	25641	±74	**25543**	**±78**
CCC3-2	765.0	±1.3	1376	±28	679.6	±2.1	0.3637	±0.0009	3333	±67	26175	±81	**26085**	**±84**
CCC3-27	901.6	±1.6	129	±4	776.8	±2.3	0.3890	±0.0010	44762	±1344	26460	±86	**26397**	**±86**
CCC3-28	1088.2	±1.8	273	±6	813.7	±2.0	0.4021	±0.0011	26430	±604	26826	±85	**26761**	**±85**
CCC7-1	379.4	±0.5	1613	±32	961.9	±2.2	0.1569	±0.0004	608.5	±12.3	8966	±27	**8906**	**±52**
CCC7-18	436.0	±0.9	356	±7	953.0	±2.7	0.1695	±0.0006	3421	±70	9768	±37	**9756**	**±38**
CCC7-4	361.0	±0.4	619	±12	957.6	±1.9	0.1789	±0.0004	1721	±35	10309	±28	**10286**	**±34**
CCC7-15	508.6	±0.7	1929	±39	957.8	±2.0	0.1784	±0.0004	776	±16	10282	±29	**10228**	**±49**
CCC7-16	462.5	±0.6	403	±8	953.2	±2.2	0.1783	±0.0004	3372	±69	10298	±27	**10288**	**±29**
CCC7-5	542.6	±0.7	3106	±62	953.1	±2.0	0.1797	±0.0005	517	±10	10382	±30	**10300**	**±67**
CCC7-6	612.4	±0.9	235	±5	946.6	±2.1	0.1888	±0.0006	8103	±170	10973	±41	**10969**	**±41**
CCC7-7	472.2	±0.7	320	±7	940.5	±2.5	0.2111	±0.0006	5129	±106	12385	±39	**12377**	**±40**
CCC7-8	571.1	±0.9	200	±4	950.8	±2.4	0.2233	±0.0006	10491	±221	13065	±39	**13062**	**±39**
CCC7-9	534.7	±0.7	723	±15	945.3	±2.0	0.2331	±0.0005	2840	±57	13716	±37	**13698**	**±39**
CCC7-10	546.9	±0.7	491	±10	944.0	±1.9	0.2434	±0.0006	4473	±91	14371	±39	**14360**	**±40**
CCC7-11	510.9	±0.7	44	±2	937.5	±2.1	0.2704	±0.0006	51734	±1924	16138	±45	**16139**	**±45**
CCC7-12	388.9	±0.5	137	±3	901.7	±2.0	0.2908	±0.0007	13561	±299	17802	±49	**17798**	**±49**
CCC7-13	371.9	±0.5	264	±5	774.8	±2.0	0.2935	±0.0007	6820	±141	19393	±54	**19384**	**±55**
CCC7-17	266.6	±0.5	1085	±22	709.7	±2.4	0.3217	±0.0010	1304	±26	22344	±82	**22277**	**±95**
CCC7-2	338.3	±0.4	3379	±68	713.5	±1.7	0.3366	±0.0008	555.7	±11.2	23432	±65	**23270**	**±133**

Analytical errors are 2σ of the mean.

[a] $\delta^{234}U = ([^{234}U/^{238}U]_{activity} - 1) \times 1000$.

[b] $\delta^{234}U_{initial}$ corrected was calculated from ^{230}Th age (T), i.e., $\delta^{234}U_{initial} = \delta^{234}U_{measured} * e^{\lambda 234 * T}$, and T is corrected age.

[c] $[^{230}Th/^{238}U]_{activity} = 1 - e^{-\lambda 230 T} + (\delta^{234}U_{measured}/1000)[\lambda_{230}/(\lambda_{230} - \lambda_{234})](1 - e^{-(\lambda 230 - \lambda 234) T})$, where *T* is the age.

Decay constants are 9.1577 x 10^{-6} yr^{-1} for ^{230}Th, 2.8263 x 10^{-6} yr^{-1} for ^{234}U, and 1.55125 x 10^{-10} yr^{-1} for ^{238}U (Cheng et al., 2000).

[d] The degree of detrital ^{230}Th contamination is indicated by the [$^{230}Th/^{232}Th$] atomic ratio instead of the activity ratio.

[e]Age corrections were calculated using an average crustal $^{230}Th/^{232}Th$ atomic ratio of 4.4 x 10^{-6} ± 2.2 x 10^{-6}.

The locations within the speleothems that were sampled for ^{230}Th age dating can be seen in Figure 3-2 for CCC-001, Figure 3-3 for CCC-003, and Figure 3-3 for CCC-007. The age dates are in chronological order, with the youngest starting from the top of the speleothems, as there were no age reversals outside the margins of error in the reported age date values. Duplicate samples are indicated by the occurrence of two sample markers within the same lamina. For CCC-001, there are several visible sample locations that are not indicated with markers. This is due to the omission of several age date estimate values that had very high margins of error, possibly due to contamination of sample material.

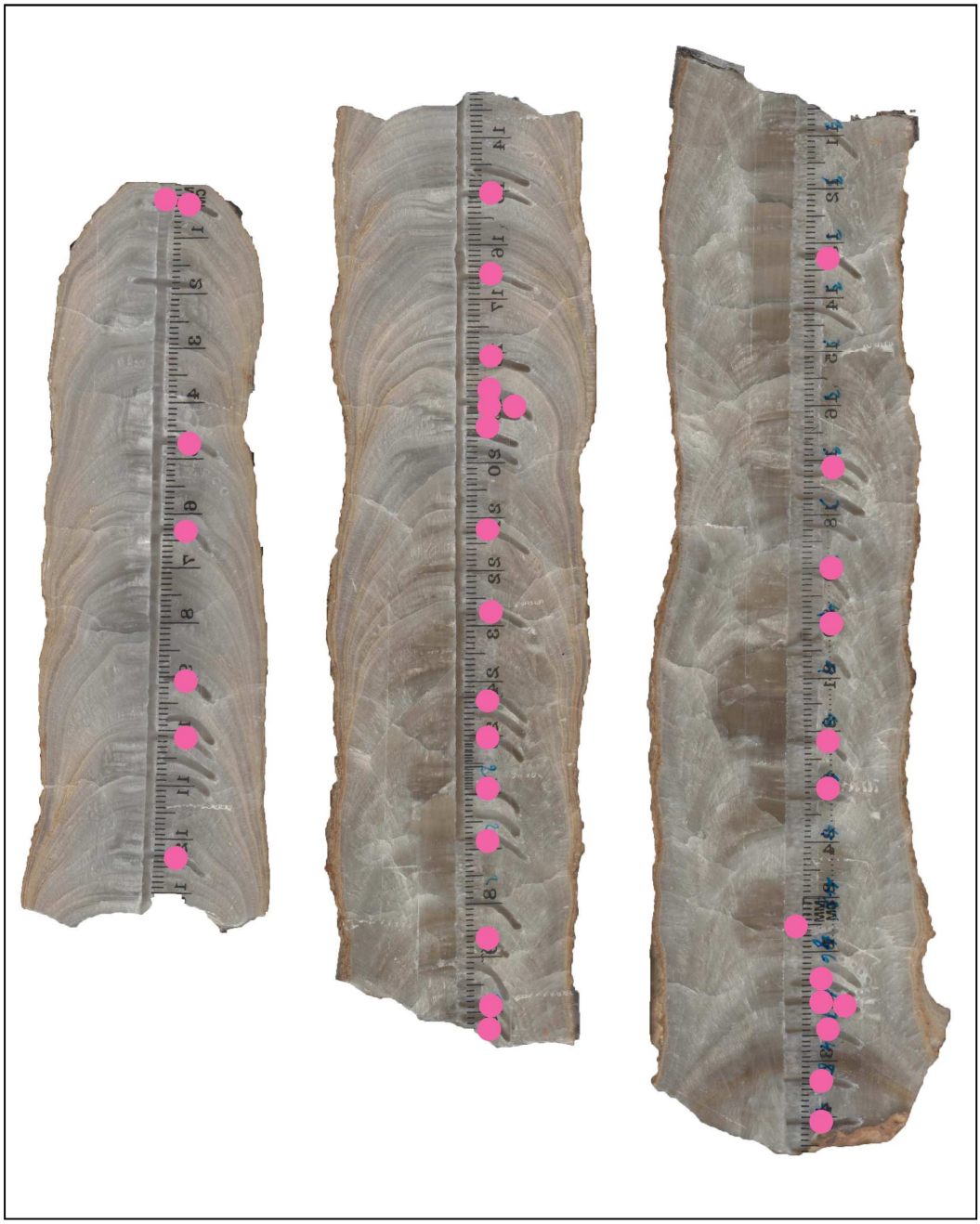

Figure 3-1 CCC-001 ^{230}Th age date sample locations

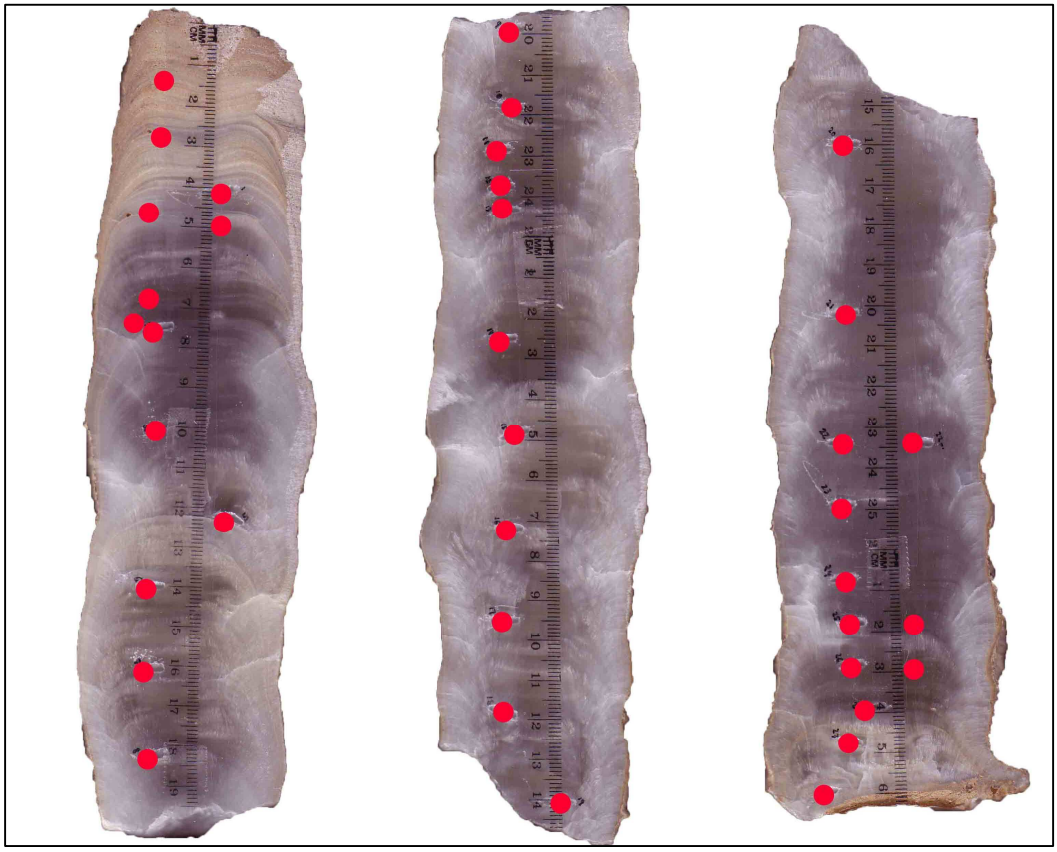

Figure 3-2 CCC-003 ^{230}Th age date sample locations

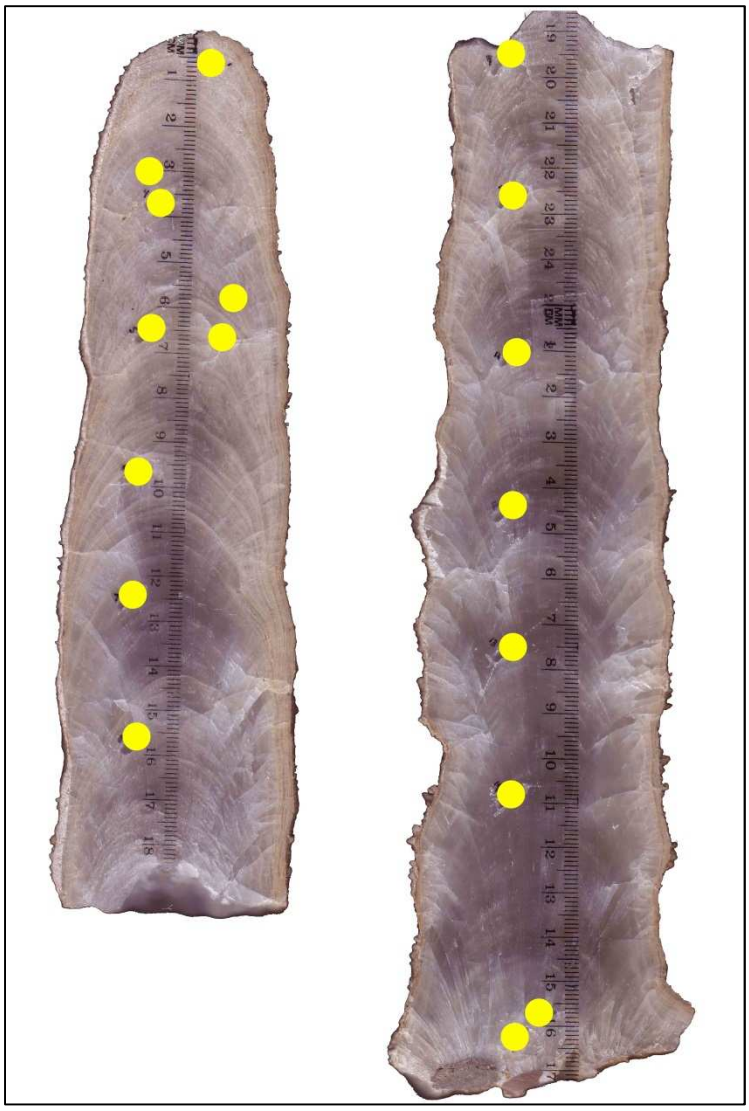

Figure 3-3 CCC-007 ^{230}Th age date sample locations

Age Models

The age models to which the speleothem proxy data are plotted were created using the StalAge algorithm (Scholz and Hoffmann 2011). Age models are seen for CCC-001 in Figure 3-4 followed by those for CCC-003 and CCC-007. These figures show a) original

age data, b) age data screened for major outliers, c) age data screened for minor outliers, and d) final age model with screened errors.

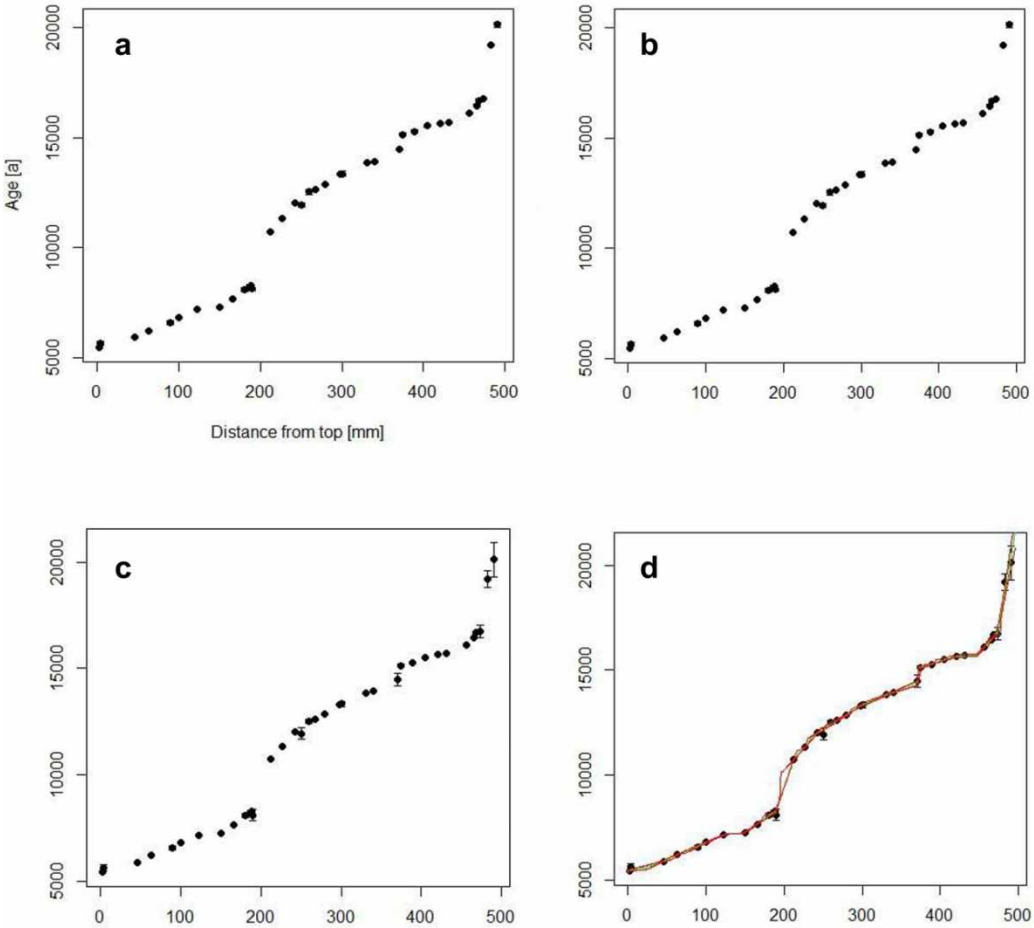

Figure 3-4 StalAge models for CCC-001

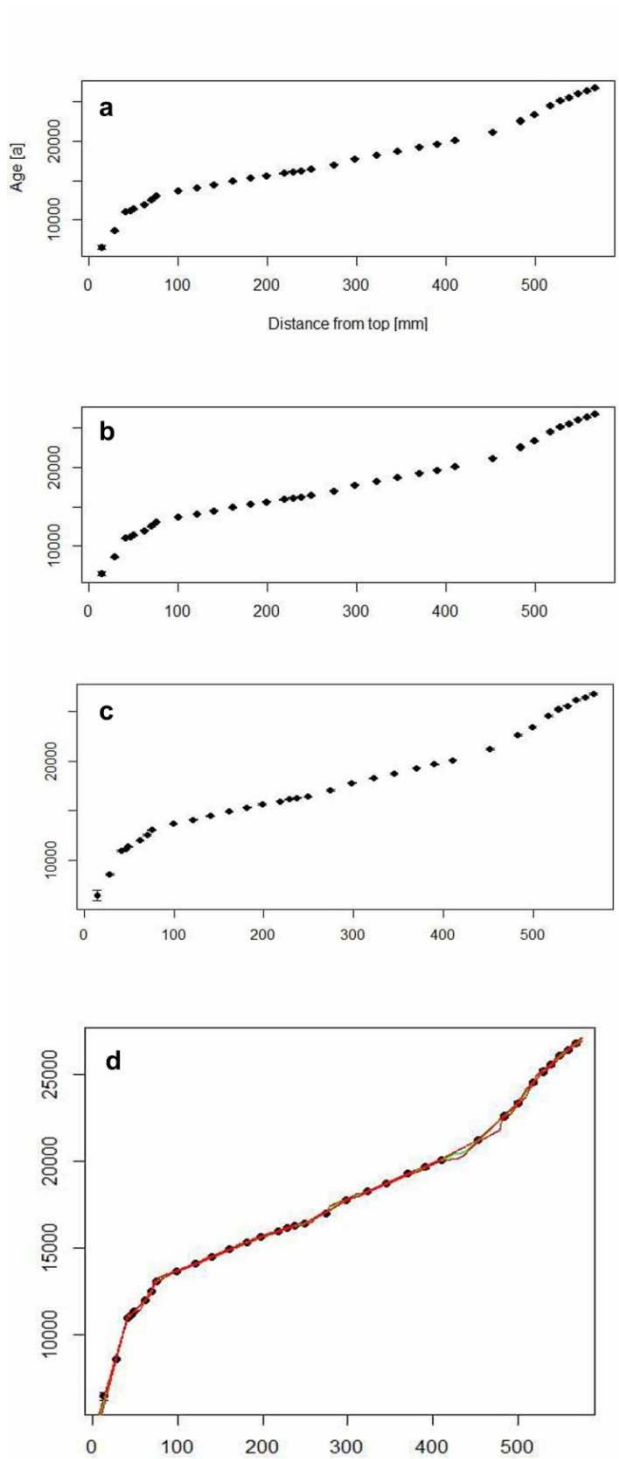

Figure 3-5 StalAge models for CCC-003

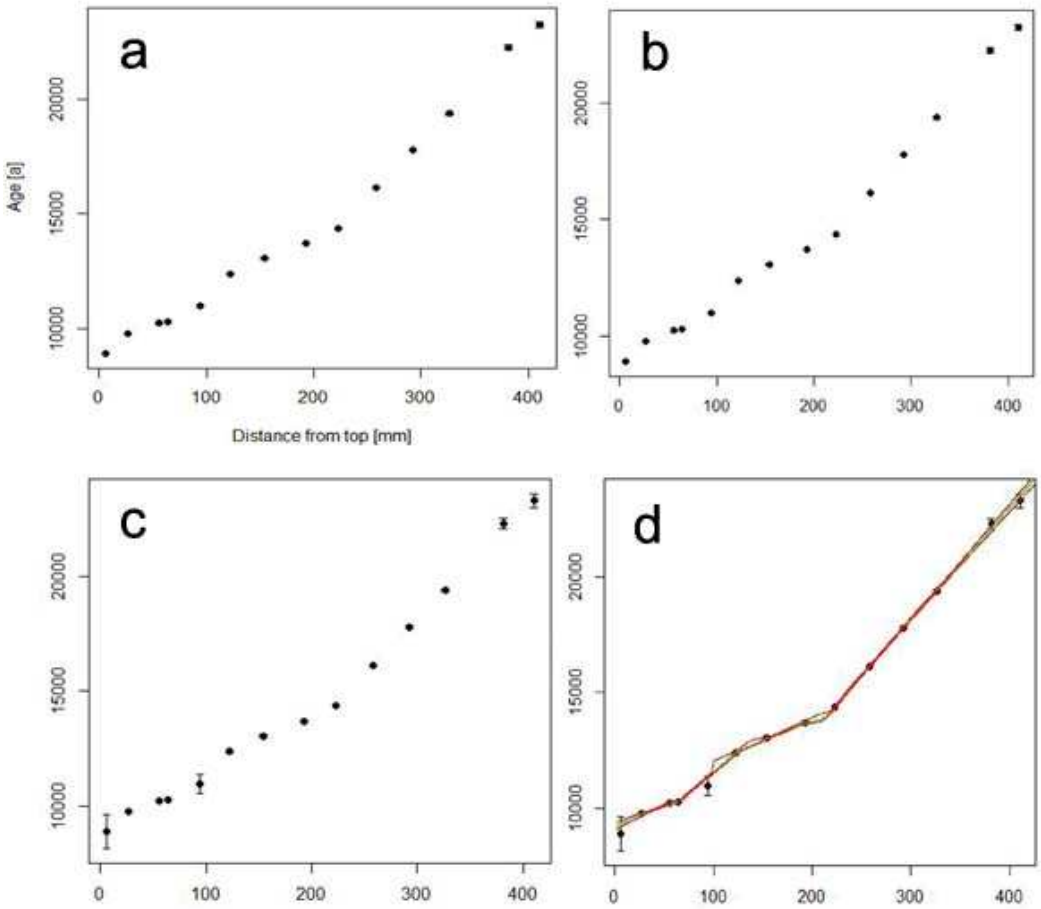

Figure 3-6 StalAge models for CCC-007

Stable Isotopes

The $\delta^{13}C_{sc}$ and $\delta^{18}O_{sc}$ values for samples CCC-001, CCC-003, and CCC-007 can be found in Appendix A. Plotted stable isotope and trace element results can be found in Stable Isotope and Trace Element Time Series.

Stable Isotope Fractionation

In order to test for isotopic disequilibria of the study speleothems (Hendy 1971), $\delta^{18}O_{sc}$ and $\delta^{13}C_{sc}$ values obtained from discrete samples are plotted below.

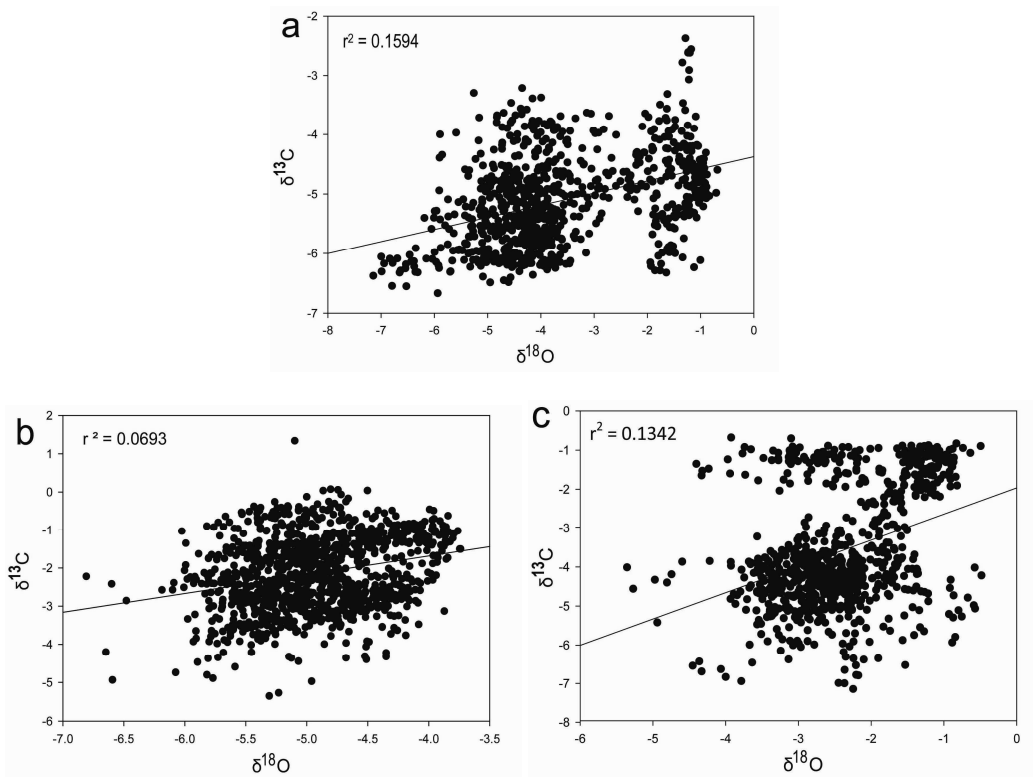

Figure 3-7 $\delta^{18}O$ and $\delta^{13}C$ with their corresponding linear correlation coefficient values of a) CCC-001, b) CCC-003, and c) CCC-007.

The low correlation coefficients (r^2) for the study speleothems in Figure 3-7 demonstrate the low degree of disequilibrium with respect to the isotopic values. The clustering of values into two general groups in both Figure 3-8 A and C warrants further investigation, as it may be indicative of two modes of calcite growth or perhaps periods of enhanced disequilibrium in isotopic fractionation.

Trace Element

The results of trace elemental analysis for the speleothem samples can be found in Appendix B. Plotted results for Sr counts can be seen as the top curves (in black) in Figure 3-9 on page 56 for CCC-003 and Figure 3-10 on page 57 for CCC-007

Stable Isotope and Trace Element Time Series

Figure 3-8 through Figure 3-10 shows the $\delta^{13}C$, $\delta^{18}O$, and Sr time series for each of the CCC speleothems. ^{230}Th age dates are shown bracketed by the associated margin of error.

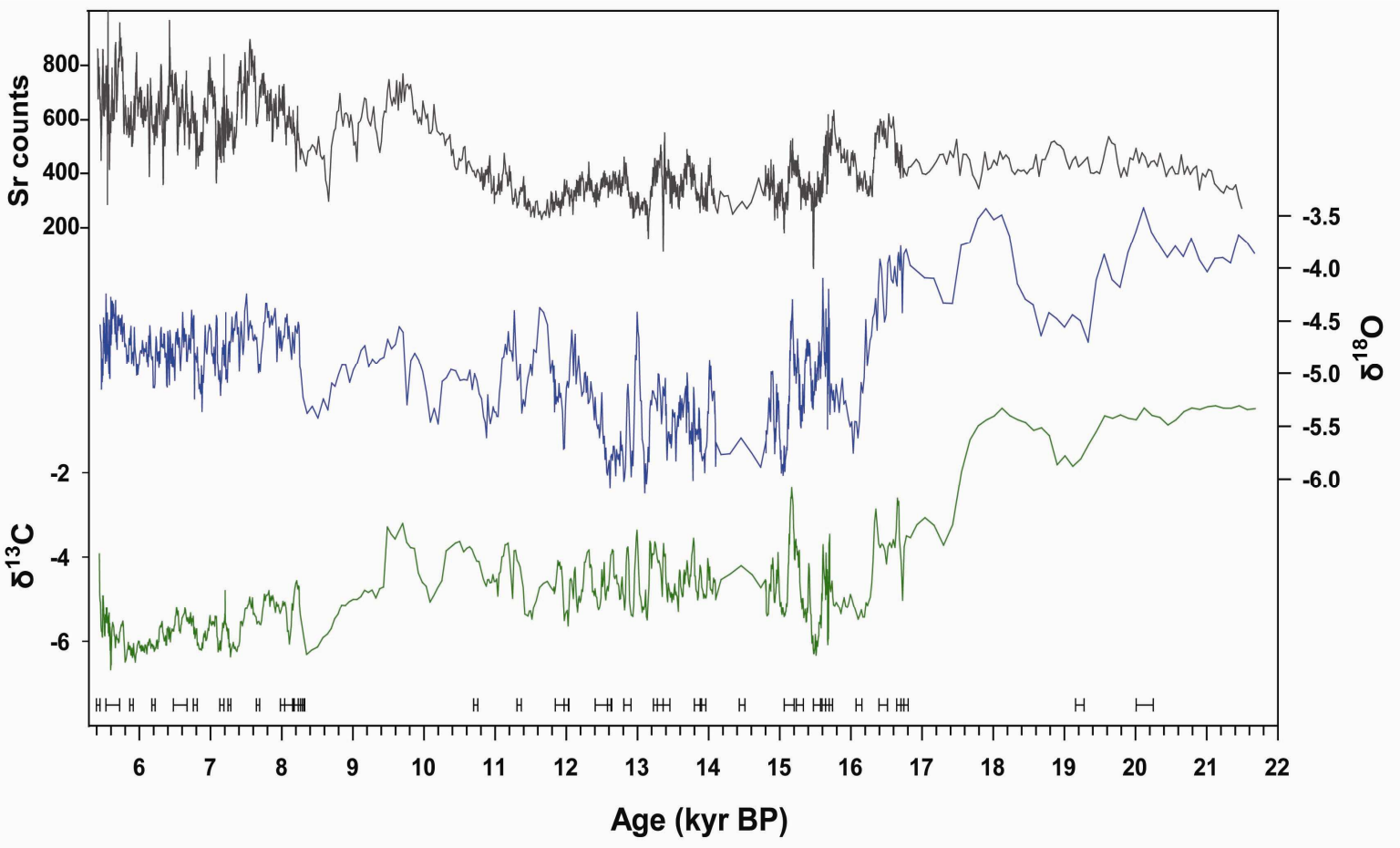

Figure 3-8 $\delta^{13}C$, $\delta^{18}O$, and Sr results for CCC-001 using StalAge age model

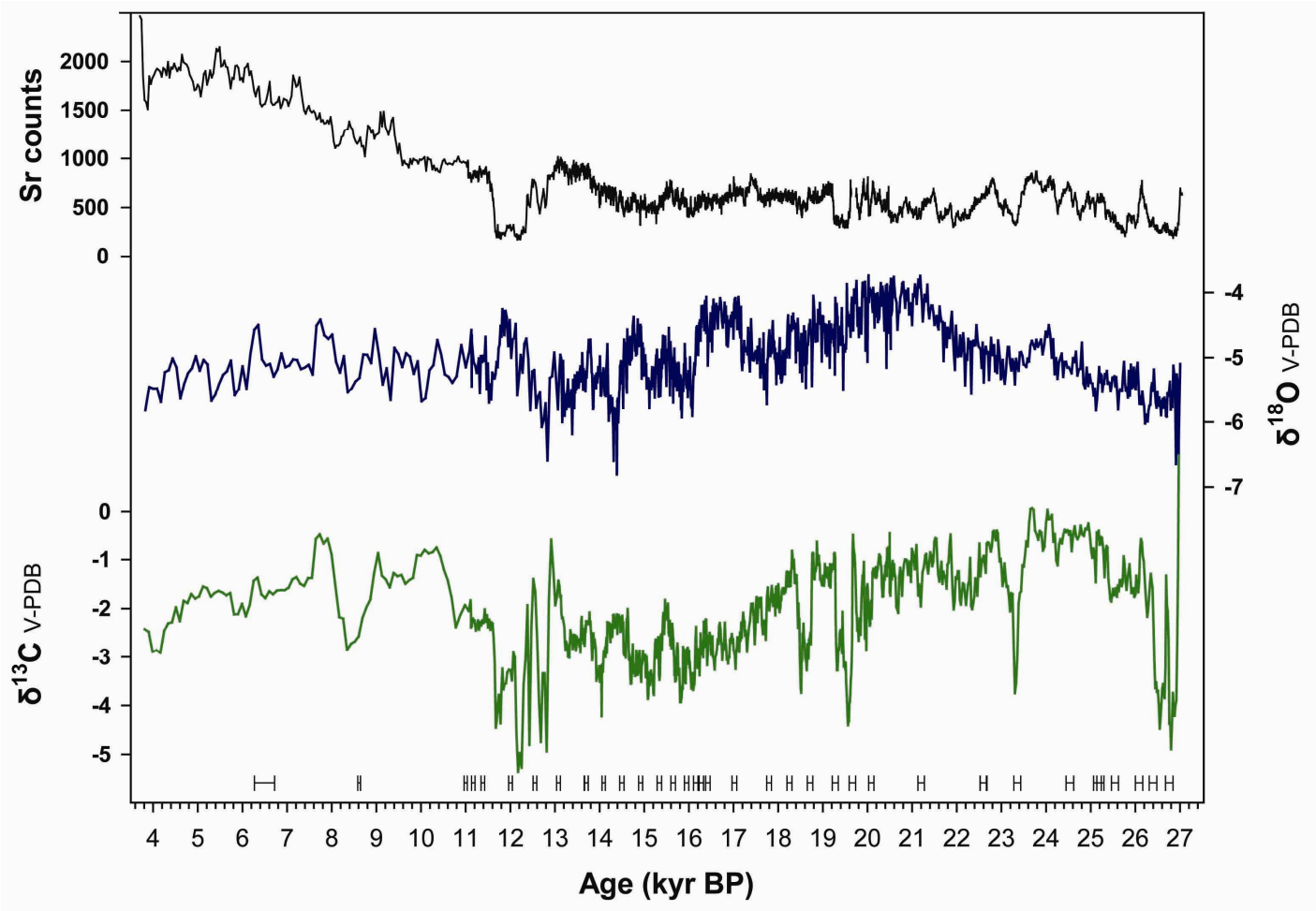

Figure 3-9 $\delta^{13}C$, $\delta^{18}O$, and Sr results for CCC-003 using StalAge age model

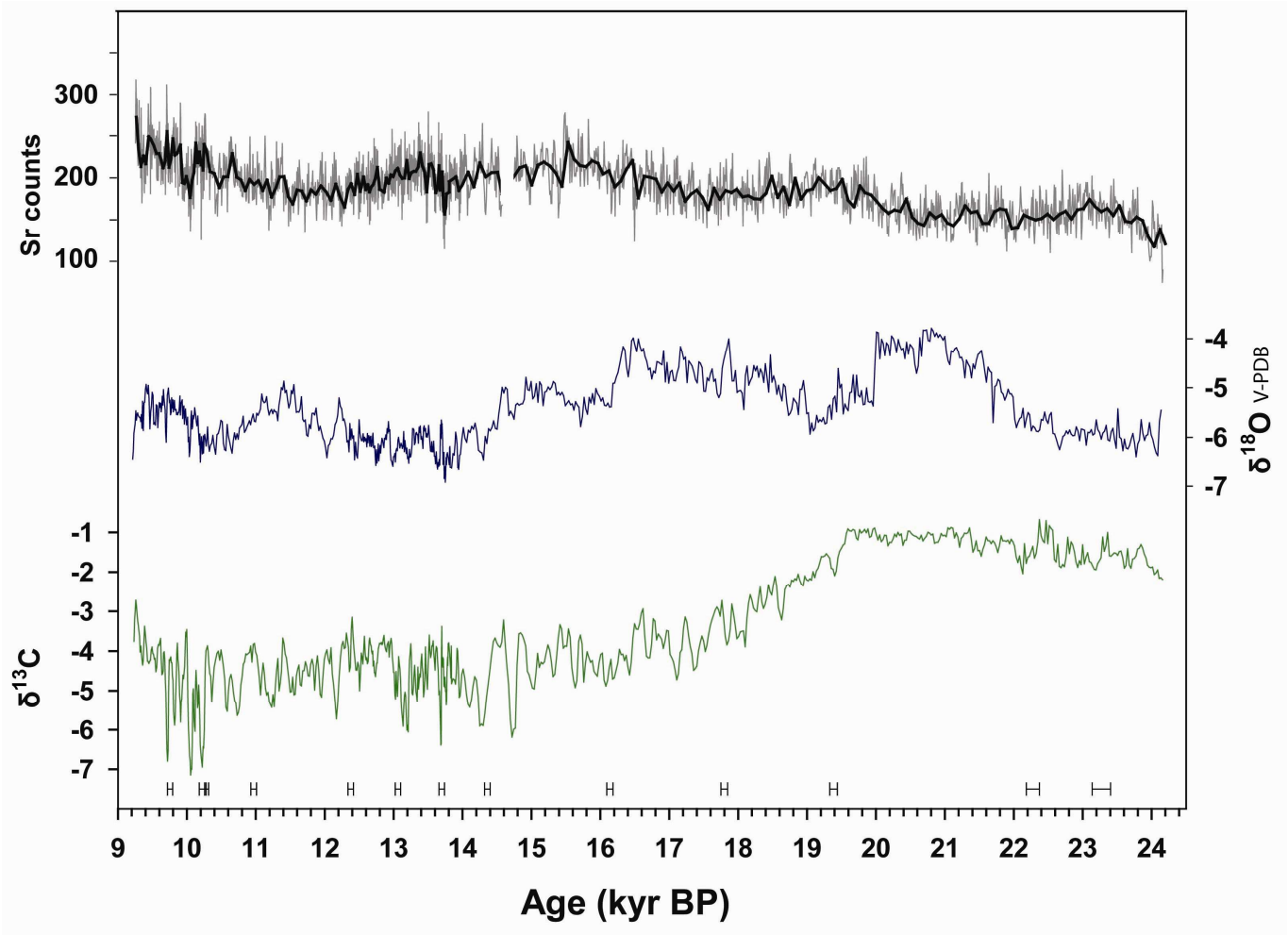

Figure 3-10 $\delta^{13}C$, $\delta^{18}O$, and Sr results for CCC-007 using StalAge age model

Chapter 4

Discussion

Geochronology

The StalAge algorithm was used in the creation of the age models for the CCC speleothems because of the reported increased accuracy over linear interpolation (Scholz et al. 2012). In order to determine whether the StalAge algorithm was superior to linear interpolation for the study data, Figure 4-1, below, shows a comparison of the CCC-001 $\delta^{13}C$ and $\delta^{18}O$ time series.

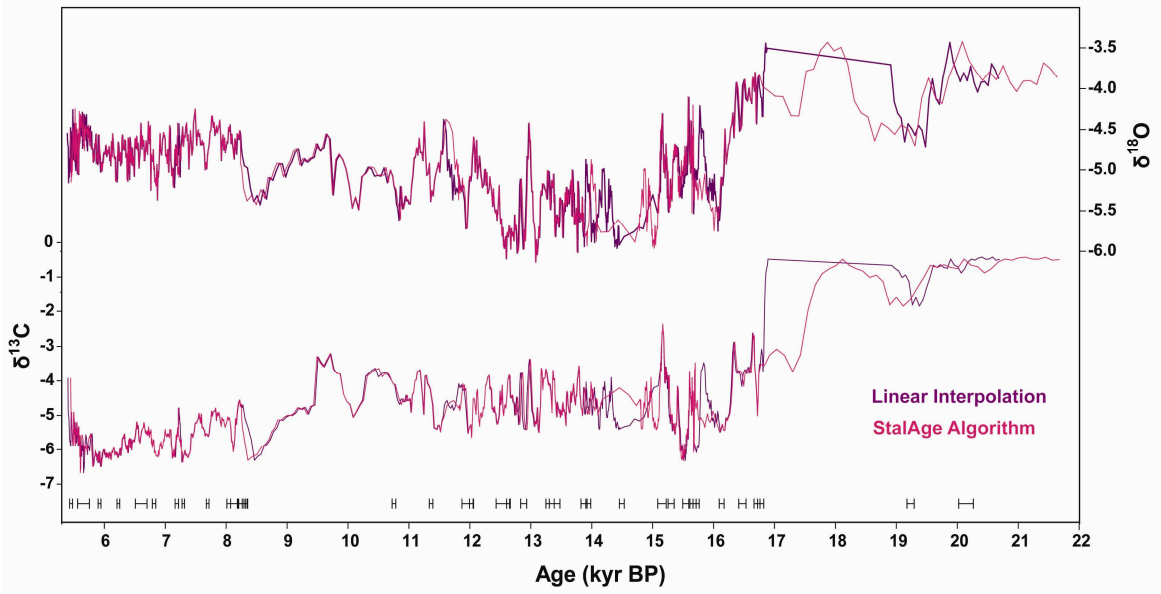

Figure 4-1 StalAge algorithm *versus* Linear Interpolation for CCC-001 $\delta^{13}C$ and $\delta^{18}O$

While much of the two time series are very similar in their temporal placement of the proxy data, attention is drawn to two slower-growing sections of the record, such as that of approximately 14.5 – 15 and 17 – 21.8 kyr BP. These intervals show the most divergence between the two models. Another important difference between the two models is the basal extension of the time series. Because basal speleothem ^{230}Th age date samples are often obtained from laminae above the basal proxy measurements, for the method of linear interpolation, the extrapolation of the growth rate between the basal date and the nearest above

is applied to the bottom segment. Because the StalAge algorithm utilizes the relationship between subsets of three adjacent data points rather than the 'stepping-stone' data points of linear interpolation, a more accurate age model is constructed. For CCC-001, the use of the StalAge algorithm yields a more accurate record during the slow-growing sections, but also extends the maximum age of the proxy data by nearly 1 ky. CCC-001 was chosen as an example to illustrate the differences in age model construction, though all speleothem samples showed similar discrepancies between the two methods.

Orbital Parameters

The astronomical theory of Milankovitch (1941) allowed for the identification of the major orbital-scale variations in the amount of insolation received at the Earth's surface, which lead to the development of theories of how orbital scale insolation influenced climate variability (Berger 1978; Clark et al. 1999). These cyclic orbital parameters are identified as 1) eccentricity (~100 kyr), where the path of the revolution of the Earth around the Sun deviates from a circle to an ellipsoid, 2) obliquity (~41 kyr), which describes the degree of axial tilt, which varies from 22 – 24º, and 3) precession (~21 kyr), which is the result of the Earth 'wobbling' on its axis as it rotates due to the combined effects of the gravity of the Sun and the Moon on Earth's orbit. Many paleoclimate records have demonstrated clear linkages between orbital parameters and climate changes (Broecker et al. 1968; Hays et al. 1976; Imbrie and Imbrie 1980; Ridgwell et al. 1999).

Imbrie and Imbrie (1980), utilizing spectral analyses of proxy records, observed that a substantial portion of the observed climatic variance over the last 730 kyr is concentrated in narrow bands focused at 19, 23, and 41 kyr, which corresponds to that of the two precessional cycles and obliquity. During this period, the 100-kyr eccentricity cycle influences the amplitude of the precession effect. Ridgwell et al (1999) obtained similar results in their spectral analysis of climate time-series, in that the spectral signature of the 100-kyr cycle does not appear in the late Pleistocene ice volume record, but only "paces" the interglacial-glacial cycles. Therefore, the orbital parameters most likely to influence the CCC record are those of precession and obliquity.

Figure 4-2 shows the change in the orbital parameters throughout the CCC record, where the black curve represents the eccentricity cycle (~100 kyr), the green curve represents the obliquity cycle (41 kyr) and the red curve represents that of precession (19 – 23 kyr) (Laskar et al. 2004).

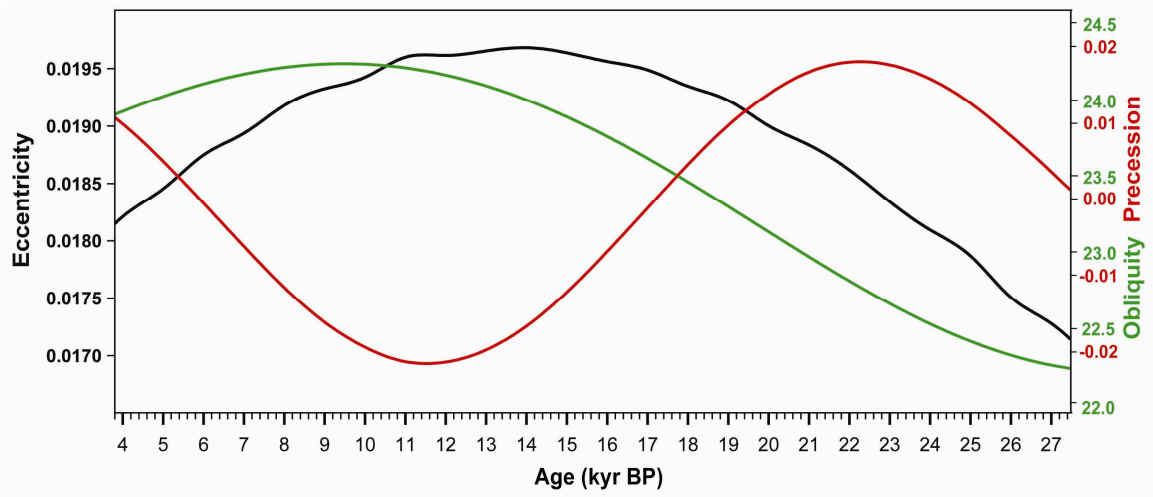

Figure 4-2 Eccentricity, Obliquity, and Precession Cycles for the CCC record duration

The CCC record spans a period in which the obliquity and eccentricity are in similar phases, i.e., they both gradually increase toward maxima at approximately 10 and 14 kyr BP, respectively, where they gradually decline toward the mid-Holocene and the end of the CCC record. In contrast, precession, because of the relatively short duration of the cycle, experiences a full cycle over this time period. Figure 4-3 shows the amount of insolation received at 38ºN for the extent of the CCC record (Laskar et al. 2004). The summer (June 21) and winter (December 21) insolation

curves have been normalized by removing the mean, facilitating a visual comparison.

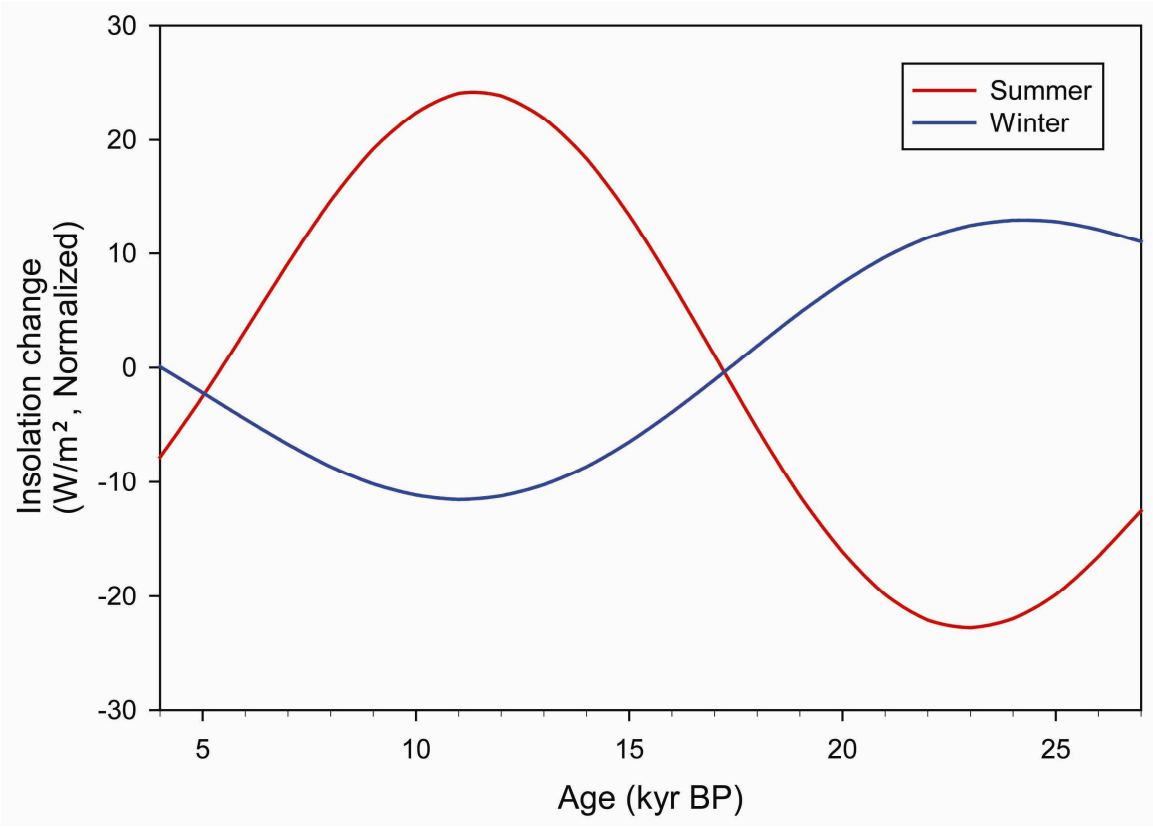

Figure 4-3 Insolation for 38ºN between 4 – 27 kyr BP.

During the CCC record, the seasonal distribution in the amount of insolation changed dramatically. During the LGM (~19-23 kyr BP), summer insolation was at a minimum and winter insolation peaked, roles that would reverse toward the summer insolation maximum and winter minimum around the time of the Younger Dryas (YD) (~11-12 kyr BP).

Comparison of CCC proxy records and growth rates

Due to the complexity of the geochemical proxy evolution, even coeval speleothems obtained from the same cave passage potentially possess a high degree of variability between proxy records. According to Fairchild et al (2006), there is much site-specific behavior and individual stalagmite-forming drips display unique geochemical characteristics as karst aquifers

possess complex flow patterns. The complexity arises due to the presence of a pervasive matrix, fractures, and conduits which can result in multi-modal transit times. In terms of stable isotopic composition, the factor most likely to cause variability between coeval speleothem records is different flow paths through the epikarst (see Figure 1-4), which may result in substantially different water residence times. A variable water residence time introduces variation through three primary mechanisms, 1) increased water-rock interaction time (generally leading to more enriched $\delta^{13}C_{sc}$ and Sr), 2) PCP occurrence (also leading to enrichment of $\delta^{13}C_{sc}$ and Sr), and 3) the lag-times and mixing of event waters.

Similar conclusions were drawn for the incorporation of trace elements in speleothem calcite. Roberts et al (1999), through an intercomparison of Sr/Ca and Mg/Ca values of coeval speleothems, found that variations in samples had a high degree of dissimilarity and the variability was controlled primarily by the existence of two end-member host rocks (calcite and dolomite) at the site, due to the variation in water residence times in the epikarst (Roberts et al. 1999). The high degree of variability between coeval speleothems highlights the importance in utilizing multiple speleothems in paleoclimate reconstruction studies (McDermott 2004).

Figure 4-4 shows the growth rates through time (bounded by the initial and basal age dates) for CCC-001 (black), -003 (purple), and -007 (cyan).

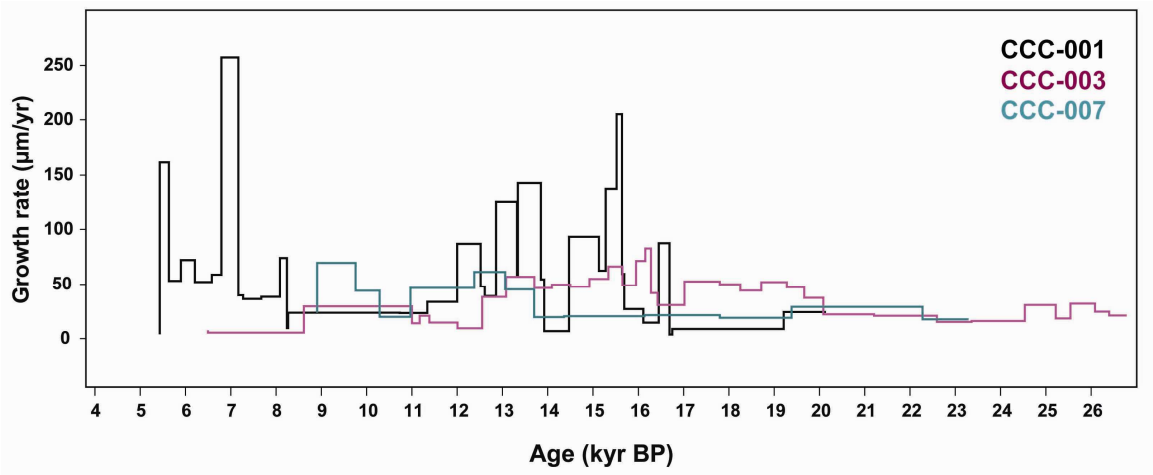

Figure 4-4 Growth rates for CCC-001, -003, and -007 with age models constructed through StalAge algorithm

While a substantial amount of variation between the growth rates of the three study speleothems is apparent, the overall trends indicate relatively low growth rates during periods such as the LGM (19 – 23 kyr BP) and relatively rapid growth rates during periods such as that from 12 – 17 kyr BP. While these growth rate relationships are worth investigating, it should be noted that there are many variables involved in the rates of speleothem deposition and these growth rate shifts should not be misconstrued as reflective only of climatic conditions.

Figure 4-5 shows an intercomparison between the CCC-001, -003, and -007 proxy records. The samples overlap between approximately 8.5 – 21.5 kyr BP. The $\delta^{13}C$ and $\delta^{18}O$ records display high frequency variability, “white noise” (Fairchild et al 2006), but both sets of curves show the same general insolation-tracking trend towards more depleted values through time, though this is much less pronounced for the CCC-003 $\delta^{13}C$ curve, which remains elevated

throughout the mid-Holocene.

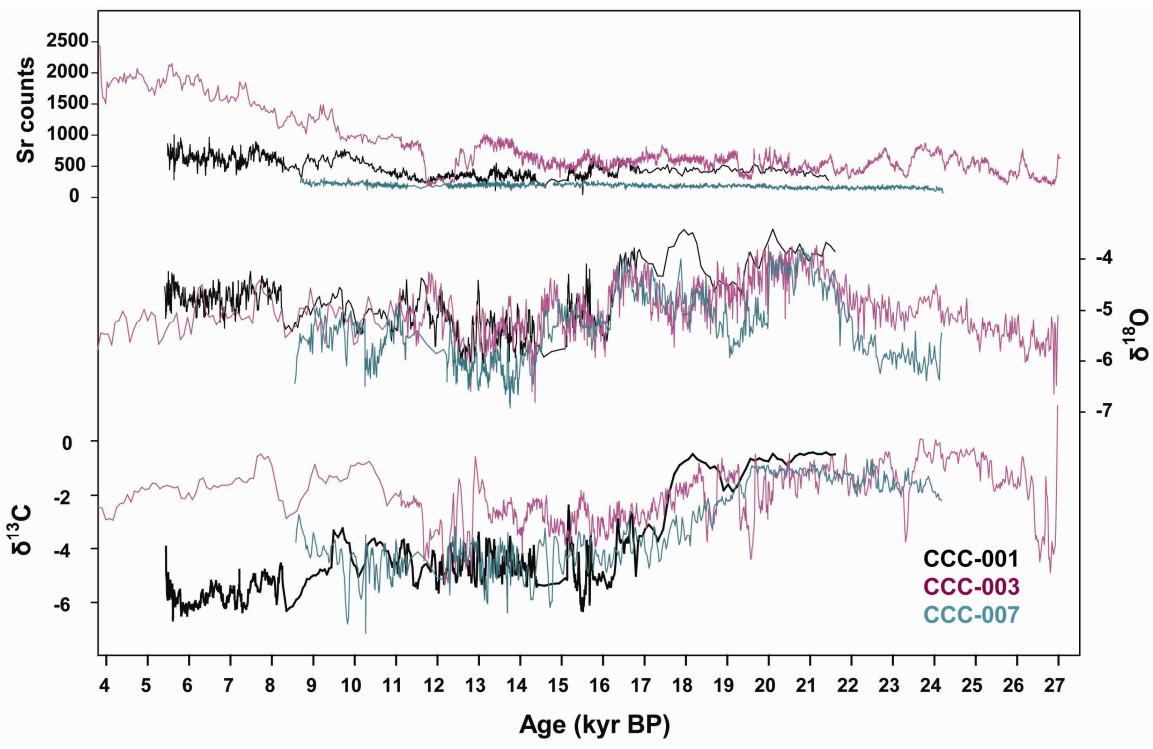

Figure 4-5 Intercomparison between $\delta^{13}C_{sc}$, $\delta^{18}O_{sc}$ and Sr of CCC-001, -003, and -007

One of the most striking variations between proxy curves is the Sr count values of CCC-007. Compared to the other two curves, this Sr record has a much more limited range of values and appears to have relatively consistent Sr values throughout the record. This may be evidence of a longer, more stable flow path from the surface to the cave, where mixing of waters reduces variability in values, for CCC-007 (see the stalagmite labeled 'B' in Figure 1-4 on page 16) in contrast to those of CCC-001 and -003, which appear to have a much wider range of variability which is likely due to more complex flow paths (stalagmites labeled C and D).

Correlation of global climate events with the CCC record

The climatic history of the late Pleistocene to mid-Holocene period is characterized by several large-scale climatic "events". Many such events occurred within the age-range of the

study interval: Dansgaard-Oeschger events 1 & 2; Heinrich events 1 & 2; the “Mystery Interval” (MI); Meltwater Pulse 1A & 1B (Mwp1a-1b); Younger Dryas (YD); “8.2k event” (8kE). Figure 4-6, Figure 4-7, and Figure 4-8 on the following pages show the climatic events within the speleothem records evidenced through changes in proxy values. The ^{230}Th ages are shown along the age axes with associated error brackets. Climatic events are labeled in the figures as follows and are discussed in the following order: LGM: Last Glacial Maximum; MI: Mystery Interval; BA: Bølling/Allerød; H1 and H2: Heinrich Events 1 and 2; M1A and M1B: Meltwater Pulse 1a and Meltwater Pulse 1b; YD: Younger Dryas; 8kE: 8.2 k yr event. Unlabeled pink bars denote possible regional-scale events and are seen most prevalently in the CCC-003 (Figure 4-7) record.

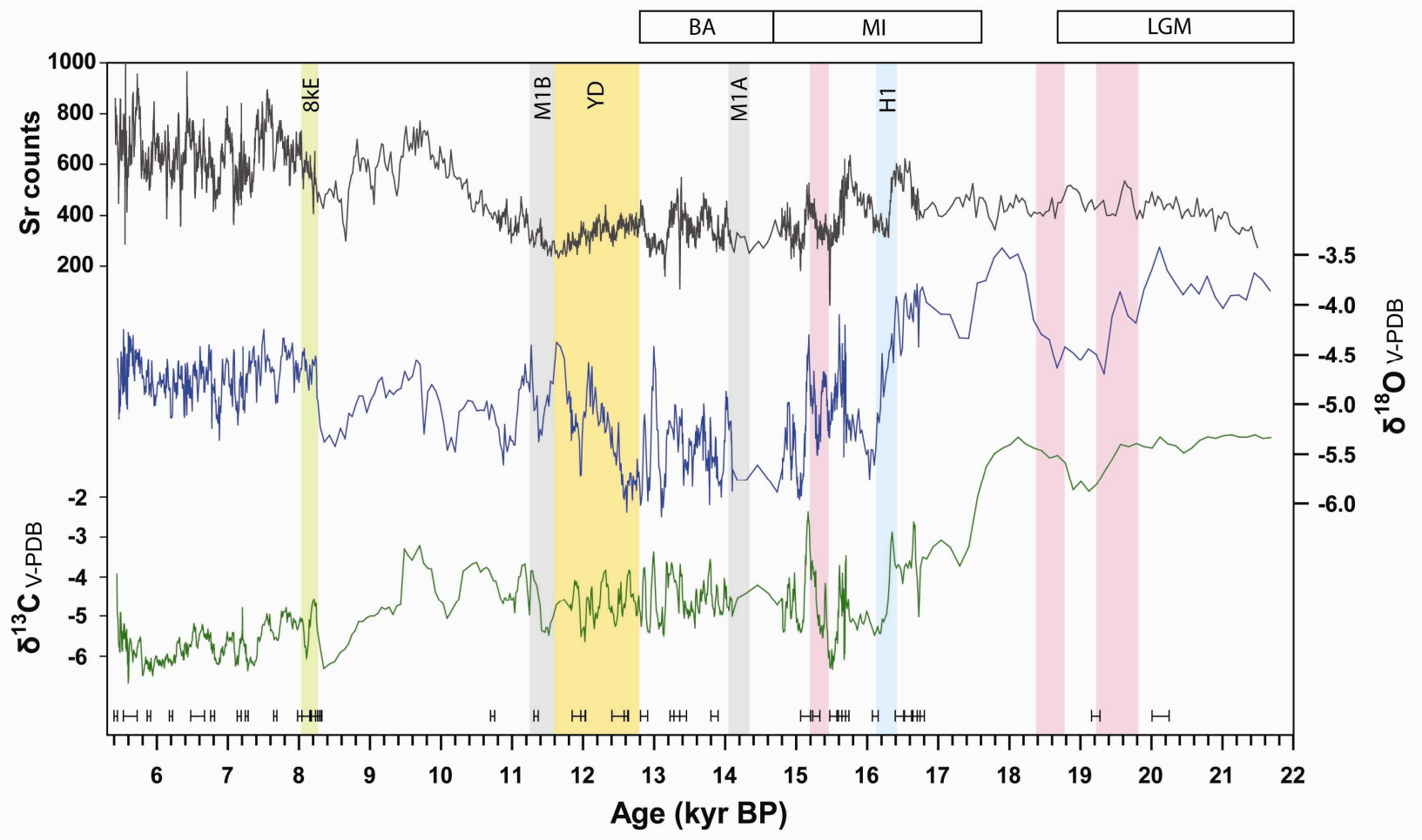

Figure 4-6 CCC-001 Climatic events from $\delta^{13}C_{sc}$, $\delta^{18}O_{sc}$ and Sr

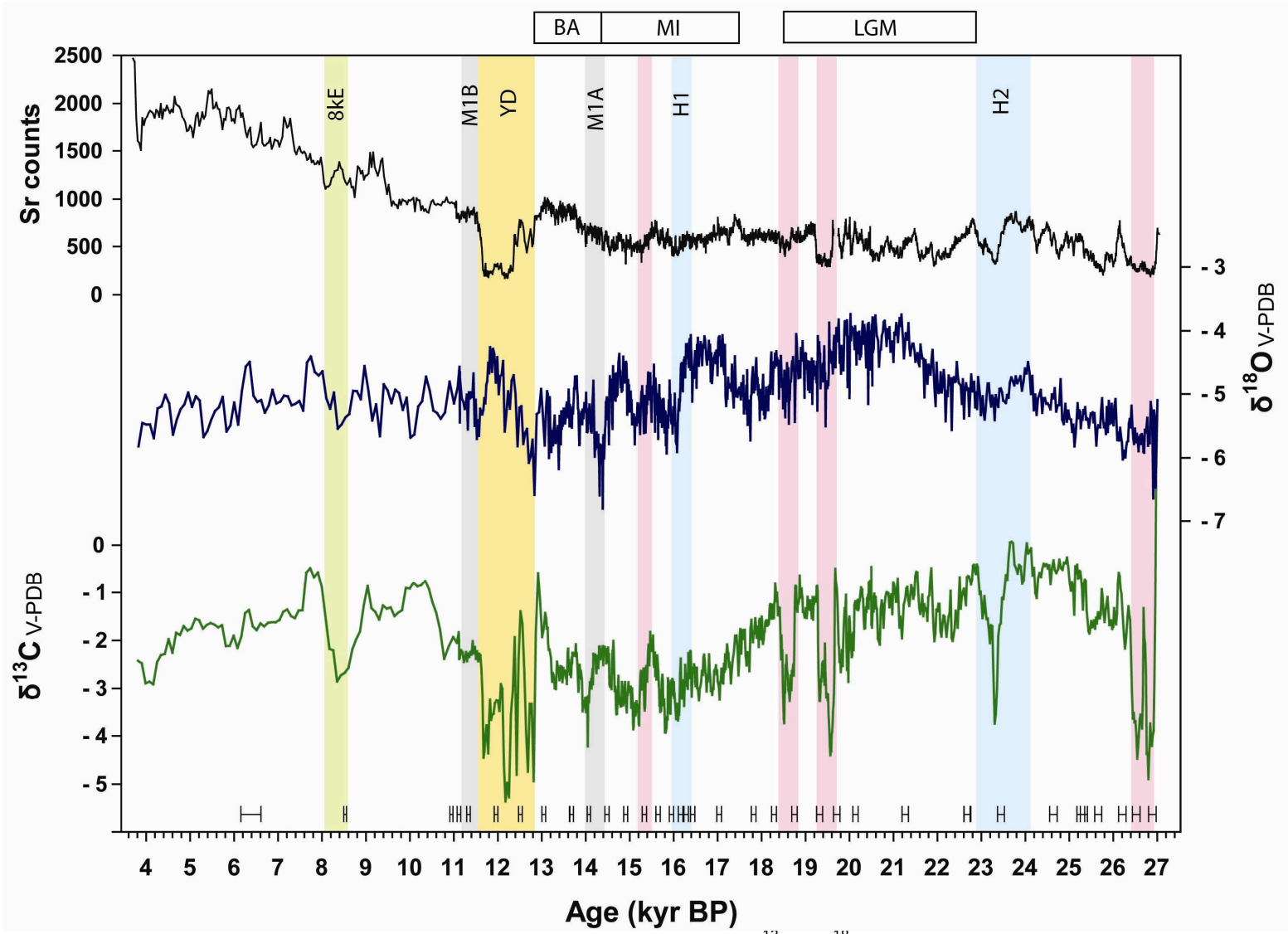

Figure 4-7 CCC-003 Climatic events from $\delta^{13}C_{sc}$, $\delta^{18}O_{sc}$ and Sr

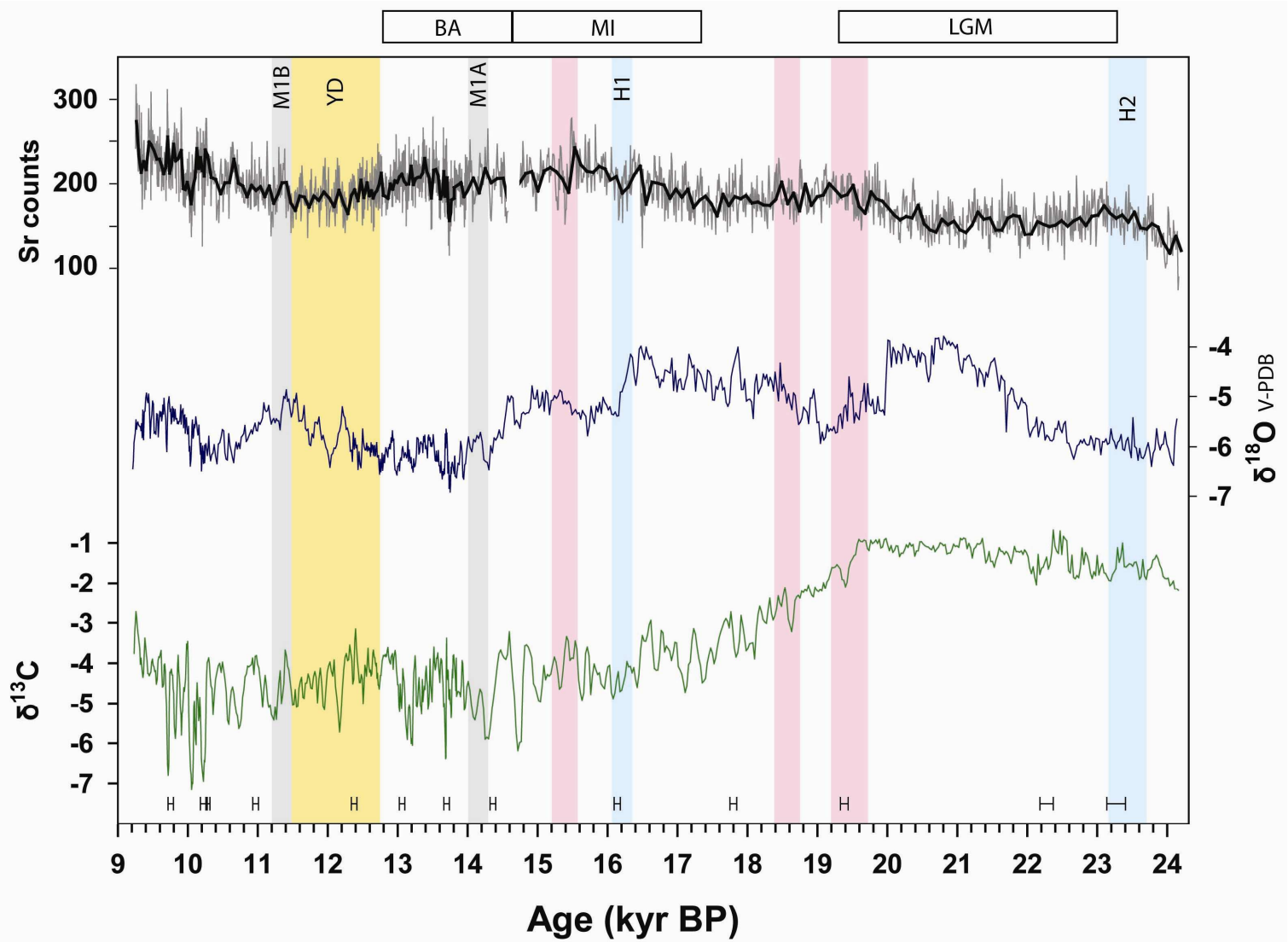

Figure 4-8 CCC-007 Climatic events from $\delta^{13}C_{sc}$, $\delta^{18}O_{sc}$ and Sr

The Last Glacial Maximum

The LGM occurred over several millennia, between approximately 19 - 23 kyr BP. The various ice sheets around the world experienced individual maximum extents at different times. The closest ice sheet to the study area and the largest of the Northern Hemisphere, the LIS, is thought to have reached its maximum extent prior to the LGM and persisted until approximately 17 kyr BP (Clark and Mix 2002). This period is characterized by low sea levels, pervasive continental ice sheets, and high degrees of aridity. In the CCC record, the LGM is evidenced through elevated $\delta^{18}O_{sc}$ and $\delta^{13}C_{sc}$ values. The enriched $\delta^{18}O_{sc}$ values are primarily the result of a change in source values (oceans become more enriched in the heavy isotope in glacial periods due to the sequestration of a greater proportion of the lighter isotope into ice sheets) and atmospheric and temperature effects on isotopic evolution. For $\delta^{13}C_{sc}$ in the CCC record, the relatively more enriched values are likely the result of less moisture availability and decreased temperatures, which both serve to lessen the amount of soil-respired CO_2 production. During a period of decreased moisture availability, the DIC is more representative of the isotopic signature of the carbonate host rock (~0‰) and produces elevated values in speleothems.

The Mystery Interval

The “Mystery Interval” occurred between 17.5 – 14.5 and is referred as such because of the enigmatic nature of much of the proxy records for this period. Much research has been conducted in order to better constrain the timing and the climatic changes (Broecker and Barker 2007; Broecker et al. 2009; Broecker and Putnam 2012; Williams et al. 2012). This period is characterized as an interruption of the deglacial warming, and denotes a period of global hydrologic reorganization induced by large volumes of water returning to the oceans from ice sheets (Broecker and Putnam 2012). Williams et al (2012), through a study of paired Mg/Ca and $\delta^{18}O$ of foraminifera from Gulf of Mexico sediment cores, determined that there were three major LIS melting episodes from 17.5 – 12.9 kyr BP. These data indicate not a single routing of

meltwater influx event, but rather that the summer melting of Northern Hemisphere ice sheets may have been an important mechanism for a reorganization of global hydrologic systems, as there is evidence of enhanced sea-ice formation, extremely cold winter temperatures, and enhanced seasonality during this period.

The Bølling/Allerød

The Bølling/Allerød interstadial, which occurred from approximately 14.5 – 12.9 kyr BP, is characterized as a warm, moist period (Alley and Clark 1999). In the CCC record, this period is characterized primarily by high speleothem growth rates, and generally lower $\delta^{18}O_{sc}$ values, but exhibits many abrupt oscillations with a high degree of variability between the individual speleothem records.

Dansgaard-Oeschger Events, Heinrich Events, and Meltwater Pulses

Dansgaard-Oeschger (D-O) cycles, which occurred during the late Pleistocene, are abrupt periods of warming (to near interglacial conditions) in a matter of a few decades, which are subsequently followed by a gradual return to glacial conditions. Of the 25 recognized D-O events, the first two (DO-1 and -2) occurred within the study interval, at approximately 14.7 kya BP and 23 kya BP, respectively (Schulz, 2002). Analogous to DO events during the Holocene are what are known as Bond events (Bond, 1999).

Heinrich events (H), which are North Atlantic ice-rafting events identified from ice-rafted debris within sediment cores, are thought to represent times of rapid calving and melting of the ice sheets in which large volumes of freshwater were rapidly introduced to the site of deep-water formation (Bond et al., 1992; Broecker, 1994; Bard et al., 2000). Of the six H (H1-H6) identified, H1 and H2 occur within the study interval. There have been various dates proposed for these events (Vidal et al. 1999; Hemming 2004). While Vidal et al. (1999) has assigned ages of 14 and 22 kya for H1 and H2, respectively, Hemming (2004) has proposed alternate ages of 16.8 and 24

kya. H1 and 2 in the CCC record occur between approximately 16 – 16.4 and 23 – 24 kyr BP, respectively, thereby supporting the Hemming (2004) event dates. For CCC-001, the H1 is seen as an abrupt change in all proxy values; Sr dropped from ~600 to 400 counts and both isotopes decreased by 2‰. For CCC-003, H1 is only seen to affect $\delta^{18}O_{sc}$ values, which dropped ~1.5‰. There was a small decrease in Sr for CCC-007 but no notable variations in the other proxy records. For H2, only CCC-003 and 007 were actively growing. For the former, $\delta^{18}O_{sc}$ values decreased by 0.5‰, but the most notable changes are an abrupt 4‰ decrease in $\delta^{13}C_{sc}$ values concurrent with a decrease in Sr counts from ~800 to 400. These decreases represent an abrupt increase in moisture availability during the H2 In contrast, there is little variation in the proxy values for this period for CCC-007. The Younger Dryas event (YD) is categorized by some researchers as a Heinrich event, and is occasionally denoted 'H0' (Broecker 1994) but for the purposes of this study, the YD is considered separately.

In addition to the two Heinrich events within the study interval are two separate abrupt increases in sea level that occurred between 14.3 – 14.0 kya BP and 11.5 – 11.2 kya BP, known as Meltwater Pulse 1a and 1b (Mwp-1a and 1b), respectively (Liu and Milliman 2004; Carlson 2009). Like the Heinrich events mentioned previously, the CCC proxy record exhibits a variety of responses. For Mwp1a, the slow growth rate of CCC-001 inhibits for the observation of major shifts during this period. For CCC-003, however, there is an abrupt 2 ‰ decrease and subsequent increase in $\delta^{18}O_{sc}$ values concurrent with a ~2‰ decrease in $\delta^{13}C_{sc}$ values (with consistent Sr values). CCC-007 displays little variation in proxy values throughout this event. For Mwp1b, CCC-001 exhibits a substantial 1.5‰ decrease in $\delta^{18}O_{sc}$ values concurrent with a rapid 1‰ increase in $\delta^{13}C_{sc}$ values. The CCC-003 record is largely invariant during this episode. The CCC-007 record exhibits a slight Sr increase concurrent with a 1‰ and 1.5‰ decrease in $\delta^{13}C_{sc}$ and $\delta^{18}O_{sc}$ values, respectively. The occurrence of MWP-1a marks the beginning of the warm B-A, which lasted until approximately 12.8 kya BP.

The Younger Dryas Event

The warming trend observed throughout the B-A was abruptly terminated by a rapid return to glacial conditions in the North Atlantic, in an event known as the Younger Dryas (YD) stadial, which occurred between approximately 12.8 – 11.5 kya BP. This event has been extensively studied, as it is the most recent occurrence of abrupt climate change within the geologic record and is evidenced through (often abrupt) proxy changes in various records (Dansgaard et al. 1989; Denton and Hendy 1994; Manabe and Stouffer 1997; Severinghaus et al. 1998; Broecker 1998; 2006; Alley 2000; McManus et al. 2004; Carlson 2010). Four hypotheses have been proposed to explain the cause of this rapid return to glacial conditions: 1) the Meltwater Hypothesis, which states that a redirection of Lake Agassiz outflow from the Gulf of Mexico to an eastern route thereby causing a reduction in Atlantic Meridional Overturning Circulation (AMOC) at the site of North Atlantic Deep Water (NADW) formation and lessened heat transport to the North Atlantic (Broecker 2006); 2) alternative freshwater input of Arctic sea ice to the North Atlantic as AMOC disruption (Bradley and England 2008); 3) changes in atmospheric circulation as YD trigger (Brauer et al. 2008); 4) an extraterrestrial impact evidenced by the occurrence of iridium and nanodiamonds in the Younger Dryas boundary sediment layer (Kennett et al. 2009). Of these hypotheses, the interruption of AMOC at the site of NADW formation has the most evidence in support. Regardless of the causal mechanisms for the YD, this period is unprecedented in terms of the rapidity and magnitude with which climate changes occurred.

Alley (2000) presented Greenland Ice Core records (GISP2) that provide evidence for YD timing and magnitude as seen in the isotopic, chemical, detrital, layer thickness, and gas isotopic ice core records. The YD occurred in a series of abrupt steps between the onset and termination. The onset of the YD involved the reduction or southward shift of North Atlantic Deep Water (NADW) formation, reduction in African and Asian monsoon strength, cooling centered on the North Atlantic, and warming centered on the South Atlantic and Antarctica. Dust accumulation within GISP2 serves as a proxy for wind activity, and for the YD, winds were likely 70% stronger

than the centuries that followed, approximately half that of the late Holocene (Alley 2000). Severinghaus et al. (1998) calculated and estimated temperatures during this time to be approximately 15^0C colder than modern, with half the change occurring in a single step and the other half in a ramp following the YD, though Cuffey et al. (1995) postulated that the development of temperature inversions over ice sheets likely caused surface temperature changes to be larger than the temperature averaged through the troposphere and that the free-tropospheric changes may have been 2/3 that of the surface temperature changes. Atmospheric CO_2 concentrations were not significantly affected, but methane concentrations were strongly reduced during the YD, suggesting that near-synchronous climate changes affected large regions, as tropical and subtropical wetlands are the primary sources of atmospheric methane. The YD termination is characterized in GISP2 records (Alley 2000) by the doubling of snow accumulation, a large drop in wind strength, a large increase in atmospheric methane, and a 5 – 10^0C warming (Severinghaus 1998). The termination of the YD is believed to have occurred in three distinct steps, each lasting approximately 5 years spanning a 40 year period, as evidenced from high-resolution examination of GISP2 and GRIP ice cores (Taylor et al. 1997).

Younger Dryas in the CCC records

The CCC-003 record exhibits the most variable proxy record for the YD, as CCC-001 and -007 proxies exhibit either a lessened proxy response or the growth rate slows during this period. Figure 4-9 shows the CCC-003 proxy record for the YD stadial. The onset of the YD in the CCC

record is indicated by a red line at approximately 12.9 kyr BP.

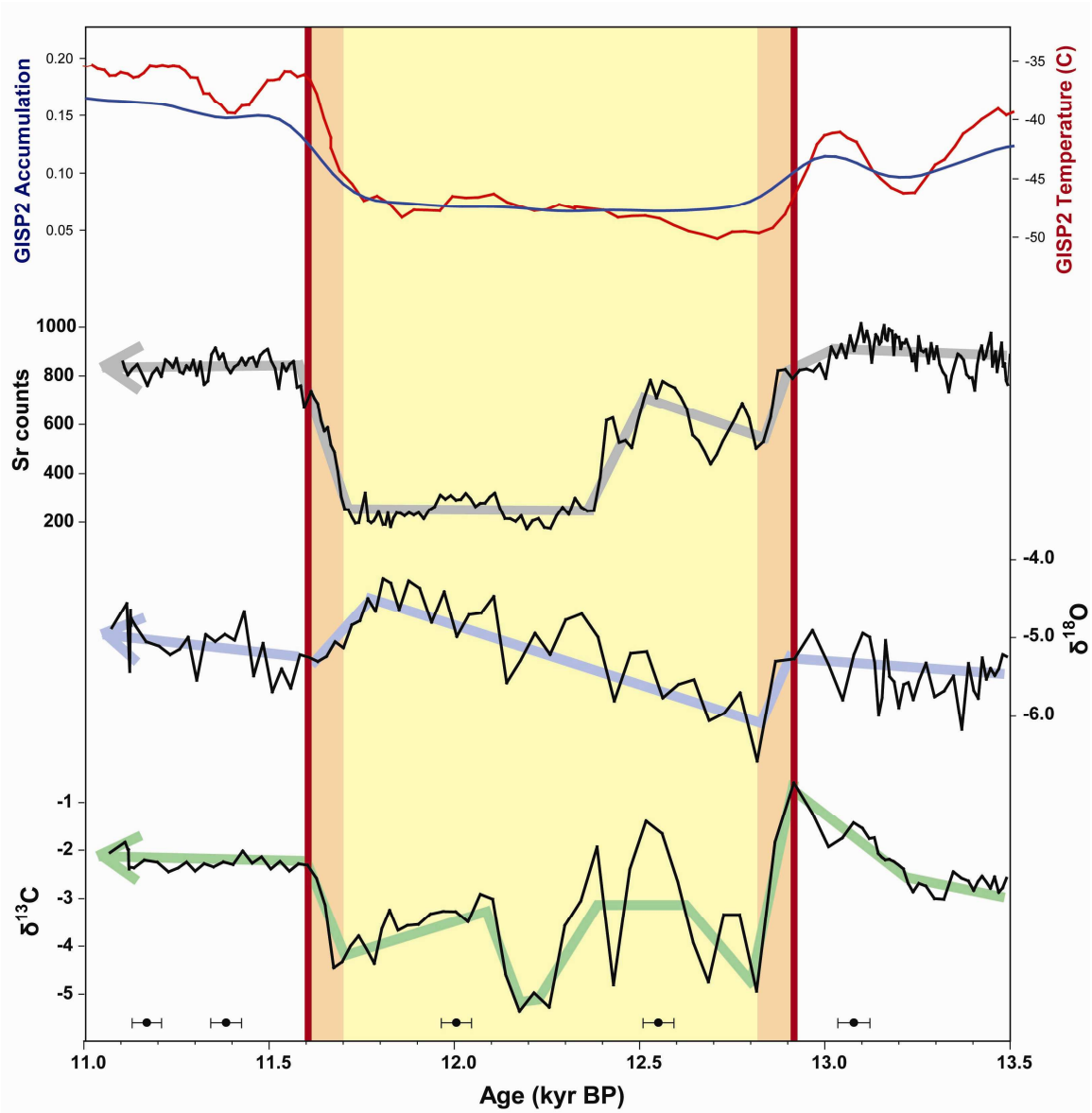

Figure 4-9 CCC-003 Younger Dryas event with GISP2 data from Alley (2000). Colored arrows in the background are provided to allow the visualization of the climatic trends.

The onset of the YD lasts approximately 100 years and is evidenced by an abrupt change in proxy values, most notably for $\delta^{13}C_{sc}$, which experiences a depletion of approximately 5‰. Throughout the middle of the YD episode, the proxies exhibit high-frequency variability during this

period. GISP2 temperature and accumulation data from Alley (2000) have been included, which illustrate that the YD record preserved in CCC-003 is congruent with climatic data from North Atlantic ice cores.

The proxy responses in the CCC-003 record indicate an overall *wetter* YD, which is anomalous with a climatic event that has been characterized as “cold and dry” (at least for the North Atlantic region). In speleothem records, Sr concentration (and Sr/Ca) are traditionally interpreted as indicators of moisture availability (see Trace Element Geochemistry on page 21), where elevated values are indicative of drier conditions. This conventional interpretation, when applied to the CCC-003 record, suggests more precipitation during the YD, as the ‘baseline’ Sr count values of approximately 800 counts first drops stepwise to 600 and ultimately to 200 counts for the remainder of the YD. At 11.7 kyr BP, Sr counts abruptly return to the previous baseline of ~800 counts. The $\delta^{13}C_{sc}$ values display the most abrupt change, with a rise to 0.5‰ at the onset of the event, followed by an abrupt decrease by 4.5‰, to values of -5‰ by 11.8 kyr BP. The $\delta^{13}C_{sc}$ during the YD event display extraordinarily variable values, which suggests a dynamic vegetation response to hydrological parameters. The $\delta^{18}O_{sc}$ record displays less overall variation that Sr counts and $\delta^{13}C_{sc}$ values, with a range of 1.5‰ for the YD event. These values abruptly decrease by ~1‰, from -5 to -6‰ from 12.9 – 12.8 kyr BP and gradually increase to -4.7 by 11.8 kyr BP. These values then abruptly decrease and return to the pre-YD baseline of approximately -5.3‰.

Younger Dryas Event in North American continental paleoarchives

There have been numerous studies utilizing continental paleoarchives such as pollen and plant macrofossils from lake and wetland sediment cores from North America that span the YD (Delcourt and Delcourt 1984; Peteet et al. 1993; 1995; Kneller and Peteet 1999; Yu and Wright Jr 2001; Kirby et al. 2002; Shuman et al. 2002; Grimm et al. 2006; Hou et al. 2007; Yu 2007;

Haynes 2008; Meltzer and Holliday 2010). This section will briefly discuss these previous studies in three general categories: Pollen, Isotopes, and Behemic acid.

Delcourt and Delcourt (1984) constructed paleovegetation sequences based on fossil pollen data obtained from 8 lacustrine sites in southeastern North America, including one (Hack Pond, VA) located approximately 50 km from the study site. Figure 4-10 (modified from Delcourt and Delcourt 1984) shows the pollen profiles for the Hack Pond site.

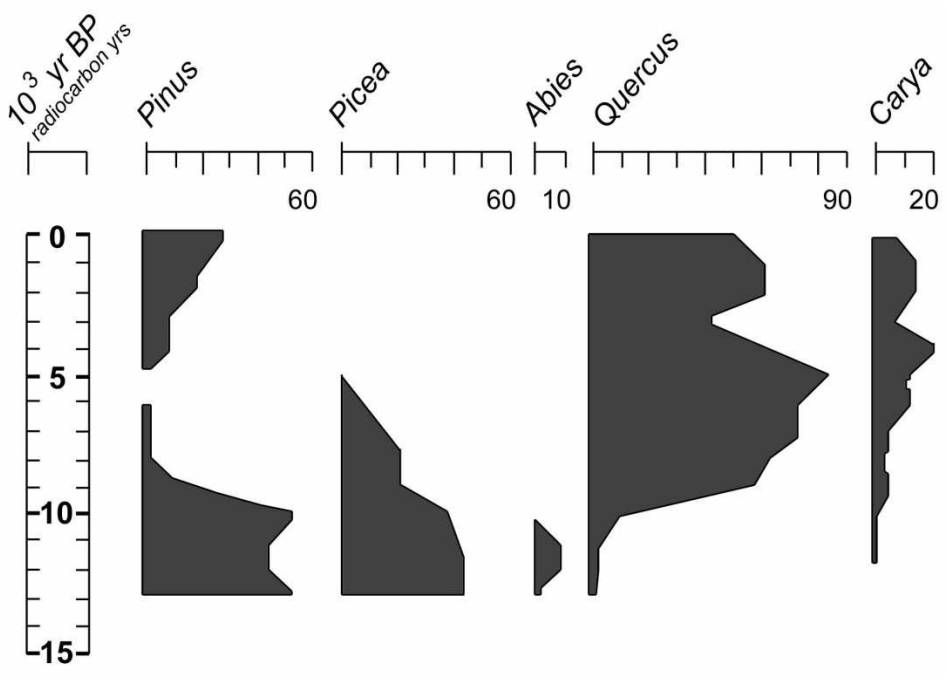

Figure 4-10 Pollen Assemblage Profile for Hack Pond, VA

The uncalibrated radiocarbon ages utilized for this time scale necessitate a conversion to years BP, which result in *radiocarbon* ages of approximately 10 – 11 k yr as concurrent with the ^{230}Th age-dated YD interval of 11.6 – 12.9 kyr BP of the CCC record. One hundred fossil pollen site datasets were utilized in the identification of key ecotone areas in order infer the mean positions of air mass boundaries. Figure 4-11 shows these air mass boundary maps (Delcourt and Delcourt 1984).

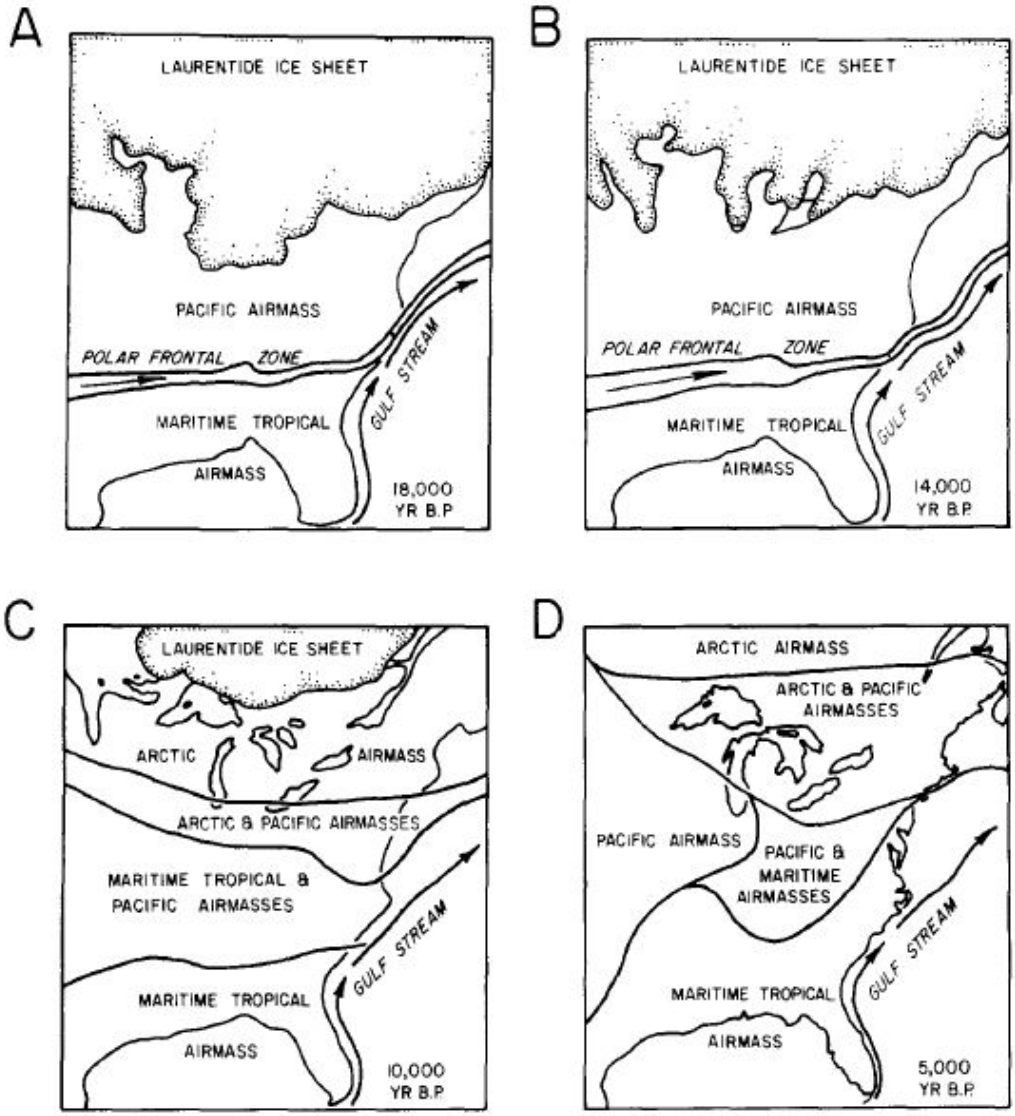

Figure 4-11 Air Mass Boundary maps for eastern North America from late Pleistocene to mid-Holocene

Similar abrupt changes in plant populations are noted in Peteet (1993) and Kneller and Peteet (1999), but chronological uncertainties in the latter make YD timing difficult. Grimm et al (2006), utilizing fossil pollen from Lake Tulane, FL, interpreted zones of increased *Pinus* as indicators of increased temperatures and summer precipitation throughout the YD. The authors proposed that a diminution in thermohaline circulation for Heinrich Events and the YD resulted in

reduced northward heat transfer and a retainment of warmth in the Gulf of Mexico. Shuman et al. (2002) established evidence for a dramatic shift (>300 km in ≤100 years) in vegetation populations at the onset and termination of the YD in eastern North America. Figure 4-12 shows the paleovegetation maps of Shuman et al (2002) which illustrate the rapidity and geographic extent of the plant population changes that occurred over this time.

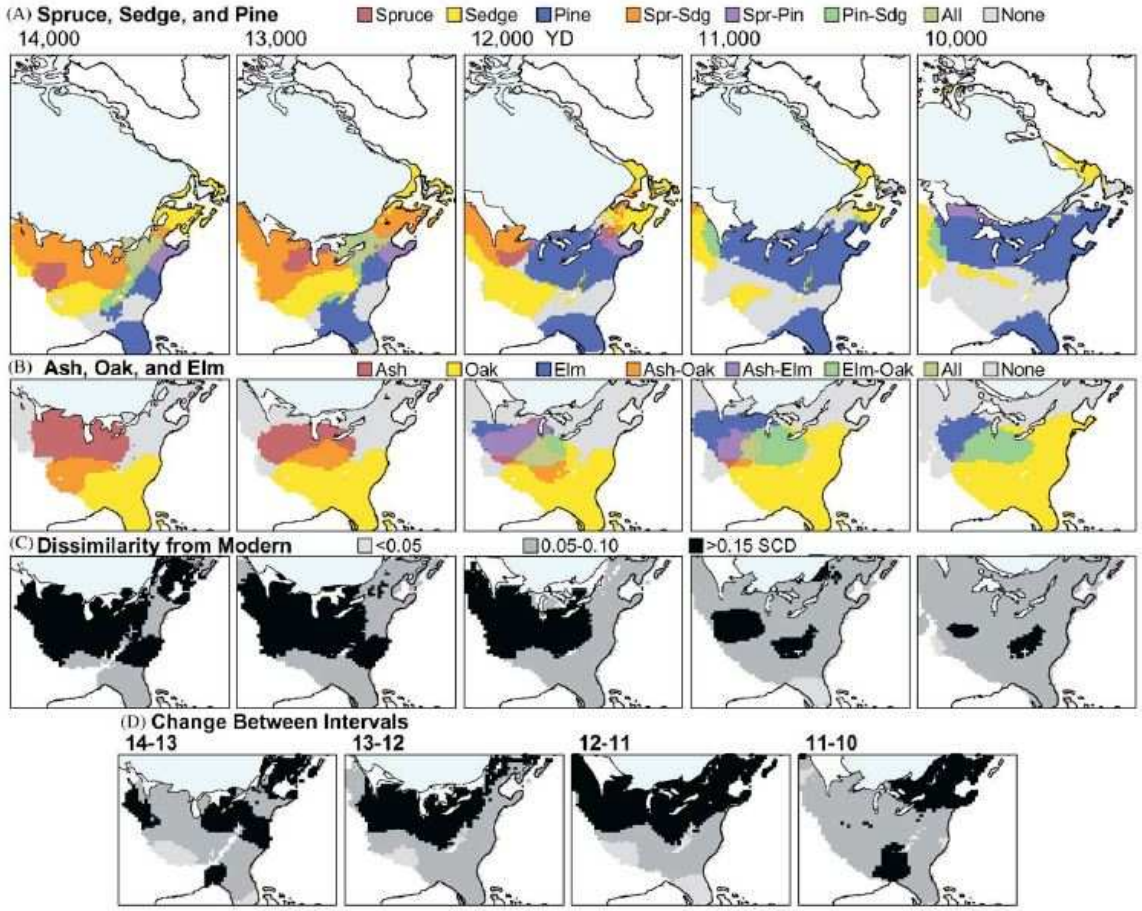

Figure 4-12 Paleovegetation Maps for eastern North America from the late Pleistocene to early Holocene

In addition to fossil pollen and plant macrofossil evidence for paleoclimate changes during the YD, $\delta^{18}O_{calcite}$ from lacustrine sediment cores also shows abrupt changes. Kirby et al (2002) noted a 1‰ increase in $\delta^{18}O_{calcite}$ at the YD termination, inferring a change in polar vortex

size, storm tracks, and $\delta^{18}O_{precipitation}$. Yu and Wright (2001), in an examination of Crawford Lake, NY $\delta^{18}O_{calcite}$, concluded that the effects of the YD are highly regional and that the geographic extent and magnitude of deglacial climate oscillations across North America are an expression of widespread climatic changes rather than local events (e.g., “lake effect”). In a later study, Yu (2007), utilizing isotopic and pollen results from White Lake, NJ, inferred a coupling of climate and vegetation due to the synchronicity with which both proxies changed. A 3‰ decrease in $\delta^{18}O_{calcite}$ was noted alongside rapid pollen distribution changes.

Isotope-based proxies for paleoclimate changes have also been shown to have responded to the YD in North America. Hou et al (2007) utilized D/H ratios of behemic acid (δD_{BA}) in a sediment core from Blood Pond, MA, which was shown to track mean annual atmospheric temperature variations. The authors concluded that there was more climatic variability in the early Holocene for North America than for Greenland due to the proximity of the retreating-LIS and freshwater outbursts.

Finally, Meltzer and Holliday (2010), in an effort to establish the magnitude of North American paleoclimate changes during the YD concluded that the effects of the YD were highly variable across North America. There is evidence for a regional climatic regime in the southeastern U.S. for more precipitation and warmer (or less decrease) in temperatures during the YD. Though the YD is characterized as a “sudden plunge back into glacial conditions” from ice cores from the North Atlantic region, the response of the continental North American climate was highly variable due to the effects of multiple teleconnections and atmospheric reorganization.

The 8.2 k Event

Though not as severe as the YD, the ‘8.2 kyr event’ has been described as a brief period of large-scale cooling and drying that interrupted HCO warming (Alley et al. 1997; Lachniet et al. 2004; Kobashi et al. 2007). According to Alley (1997), who examined $\delta^{18}O$ data from the GISP2 ice core record, the 8.2 kyr event occurred between 8 – 8.4 kya BP. Though it is only half of the

severity of the temperature decrease experienced during the YD, this event is described as the most prominent Holocene climatic event. Lachniet et al. (2004) produced a Costa Rica speleothem record of high $\delta^{18}O$ values from 8 – 8.3 yr BP that was interpreted as indicating reduced rainfall via a weakened monsoon. Kobashi et al. (2007), using CH_4 concentrations in GISP2 ice cores, calculated a temperature decrease in Greenland of 3.3±1.1 ºC in less than 20 years and a 15% decline in CH_4 concentrations over 40 years during the 150-year duration of the 8.2 k event. For the CCC record, only CCC-001 and -003 were being deposited over this period. For CCC-001, a 1‰ increase in $\delta^{18}O_{sc}$ is accompanied by a 1.5‰ rapid rise and fall in $\delta^{13}C_{sc}$ values. Sr count values also increase slightly during this time, as does the growth rate, which increases abruptly for the period of the 8.2 k event (see Figure 4-4 on page 63). CCC-003, however, has a relatively low growth rate throughout this section, but does display a 1‰ increase in $\delta^{18}O_{sc}$ values and a 1‰ increase in $\delta^{13}C_{sc}$. Sr counts increase by approximately 500 counts and quickly return to previous values over this time period.

Comparison of the CCC-003 record with global paleoarchives

Of the three CCC speleothems, CCC-003 displays the greatest sensitivity during episodes of documented climate change. Because of the exceptional age constraints for this speleothem, it is compared to other global paleoarchives of the late Pleistocene to mid-Holocene. Figure 4-13 shows a comparison between the CCC-003 $\delta^{13}C$, $\delta^{18}O$, Sr counts, (from bottom to top) Cariaco Basin marine sediment core record (grey scale) (Hughen et al. 1996), Chinese Hulu Cave speleothem composite $\delta^{18}O$ record for speleothems PD and MSD, Chinese Dongge Cave $\delta^{18}O$ record for speleothem D4 (Dykoski et al. 2005), N-GRIP GICC05 20-yr $\delta^{18}O$ (VSMOW) (Rasmussen et al. 2008), and the Sofular Cave, Turkey, $\delta^{18}O$ record for speleothem SO-1 (Fleitmann et al. 2009).

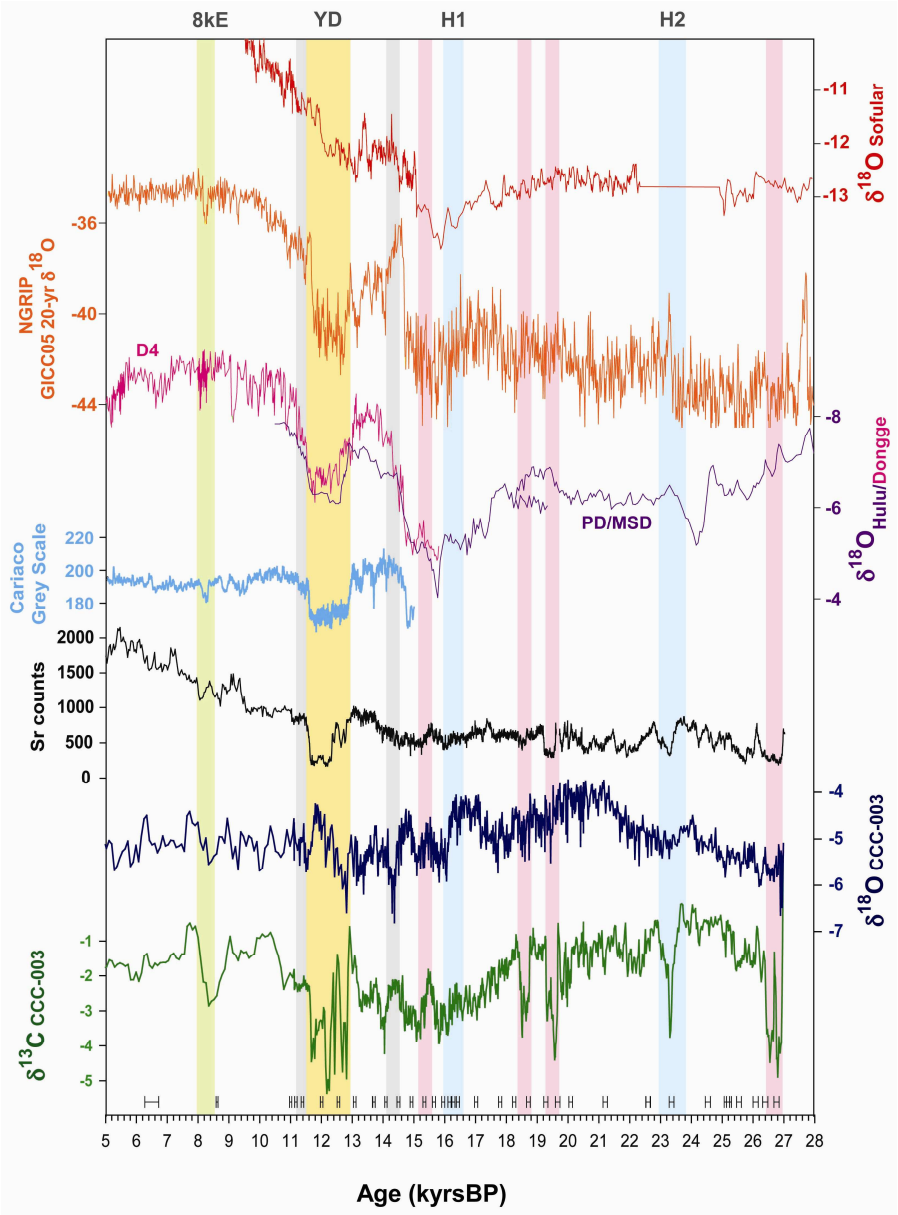

Figure 4-13 comparison between the CCC-003 $\delta^{13}C$, $\delta^{18}O$, Sr counts, (from bottom to top) Cariaco Basin marine sediment core record (grey scale) (Hughen et al. 1996), Chinese Hulu Cave speleothem composite $\delta^{18}O$ record for speleothems PD and MSD, Chinese Dongge Cave $\delta^{18}O$ record for speleothem D4 (Dykoski et al. 2005), N-GRIP GICC05 20-yr $\delta^{18}O$ (VSMOW) (Rasmussen et al. 2008), and the Sofular Cave, Turkey, $\delta^{18}O$ record for speleothem SO-1 (Fleitmann et al. 2009).

The Cariaco Basin marine sediment core described in Hughen et al. (1996) of the relative reflectivity ("grey scale") serves as a record of upwelling and trade wind strength in the tropical Atlantic. These cores contain annual varve couplets of light-colored plankton-rich layers and relatively darker-colored terrigenous layers, which represent seasonal cycles of winter upwelling and increased rainfall in the summer. The seasonal cycle is the result of the annual migration of the Intertropical Convergence Zone (ITCZ). Primary productivity was shown to increase at times of cold in the North Atlantic because of the strengthening of the wind-controlled upwelling strength. The plotted results of the Cariaco Basin Grey Scale record show an abrupt and substantial decrease in values during the YD which has been interpreted as indicating a change in the strength of upwelling as a result of greater trade wind strength. This record also shows evidence of the 8.2 k event, as an abrupt (and brief) decrease in grey scale, with approximately half the magnitude of the YD. The timing of the 8.2 k event in the Cariaco record is consistent with that of CCC-001, though the relatively low speleothem growth rate disallows for an comparison of the same resolution in proxy values.

The speleothem records from Hulu Cave (Wang et al. 2001) and Dongge Cave (Dykoski et al. 2005) from eastern and southern China, respectively, reveal synchronous changes in $\delta^{18}O$ values during the YD. In eastern Asia, the summer monsoon contributes ~80% of the annual precipitation amounts. Long-term changes in $\delta^{18}O$ values were shown to be governed by insolation and variation in the seasonal distribution of precipitation. Smaller-scale variations in the $\delta^{18}O$ values were demonstrated to reflect the intensity of the EAM. The timing of the abrupt increase in $\delta^{18}O$ values in the Hulu and Dongge Cave records indicates an increase in EAM strength, which is a result of atmospheric and oceanic circulation changes associated with the YD. Of these speleothems, only speleothem D4 from Dongge Cave grew over the course of the 8.2 k event, during which the growth rate of D4 increased abruptly by ten-fold. The isotopic values during this period appear to have a high degree of variability, but because of the high growth rate, there is a lot of 'noise' in this section of the record.

The North Greenland Ice core Project (NGRIP) GICC05 20-yr $\delta^{18}O$ values from Rasmussen et al. (2008) are plotted to compare the timing of the YD. Further information about the proxies and paleoclimatic implications of ice core records can be found in the discussion of GISP2 on page 68. The $\delta^{18}O$ record demonstrates climatic changes consistent with the H2, meltwater pulses (gray bars), YD, and the 8.2 k event. The most significant shift in isotopic values, from approximately -43 to -36‰ is consistent with the timing of Mwp1b at 14.5 kyr BP. The 8.2 k event decrease of approximately 2‰ is substantially less than the 5‰ decrease observed during the YD.

Speleothem records from Sofular, Turkey (Fleitmann et al. 2009) also record $\delta^{18}O$ changes over this time period. A hiatus in the speleothem record is indicated by a horizontal line from ~22.5 – 25 kyr BP. Due to the use of linear interpolation between age dates, the values in the age model might be slightly offset. If the $\delta^{18}O$ time series was shifted to the left by 500 years, the abrupt 1‰ increase at 15 kyr BP would coincide with mwp1b and the decrease and increase of 1‰ at 13.5 and 12 kyr BP would be consistent with the onset and termination of the YD.

Correlation of the CCC record with GOM records

The Mississippi Meltwater record of Aharon (2003) based on $\delta^{18}O$ g. ruber (white) from GOM sediment cores documents the influx of meltwater pulses. Aharon (2006) describes five exceptionally large outbursts of floodwaters in the GOM based on these data and determines 5 main events: Meltwater Floods (MWF) (1-5) that occurred between 8.9 – 16 ka BP. Figure 4-14 shows the CCC-003 record compared to GOM records of SST (Aharon 2006). Increases in GOM SST are synchronous with the depletion of CCC-003 $\delta^{18}O$ after the LGM. MWF-2, -3, and -4 are synchronous with $\delta^{18}O$ enrichments while MWF-1 is synchronous with multi-millenial depletion in $\delta^{13}C$.

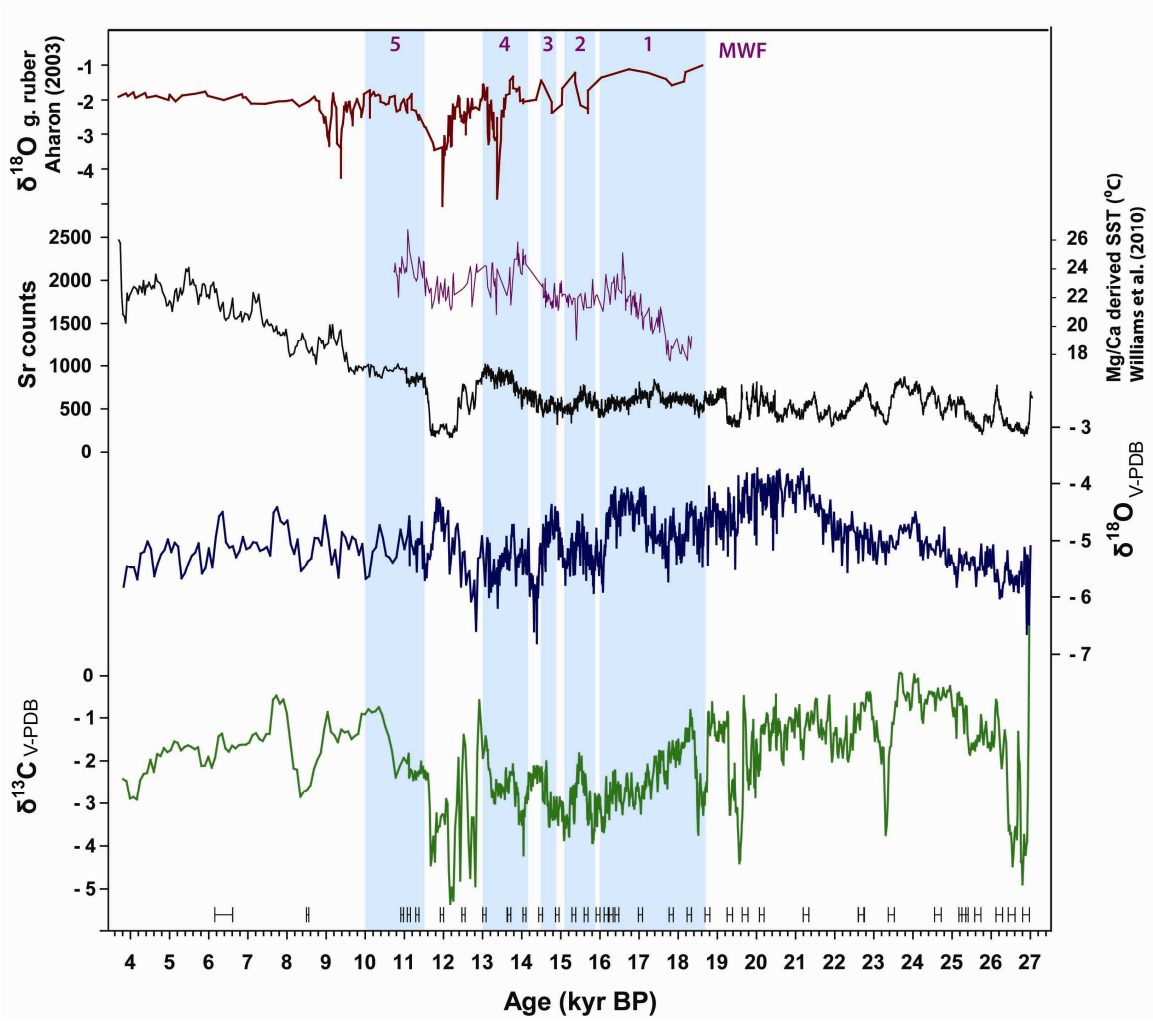

Figure 4-14 CCC-003 record compared to GOM archives

Regional climate changes for east-central North America

In addition to globally-synchronous climate changes, the CCC-003 record also displays possible regional-scale climatic events. The pink bars in Figure 4-13 on page 81 highlight the time periods of four main regional climatic events at 15.2 – 15.5, 18.4 – 18.8, 19.2 – 19.7, and 26.6 – 27 kyr BP. These time periods will be referenced as R1 – R4, labeled from the most recent to most remote. In the CCC-003 proxy time series, R4, which lasts approximately 500 years, is demonstrated by $\delta^{13}C$ values oscillating significantly within a range of 4‰ (-1‰ to -5‰), $\delta^{18}O$

values decreasing and subsequently increasing by 0.5‰, and Sr values decreasing by ~500 counts. This isotopic behavior is comparable to that of the YD, mentioned previously, and indicates an increase in available moisture to the region. A slight decrease in $\delta^{18}O$ values in the Hulu Cave record is also consistent with R4, though little variability is noted for the other global paleoarchives during this period. R2 and R3, which are separated in time by approximately 1 kyr, have similar isotopic responses in the CCC-003 $\delta^{13}C$ values, but dissimilar behaviors in the Sr counts. R3 displays an abrupt decrease of nearly 500 in Sr counts while R2 shows only a slight decrease. Concurrent isotopic responses are not visible in the Hulu/Dongge Cave or Sofular records, through slight increases in $\delta^{18}O$ values for NGRIP are noted at these times. R1, which occurred after H1 but before Mwp1b is characterized by a sudden increase in $\delta^{13}C$, $\delta^{18}O$, and Sr counts values. These proxy results are interpreted as representing a brief period of low moisture availability for the region. There is a slight decrease in $\delta^{18}O$ values for the Hulu/Dongge Cave records at this time, but is not evident in any of the other paleoarchives compared. The low growth rate of CCC-003 from 11 kyr to the mid-Holocene hinders the identification of regional climatic events, as the years per isotopic or Sr value increase dramatically compared to that of the earlier record. CCC-001 and -007 display similar isotopic and trace element variations for some of the regional events (refer to Figure 4-6 on page 66 and Figure 4-8 on 68). For R4, neither CCC-001 nor -007 were active over this time period. For R3, the slow growth rate of CCC-001 prohibits a correlation, whereas -007 displays similar results as CCC-007, with a 1‰ decrease in $\delta^{13}C$ values and a 0.8‰ increase and decrease in $\delta^{18}O$ values. Like R3, for R2, CCC-001 has a slow growth rate. CCC-007, however, displays a 1‰ decrease in $\delta^{13}C$ values, which is similar to the 2‰ decrease of CCC-003. Both CCC-001 and -007 display concurrent proxy responses for R1. CCC-001 displayed a 1 - 2‰ increase for $\delta^{13}C$ values, a 1‰ increase in $\delta^{18}O$ values, and a slight Sr count increase. CCC-007 had similar behavior for $\delta^{13}C$ values and Sr counts, but little variation in $\delta^{18}O$ values. The lack of consistent proxy behavior is not surprising, given the high variability of speleothem geochemical proxy evolution and growth rate effects,

though consistency in proxy responses for these regional-scale events would help to eliminate the possibility of causes that are unrelated to regional climate parameters.

Factors affecting regional climate of east-central North America

The region of east-central North America lies at a confluence of multiple teleconnections that brings moisture from the Pacific and Atlantic Oceans. Throughout the LGM, with the climatic effects of the nearby LIS and meltwater runoff over the course of ice sheet melting, there are numerous mechanisms possible for regional climate changes that are not evidenced in global archives. The GOM, for example, is an important moisture source for the region and is sensitive to changes in the ITCZ and AMOC. The anomalous (compared to most North American records) *wetter* YD record of CCC-003 is evidence of the influx of moisture from the GOM.

Chapter 5

Conclusions

Stable isotope and trace element concentrations obtained from absolute-dated speleothems have the capability to provide high-quality paleoclimate records. Due to the high preservation potential, their ability to be absolute dated, and their multi-proxy nature, speleothems are ideal archives for paleoclimate changes over time, especially from historically underrepresented continental locales. Oxygen isotopes provide evidence for atmospheric temperature, as well as the sourcing and seasonality of meteoric precipitation. Carbon isotopes, derived primarily from soil-respired CO_2, provide evidence for vegetation patterns over time. When paired with isotope results, Sr counts obtained through the non-conventional method of μ-XRF provide evidence for moisture availability and water residence time in the epikarst and ultimately allow for the inference of paleohydrological histories for the cave region.

Age models for the CCC speleothem geochemical and trace element datasets were constructed using the StalAge algorithm, which has been demonstrated to provide a higher degree of accuracy than linear interpolation, especially for problematic and slow-growing sections.

Intercomparison between the three coeval speleothems for the overlapping time series reveals the wide variability in speleothem proxy response to changing climate parameters and dripwater chemical evolution. While broad correlations between speleothem growth rate and climate parameters can be made, variation in growth rates should not be used as an indicator for specific climate regimes.

Long, continuous paleoclimate archives such as those obtained from ice cores, marine sediment cores, and speleothems provide evidence of global climate changes through time. The Culverson Creek Cave record has been demonstrated, through synchronicity of six major climatic events with global paleoarchives, to represent a well-constrained record of east-central North American climate. Additionally, regional-scale climatic events were identified that were not

observed in global records, but are correlative with other regional records. Possible mechanisms for regional-scale climate changes in the CCC record include proximity to ice sheet margins, moisture sourcing and Bermuda High circulation, latitudinal migration of the ITCZ, and regional drought events. The CCC-record displayed synchronicity with GOM records of SST and meltwater flood events, which demonstrates the linkage between the paleoclimate of the study area and the GOM.

Appendix A

Supplemental Material

List of Acronyms

8kE	8.2 kyr Event
AMOC	Atlantic Meridional Overturning Circulation
B-A	Bølling/Allerød
BCC	Buckeye Creek Cave, WV
BH	Bermuda High
BP	Before Present (present = 1950 A.D.)
CCC	Culverson Creek Cave, WV
DIC	Dissolved Inorganic Carbon
EAM	East Asia Monsoon
ENSO	El Niño Southern Oscillation
EPICA	European Project for Ice Coring in Antarctica
GCM	General Circulation Model
GISP	Greenland Ice Sheet Project
GOM	Gulf of Mexico
H1/H2	Heinrich Event 1; 2
HCO	Holocene Climatic Optimum
IRMS	Isotope Ratio Mass Spectrometry
ITCZ	Inter-tropical Convergence Zone
LGM	Last Glacial Maximum
LIS	Laurentide Ice Sheet
LWC	Lost World Caverns, WV
MI	Mystery Interval
MWP1A/1B	Meltwater Pulse 1A; 1B
µ-XRF	Micro X-Ray Fluorescence
NADW	North Atlantic Deep Water

NAO	North Atlantic Oscillation
NGRIP	North Greenland Ice Core Project
PCP	Prior Calcite Precipitation
PDO	Pacific Decadal Oscillation
RCCI	Regional Climate Change Index
VPDB	Vienna PeeDee Belemnite
VSMOW	Vienna Standard Mean Ocean Water
YD	Younger Dryas

Table 0-1 Stable isotope results for CCC-001

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
0.25	-3.931	-4.539
0.75	-4.887	-4.627
1.25	-5.024	-4.684
1.75	-5.067	-4.704
2.25	-5.327	-5.148
2.75	-5.666	-4.860
3.25	-5.759	-5.078
3.75	-5.741	-4.953
4.25	-5.879	-5.017
4.75	-5.896	-4.767
5.25	-4.914	-4.471
5.75	-4.917	-4.579
6.25	-5.150	-4.522
6.75	-5.428	-4.805
7.25	-5.709	-4.624
7.75	-5.848	-4.899
8.25	-5.867	-4.682
8.75	-5.379	-4.246
9.25	-5.449	-4.538
9.75	-5.555	-4.875
10.25	-5.223	-4.754
10.75	-5.197	-4.423
11.25	-5.223	-4.693
11.75	-5.567	-4.807
12.25	-5.440	-4.823
12.75	-5.444	-4.940
13.25	-5.794	-5.000
13.75	-5.760	-4.817
14.25	-5.425	-4.492
14.75	-5.395	-4.616
15.25	-5.541	-4.771
15.75	-5.872	-5.040
16.25	-5.397	-4.755
16.75	-5.335	-4.545
17.25	-5.666	-4.884
17.75	-5.837	-5.047
18.25	-5.662	-4.564
18.75	-5.578	-4.559
19.25	-5.720	-4.659
19.75	-6.004	-4.600
20.25	-6.008	-4.470
20.75	-6.069	-4.469
21.25	-6.204	-4.467
21.75	-5.870	-4.399
22.25	-6.035	-4.573
22.75	-5.984	-4.421

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
124.25	-6.169	-5.055
124.75	-6.032	-5.001
125.25	-5.991	-4.863
125.75	-5.860	-4.753
126.25	-5.761	-4.765
126.75	-5.746	-4.804
127.25	-5.573	-4.684
127.75	-5.668	-4.812
128.25	-5.604	-4.763
128.75	-5.676	-4.923
129.25	-5.618	-4.729
129.75	-5.533	-4.774
130.25	-5.579	-4.856
130.75	-5.551	-4.826
131.25	-5.453	-4.940
131.75	-5.476	-4.880
132.25	-5.356	-4.814
132.75	-5.360	-4.714
133.25	-5.445	-4.772
133.75	-5.355	-4.694
134.25	-5.463	-4.623
134.75	-5.450	-4.574
135.25	-5.358	-4.930
135.75	-5.404	-4.806
136.25	-5.301	-4.794
136.75	-4.992	-4.767
137.25	-4.931	-4.724
137.75	-4.887	-4.738
138.25	-4.788	-4.752
138.75	-4.894	-4.732
139.25	-4.997	-4.751
139.75	-5.091	-4.809
140.25	-5.009	-4.716
140.75	-5.051	-4.422
141.25	-5.099	-4.511
141.75	-5.169	-4.472
142.25	-5.208	-4.645
142.75	-5.233	-4.698
143.25	-5.229	-4.568
143.75	-5.317	-4.792
144.25	-5.548	-5.054
144.75	-5.594	-5.021
145.25	-5.587	-4.998
145.75	-5.634	-4.969
146.25	-5.748	-5.084
146.75	-5.688	-4.891

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
248.25	-4.808	-5.098
248.75	-5.127	-4.990
249.25	-5.307	-4.945
249.75	-4.995	-4.832
250.25	-4.921	-4.922
250.75	-5.056	-5.062
251.25	-4.989	-5.122
251.75	-4.774	-5.214
252.25	-4.800	-5.187
252.75	-4.557	-5.173
253.25	-4.126	-4.999
253.75	-4.117	-4.992
254.25	-4.022	-5.180
254.75	-3.896	-5.031
255.25	-3.865	-5.284
255.75	-3.835	-5.269
256.25	-4.243	-5.229
256.75	-4.184	-5.083
257.25	-4.260	-5.156
257.75	-4.810	-5.206
258.25	-4.801	-5.309
258.75	-4.901	-5.438
259.25	-4.748	-5.229
259.75	-4.920	-5.412
260.25	-4.950	-5.488
260.75	-5.167	-5.520
261.25	-5.248	-5.487
261.75	-5.213	-5.607
262.25	-5.099	-5.530
262.75	-4.961	-5.361
263.25	-4.302	-5.186
263.75	-4.687	-5.515
264.25	-4.531	-5.660
264.75	-4.132	-5.595
265.25	-4.845	-5.812
265.75	-5.002	-5.706
266.25	-4.786	-5.933
266.75	-4.694	-5.958
267.25	-4.789	-5.873
267.75	-4.579	-5.825
268.25	-4.255	-6.086
268.75	-3.956	-5.786
269.25	-3.924	-5.767
269.75	-3.827	-5.818
270.25	-3.866	-5.689
270.75	-4.455	-5.687

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
372.25	-5.102	-5.760
372.75	-5.157	-5.697
373.25	-5.054	-5.722
373.75	-4.627	-5.475
374.25	-4.200	-5.297
374.75	-4.137	-5.522
375.25	-3.467	-5.217
375.75	-3.695	-5.262
376.25	-3.070	-4.782
376.75	-2.911	-4.871
377.25	-2.608	-4.503
377.75	-2.620	-4.664
378.25	-2.374	-4.484
378.75	-2.558	-4.419
379.25	-2.618	-4.301
379.75	-2.783	-4.571
380.25	-3.316	-4.704
380.75	-3.495	-4.936
381.25	-4.037	-5.018
381.75	-4.064	-4.813
382.25	-3.645	-4.924
382.75	-3.588	-4.964
383.25	-3.771	-5.092
383.75	-3.759	-4.951
384.25	-3.948	-4.991
384.75	-3.871	-4.671
385.25	-3.947	-4.852
385.75	-4.235	-4.851
386.25	-3.919	-4.980
386.75	-3.846	-5.341
387.25	-4.598	-5.014
387.75	-4.771	-5.298
388.25	-4.878	-5.489
388.75	-5.050	-5.512
389.25	-4.982	-5.305
389.75	-5.229	-5.313
390.25	-5.033	-5.449
390.75	-4.976	-5.107
391.25	-5.210	-5.228
391.75	-5.439	-5.276
392.25	-5.358	-5.374
392.75	-5.335	-5.100
393.25	-5.244	-4.874
393.75	-5.346	-4.897
394.25	-5.542	-4.766
394.75	-5.520	-4.872

Table 0-1—*Continued*

23.25	-5.678	-4.277	**147.25**	-5.784	-4.780	**271.25**	-4.503	-5.780	**395.25**	-5.226	-4.684
23.75	-5.925	-4.723	**147.75**	-5.934	-4.725	**271.75**	-4.448	-5.966	**395.75**	-5.313	-4.676
24.25	-6.669	-4.532	**148.25**	-5.714	-4.695	**272.25**	-4.423	-5.721	**396.25**	-5.174	-4.828
24.75	-6.554	-4.533	**148.75**	-6.123	-4.883	**272.75**	-4.623	-5.772	**396.75**	-4.545	-4.690
25.25	-6.548	-4.619	**149.25**	-6.137	-4.709	**273.25**	-4.622	-5.810	**397.25**	-4.160	-4.755
25.75	-6.186	-4.313	**149.75**	-6.062	-4.701	**273.75**	-4.686	-5.766	**397.75**	-4.275	-4.826
26.25	-6.067	-4.378	**150.25**	-6.362	-4.672	**274.25**	-4.986	-5.870	**398.25**	-4.783	-4.712
26.75	-5.777	-4.320	**150.75**	-6.273	-4.588	**274.75**	-4.970	-5.550	**398.75**	-5.073	-4.787
27.25	-5.677	-4.473	**151.25**	-6.193	-4.464	**275.25**	-4.657	-5.726	**399.25**	-5.334	-5.017
27.75	-5.560	-4.342	**151.75**	-6.122	-4.693	**275.75**	-4.474	-5.679	**399.75**	-5.378	-4.959
28.25	-5.609	-4.448	**152.25**	-6.028	-4.573	**276.25**	-4.854	-5.796	**400.25**	-5.745	-5.262
28.75	-5.668	-4.443	**152.75**	-6.168	-4.584	**276.75**	-4.923	-6.017	**400.75**	-6.043	-5.083
29.25	-5.854	-4.619	**153.25**	-6.136	-4.453	**277.25**	-5.255	-5.981	**401.25**	-5.922	-5.319
29.75	-5.900	-4.306	**153.75**	-6.206	-4.416	**277.75**	-4.958	-5.884	**401.75**	-5.879	-5.069
30.25	-6.147	-4.694	**154.25**	-6.235	-4.620	**278.25**	-4.142	-5.561	**402.25**	-6.180	-5.338
30.75	-5.950	-4.684	**154.75**	-6.130	-4.563	**278.75**	-3.799	-5.192	**402.75**	-6.290	-5.220
31.25	-5.848	-4.765	**155.25**	-6.108	-4.978	**279.25**	-3.766	-5.106	**403.25**	-6.288	-5.177
31.75	-5.908	-4.458	**155.75**	-5.998	-4.698	**279.75**	-4.123	-5.267	**403.75**	-6.217	-5.202
32.25	-5.956	-4.585	**156.25**	-5.544	-4.508	**280.25**	-5.017	-5.540	**404.25**	-6.155	-5.067
32.75	-5.949	-4.446	**156.75**	-5.534	-4.640	**280.75**	-5.237	-5.775	**404.75**	-5.840	-4.886
33.25	-6.031	-4.541	**157.25**	-5.632	-4.814	**281.25**	-5.381	-5.975	**405.25**	-5.991	-5.036
33.75	-6.010	-4.531	**157.75**	-5.536	-4.736	**281.75**	-5.386	-5.736	**405.75**	-6.325	-5.161
34.25	-5.793	-4.478	**158.25**	-5.441	-4.409	**282.25**	-5.412	-5.871	**406.25**	-6.237	-5.017
34.75	-5.759	-4.622	**158.75**	-5.239	-4.329	**282.75**	-5.151	-5.568	**406.75**	-5.999	-5.076
35.25	-5.671	-4.487	**159.25**	-5.212	-4.246	**283.25**	-4.371	-5.264	**407.25**	-6.071	-4.955
35.75	-5.612	-4.446	**159.75**	-5.221	-4.434	**283.75**	-3.999	-4.826	**407.75**	-6.116	-4.972
36.25	-5.631	-4.692	**160.25**	-5.137	-4.677	**284.25**	-3.561	-4.863	**408.25**	-5.983	-4.930
36.75	-5.559	-4.575	**160.75**	-5.093	-4.554	**284.75**	-3.375	-4.418	**408.75**	-5.891	-4.831
37.25	-5.527	-4.557	**161.25**	-4.942	-4.500	**285.25**	-3.819	-4.594	**409.25**	-5.862	-5.061
37.75	-5.626	-4.523	**161.75**	-5.091	-4.566	**285.75**	-4.355	-4.660	**409.75**	-5.565	-4.699
38.25	-5.957	-4.739	**162.25**	-5.217	-4.546	**286.25**	-4.871	-5.049	**410.25**	-5.559	-4.794
38.75	-6.144	-4.716	**162.75**	-4.960	-4.669	**286.75**	-4.935	-5.256	**410.75**	-5.558	-4.824
39.25	-6.485	-4.731	**163.25**	-5.358	-4.685	**287.25**	-5.076	-5.264	**411.25**	-5.581	-4.913
39.75	-6.454	-4.763	**163.75**	-5.344	-4.630	**287.75**	-5.312	-5.624	**411.75**	-5.392	-4.948
40.25	-6.406	-4.903	**164.25**	-5.400	-4.670	**288.25**	-5.167	-5.664	**412.25**	-5.504	-5.048
40.75	-6.304	-4.824	**164.75**	-5.427	-4.657	**288.75**	-5.244	-5.741	**412.75**	-5.680	-4.789
41.25	-6.208	-4.832	**165.25**	-5.586	-4.784	**289.25**	-5.164	-6.133	**413.25**	-5.455	-4.931
41.75	-6.179	-4.882	**165.75**	-5.544	-4.993	**289.75**	-4.776	-5.856	**413.75**	-4.860	-4.715
42.25	-6.028	-4.668	**166.25**	-5.533	-4.912	**290.25**	-5.412	-6.041	**414.25**	-5.021	-4.675
42.75	-6.173	-4.666	**166.75**	-5.591	-4.982	**290.75**	-5.493	-5.928	**414.75**	-4.796	-4.636
43.25	-6.192	-4.723	**167.25**	-5.608	-4.813	**291.25**	-5.061	-5.699	**415.25**	-4.045	-4.345
43.75	-6.114	-4.607	**167.75**	-5.514	-4.743	**291.75**	-4.691	-5.833	**415.75**	-3.716	-4.099
44.25	-6.148	-4.550	**168.25**	-5.283	-4.660	**292.25**	-3.631	-5.353	**416.25**	-4.041	-4.385
44.75	-6.321	-4.908	**168.75**	-5.136	-4.518	**292.75**	-3.690	-5.259	**416.75**	-4.204	-4.427
45.25	-6.325	-4.855	**169.25**	-4.876	-4.504	**293.25**	-4.258	-5.295	**417.25**	-4.378	-4.677
45.75	-6.165	-4.804	**169.75**	-5.017	-4.334	**293.75**	-3.926	-5.167	**417.75**	-4.508	-4.805
46.25	-6.378	-4.794	**170.25**	-4.893	-4.334	**294.25**	-3.943	-5.171	**418.25**	-4.464	-4.903
46.75	-6.307	-4.926	**170.75**	-4.894	-4.464	**294.75**	-3.915	-5.200	**418.75**	-4.584	-4.921
47.25	-6.058	-4.562	**171.25**	-4.872	-4.411	**295.25**	-3.647	-5.237	**419.25**	-4.710	-4.799
47.75	-6.314	-4.737	**171.75**	-4.788	-4.557	**295.75**	-3.726	-5.241	**419.75**	-4.993	-5.028
48.25	-6.392	-4.805	**172.25**	-5.149	-4.521	**296.25**	-3.874	-5.294	**420.25**	-4.566	-4.949
48.75	-6.489	-4.857	**172.75**	-4.920	-4.453	**296.75**	-4.036	-5.353	**420.75**	-4.255	-4.954

Table 0-1—*Continued*

49.25	-6.304	-5.016	**173.25**	-5.010	-4.535	**297.25**	-4.124	-5.007	**421.25**	-3.909	-4.388
49.75	-6.249	-4.909	**173.75**	-4.906	-4.481	**297.75**	-4.092	-5.015	**421.75**	-4.305	-4.704
50.25	-6.096	-5.008	**174.25**	-5.000	-4.452	**298.25**	-4.171	-5.135	**422.25**	-4.877	-4.886
50.75	-6.053	-4.927	**174.75**	-5.191	-4.384	**298.75**	-4.303	-5.253	**422.75**	-4.761	-4.707
51.25	-6.000	-4.914	**175.25**	-5.315	-4.543	**299.25**	-4.511	-5.475	**423.25**	-4.375	-4.615
51.75	-6.008	-4.811	**175.75**	-5.060	-4.882	**299.75**	-4.918	-5.380	**423.75**	-4.477	-4.592
52.25	-6.153	-4.780	**176.25**	-5.149	-4.638	**300.25**	-4.009	-5.129	**424.25**	-4.299	-4.565
52.75	-6.114	-4.782	**176.75**	-5.123	-4.560	**300.75**	-3.686	-5.160	**424.75**	-4.346	-4.879
53.25	-6.228	-4.803	**177.25**	-5.266	-4.752	**301.25**	-3.973	-5.211	**425.25**	-4.352	-4.630
53.75	-6.100	-4.685	**177.75**	-5.337	-4.595	**301.75**	-3.982	-5.157	**425.75**	-4.563	-4.827
54.25	-6.214	-4.751	**178.25**	-5.265	-4.781	**302.25**	-3.936	-5.050	**426.25**	-5.030	-4.826
54.75	-6.125	-4.829	**178.75**	-5.182	-4.707	**302.75**	-4.398	-5.394	**426.75**	-5.165	-4.832
55.25	-6.224	-4.763	**179.25**	-5.040	-4.645	**303.25**	-4.629	-5.296	**427.25**	-5.479	-4.949
55.75	-6.255	-4.783	**179.75**	-5.133	-4.650	**303.75**	-4.645	-5.697	**427.75**	-5.784	-4.874
56.25	-6.088	-4.788	**180.25**	-5.064	-4.473	**304.25**	-4.913	-5.817	**428.25**	-5.890	-4.913
56.75	-6.093	-4.704	**180.75**	-5.153	-4.508	**304.75**	-5.044	-5.653	**428.75**	-5.947	-4.991
57.25	-6.172	-4.883	**181.25**	-5.358	-4.436	**305.25**	-4.617	-5.555	**429.25**	-5.971	-5.017
57.75	-6.290	-4.816	**181.75**	-5.765	-4.664	**305.75**	-4.716	-5.554	**429.75**	-5.771	-5.074
58.25	-6.138	-4.937	**182.25**	-5.754	-4.550	**306.25**	-4.787	-5.638	**430.25**	-5.886	-5.005
58.75	-6.029	-4.642	**182.75**	-6.060	-4.681	**306.75**	-4.866	-5.659	**430.75**	-5.833	-5.525
59.25	-6.090	-4.832	**183.25**	-5.868	-4.777	**307.25**	-4.941	-5.580	**431.25**	-5.874	-5.378
59.75	-5.979	-4.546	**183.75**	-5.635	-4.859	**307.75**	-4.834	-5.702	**431.75**	-6.006	-4.981
60.25	-5.950	-4.638	**184.25**	-5.098	-4.610	**308.25**	-5.054	-5.620	**432.25**	-6.021	-5.070
60.75	-6.005	-4.777	**184.75**	-5.257	-4.694	**308.75**	-4.871	-5.345	**432.75**	-6.077	-5.191
61.25	-6.161	-4.853	**185.25**	-4.953	-4.800	**309.25**	-4.871	-5.359	**433.25**	-5.946	-5.004
61.75	-6.067	-4.864	**185.75**	-4.746	-4.548	**309.75**	-4.991	-5.401	**433.75**	-5.880	-5.064
62.25	-6.106	-4.838	**186.25**	-4.614	-4.590	**310.25**	-4.758	-5.412	**434.25**	-5.914	-5.114
62.75	-6.084	-5.135	**186.75**	-4.556	-4.613	**310.75**	-4.632	-5.375	**434.75**	-5.937	-4.993
63.25	-6.162	-5.128	**187.25**	-4.742	-4.512	**311.25**	-4.879	-5.575	**435.25**	-5.738	-4.977
63.75	-6.115	-5.136	**187.75**	-4.676	-4.546	**311.75**	-4.824	-5.826	**435.75**	-5.301	-4.580
64.25	-6.232	-5.102	**188.25**	-4.774	-4.727	**312.25**	-4.892	-5.563	**436.25**	-4.775	-4.517
64.75	-6.199	-4.819	**188.75**	-4.702	-4.820	**312.75**	-4.921	-5.507	**436.75**	-3.990	-4.202
65.25	-6.154	-4.650	**189.25**	-5.092	-4.936	**313.25**	-5.095	-5.403	**437.25**	-3.702	-4.303
65.75	-6.155	-4.704	**189.75**	-5.356	-4.969	**313.75**	-5.291	-5.497	**437.75**	-3.668	-4.473
66.25	-5.995	-4.875	**190.25**	-5.715	-5.226	**314.25**	-4.517	-5.277	**438.25**	-3.662	-4.596
66.75	-5.975	-4.823	**190.75**	-6.312	-5.379	**314.75**	-4.306	-5.421	**438.75**	-3.586	-4.476
67.25	-6.171	-4.792	**191.25**	-6.204	-5.312	**315.25**	-4.347	-5.213	**439.25**	-3.532	-4.510
67.75	-6.013	-4.942	**191.75**	-6.135	-5.423	**315.75**	-4.690	-5.437	**439.75**	-3.471	-4.520
68.25	-6.008	-4.788	**192.25**	-5.913	-5.242	**316.25**	-4.757	-5.347	**440.25**	-3.523	-4.515
68.75	-5.722	-4.906	**192.75**	-5.828	-5.346	**316.75**	-4.863	-5.241	**440.75**	-3.596	-4.825
69.25	-5.658	-4.604	**193.25**	-5.699	-5.093	**317.25**	-4.928	-5.312	**441.25**	-3.842	-4.828
69.75	-5.632	-4.562	**193.75**	-5.468	-5.123	**317.75**	-4.909	-5.411	**441.75**	-4.289	-4.842
70.25	-5.659	-4.740	**194.25**	-5.361	-5.012	**318.25**	-4.438	-5.299	**442.25**	-4.387	-4.996
70.75	-5.570	-4.722	**194.75**	-5.132	-4.919	**318.75**	-4.309	-5.267	**442.75**	-4.366	-4.916
71.25	-5.536	-4.741	**195.25**	-5.137	-4.920	**319.25**	-4.621	-5.202	**443.25**	-4.372	-5.049
71.75	-5.783	-4.754	**195.75**	-5.047	-5.084	**319.75**	-4.374	-5.149	**443.75**	-4.596	-5.255
72.25	-5.828	-4.621	**196.25**	-4.996	-4.964	**320.25**	-4.411	-5.125	**444.25**	-4.547	-5.358
72.75	-5.934	-4.626	**196.75**	-4.996	-4.893	**320.75**	-4.275	-5.557	**444.75**	-4.570	-5.212
73.25	-5.990	-4.841	**197.25**	-4.930	-4.777	**321.25**	-4.091	-4.998	**445.25**	-4.738	-5.386
73.75	-5.950	-4.804	**197.75**	-4.779	-4.733	**321.75**	-4.242	-5.105	**445.75**	-4.808	-5.211
74.25	-5.871	-4.810	**198.25**	-4.829	-4.937	**322.25**	-4.501	-5.366	**446.25**	-4.681	-5.103
74.75	-6.087	-5.112	**198.75**	-4.772	-4.862	**322.75**	-4.626	-5.275	**446.75**	-4.567	-5.179

Table 0-1—*Continued*

75.25	-6.092	-5.128
75.75	-5.712	-4.600
76.25	-5.719	-4.658
76.75	-5.661	-4.938
77.25	-5.942	-5.107
77.75	-5.843	-4.590
78.25	-5.691	-4.670
78.75	-6.010	-4.897
79.25	-5.824	-4.761
79.75	-5.777	-4.935
80.25	-5.714	-4.717
80.75	-5.750	-4.940
81.25	-5.725	-4.840
81.75	-5.758	-4.933
82.25	-5.647	-5.067
82.75	-5.612	-4.707
83.25	-5.423	-4.612
83.75	-5.377	-4.608
84.25	-5.191	-4.717
84.75	-5.258	-4.576
85.25	-5.381	-4.676
85.75	-5.290	-4.745
86.25	-5.548	-4.659
86.75	-5.745	-4.851
87.25	-5.737	-4.974
87.75	-5.797	-4.864
88.25	-5.621	-4.779
88.75	-5.591	-4.634
89.25	-5.449	-4.419
89.75	-5.423	-4.606
90.25	-5.394	-4.745
90.75	-5.361	-4.573
91.25	-5.337	-4.687
91.75	-5.213	-4.628
92.25	-5.258	-4.629
92.75	-5.372	-4.877
93.25	-5.482	-4.879
93.75	-5.522	-4.810
94.25	-5.448	-4.722
94.75	-5.505	-4.633
95.25	-5.574	-4.764
95.75	-5.436	-4.668
96.25	-5.568	-4.800
96.75	-5.330	-4.527
97.25	-5.454	-4.399
97.75	-5.629	-4.525
98.25	-5.472	-4.662
98.75	-5.532	-4.483
99.25	-5.411	-4.450
99.75	-5.821	-5.241
100.25	-5.676	-4.805
100.75	-5.926	-4.857

199.25	-4.958	-4.904
199.75	-4.743	-4.862
200.25	-4.701	-4.843
200.75	-3.297	-4.673
201.25	-3.465	-4.762
201.75	-3.578	-4.720
202.25	-3.389	-4.554
202.75	-3.214	-4.606
203.25	-3.655	-5.297
203.75	-3.779	-4.876
204.25	-3.801	-4.805
204.75	-4.377	-4.869
205.25	-4.592	-4.982
205.75	-4.686	-5.181
206.25	-5.053	-5.460
206.75	-4.900	-5.332
207.25	-4.717	-5.477
207.75	-4.557	-5.076
208.25	-3.856	-5.042
208.75	-3.767	-4.963
209.25	-3.675	-4.976
209.75	-3.633	-5.068
210.25	-3.878	-5.059
210.75	-3.795	-5.065
211.25	-3.761	-4.971
211.75	-3.823	-5.153
212.25	-3.967	-5.005
212.75	-4.093	-5.069
213.25	-4.106	-5.195
213.75	-4.328	-5.241
214.25	-4.513	-5.410
214.75	-4.616	-5.462
215.25	-4.680	-5.606
215.75	-4.534	-5.204
216.25	-4.525	-5.393
216.75	-4.605	-5.473
217.25	-4.590	-5.407
217.75	-4.416	-5.317
218.25	-4.571	-5.366
218.75	-4.568	-5.366
219.25	-4.517	-5.407
219.75	-4.913	-5.408
220.25	-4.394	-5.192
220.75	-4.345	-5.070
221.25	-4.001	-4.854
221.75	-3.974	-4.839
222.25	-3.714	-4.721
222.75	-3.706	-4.812
223.25	-3.673	-4.602
223.75	-4.029	-4.779
224.25	-4.471	-4.781
224.75	-4.965	-4.875

323.25	-4.696	-5.666
323.75	-4.429	-5.561
324.25	-4.446	-5.546
324.75	-4.214	-5.664
325.25	-3.951	-5.468
325.75	-3.867	-5.640
326.25	-3.704	-6.010
326.75	-3.563	-5.136
327.25	-3.754	-5.252
327.75	-4.435	-5.480
328.25	-4.454	-5.636
328.75	-4.747	-5.529
329.25	-4.807	-5.576
329.75	-4.822	-5.558
330.25	-5.001	-5.533
330.75	-4.927	-5.621
331.25	-4.571	-5.330
331.75	-4.486	-5.362
332.25	-4.198	-5.737
332.75	-4.254	-5.526
333.25	-4.414	-5.756
333.75	-4.704	-5.788
334.25	-4.756	-5.824
334.75	-4.809	-5.790
335.25	-4.961	-5.801
335.75	-4.873	-5.761
336.25	-4.900	-5.936
336.75	-4.952	-5.733
337.25	-4.958	-5.710
337.75	-4.888	-5.690
338.25	-4.608	-5.630
338.75	-4.040	-5.365
339.25	-4.179	-5.376
339.75	-4.536	-5.035
340.25	-4.239	-4.874
340.75	-4.719	-5.056
341.25	-4.769	-4.934
341.75	-4.769	-5.166
342.25	-4.859	-5.257
342.75	-4.499	-5.173
343.25	-4.587	-5.172
343.75	-4.542	-5.380
344.25	-4.542	-5.275
344.75	-4.614	-5.467
345.25	-4.995	-5.875
345.75	-4.945	-5.657
346.25	-4.531	-5.766
346.75	-4.402	-5.760
347.25	-4.201	-5.610
347.75	-4.416	-5.758
348.25	-4.716	-5.886
348.75	-4.537	-5.675

447.25	-4.939	-5.251
447.75	-5.121	-5.164
448.25	-5.146	-5.361
448.75	-5.068	-5.107
449.25	-5.133	-5.218
449.75	-5.196	-5.367
450.25	-5.343	-5.184
450.75	-5.124	-5.050
451.25	-4.954	-5.290
451.75	-5.148	-5.262
452.25	-5.196	-5.350
452.75	-5.072	-5.433
453.25	-4.879	-5.504
453.75	-4.982	-5.460
454.25	-5.129	-5.752
454.75	-5.236	-5.455
455.25	-5.350	-5.459
455.75	-5.477	-5.608
456.25	-5.382	-5.449
456.75	-5.257	-5.089
457.25	-5.426	-5.184
457.75	-5.427	-5.041
458.25	-5.073	-4.488
458.75	-5.137	-4.925
459.25	-5.039	-4.809
459.75	-4.939	-4.683
460.25	-4.629	-4.640
460.75	-4.100	-4.471
461.25	-3.192	-4.429
461.75	-2.880	-4.291
462.25	-3.324	-4.585
462.75	-3.684	-4.163
463.25	-3.776	-3.918
463.75	-3.696	-4.006
464.25	-3.728	-4.273
464.75	-3.851	-4.507
465.25	-4.158	-4.440
465.75	-3.759	-3.953
466.25	-3.668	-3.884
466.75	-3.776	-4.109
467.25	-3.597	-4.139
467.75	-3.775	-3.987
468.25	-3.342	-4.122
468.75	-2.623	-4.169
469.25	-2.786	-3.898
469.75	-2.700	-3.856
470.25	-3.559	-3.938
470.75	-3.830	-4.018
471.25	-4.094	-3.793
471.75	-4.511	-3.966
472.25	-5.011	-4.420
472.75	-4.526	-4.072

Table 0-1—*Continued*

101.25	-5.830	-4.835	**225.25**	-3.857	-4.405	**349.25**	-4.796	-5.644	**473.25**	-3.761	-3.866
101.75	-5.708	-4.886	**225.75**	-3.844	-4.785	**349.75**	-4.564	-5.711	**473.75**	-3.505	-3.823
102.25	-5.710	-4.748	**226.25**	-4.079	-5.064	**350.25**	-4.725	-5.748	**474.25**	-3.549	-3.975
102.75	-6.092	-4.978	**226.75**	-4.139	-5.041	**350.75**	-4.892	-5.547	**474.75**	-3.245	-4.025
103.25	-6.039	-4.961	**227.25**	-4.235	-4.917	**351.25**	-5.317	-5.545	**475.25**	-3.080	-4.092
103.75	-6.072	-5.144	**227.75**	-4.475	-5.375	**351.75**	-5.397	-5.571	**475.75**	-3.259	-4.097
104.25	-6.165	-5.104	**228.25**	-4.712	-5.251	**352.25**	-5.356	-5.417	**476.25**	-3.724	-4.330
104.75	-6.192	-5.169	**228.75**	-5.358	-5.309	**352.75**	-4.852	-5.236	**476.75**	-3.242	-4.334
105.25	-6.178	-5.192	**229.25**	-5.377	-5.132	**353.25**	-4.649	-5.256	**477.25**	-1.983	-3.782
105.75	-6.195	-4.932	**229.75**	-5.403	-5.036	**353.75**	-4.671	-5.362	**477.75**	-1.226	-3.756
106.25	-6.206	-5.360	**230.25**	-5.289	-4.979	**354.25**	-4.627	-5.409	**478.25**	-0.897	-3.528
106.75	-6.042	-5.021	**230.75**	-5.283	-4.911	**354.75**	-4.796	-5.453	**478.75**	-0.761	-3.432
107.25	-6.156	-5.085	**231.25**	-5.474	-5.019	**355.25**	-4.196	-4.989	**479.25**	-0.669	-3.537
107.75	-5.926	-4.957	**231.75**	-5.183	-4.771	**355.75**	-4.190	-5.007	**479.75**	-0.483	-3.493
108.25	-5.825	-4.748	**232.25**	-5.036	-4.795	**356.25**	-4.271	-4.992	**480.25**	-0.660	-3.694
108.75	-5.897	-4.545	**232.75**	-4.715	-4.374	**356.75**	-4.027	-4.983	**480.75**	-0.754	-4.149
109.25	-5.765	-4.745	**233.25**	-4.617	-4.419	**357.25**	-4.286	-5.075	**481.25**	-0.824	-4.295
109.75	-5.981	-4.789	**233.75**	-4.570	-4.533	**357.75**	-4.539	-5.285	**481.75**	-1.006	-4.346
110.25	-5.971	-4.809	**234.25**	-4.694	-4.997	**358.25**	-4.989	-5.527	**482.25**	-0.942	-4.638
110.75	-5.925	-4.731	**234.75**	-4.757	-4.874	**358.75**	-5.060	-5.575	**482.75**	-1.130	-4.421
111.25	-5.797	-4.612	**235.25**	-4.787	-5.080	**359.25**	-5.056	-5.757	**483.25**	-1.817	-4.476
111.75	-5.702	-4.587	**235.75**	-4.705	-4.933	**359.75**	-4.884	-5.524	**483.75**	-1.602	-4.557
112.25	-5.738	-4.535	**236.25**	-4.854	-5.362	**360.25**	-4.845	-5.643	**484.25**	-1.854	-4.440
112.75	-5.527	-4.571	**236.75**	-4.778	-5.064	**360.75**	-4.676	-5.506	**484.75**	-1.677	-4.497
113.25	-5.397	-4.567	**237.25**	-4.612	-5.289	**361.25**	-4.309	-5.106	**485.25**	-1.333	-4.698
113.75	-5.561	-4.597	**237.75**	-4.361	-5.224	**361.75**	-4.611	-5.456	**485.75**	-1.019	-4.113
114.25	-5.584	-4.806	**238.25**	-4.088	-5.270	**362.25**	-4.428	-5.359	**486.25**	-0.661	-3.870
114.75	-5.621	-4.826	**238.75**	-4.195	-5.099	**362.75**	-3.900	-5.188	**486.75**	-0.721	-4.109
115.25	-5.534	-4.808	**239.25**	-4.121	-5.227	**363.25**	-4.223	-5.323	**487.25**	-0.641	-4.182
115.75	-5.588	-4.908	**239.75**	-4.279	-5.191	**363.75**	-4.489	-5.264	**487.75**	-0.719	-3.853
116.25	-5.543	-4.747	**240.25**	-4.225	-5.266	**364.25**	-4.811	-5.451	**488.25**	-0.753	-3.653
116.75	-5.577	-4.917	**240.75**	-4.540	-5.370	**364.75**	-4.985	-5.614	**488.75**	-0.477	-3.425
117.25	-5.639	-5.021	**241.25**	-4.999	-5.715	**365.25**	-5.150	-5.632	**489.25**	-0.654	-3.656
117.75	-5.408	-4.627	**241.75**	-5.506	-5.705	**365.75**	-5.095	-5.808	**489.75**	-0.700	-3.782
118.25	-5.450	-4.450	**242.25**	-5.365	-5.333	**366.25**	-5.072	-5.732	**490.25**	-0.878	-3.899
118.75	-5.420	-4.484	**242.75**	-5.310	-5.136	**366.75**	-5.299	-5.940	**490.75**	-0.758	-3.792
119.25	-5.884	-4.892	**243.25**	-5.272	-5.079	**367.25**	-5.359	-5.866	**491.25**	-0.564	-3.891
119.75	-5.941	-4.936	**243.75**	-5.634	-5.133	**367.75**	-5.237	-5.903	**491.75**	-0.477	-3.715
120.25	-6.246	-5.056	**244.25**	-5.141	-5.062	**368.25**	-5.194	-5.862	**492.25**	-0.512	-3.920
120.75	-6.184	-5.036	**244.75**	-4.546	-4.860	**368.75**	-5.272	-5.961	**492.75**	-0.445	-4.035
121.25	-6.187	-5.077	**245.25**	-4.506	-4.744	**369.25**	-5.357	-5.920	**493.25**	-0.423	-3.909
121.75	-6.061	-4.977	**245.75**	-4.562	-4.588	**369.75**	-5.412	-5.688	**493.75**	-0.479	-3.901
122.25	-6.128	-5.152	**246.25**	-4.764	-4.736	**370.25**	-5.348	-5.701	**494.25**	-0.484	-3.951
122.75	-5.993	-5.207	**246.75**	-4.970	-5.021	**370.75**	-5.380	-5.924	**494.75**	-0.425	-3.681
123.25	-6.150	-5.093	**247.25**	-4.353	-4.759	**371.25**	-5.316	-5.821	**495.25**	-0.513	-3.749
123.75	-6.216	-5.092	**247.75**	-4.248	-4.626	**371.75**	-5.289	-5.785	**495.75**	-0.493	-3.859

Table 0-2 Stable isotope results for CCC-003

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
0.25	-2.424	-5.819
0.75	-2.479	-5.453
1.25	-2.894	-5.477
1.75	-2.859	-5.477
2.25	-2.915	-5.69
2.75	-2.452	-5.227
3.25	-2.307	-5.192
3.75	-2.281	-5.014
4.25	-1.976	-5.149
4.75	-2.256	-5.635
5.25	-1.842	-5.404
5.75	-1.889	-5.24
6.25	-1.703	-5.162
6.75	-1.796	-4.979
7.25	-1.75	-5.199
7.75	-1.546	-5.034
8.25	-1.582	-5.104
8.75	-1.756	-5.673
9.25	-1.678	-5.579
9.75	-1.639	-5.404
10.25	-1.672	-5.266
10.75	-1.727	-5.208
11.25	-1.684	-5.047
11.75	-2.118	-5.586
12.25	-2.114	-5.491
12.75	-1.905	-5.135
13.25	-2.159	-5.479
13.75	-1.924	-4.943
14.25	-1.433	-4.572
14.75	-1.365	-4.499
15.25	-1.707	-5.026
15.75	-1.787	-5.124
16.25	-1.647	-5.096
16.75	-1.711	-5.292
17.25	-1.635	-5.18
17.75	-1.623	-4.937
18.25	-1.623	-5.148
18.75	-1.572	-5.12
19.25	-1.404	-5.026
19.75	-1.355	-5.038
20.25	-1.491	-5.178
20.75	-1.537	-5.152
21.25	-1.378	-5.109
21.75	-1.373	-5.26
22.25	-0.575	-4.509
22.75	-0.482	-4.415
23.25	-0.671	-4.656
23.75	-0.571	-4.712

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
143.75	-2.972	-4.98
144.25	-2.952	-5.438
144.75	-3.016	-5.545
145.25	-2.468	-4.567
145.75	-2.225	-4.879
146.25	-2.257	-5.086
146.75	-2.01	-4.835
147.25	-2.249	-4.704
147.75	-2.674	-4.694
148.25	-3.055	-5.104
148.75	-2.972	-4.681
149.25	-3.062	-5.039
149.75	-3.45	-4.755
150.25	-3.552	-5.011
150.75	-3.543	-4.726
151.25	-3.289	-4.518
151.75	-2.991	-4.44
152.25	-2.74	-4.375
152.75	-3.1	-4.619
153.25	-3.2	-4.649
153.75	-3.334	-4.889
154.25	-3.226	-4.8
154.75	-3.391	-4.963
155.25	-3.345	-4.872
155.75	-3.38	-4.939
156.25	-2.867	-4.648
156.75	-3.049	-4.416
157.25	-3.141	-4.611
157.75	-3.365	-4.617
158.25	-3.318	-4.784
158.75	-3.12	-4.82
159.25	-2.946	-4.606
159.75	-2.869	-4.498
160.25	-3.127	-4.527
160.75	-3.267	-4.744
161.25	-3.422	-5.323
161.75	-3.513	-4.979
162.25	-3.143	-4.783
162.75	-3.137	-5.046
163.25	-2.969	-4.868
163.75	-2.872	-5.274
164.25	-3.072	-5.018
164.75	-3.015	-5.1
165.25	-2.965	-4.965
165.75	-3.062	-5.195
166.25	-2.965	-5.099
166.75	-3.419	-5.473
167.25	-3.264	-5.364

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
287.25	-2.275	-4.852
287.75	-1.902	-4.888
288.25	-1.787	-4.718
288.75	-1.893	-5.302
289.25	-1.887	-5.07
289.75	-1.954	-5.189
290.25	-1.97	-5.237
290.75	-1.781	-5.053
291.25	-2.117	-4.874
291.75	-2.339	-5.305
292.25	-2.412	-4.629
292.75	-2.52	-5.483
293.25	-2.401	-5.33
293.75	-2.247	-5.458
294.25	-2.355	-5.292
294.75	-2.254	-5.105
295.25	-2.429	-5.411
295.75	-2.641	-5.726
296.25	-2.218	-5.032
296.75	-1.781	-5.005
297.25	-1.686	-4.78
297.75	-1.571	-4.664
298.25	-1.838	-4.582
298.75	-1.817	-4.735
299.25	-2.035	-4.974
299.75	-1.943	-4.87
300.25	-1.818	-4.743
300.75	-1.852	-4.928
301.25	-1.686	-4.553
301.75	-1.54	-4.442
302.25	-1.636	-4.712
302.75	-1.778	-4.736
303.25	-1.944	-4.762
303.75	-1.887	-5.009
304.25	-1.714	-4.865
304.75	-1.9	-5.055
305.25	-1.828	-5.124
305.75	-2.138	-5.404
306.25	-1.589	-4.991
306.75	-1.554	-4.939
307.25	-1.679	-5.096
307.75	-1.766	-5.073
308.25	-1.975	-5.243
308.75	-1.708	-5.053
309.25	-1.505	-4.838
309.75	-1.59	-4.703
310.25	-1.978	-5.024
310.75	-2.072	-5.315

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
430.75	-0.869	-4.098
431.25	-0.627	-3.841
431.75	-0.459	-3.992
432.25	-1.088	-3.79
432.75	-1.675	-3.929
433.25	-1.432	-3.874
433.75	-1.735	-4.341
434.25	-1.365	-4.269
434.75	-1.38	-3.987
435.25	-1.399	-3.998
435.75	-1.09	-3.802
436.25	-1.027	-3.76
436.75	-1.16	-3.864
437.25	-1.337	-3.963
437.75	-1.093	-4.077
438.25	-1.268	-4.096
438.75	-1.363	-4.16
439.25	-1.965	-4.571
439.75	-2.017	-4.327
440.25	-2.087	-4.301
440.75	-1.346	-4.079
441.25	-1.169	-4.015
441.75	-1.288	-3.862
442.25	-1.734	-3.843
442.75	-1.267	-4.027
443.25	-1.093	-4.233
443.75	-0.994	-3.974
444.25	-0.998	-4.117
444.75	-1.021	-3.945
445.25	-1.309	-4.337
445.75	-1.113	-4.203
446.25	-1.044	-4.168
446.75	-1.452	-4.499
447.25	-0.78	-4.031
447.75	-0.846	-4.058
448.25	-1.014	-3.879
448.75	-1.194	-3.999
449.25	-0.923	-4.174
449.75	-0.703	-3.955
450.25	-1.218	-3.801
450.75	-1.733	-3.923
451.25	-1.507	-3.744
451.75	-1.677	-3.962
452.25	-1.956	-4.155
452.75	-1.628	-4.442
453.25	-1.257	-4.259
453.75	-1.191	-4.038
454.25	-1.089	-4.044

Table 0-2—*Continued*

24.25	-0.885	-4.647	**167.75**	-3.001	-5.319	**311.25**	-2.03	-5.22	**454.75**	-0.916	-4.136
24.75	-1.53	-5.063	**168.25**	-3.183	-5.356	**311.75**	-1.975	-5.378	**455.25**	-0.883	-3.88
25.25	-2.176	-5.23	**168.75**	-3.719	-5.325	**312.25**	-1.819	-5.364	**455.75**	-1.152	-4.271
25.75	-2.208	-4.979	**169.25**	-3.864	-5.399	**312.75**	-1.822	-5.297	**456.25**	-1.281	-4.395
26.25	-2.855	-5.542	**169.75**	-3.796	-5.785	**313.25**	-1.672	-4.901	**456.75**	-1.076	-4.264
26.75	-2.728	-5.475	**170.25**	-3.467	-5.416	**313.75**	-1.624	-5.091	**457.25**	-0.852	-4.2
27.25	-2.673	-5.367	**170.75**	-3.568	-5.454	**314.25**	-1.596	-5.048	**457.75**	-0.922	-4.2
27.75	-2.57	-5.312	**171.25**	-3.323	-5.368	**314.75**	-1.586	-5.018	**458.25**	-1.131	-4.306
28.25	-2.189	-4.951	**171.75**	-3.577	-5.49	**315.25**	-1.678	-5.078	**458.75**	-1.038	-4.495
28.75	-1.979	-4.958	**172.25**	-3.389	-5.343	**315.75**	-1.695	-5.254	**459.25**	-0.637	-4.438
29.25	-1.816	-5.081	**172.75**	-3.284	-5.146	**316.25**	-1.585	-4.89	**459.75**	-0.556	-4.363
29.75	-1.266	-4.563	**173.25**	-3.408	-5.344	**316.75**	-1.669	-4.986	**460.25**	-0.573	-4.51
30.25	-0.866	-4.95	**173.75**	-3.364	-5.156	**317.25**	-1.664	-4.87	**460.75**	-1.005	-4.565
30.75	-1.326	-5.413	**174.25**	-3.499	-5.441	**317.75**	-1.606	-4.997	**461.25**	-1.322	-4.217
31.25	-1.408	-5.164	**174.75**	-3.504	-5.324	**318.25**	-1.386	-4.674	**461.75**	-1.446	-4.355
31.75	-1.567	-5.661	**175.25**	-3.744	-5.44	**318.75**	-1.263	-4.441	**462.25**	-1.297	-4.444
32.25	-1.272	-4.85	**175.75**	-3.781	-5.625	**319.25**	-1.245	-4.352	**462.75**	-1.047	-4.45
32.75	-1.338	-4.944	**176.25**	-3.216	-5.363	**319.75**	-1.387	-4.909	**463.25**	-1.496	-5.054
33.25	-1.313	-5.142	**176.75**	-2.98	-5.104	**320.25**	-1.371	-4.588	**463.75**	-1.245	-4.472
33.75	-1.493	-4.933	**177.25**	-2.716	-4.971	**320.75**	-1.546	-4.997	**464.25**	-1.369	-4.613
34.25	-1.422	-4.986	**177.75**	-2.635	-5.029	**321.25**	-1.324	-4.685	**464.75**	-1.338	-4.838
34.75	-1.371	-5.247	**178.25**	-2.822	-4.88	**321.75**	-1.256	-4.505	**465.25**	-1.592	-4.543
35.25	-0.906	-5.059	**178.75**	-3.022	-5.069	**322.25**	-1.316	-4.572	**465.75**	-1.102	-4.591
35.75	-0.916	-5.682	**179.25**	-2.896	-5.158	**322.75**	-1.538	-4.585	**466.25**	-1.055	-4.696
36.25	-0.798	-5.633	**179.75**	-2.969	-5.437	**323.25**	-1.532	-4.372	**466.75**	-0.695	-4.46
36.75	-0.872	-5.196	**180.25**	-2.785	-5.609	**323.75**	-1.24	-4.486	**467.25**	-0.488	-4.3
37.25	-0.844	-5.113	**180.75**	-2.587	-5.031	**324.25**	-1.146	-4.511	**467.75**	-1.094	-4.629
37.75	-0.753	-4.73	**181.25**	-2.929	-5.291	**324.75**	-0.818	-4.326	**468.25**	-1.664	-4.938
38.25	-0.929	-4.951	**181.75**	-3.381	-5.182	**325.25**	-0.908	-4.551	**468.75**	-2.016	-5.188
38.75	-1.212	-5.258	**182.25**	-3.473	-5.601	**325.75**	-1.18	-4.444	**469.25**	-1.849	-4.511
39.25	-1.419	-5.297	**182.75**	-3.378	-5.34	**326.25**	-1.152	-4.554	**469.75**	-1.362	-4.87
39.75	-1.77	-5.387	**183.25**	-3.026	-5.297	**326.75**	-1.005	-4.538	**470.25**	-1.393	-4.982
40.25	-2.384	-5.288	**183.75**	-2.57	-4.878	**327.25**	-1.177	-4.548	**470.75**	-1.238	-4.965
40.75	-2.127	-4.808	**184.25**	-2.532	-5.158	**327.75**	-1.474	-5.071	**471.25**	-1.238	-4.663
41.25	-1.931	-5.147	**184.75**	-2.715	-4.884	**328.25**	-1.478	-4.481	**471.75**	-1.813	-4.975
41.75	-2.05	-4.892	**185.25**	-2.859	-4.667	**328.75**	-1.315	-4.52	**472.25**	-1.919	-4.855
42.25	-1.833	-4.575	**185.75**	-2.494	-4.74	**329.25**	-1.333	-4.71	**472.75**	-1.651	-4.627
42.75	-1.994	-5.445	**186.25**	-2.237	-4.707	**329.75**	-1.325	-4.407	**473.25**	-1.483	-4.781
43.25	-1.988	-4.973	**186.75**	-2.091	-4.768	**330.25**	-1.642	-4.577	**473.75**	-1.508	-5.428
43.75	-2.31	-4.662	**187.25**	-2.476	-5.082	**330.75**	-2.01	-4.889	**474.25**	-1.733	-4.954
44.25	-2.389	-4.859	**187.75**	-2.517	-4.679	**331.25**	-2.393	-4.802	**474.75**	-1.923	-5.033
44.75	-2.349	-4.774	**188.25**	-2.242	-4.99	**331.75**	-1.898	-4.769	**475.25**	-1.689	-4.713
45.25	-2.363	-4.873	**188.75**	-1.824	-5.205	**332.25**	-2.279	-5.223	**475.75**	-1.508	-4.852
45.75	-2.204	-5.067	**189.25**	-2.058	-5.433	**332.75**	-2.213	-4.858	**476.25**	-1.432	-4.755
46.25	-2.247	-5.123	**189.75**	-2.147	-4.915	**333.25**	-2.98	-4.84	**476.75**	-0.966	-5.563
46.75	-2.447	-5.233	**190.25**	-2.164	-4.962	**333.75**	-3.346	-4.638	**477.25**	-1.947	-4.768
47.25	-2.367	-5.163	**190.75**	-2.221	-4.883	**334.25**	-3.651	-5.075	**477.75**	-2.012	-4.74
47.75	-2.243	-5.01	**191.25**	-2.021	-4.982	**334.75**	-3.739	-5.364	**478.25**	-1.896	-4.813
48.25	-2.433	-5.554	**191.75**	-2.101	-4.839	**335.25**	-3.12	-4.935	**478.75**	-1.747	-4.803
48.75	-2.277	-4.975	**192.25**	-1.901	-4.545	**335.75**	-3.078	-5.113	**479.25**	-1.382	-4.502
49.25	-2.344	-5.066	**192.75**	-2.182	-5.092	**336.25**	-2.516	-4.78	**479.75**	-1.459	-4.732
49.75	-2.241	-4.974	**193.25**	-2.495	-5.275	**336.75**	-2.651	-4.519	**480.25**	-1.736	-4.828

Table 0-2—*Continued*

50.25	-2.296	-5.049
50.75	-2.017	-4.68
51.25	-2.268	-5.498
51.75	-2.137	-5.09
52.25	-2.388	-5.702
52.75	-2.228	-5.411
53.25	-2.433	-5.655
53.75	-2.28	-5.231
54.25	-2.309	-5.266
54.75	-2.583	-5.319
55.25	-3.135	-5.254
55.75	-4.452	-5.067
56.25	-4.329	-5.146
56.75	-3.998	-4.855
57.25	-3.784	-4.801
57.75	-4.064	-4.512
58.25	-4.362	-4.677
58.75	-3.634	-4.256
59.25	-3.242	-4.314
59.75	-3.669	-4.653
60.25	-3.566	-4.284
60.75	-3.543	-4.38
61.25	-3.323	-4.821
61.75	-3.266	-4.425
62.25	-3.272	-5.001
62.75	-3.485	-4.72
63.25	-2.91	-4.7
63.75	-3.012	-4.483
64.25	-4.597	-5.588
64.75	-5.355	-5.307
65.25	-4.972	-4.959
65.75	-5.271	-5.229
66.25	-3.568	-4.789
66.75	-3.048	-4.709
67.25	-1.932	-5.008
67.75	-4.805	-5.818
68.25	-2.393	-5.214
68.75	-1.395	-5.192
69.25	-1.654	-5.78
69.75	-2.654	-5.609
70.25	-3.926	-5.548
70.75	-4.743	-6.075
71.25	-3.338	-5.975
71.75	-3.338	-5.715
72.25	-4.938	-6.592
72.75	-1.831	-5.316
73.25	-0.587	-5.285
73.75	-1.216	-4.923
74.25	-1.931	-5.367
74.75	-1.747	-5.805
75.25	-1.429	-5.23
75.75	-1.543	-4.958

193.75	-2.549	-5.59
194.25	-2.376	-4.762
194.75	-2.254	-4.87
195.25	-2.745	-5.029
195.75	-2.544	-5.006
196.25	-2.558	-5.081
196.75	-2.815	-5.32
197.25	-2.558	-5.064
197.75	-2.315	-5.701
198.25	-2.381	-5.043
198.75	-2.551	-5.131
199.25	-2.638	-4.863
199.75	-2.913	-5.436
200.25	-3.018	-5.071
200.75	-3.367	-5.187
201.25	-3.372	-5.215
201.75	-3.507	-5.159
202.25	-3.402	-5.102
202.75	-3.475	-5.512
203.25	-3.373	-5.267
203.75	-2.862	-5.355
204.25	-2.788	-5.085
204.75	-2.718	-5.081
205.25	-2.856	-5.124
205.75	-3.239	-5.315
206.25	-3.349	-5.6
206.75	-3.368	-5.269
207.25	-3.252	-5.515
207.75	-3.553	-5.286
208.25	-3.929	-5.799
208.75	-3.613	-5.601
209.25	-3.932	-5.929
209.75	-3.888	-5.676
210.25	-3.842	-5.337
210.75	-3.704	-5.395
211.25	-3.673	-5.522
211.75	-3.657	-5.27
212.25	-2.792	-5.104
212.75	-2.826	-5.301
213.25	-2.852	-4.791
213.75	-2.906	-5.052
214.25	-3.175	-5.017
214.75	-3.274	-5.295
215.25	-3.528	-5.418
215.75	-3.54	-5.457
216.25	-3.114	-5.39
216.75	-2.843	-5.4
217.25	-2.965	-5.616
217.75	-2.983	-5.353
218.25	-2.805	-5.208
218.75	-2.836	-5.487
219.25	-3.112	-5.423

337.25	-2.312	-4.799
337.75	-2.591	-5.031
338.25	-2.67	-4.598
338.75	-2.783	-5.464
339.25	-3.031	-4.879
339.75	-3.064	-5.086
340.25	-3.132	-4.813
340.75	-3.276	-4.803
341.25	-3.114	-4.752
341.75	-2.73	-4.562
342.25	-2.898	-4.493
342.75	-3.035	-4.597
343.25	-2.644	-4.425
343.75	-2.658	-4.63
344.25	-2.579	-4.592
344.75	-2.505	-4.744
345.25	-2.732	-5.436
345.75	-2.218	-4.983
346.25	-1.33	-4.701
346.75	-0.902	-4.052
347.25	-0.862	-4.14
347.75	-0.879	-4.279
348.25	-1.158	-4.52
348.75	-1.32	-4.523
349.25	-1.401	-4.752
349.75	-1.187	-4.486
350.25	-1.235	-4.698
350.75	-1.196	-4.493
351.25	-1.109	-4.741
351.75	-0.635	-4.269
352.25	-0.9	-4.389
352.75	-1.026	-4.3
353.25	-1.111	-4.477
353.75	-0.92	-4.163
354.25	-1.06	-4.42
354.75	-1.117	-4.425
355.25	-1.403	-4.571
355.75	-1.409	-5.058
356.25	-1.429	-4.461
356.75	-1.482	-4.364
357.25	-1.522	-4.374
357.75	-1.42	-4.602
358.25	-1.328	-4.485
358.75	-1.457	-4.487
359.25	-1.533	-4.696
359.75	-1.446	-4.929
360.25	-1.091	-4.494
360.75	-1.211	-4.718
361.25	-1.268	-4.971
361.75	-1.355	-4.861
362.25	-1.21	-4.795
362.75	-1.167	-4.503

480.75	-1.189	-4.85
481.25	-0.673	-4.874
481.75	-1.338	-5.155
482.25	-1.094	-4.771
482.75	-0.988	-5.381
483.25	-0.925	-4.926
483.75	-1.093	-4.835
484.25	-1.265	-4.935
484.75	-0.673	-4.917
485.25	-0.646	-5.343
485.75	-0.657	-5.003
486.25	-0.735	-4.696
486.75	-0.834	-4.959
487.25	-0.724	-4.903
487.75	-0.432	-4.808
488.25	-0.412	-5.209
488.75	-0.542	-4.975
489.25	-0.602	-5.234
489.75	-0.407	-4.736
490.25	-0.462	-4.866
490.75	-0.779	-5.014
491.25	-1.032	-5.331
491.75	-0.985	-5.129
492.25	-1.173	-5.036
492.75	-1.536	-5.307
493.25	-1.438	-5.398
493.75	-1.079	-5.245
494.25	-1.325	-5.015
494.75	-1.555	-4.836
495.25	-1.545	-4.835
495.75	-1.766	-5.088
496.25	-2.058	-5.195
496.75	-1.686	-5.027
497.25	-1.708	-5.074
497.75	-2.705	-5.409
498.25	-3.747	-5.02
498.75	-3.549	-5.139
499.25	-2.998	-5.202
499.75	-1.905	-4.923
500.25	-1.691	-4.913
500.75	-1.64	-4.971
501.25	-1.116	-5.104
501.75	-1.141	-5.121
502.25	-0.918	-5.141
502.75	-0.628	-5.016
503.25	-0.725	-5.059
503.75	-0.253	-4.819
504.25	0.055	-4.743
504.75	0.071	-4.803
505.25	0.036	-4.865
505.75	-0.407	-4.727
506.25	-0.485	-4.83

Table 0-2—*Continued*

76.25	-1.759	-5.009
76.75	-1.739	-5.33
77.25	-2.068	-6.002
77.75	-2.143	-5.778
78.25	-2.199	-5.051
78.75	-2.188	-5.508
79.25	-2.233	-5.574
79.75	-2.304	-5.906
80.25	-2.386	-5.61
80.75	-2.678	-5.584
81.25	-2.861	-5.802
81.75	-2.684	-5.553
82.25	-2.739	-5.339
82.75	-2.999	-5.765
83.25	-3.013	-5.691
83.75	-2.446	-5.501
84.25	-2.578	-6.187
84.75	-2.635	-5.343
85.25	-2.829	-5.687
85.75	-2.645	-5.785
86.25	-2.536	-5.273
86.75	-2.65	-5.541
87.25	-2.785	-5.405
87.75	-2.551	-5.495
88.25	-2.869	-5.409
88.75	-2.778	-5.229
89.25	-2.577	-5.255
89.75	-2.673	-5.236
90.25	-2.712	-5.458
90.75	-2.63	-5.388
91.25	-2.709	-5.254
91.75	-2.731	-5.174
92.25	-2.779	-5.134
92.75	-2.716	-5.165
93.25	-2.907	-5.307
93.75	-2.575	-5.364
94.25	-2.239	-4.933
94.75	-2.174	-5.134
95.25	-2.644	-5.504
95.75	-2.414	-5.177
96.25	-2.558	-5.358
96.75	-2.709	-5.498
97.25	-2.684	-5.401
97.75	-2.761	-5.527
98.25	-2.661	-5.289
98.75	-2.361	-5.211
99.25	-2.47	-5.303
99.75	-2.261	-5.19
100.25	-2.262	-5.102
100.75	-2.302	-4.909
101.25	-2.272	-4.885
101.75	-2.265	-4.728

219.75	-3.146	-5.381
220.25	-2.873	-4.996
220.75	-3.22	-5.427
221.25	-3.114	-5.524
221.75	-3.296	-5.743
222.25	-3.393	-5.776
222.75	-3.494	-5.609
223.25	-3.653	-5.908
223.75	-3.561	-5.645
224.25	-3.461	-5.417
224.75	-3.337	-5.28
225.25	-3.554	-5.212
225.75	-3.68	-5.087
226.25	-3.645	-5.256
226.75	-3.447	-5.143
227.25	-3.567	-5.102
227.75	-3.409	-4.884
228.25	-3.063	-4.618
228.75	-2.686	-4.54
229.25	-2.536	-4.609
229.75	-2.378	-4.517
230.25	-2.781	-4.696
230.75	-2.994	-4.634
231.25	-3.2	-4.958
231.75	-3.226	-4.621
232.25	-3.138	-4.555
232.75	-3.042	-4.474
233.25	-3.174	-4.678
233.75	-2.832	-4.428
234.25	-3.11	-4.708
234.75	-3.38	-4.738
235.25	-3.078	-4.518
235.75	-2.864	-4.525
236.25	-2.511	-4.211
236.75	-2.604	-4.343
237.25	-2.766	-4.4
237.75	-2.852	-4.267
238.25	-2.947	-4.429
238.75	-2.742	-4.206
239.25	-2.7	-4.281
239.75	-2.782	-4.456
240.25	-3.007	-4.579
240.75	-2.768	-4.347
241.25	-2.267	-4.173
241.75	-2.366	-4.131
242.25	-2.645	-4.413
242.75	-2.42	-4.283
243.25	-2.709	-4.27
243.75	-2.784	-4.619
244.25	-2.402	-4.068
244.75	-2.268	-4.288
245.25	-2.224	-4.357

363.25	-1.368	-4.834
363.75	-1.211	-4.448
364.25	-1.399	-5.154
364.75	-1.532	-4.748
365.25	-1.408	-4.762
365.75	-1.093	-4.492
366.25	-1.57	-4.686
366.75	-1.245	-4.569
367.25	-1.239	-4.705
367.75	-1.161	-4.697
368.25	-1.116	-4.697
368.75	-1.124	-4.817
369.25	-1.092	-4.499
369.75	-1.191	-5.26
370.25	-0.882	-4.083
370.75	-0.866	-4.252
371.25	-0.973	-4.266
371.75	-2.176	-4.179
372.25	-2.713	-4.346
372.75	-3.003	-4.375
373.25	-3.277	-4.909
373.75	-3.274	-4.762
374.25	-3.103	-4.595
374.75	-2.822	-4.58
375.25	-2.848	-4.578
375.75	-2.702	-4.528
376.25	-2.497	-4.803
376.75	-2.458	-4.523
377.25	-2.442	-4.243
377.75	-2.684	-4.758
378.25	-2.756	-4.678
378.75	-2.922	-5.504
379.25	-2.068	-4.836
379.75	-2.638	-4.827
380.25	-2.876	-4.806
380.75	-3.202	-4.907
381.25	-3.149	-4.83
381.75	-3.115	-4.857
382.25	-3.259	-4.674
382.75	-3.131	-3.871
383.25	-3.551	-4.381
383.75	-3.73	-4.309
384.25	-3.938	-4.488
384.75	-4.232	-4.348
385.25	-4.402	-4.51
385.75	-4.33	-4.349
386.25	-4.32	-4.522
386.75	-3.97	-4.676
387.25	-3.923	-4.505
387.75	-3.767	-4.187
388.25	-3.48	-4.081
388.75	-3.364	-4.192

506.75	-0.593	-4.78
507.25	-0.414	-4.724
507.75	-0.444	-4.947
508.25	-0.814	-4.805
508.75	-0.734	-4.603
509.25	-0.252	-4.678
509.75	0.036	-4.501
510.25	-0.171	-4.659
510.75	-0.129	-4.999
511.25	-0.067	-4.717
511.75	-0.635	-5.254
512.25	-0.478	-5.009
512.75	-1.014	-5.327
513.25	-1.115	-5.074
513.75	-0.682	-5.003
514.25	-0.583	-4.937
514.75	-0.665	-5.296
515.25	-0.49	-5.066
515.75	-0.39	-5.063
516.25	-0.434	-5.154
516.75	-0.4	-5.15
517.25	-0.486	-5.188
517.75	-0.421	-5.241
518.25	-0.825	-5.008
518.75	-0.471	-5.066
519.25	-0.319	-4.911
519.75	-0.519	-5.274
520.25	-0.581	-5.181
520.75	-0.509	-5.172
521.25	-0.306	-4.771
521.75	-0.481	-5.4
522.25	-0.515	-5.47
522.75	-0.368	-5.155
523.25	-0.379	-5.433
523.75	-0.261	-5.262
524.25	-0.485	-5.386
524.75	-0.802	-5.401
525.25	-0.962	-5.593
525.75	-0.773	-5.481
526.25	-0.899	-5.819
526.75	-1.463	-5.658
527.25	-0.443	-5.409
527.75	-0.585	-5.145
528.25	-0.41	-5.377
528.75	-0.694	-5.258
529.25	-0.683	-5.279
529.75	-0.538	-5.534
530.25	-0.556	-5.406
530.75	-0.679	-5.403
531.25	-0.926	-5.252
531.75	-1.356	-5.303
532.25	-0.813	-5.207

Table 0-2—*Continued*

102.25	-2.315	-4.83
102.75	-2.292	-4.913
103.25	-2.261	-4.756
103.75	-2.082	-4.724
104.25	-2.329	-4.957
104.75	-2.272	-5.03
105.25	-2.419	-5.224
105.75	-2.565	-5.253
106.25	-2.818	-5.563
106.75	-3.066	-5.799
107.25	-2.998	-5.777
107.75	-2.508	-5.328
108.25	-2.511	-5.314
108.75	-2.636	-5.401
109.25	-2.797	-5.28
109.75	-2.637	-5.28
110.25	-2.729	-5.471
110.75	-2.788	-5.246
111.25	-2.946	-5.271
111.75	-3.492	-5.375
112.25	-3.366	-5.246
112.75	-3.301	-5.145
113.25	-3.283	-5.273
113.75	-3.29	-5.252
114.25	-3.403	-5.248
114.75	-3.197	-4.982
115.25	-3.432	-5.331
115.75	-3.51	-5.591
116.25	-3.2	-5.596
116.75	-3.462	-5.548
117.25	-3.185	-5.243
117.75	-4.219	-5.453
118.25	-3.301	-5.247
118.75	-3.16	-5.167
119.25	-3.306	-5.346
119.75	-3.053	-5.427
120.25	-2.876	-5.582
120.75	-2.897	-5.332
121.25	-2.868	-5.602
121.75	-2.803	-5.183
122.25	-3.001	-5.132
122.75	-2.719	-4.995
123.25	-2.6	-4.793
123.75	-2.915	-5.195
124.25	-2.28	-5.612
124.75	-2.296	-5.979
125.25	-2.409	-5.758
125.75	-2.414	-5.861
126.25	-2.298	-5.643
126.75	-2.415	-5.601
127.25	-2.599	-5.71
127.75	-2.682	-5.833

245.75	-2.236	-4.471
246.25	-2.425	-4.572
246.75	-2.921	-5.121
247.25	-3.17	-4.892
247.75	-3.052	-4.693
248.25	-2.922	-4.719
248.75	-2.567	-4.58
249.25	-2.621	-4.746
249.75	-2.66	-4.65
250.25	-2.603	-4.448
250.75	-2.5	-4.32
251.25	-2.532	-4.443
251.75	-2.585	-4.413
252.25	-2.87	-4.589
252.75	-2.953	-4.904
253.25	-2.82	-4.223
253.75	-2.806	-4.303
254.25	-2.571	-4.109
254.75	-2.999	-4.332
255.25	-3.007	-4.559
255.75	-3.108	-4.359
256.25	-3.262	-4.283
256.75	-3.012	-4.177
257.25	-2.953	-4.341
257.75	-2.859	-4.548
258.25	-2.636	-4.22
258.75	-2.724	-4.26
259.25	-2.356	-4.088
259.75	-2.298	-4.145
260.25	-2.433	-4.266
260.75	-2.662	-4.451
261.25	-2.766	-4.538
261.75	-3.064	-4.352
262.25	-2.811	-4.366
262.75	-2.852	-4.157
263.25	-2.596	-4.457
263.75	-2.291	-4.219
264.25	-2.658	-4.803
264.75	-2.77	-4.366
265.25	-3.057	-4.827
265.75	-3.006	-4.693
266.25	-3.134	-4.511
266.75	-2.998	-4.443
267.25	-3.013	-4.409
267.75	-2.642	-4.359
268.25	-2.617	-4.518
268.75	-2.621	-4.311
269.25	-2.52	-4.324
269.75	-2.702	-4.705
270.25	-2.63	-4.185
270.75	-2.862	-4.106
271.25	-2.917	-4.086

389.25	-3.099	-4.512
389.75	-2.625	-4.582
390.25	-0.827	-4.123
390.75	-0.494	-3.959
391.25	-0.737	-3.969
391.75	-0.837	-4.161
392.25	-0.909	-4.106
392.75	-1.065	-3.951
393.25	-1.311	-3.824
393.75	-1.699	-4.224
394.25	-2.079	-4.509
394.75	-2.156	-4.251
395.25	-2.447	-4.438
395.75	-2.403	-4.682
396.25	-2.467	-4.238
396.75	-2.662	-4.37
397.25	-2.432	-4.375
397.75	-2.203	-4.434
398.25	-2.493	-4.629
398.75	-2.533	-4.355
399.25	-2.119	-4.006
399.75	-1.772	-3.856
400.25	-1.559	-3.891
400.75	-1.332	-3.849
401.25	-1.398	-3.973
401.75	-1.278	-4.064
402.25	-1.049	-3.837
402.75	-2.09	-4.892
403.25	-2.614	-4.15
403.75	-2.522	-4.168
404.25	-2.353	-4.088
404.75	-2.864	-5.063
405.25	-1.56	-4.087
405.75	-1.506	-3.738
406.25	-1.612	-4.145
406.75	-1.886	-4.053
407.25	-2.194	-3.938
407.75	-2.157	-3.98
408.25	-2.346	-4.008
408.75	-2.318	-3.966
409.25	-1.886	-3.966
409.75	-1.844	-4.209
410.25	-2.202	-4.297
410.75	-1.851	-3.93
411.25	-1.259	-4.035
411.75	-1.225	-4.244
412.25	-1.184	-4.537
412.75	-1.329	-4.182
413.25	-1.242	-4.211
413.75	-1.319	-4.029
414.25	-1.359	-4.365
414.75	-1.154	-4.308

532.75	-0.723	-5.4
533.25	-0.752	-5.38
533.75	-1.377	-5.399
534.25	-1.596	-5.523
534.75	-1.812	-5.433
535.25	-1.855	-5.306
535.75	-1.741	-5.313
536.25	-1.599	-5.289
536.75	-1.726	-5.442
537.25	-1.693	-5.3
537.75	-1.583	-5.559
538.25	-1.756	-5.805
538.75	-1.528	-5.556
539.25	-1.646	-5.491
539.75	-1.418	-5.5
540.25	-1.417	-5.521
540.75	-1.539	-5.264
541.25	-1.459	-5.066
541.75	-0.933	-5.379
542.25	-1.096	-5.519
542.75	-1.445	-5.462
543.25	-1.615	-5.626
543.75	-1.386	-5.206
544.25	-1.225	-5.596
544.75	-1.096	-5.11
545.25	-1.414	-5.465
545.75	-1.68	-5.435
546.25	-1.631	-5.155
546.75	-1.587	-5.451
547.25	-1.758	-5.487
547.75	-1.713	-5.184
548.25	-1.329	-5.081
548.75	-1.547	-5.419
549.25	-1.665	-5.723
549.75	-1.453	-5.606
550.25	-0.801	-5.725
550.75	-0.582	-5.529
551.25	-0.643	-5.666
551.75	-0.925	-5.761
552.25	-1.033	-6.023
552.75	-1.353	-5.991
553.25	-1.632	-5.886
553.75	-1.926	-5.991
554.25	-2.168	-5.823
554.75	-2.042	-5.752
555.25	-1.787	-5.737
555.75	-1.506	-5.464
556.25	-1.29	-5.391
556.75	-1.46	-5.521
557.25	-1.578	-5.183
557.75	-2.298	-5.494
558.25	-3.08	-5.697

Table 0-2—*Continued*

128.25	-2.404	-5.778
128.75	-2.323	-5.637
129.25	-2.406	-5.926
129.75	-2.577	-6.1
130.25	-2.421	-6.599
130.75	-2.138	-5.791
131.25	-2.128	-5.84
131.75	-2.231	-5.917
132.25	-2.391	-6.089
132.75	-2.242	-5.953
133.25	-2.196	-5.805
133.75	-2.224	-6.807
134.25	-2.172	-5.68
134.75	-2.12	-5.645
135.25	-2.513	-6.006
135.75	-2.256	-5.807
136.25	-2.16	-5.568
136.75	-2.135	-5.476
137.25	-2.233	-5.133
137.75	-2.177	-5.106
138.25	-2.2	-5.055
138.75	-2.476	-5.12
139.25	-2.45	-5.394
139.75	-2.311	-5.361
140.25	-2.432	-5.29
140.75	-2.15	-5.784
141.25	-2.306	-4.974
141.75	-2.289	-4.722
142.25	-2.91	-4.948
142.75	-2.951	-5.005
143.25	-2.775	-4.778

271.75	-2.993	-4.393
272.25	-3.246	-4.245
272.75	-2.894	-4.56
273.25	-2.805	-4.168
273.75	-2.59	-4.069
274.25	-2.73	-4.225
274.75	-2.883	-4.605
275.25	-2.896	-4.686
275.75	-2.494	-4.221
276.25	-2.652	-5.044
276.75	-2.29	-5.188
277.25	-2.599	-5.031
277.75	-2.292	-5.071
278.25	-2.085	-4.745
278.75	-2.227	-4.899
279.25	-2.271	-4.851
279.75	-2.555	-4.888
280.25	-2.46	-4.873
280.75	-2.652	-4.947
281.25	-2.894	-4.545
281.75	-2.644	-4.967
282.25	-2.404	-5.21
282.75	-2.251	-4.413
283.25	-1.904	-5.033
283.75	-1.899	-5.043
284.25	-2.193	-4.93
284.75	-2.729	-4.9
285.25	-2.429	-4.99
285.75	-1.905	-5.082
286.25	-1.766	-4.833
286.75	-2.141	-5.032

415.25	-1.368	-4.012
415.75	-1.334	-4.453
416.25	-1.209	-4.101
416.75	-1.185	-4.41
417.25	-1.077	-4.369
417.75	-0.972	-4.17
418.25	-0.896	-3.966
418.75	-0.921	-3.857
419.25	-0.941	-4.082
419.75	-1.091	-4.201
420.25	-1.144	-3.913
420.75	-1.545	-4.014
421.25	-1.754	-4.276
421.75	-1.743	-4.583
422.25	-1.315	-4.154
422.75	-1.404	-3.899
423.25	-1.125	-5.156
423.75	-1.1	-3.877
424.25	-1.054	-4.089
424.75	-1.332	-4.009
425.25	-0.777	-4.618
425.75	-0.885	-4.293
426.25	-1.13	-4.28
426.75	-1.112	-4.409
427.25	-0.962	-4.469
427.75	-1.023	-4.422
428.25	-0.748	-4.345
428.75	-0.764	-3.906
429.25	-0.944	-4.573
429.75	-1.278	-4.864
430.25	-1.059	-4.78

558.75	-3.644	-5.78
559.25	-3.526	-5.541
559.75	-3.722	-5.752
560.25	-3.7	-5.624
560.75	-3.981	-5.733
561.25	-4.474	-5.895
561.75	-4.223	-5.683
562.25	-3.946	-5.648
562.75	-3.656	-5.78
563.25	-3.559	-5.629
563.75	-3.663	-5.687
564.25	-3.847	-5.906
564.75	-3.221	-5.916
565.25	-1.326	-5.56
565.75	-1.94	-5.596
566.25	-2.065	-5.519
566.75	-2.63	-5.372
567.25	-4.375	-5.808
567.75	-4.351	-5.728
568.25	-4.893	-5.768
568.75	-4.366	-5.125
569.25	-3.743	-5.255
569.75	-4.019	-5.455
570.25	-4.209	-6.647
570.75	-3.999	-5.26
571.25	-3.909	-5.376
571.75	-2.858	-6.478
572.25	-1.159	-5.713
572.75	1.336	-5.097

Table 0-3 Stable isotope results for CCC-007

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
0.25	-3.755	-6.436
0.75	-3.218	-6.277
1.25	-2.98	-5.915
1.75	-2.723	-5.824
2.25	-2.857	-5.731
2.75	-3.09	-5.467
3.25	-3.249	-5.65
3.75	-3.36	-5.548
4.25	-3.507	-5.511
4.75	-3.63	-5.556
5.25	-4.023	-5.579
5.75	-3.876	-5.597
6.25	-4.085	-5.6
6.75	-4.226	-5.678

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
107.25	-4.3577	-5.5172
107.75	-4.9795	-5.5128
108.25	-4.3815	-5.5482
108.75	-4.1227	-5.4112
109.25	-4.4823	-5.6722
109.75	-5.0863	-5.8598
110.25	-5.1625	-5.777
110.75	-4.6777	-5.8904
111.25	-4.2217	-6.0162
111.75	-4.0613	-6.0708
112.25	-3.9697	-6.2072
112.75	-4.1952	-6.407
113.25	-4.3168	-6.1656
113.75	-3.9182	-6.1306

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
214.25	-4.9	-6.365
214.75	-4.591	-6.334
215.25	-4.454	-6.051
215.75	-4.676	-5.805
216.25	-5.085	-6.02
216.75	-5.344	-6.098
217.25	-5.421	-5.856
217.75	-5.225	-5.902
218.25	-4.877	-5.779
218.75	-4.646	-5.832
219.25	-4.735	-5.715
219.75	-5.127	-5.89
220.25	-5.9	-6.257
220.75	-5.852	-6.292

DEPTH (mm)	$\delta^{13}C$	$\delta^{18}O$
321.25	-1.77	-5.693
321.75	-1.61	-5.644
322.25	-1.613	-5.679
322.75	-1.594	-5.602
323.25	-1.539	-5.727
323.75	-1.59	-5.71
324.25	-1.652	-5.396
324.75	-1.907	-5.35
325.25	-1.927	-5.633
325.75	-2.092	-5.225
326.25	-1.977	-5.173
326.75	-1.631	-5.485
327.25	-1.477	-4.615
327.75	-1.406	-5.002

Table 0-3—*Continued*

7.25	-4.349	-5.544
7.75	-4.234	-5.814
8.25	-3.792	-5.276
8.75	-3.378	-5.86
9.25	-3.564	-5.308
9.75	-3.777	-5.289
10.25	-3.938	-5.031
10.75	-4.252	-4.936
11.25	-4.265	-5.07
11.75	-4.308	-5.122
12.25	-4.264	-4.955
12.75	-4.221	-5.215
13.25	-3.981	-5.827
13.75	-3.9	-5.478
14.25	-4.052	-5.365
14.75	-4.084	-5.094
15.25	-4.202	-5.155
15.75	-4.188	-5.732
16.25	-4.517	-5.704
16.75	-4.406	-5.749
17.25	-3.931	-5.346
17.75	-3.841	-5.366
18.25	-3.854	-5.801
18.75	-3.761	-5.514
19.25	-3.685	-5.301
19.75	-4.171	-5.395
20.25	-4.586	-5.315
20.75	-4.569	-5.483
21.25	-4.505	-5.381
21.75	-4.05	-5.175
22.25	-4.019	-5.347
22.75	-4.221	-5.04
23.25	-4.788	-5.2
23.75	-5.066	-5.328
24.25	-5.936	-5.444
24.75	-6.524	-5.899
25.25	-6.793	-6.096
25.75	-6.531	-5.515
26.25	-4.978	-5.154
26.75	-4.225	-5.079
27.25	-4.24	-5.009
27.75	-4.181	-5.151
28.25	-4.15	-5.298
28.75	-4.287	-5.252
29.25	-4.296	-5.543
29.75	-4.642	-5.493
30.25	-4.731	-5.207
30.75	-5.545	-5.409
31.25	-5.747	-5.247
31.75	-5.878	-5.484
32.25	-5.647	-5.356
32.75	-5.108	-5.259

114.25	-4.5775	-6.0248
114.75	-4.853	-6.0332
115.25	-5.2835	-5.9554
115.75	-5.7208	-5.7418
116.25	-5.3093	-5.6828
116.75	-4.6807	-5.5504
117.25	-4.1562	-5.2064
117.75	-3.849	-5.3768
118.25	-3.763	-5.4276
118.75	-3.9338	-5.6552
119.25	-3.9092	-5.6298
119.75	-3.5527	-5.708
120.25	-3.7257	-5.811
120.75	-3.9073	-6.0888
121.25	-4.5103	-6.0656
121.75	-4.3973	-6.289
122.25	-3.4438	-5.7242
122.75	-3.1502	-6.044
123.25	-3.6393	-5.835
123.75	-3.9435	-6.0188
124.25	-4.2047	-5.9724
124.75	-4.4775	-6.4522
125.25	-4.4802	-6.0998
125.75	-4.2842	-6.3488
126.25	-4.3812	-6.4142
126.75	-4.9967	-6.1066
127.25	-4.5645	-5.6468
127.75	-4.053	-5.9106
128.25	-4.1318	-6.0046
128.75	-4.3218	-6.0652
129.25	-3.9627	-6.0646
129.75	-3.6308	-5.9296
130.25	-4.0812	-6.0864
130.75	-4.218	-5.9992
131.25	-4.1688	-6.0656
131.75	-4.3135	-6.0276
132.25	-4.2588	-6.1878
132.75	-3.9278	-5.9218
133.25	-3.7438	-6.1066
133.75	-3.6758	-5.9674
134.25	-3.7855	-5.9686
134.75	-3.8467	-6.0462
135.25	-3.8707	-6.1734
135.75	-4.0008	-5.99
136.25	-4.0697	-5.979
136.75	-4.0033	-6.1804
137.25	-4.371	-6.1638
137.75	-4.2528	-5.9988
138.25	-4.536	-5.919
138.75	-4.5545	-6.198
139.25	-4.64	-6.207
139.75	-4.4682	-6.1752

221.25	-5.891	-6.312
221.75	-5.59	-6.455
222.25	-5.156	-5.984
222.75	-4.824	-6.119
223.25	-4.474	-5.826
223.75	-4.065	-5.867
224.25	-3.762	-5.802
224.75	-3.674	-5.668
225.25	-3.792	-5.819
225.75	-3.868	-5.836
226.25	-3.903	-5.53
226.75	-3.78	-5.281
227.25	-3.22	-4.994
227.75	-3.849	-5.106
228.25	-4.396	-4.994
228.75	-4.856	-5.034
229.25	-5.737	-5.557
229.75	-6.184	-5.476
230.25	-5.992	-5.537
230.75	-5.958	-5.632
231.25	-4.349	-5.35
231.75	-3.57	-5.315
232.25	-3.543	-5.352
232.75	-3.596	-5.328
233.25	-3.714	-5.324
233.75	-3.871	-5.235
234.25	-4.51	-4.791
234.75	-4.598	-5.041
235.25	-4.762	-5.056
235.75	-4.927	-4.877
236.25	-4.953	-5.225
236.75	-4.57	-5.17
237.25	-4.059	-4.921
237.75	-4.407	-5.292
238.25	-4.282	-4.884
238.75	-4.32	-4.947
239.25	-4.27	-5.36
239.75	-4.051	-5.086
240.25	-3.847	-5.071
240.75	-3.97	-4.988
241.25	-4.25	-5.038
241.75	-4.643	-4.986
242.25	-4.583	-4.877
242.75	-4.182	-4.914
243.25	-3.696	-5.144
243.75	-3.341	-5.093
244.25	-3.445	-5.149
244.75	-3.93	-5.094
245.25	-3.872	-5.161
245.75	-3.879	-5.362
246.25	-3.445	-5.312
246.75	-3.653	-5.262

328.25	-1.324	-4.934
328.75	-1.287	-5.525
329.25	-1.033	-5.327
329.75	-0.913	-5.412
330.25	-0.962	-5.459
330.75	-0.97	-5.101
331.25	-0.928	-5.087
331.75	-0.95	-4.742
332.25	-1.142	-5.301
332.75	-1.188	-4.751
333.25	-0.935	-5.15
333.75	-1.015	-5.187
334.25	-0.982	-5.061
334.75	-0.927	-5.34
335.25	-1.011	-5.331
335.75	-0.916	-5.007
336.25	-1.124	-5.276
336.75	-1.098	-5.295
337.25	-0.926	-5.267
337.75	-0.892	-5.367
338.25	-1.053	-4.563
338.75	-1.188	-3.866
339.25	-1.068	-3.883
339.75	-1.234	-4.412
340.25	-1.18	-4.011
340.75	-1.07	-4.098
341.25	-1.079	-4.344
341.75	-1.337	-4.086
342.25	-1.252	-4.133
342.75	-1.256	-4.345
343.25	-1.171	-3.947
343.75	-1.047	-3.994
344.25	-1.109	-4.099
344.75	-0.999	-4.283
345.25	-1.076	-4.018
345.75	-1.04	-4.14
346.25	-1.327	-4.222
346.75	-1.2	-4.201
347.25	-1.195	-4.41
347.75	-0.971	-4.07
348.25	-0.972	-4.315
348.75	-1.03	-4.116
349.25	-1.068	-4.154
349.75	-1.092	-4.206
350.25	-1.104	-4.529
350.75	-1.145	-4.706
351.25	-1.169	-4.563
351.75	-1.072	-3.98
352.25	-1.216	-4.355
352.75	-1.153	-3.831
353.25	-1.102	-3.834
353.75	-0.998	-3.823

Table 0-3—*Continued*

33.25	-4.628	-5.447	**140.25**	-4.3085	-6.389	**247.25**	-4.414	-5.343	**354.25**	-1.021	-4.035
33.75	-4.056	-5.439	**140.75**	-4.2995	-6.5604	**247.75**	-4.727	-5.325	**354.75**	-1.068	-4.049
34.25	-3.803	-5.443	**141.25**	-4.1232	-6.2506	**248.25**	-4.917	-5.451	**355.25**	-1.044	-3.791
34.75	-4.186	-5.539	**141.75**	-3.939	-6.5118	**248.75**	-4.739	-5.282	**355.75**	-1.274	-3.847
35.25	-4.333	-5.506	**142.25**	-3.8745	-6.3764	**249.25**	-3.751	-5.348	**356.25**	-1.252	-3.951
35.75	-4.538	-5.542	**142.75**	-3.8062	-6.1332	**249.75**	-3.599	-5.395	**356.75**	-1.248	-3.887
36.25	-5.11	-5.498	**143.25**	-3.8203	-6.4676	**250.25**	-3.817	-5.782	**357.25**	-1.169	-3.971
36.75	-5.297	-5.495	**143.75**	-3.8163	-6.3038	**250.75**	-4.777	-5.582	**357.75**	-1.032	-3.917
37.25	-5.796	-5.39	**144.25**	-3.7868	-6.164	**251.25**	-4.309	-5.196	**358.25**	-1.087	-3.967
37.75	-5.27	-5.169	**144.75**	-3.836	-6.3126	**251.75**	-4.019	-5.427	**358.75**	-1.075	-4.027
38.25	-5.209	-5.548	**145.25**	-3.8095	-6.123	**252.25**	-4.156	-5.533	**359.25**	-1.106	-3.953
38.75	-4.88	-5.318	**145.75**	-3.6937	-6.019	**252.75**	-4.282	-5.2	**359.75**	-0.888	-4.288
39.25	-4.605	-5.283	**146.25**	-3.611	-6.0554	**253.25**	-4.238	-5.304	**360.25**	-0.923	-4.461
39.75	-4.694	-5.249	**146.75**	-3.8157	-6.142	**253.75**	-4.508	-5.121	**360.75**	-0.879	-4.532
40.25	-4.567	-5.619	**147.25**	-3.9092	-6.2034	**254.25**	-4.576	-5.335	**361.25**	-0.898	-4.249
40.75	-4.4	-5.392	**147.75**	-3.9833	-6.0206	**254.75**	-4.63	-5.018	**361.75**	-1.142	-4.276
41.25	-3.882	-5.371	**148.25**	-4.0148	-6.036	**255.25**	-4.301	-5.121	**362.25**	-1.013	-4.207
41.75	-3.526	-5.729	**148.75**	-3.8495	-5.9514	**255.75**	-4.091	-5.171	**362.75**	-1.12	-4.181
42.25	-3.636	-5.52	**149.25**	-3.8003	-6.0402	**256.25**	-4.053	-5.267	**363.25**	-1.371	-4.267
42.75	-3.461	-5.428	**149.75**	-3.7657	-5.8264	**256.75**	-4.727	-5.205	**363.75**	-1.149	-4.395
43.25	-4.294	-5.623	**150.25**	-4.1477	-5.9108	**257.25**	-4.88	-5.353	**364.25**	-1.104	-4.382
43.75	-5.271	-5.746	**150.75**	-3.8792	-5.684	**257.75**	-4.74	-5.364	**364.75**	-1.019	-4.478
44.25	-5.965	-5.738	**151.25**	-3.7872	-5.8796	**258.25**	-4.42	-5.31	**365.25**	-1.03	-4.8
44.75	-6.311	-5.596	**151.75**	-3.6863	-5.8494	**258.75**	-4.21	-5.393	**365.75**	-1.01	-4.446
45.25	-6.651	-6.086	**152.25**	-3.8	-6.2952	**259.25**	-4.702	-5.381	**366.25**	-0.891	-4.519
45.75	-6.781	-5.995	**152.75**	-4.1732	-6.4532	**259.75**	-4.668	-4.915	**366.75**	-1.171	-4.58
46.25	-7.145	-6.383	**153.25**	-4.339	-6.483	**260.25**	-4.495	-4.904	**367.25**	-1.495	-4.799
46.75	-6.989	-6.271	**153.75**	-4.5312	-6.5424	**260.75**	-4.306	-4.784	**367.75**	-1.41	-4.525
47.25	-6.996	-6.051	**154.25**	-4.5407	-6.5782	**261.25**	-3.96	-4.693	**368.25**	-1.215	-4.614
47.75	-6.354	-5.587	**154.75**	-5.106	-6.3898	**261.75**	-4.089	-4.523	**368.75**	-1.464	-4.447
48.25	-5.086	-5.468	**155.25**	-5.2058	-6.3826	**262.25**	-4.077	-4.343	**369.25**	-1.455	-4.325
48.75	-4.95	-5.827	**155.75**	-4.5145	-6.3252	**262.75**	-4.239	-4.164	**369.75**	-1.598	-4.295
49.25	-5.694	-5.787	**156.25**	-4.8908	-6.492	**263.25**	-4.109	-4.228	**370.25**	-1.423	-4.241
49.75	-5.909	-5.561	**156.75**	-5.1355	-6.264	**263.75**	-4.392	-4.578	**370.75**	-1.305	-4.429
50.25	-6.037	-5.623	**157.25**	-4.7323	-6.225	**264.25**	-4.599	-4.778	**371.25**	-1.12	-4.674
50.75	-4.866	-5.547	**157.75**	-4.1405	-6.2658	**264.75**	-4.285	-4.519	**371.75**	-1.209	-4.888
51.25	-4.487	-5.407	**158.25**	-4.3125	-6.0568	**265.25**	-3.666	-4.043	**372.25**	-1.213	-4.587
51.75	-4.85	-5.509	**158.75**	-4.4587	-6.0002	**265.75**	-3.315	-3.987	**372.75**	-1.284	-4.662
52.25	-5.023	-5.572	**159.25**	-4.7387	-6.1066	**266.25**	-3.444	-4.132	**373.25**	-1.212	-4.695
52.75	-5.439	-5.682	**159.75**	-5.301	-6.21	**266.75**	-3.455	-4.265	**373.75**	-1.262	-5.7
53.25	-5.324	-5.764	**160.25**	-5.5443	-6.166	**267.25**	-3.31	-4.006	**374.25**	-1.357	-4.979
53.75	-4.854	-5.699	**160.75**	-5.7408	-6.1202	**267.75**	-3.048	-4.162	**374.75**	-1.504	-4.949
54.25	-5.125	-5.572	**161.25**	-5.9065	-6.1608	**268.25**	-2.938	-4.259	**375.25**	-1.329	-4.834
54.75	-5.662	-5.856	**161.75**	-5.4547	-6.2198	**268.75**	-3.595	-4.203	**375.75**	-1.089	-4.867
55.25	-6.377	-6.019	**162.25**	-5.1193	-6.1842	**269.25**	-4.131	-4.372	**376.25**	-1.218	-5.084
55.75	-6.542	-6.15	**162.75**	-5.0365	-5.8828	**269.75**	-4.172	-4.469	**376.75**	-1.213	-5.127
56.25	-6.693	-5.933	**163.25**	-5.1233	-6.2846	**270.25**	-4.171	-4.637	**377.25**	-1.229	-5.247
56.75	-6.835	-6.495	**163.75**	-5.6193	-6.0652	**270.75**	-3.841	-4.605	**377.75**	-1.199	-5.162
57.25	-6.942	-6.193	**164.25**	-6.0062	-6.1838	**271.25**	-3.19	-4.821	**378.25**	-1.282	-5.034
57.75	-6.632	-5.989	**164.75**	-5.8903	-6.3204	**271.75**	-3.249	-4.664	**378.75**	-1.175	-5.122
58.25	-6.431	-6.054	**165.25**	-6.052	-6.2186	**272.25**	-3.718	-4.703	**379.25**	-1.233	-5.123
58.75	-6.462	-6.33	**165.75**	-4.7698	-6.424	**272.75**	-3.573	-4.476	**379.75**	-1.339	-5.188

Table 0-3—*Continued*

59.25	-6.149	-6.093
59.75	-5.992	-6.292
60.25	-5.471	-6.156
60.75	-5.357	-6.094
61.25	-5.17	-5.97
61.75	-5.067	-6.315
62.25	-4.66	-6.198
62.75	-4.293	-5.996
63.25	-3.985	-5.942
63.75	-3.936	-6.045
64.25	-3.869	-6.172
64.75	-4.013	-6.028
65.25	-4.329	-5.791
65.75	-4.56	-6.141
66.25	-4.629	-6.277
66.75	-5.286	-6.158
67.25	-4.785	-6.123
67.75	-4.402	-5.959
68.25	-4.234	-6.183
68.75	-4.061	-6.336
69.25	-4.005	-5.95
69.75	-4.227	-5.916
70.25	-3.974	-5.806
70.75	-4.189	-5.661
71.25	-4.419	-5.686
71.75	-4.718	-6.123
72.25	-5.422	-6.243
72.75	-5.529	-6.265
73.25	-4.981	-5.742
73.75	-4.684	-5.972
74.25	-4.591	-6.082
74.75	-4.745	-6.217
75.25	-5.033	-6.315
75.75	-5.245	-6.061
76.25	-5.327	-5.911
76.75	-5.634	-6.039
77.25	-5.562	-5.931
77.75	-5.389	-6.034
78.25	-4.85	-5.81
78.75	-4.662	-5.78
79.25	-4.332	-5.736
79.75	-4.267	-5.577
80.25	-4.071	-5.897
80.75	-4.09	-5.858
81.25	-4.063	-5.794
81.75	-4.032	-5.729
82.25	-3.875	-5.667
82.75	-4.275	-5.743
83.25	-3.836	-5.623
83.75	-3.809	-5.534
84.25	-4.029	-5.674
84.75	-4.114	-5.685

166.25	-4.222	-6.3912
166.75	-4.0783	-6.518
167.25	-3.8178	-6.2446
167.75	-4.1498	-6.3952
168.25	-5.0508	-6.3836
168.75	-5.0992	-6.3228
169.25	-4.9478	-6.16
169.75	-4.632	-5.823
170.25	-4.3596	-5.8267
170.75	-4.6533	-5.8541
171.25	-5.0261	-6.1411
171.75	-5.1156	-6.1017
172.25	-5.267	-5.9245
172.75	-4.4055	-5.9027
173.25	-4.9505	-5.9415
173.75	-4.7683	-5.9413
174.25	-4.5723	-6.1141
174.75	-4.6515	-5.7989
175.25	-4.2741	-5.9019
175.75	-4.0763	-5.7719
176.25	-4.4113	-6.0351
176.75	-4.5483	-5.9849
177.25	-5.1506	-6.0489
177.75	-4.9965	-6.2203
178.25	-4.6806	-5.8147
178.75	-3.898	-5.7689
179.25	-4.5455	-5.8685
179.75	-4.7153	-5.8219
180.25	-4.9566	-5.9869
180.75	-4.4591	-5.9255
181.25	-3.9635	-5.9925
181.75	-3.6001	-5.9261
182.25	-3.9837	-5.7624
182.75	-4.1593	-5.9019
183.25	-4.0811	-6.1109
183.75	-3.8735	-6.2671
184.25	-3.8726	-6.2823
184.75	-3.7475	-6.0873
185.25	-4.0528	-6.2875
185.75	-4.2201	-6.2885
186.25	-4.476	-6.0797
186.75	-4.0356	-6.3743
187.25	-3.8905	-6.3793
187.75	-3.9346	-6.5305
188.25	-4.258	-6.2925
188.75	-4.4913	-6.5163
189.25	-5.0993	-6.6549
189.75	-5.0031	-6.5045
190.25	-5.3506	-6.5155
190.75	-5.702	-6.5787
191.25	-5.921	-6.4511
191.75	-6.3815	-6.4397

273.25	-3.633	-4.488
273.75	-3.704	-4.515
274.25	-3.931	-4.536
274.75	-3.749	-4.244
275.25	-3.482	-4.883
275.75	-3.498	-4.494
276.25	-4.082	-4.907
276.75	-4.164	-4.681
277.25	-4.266	-4.651
277.75	-4.474	-4.854
278.25	-4.722	-4.862
278.75	-4.564	-4.696
279.25	-4.037	-4.582
279.75	-3.965	-4.167
280.25	-3.424	-4.269
280.75	-3.144	-4.427
281.25	-3.276	-4.384
281.75	-3.61	-4.894
282.25	-3.881	-4.462
282.75	-4.063	-4.51
283.25	-4.483	-4.566
283.75	-4.439	-4.686
284.25	-4.375	-4.837
284.75	-3.993	-4.902
285.25	-3.792	-4.479
285.75	-3.624	-4.51
286.25	-3.748	-4.595
286.75	-4.01	-5.07
287.25	-3.869	-5.075
287.75	-3.595	-4.801
288.25	-3.376	-4.857
288.75	-3.219	-4.712
289.25	-3.098	-4.625
289.75	-2.968	-4.871
290.25	-2.894	-4.829
290.75	-2.961	-5.116
291.25	-3.122	-5.196
291.75	-2.729	-5.116
292.25	-3.135	-4.608
292.75	-3.627	-4.442
293.25	-3.845	-4.299
293.75	-3.737	-4.166
294.25	-3.449	-4.005
294.75	-2.818	-4.405
295.25	-3.056	-4.866
295.75	-3.348	-4.862
296.25	-3.69	-4.655
296.75	-3.634	-5.094
297.25	-3.522	-5.064
297.75	-3.502	-5.055
298.25	-3.494	-5.109
298.75	-3.892	-5.439

380.25	-1.621	-5.636
380.75	-1.759	-5.801
381.25	-1.592	-5.698
381.75	-1.855	-5.622
382.25	-2.04	-5.593
382.75	-1.287	-5.416
383.25	-1.777	-5.798
383.75	-1.631	-5.627
384.25	-1.599	-5.501
384.75	-1.477	-5.544
385.25	-1.353	-5.864
385.75	-1.648	-5.772
386.25	-1.532	-5.804
386.75	-1.239	-5.875
387.25	-0.682	-5.883
387.75	-1.087	-5.851
388.25	-1.204	-5.64
388.75	-1.258	-5.656
389.25	-0.705	-5.492
389.75	-1.284	-5.649
390.25	-0.834	-5.719
390.75	-0.898	-5.554
391.25	-0.948	-5.5
391.75	-1.686	-5.919
392.25	-1.745	-5.933
392.75	-1.304	-6.035
393.25	-1.85	-6.157
393.75	-1.889	-6.245
394.25	-1.809	-6.122
394.75	-1.859	-5.985
395.25	-1.623	-5.953
395.75	-1.124	-5.872
396.25	-1.53	-5.924
396.75	-1.242	-5.852
397.25	-1.313	-5.935
397.75	-1.481	-5.967
398.25	-1.743	-5.958
398.75	-1.883	-5.788
399.25	-1.716	-5.871
399.75	-1.808	-6.065
400.25	-1.312	-5.83
400.75	-1.792	-5.839
401.25	-1.625	-5.857
401.75	-1.515	-6.154
402.25	-1.74	-5.897
402.75	-1.759	-5.906
403.25	-1.856	-5.845
403.75	-1.931	-5.952
404.25	-1.942	-5.924
404.75	-1.788	-5.651
405.25	-1.718	-5.844
405.75	-1.642	-5.903

Table 0-3—*Continued*

85.25	-4.405	-5.516
85.75	-4.701	-5.551
86.25	-5.102	-5.5
86.75	-4.648	-5.427
87.25	-4.304	-5.127
87.75	-4.551	-5.262
88.25	-4.937	-5.301
88.75	-5.108	-5.285
89.25	-5.041	-5.181
89.75	-5.287	-5.424
90.25	-5.358	-5.548
90.75	-5.424	-5.475
91.25	-5.101	-5.439
91.75	-5.409	-5.52
92.25	-4.899	-5.445
92.75	-4.499	-5.481
93.25	-4.189	-5.488
93.75	-4.996	-5.663
94.25	-4.796	-5.354
94.75	-4.507	-5.201
95.25	-3.676	-5.001
95.75	-3.809	-5.039
96.25	-4.078	-4.87
96.75	-4.168	-5.098
97.25	-4.46	-5.056
97.75	-4.722	-5.248
98.25	-5.03	-5.405
98.75	-5.018	-5.31
99.25	-4.657	-5.061
99.75	-5.1	-5.117
100.25	-5.082	-4.941
100.75	-4.621	-5.213
101.25	-4.45	-5.493
101.75	-4.354	-5.484
102.25	-4.845	-5.492
102.75	-4.872	-5.427
103.25	-4.498	-5.185
103.75	-4.491	-5.634
104.25	-4.27	-5.679
104.75	-4.385	-5.651
105.25	-4.614	-5.949
105.75	-4.63	-5.976
106.25	-4.332	-5.745
106.75	-4.209	-5.82

192.25	-6.3481	-6.5541
192.75	-4.079	-6.1903
193.25	-3.3823	-5.7485
193.75	-4.1886	-5.9499
194.25	-4.3441	-6.0177
194.75	-4.4028	-5.6515
195.25	-4.1691	-5.7479
195.75	-4.2066	-5.7301
196.25	-4.5843	-5.8645
196.75	-4.8761	-6.0595
197.25	-4.7675	-6.5393
197.75	-4.909	-6.4143
198.25	-4.658	-6.3089
198.75	-4.8641	-6.3049
199.25	-5.0038	-6.8415
199.75	-5.0065	-6.8353
200.25	-5.362	-6.5939
200.75	-5.2563	-6.9173
201.25	-4.556	-6.7733
201.75	-4.2638	-6.5539
202.25	-4.1538	-6.4075
202.75	-4.3495	-6.5473
203.25	-4.3595	-6.5403
203.75	-3.8181	-6.3443
204.25	-3.7945	-6.3103
204.75	-4.103	-6.4211
205.25	-4.4525	-6.5457
205.75	-4.6721	-6.4821
206.25	-4.5815	-6.2105
206.75	-4.2186	-6.3013
207.25	-4.1321	-6.4015
207.75	-3.966	-6.1861
208.25	-3.8776	-6.2397
208.75	-4.1538	-6.3021
209.25	-4.8195	-6.5975
209.75	-4.6961	-6.6317
210.25	-4.723	-6.3297
210.75	-4.8275	-6.3535
211.25	-4.5352	-6.1316
211.75	-3.9342	-5.895
212.25	-4.0006	-5.981
212.75	-4.4447	-6.1336
213.25	-5.1676	-6.6094
213.75	-5.1265	-6.6579

299.25	-3.196	-4.756
299.75	-2.795	-4.565
300.25	-2.585	-4.947
300.75	-2.719	-4.855
301.25	-2.914	-4.785
301.75	-2.977	-4.555
302.25	-3.011	-4.657
302.75	-2.672	-4.569
303.25	-2.386	-4.786
303.75	-2.772	-4.623
304.25	-2.926	-4.698
304.75	-2.826	-4.892
305.25	-2.649	-4.518
305.75	-2.327	-4.797
306.25	-2.503	-5.088
306.75	-2.589	-4.339
307.25	-2.317	-4.886
307.75	-2.112	-4.762
308.25	-2.373	-4.885
308.75	-2.905	-5.132
309.25	-3.059	-4.952
309.75	-3.215	-5.131
310.25	-2.932	-5.261
310.75	-2.447	-4.932
311.25	-2.352	-4.983
311.75	-2.315	-5.318
312.25	-2.382	-5.555
312.75	-2.211	-5.515
313.25	-2.24	-5.431
313.75	-2.171	-5.214
314.25	-2.208	-5.266
314.75	-2.053	-5.314
315.25	-2.209	-5.538
315.75	-2.313	-5.031
316.25	-2.353	-5.033
316.75	-2.105	-4.859
317.25	-2.196	-5.13
317.75	-2.223	-5.521
318.25	-2.171	-5.507
318.75	-2.202	-5.932
319.25	-1.99	-5.712
319.75	-2.138	-5.868
320.25	-1.968	-5.811
320.75	-1.904	-5.56

406.25	-1.12	-6.035
406.75	-1.478	-5.916
407.25	-1.336	-5.873
407.75	-1.002	-5.76
408.25	-1.586	-6.048
408.75	-1.599	-6.07
409.25	-1.556	-5.886
409.75	-1.519	-5.819
410.25	-1.528	-6.036
410.75	-1.577	-6.215
411.25	-1.484	-5.425
411.75	-1.472	-5.992
412.25	-1.631	-6.029
412.75	-1.901	-6.267
413.25	-1.837	-6.036
413.75	-1.413	-6.212
414.25	-1.821	-6.231
414.75	-1.899	-6.164
415.25	-1.674	-6.031
415.75	-1.655	-5.923
416.25	-1.595	-6.114
416.75	-1.424	-6.387
417.25	-1.396	-6.131
417.75	-1.309	-6.048
418.25	-1.395	-5.645
418.75	-1.549	-5.919
419.25	-1.642	-6.059
419.75	-1.827	-5.965
420.25	-1.876	-5.942
420.75	-1.887	-5.706
421.25	-1.872	-5.949
421.75	-2.061	-6.043
422.25	-2.022	-6.199
422.75	-1.947	-6.312
423.25	-2.159	-6.367
423.75	-2.141	-5.674
424.25	-2.191	-5.454

Appendix B

Sr counts datasets for CCC record

Table 0-1 Sr count results for CCC-001

Depth (mm)	Age (yr BP)	Sr counts
0.00	5443.12	**859**
0.20	5445.07	**857**
0.40	5447.02	**776**
0.60	5448.96	**677**
0.80	5450.90	**758**
1.01	5452.84	**824**
1.21	5454.78	**762**
1.41	5456.71	**755**
1.61	5458.64	**746**
1.80	5460.48	**725**
2.00	5462.41	**747**
2.20	5464.36	**792**
2.40	5466.31	**714**
2.61	5468.26	**763**
2.81	5470.22	**716**
3.01	5472.18	**682**
3.21	5474.14	**676**
3.41	5476.10	**685**
3.61	5478.07	**661**
3.81	5480.03	**633**
4.01	5481.99	**658**
4.21	5483.95	**618**
4.42	5485.90	**579**
4.62	5487.87	**553**
4.82	5489.82	**448**
5.01	5491.68	**528**
5.21	5493.64	**513**
5.41	5495.60	**580**
5.61	5497.56	**541**
5.81	5499.52	**592**
6.02	5501.48	**629**
6.22	5503.45	**674**
6.42	5505.41	**752**
6.62	5507.38	**734**
6.82	5509.34	**755**
7.02	5511.31	**785**
7.22	5513.27	**798**
7.42	5515.24	**857**
7.62	5517.20	**855**
7.83	5519.16	**796**
8.03	5521.13	**705**
8.22	5522.99	**640**
8.42	5524.94	**617**
8.62	5526.90	**645**
8.82	5528.85	**641**
9.02	5530.81	**642**
9.22	5532.77	**614**
9.43	5534.73	**616**
9.63	5536.70	**654**
9.83	5538.69	**731**
10.03	5540.68	**711**
10.23	5542.68	**674**
10.43	5544.68	**638**
10.63	5546.68	**650**
10.83	5548.67	**694**

Depth (mm)	Age (yr BP)	Sr counts
123.52	7148.45	**512**
123.72	7150.11	**554**
123.92	7151.76	**580**
124.13	7153.41	**564**
124.33	7155.06	**541**
124.53	7156.71	**565**
124.74	7158.36	**513**
124.94	7160.01	**452**
125.14	7161.65	**535**
125.34	7163.30	**519**
125.54	7164.95	**525**
125.75	7166.61	**513**
125.95	7168.27	**508**
126.15	7169.93	**531**
126.36	7171.60	**496**
126.56	7173.27	**440**
126.76	7174.94	**477**
126.96	7176.61	**522**
127.16	7178.27	**556**
127.37	7179.93	**588**
127.57	7181.57	**612**
127.77	7183.21	**578**
127.97	7184.84	**639**
128.18	7186.45	**588**
128.38	7188.04	**644**
128.58	7189.61	**625**
128.78	7191.15	**602**
128.99	7192.66	**562**
129.19	7194.14	**609**
129.39	7195.57	**637**
129.59	7196.95	**529**
129.80	7198.28	**465**
130.00	7199.56	**548**
130.19	7200.72	**598**
130.39	7201.88	**526**
130.60	7202.98	**481**
130.80	7204.03	**622**
131.00	7205.04	**544**
131.20	7205.99	**632**
131.41	7206.90	**715**
131.61	7207.76	**674**
131.81	7208.59	**667**
132.01	7209.38	**565**
132.22	7210.13	**620**
132.42	7210.83	**703**
132.62	7211.45	**708**
132.82	7211.99	**718**
133.03	7212.42	**734**
133.23	7212.73	**683**
133.43	7212.90	**668**
133.63	7212.92	**674**
133.84	7212.92	**571**
134.00	7212.92	**442**
134.04	7212.92	**699**
134.20	7212.92	**703**

Depth (mm)	Age (yr BP)	Sr counts
248.23	12137.21	**317**
248.42	12141.82	**318**
248.62	12146.42	**347**
248.81	12151.00	**336**
249.01	12155.56	**299**
249.20	12160.11	**374**
249.40	12164.65	**340**
249.59	12169.17	**370**
249.79	12173.69	**331**
249.98	12178.18	**353**
250.18	12182.68	**370**
250.36	12186.94	**319**
250.56	12191.44	**321**
250.76	12195.93	**378**
250.95	12200.43	**356**
251.15	12204.96	**391**
251.34	12209.51	**355**
251.54	12214.08	**319**
251.73	12218.68	**376**
251.93	12223.32	**381**
252.12	12228.01	**373**
252.32	12232.74	**392**
252.51	12237.51	**404**
252.71	12242.32	**384**
252.90	12247.16	**379**
253.10	12252.05	**380**
253.29	12256.97	**367**
253.49	12261.93	**307**
253.68	12266.90	**298**
253.88	12271.91	**327**
254.07	12276.94	**332**
254.27	12282.02	**338**
254.46	12287.08	**353**
254.66	12292.17	**367**
254.85	12297.26	**367**
255.00	12301.07	**334**
255.05	12302.36	**352**
255.20	12306.22	**341**
255.40	12311.36	**341**
255.59	12316.49	**364**
255.79	12321.59	**394**
255.99	12326.67	**359**
256.19	12331.70	**440**
256.38	12336.71	**402**
256.58	12341.68	**337**
256.78	12346.63	**355**
256.98	12351.54	**380**
257.18	12356.42	**369**
257.37	12361.28	**348**
257.57	12366.11	**337**
257.77	12370.92	**373**
257.97	12375.70	**360**
258.16	12380.46	**341**
258.36	12385.20	**329**
258.56	12389.92	**314**

Depth (mm)	Age (yr BP)	Sr counts
372.36	15123.70	**327**
372.56	15131.85	**325**
372.76	15135.36	**301**
372.96	15135.42	**296**
373.15	15135.48	**303**
373.35	15135.53	**296**
373.55	15135.59	**304**
373.75	15135.65	**302**
373.94	15135.71	**331**
374.14	15135.76	**267**
374.34	15135.82	**320**
374.54	15135.88	**307**
374.73	15135.94	**284**
374.93	15137.53	**325**
375.13	15139.90	**379**
375.32	15142.66	**424**
375.52	15145.86	**409**
375.71	15149.12	**375**
375.91	15152.22	**393**
376.11	15154.92	**379**
376.31	15157.15	**365**
376.50	15158.96	**375**
376.70	15160.42	**413**
376.90	15161.61	**432**
377.10	15162.58	**446**
377.29	15163.39	**454**
377.49	15164.12	**501**
377.69	15164.84	**469**
377.89	15165.59	**518**
378.08	15166.46	**467**
378.28	15167.47	**483**
378.48	15168.93	**443**
378.68	15171.40	**466**
378.88	15174.03	**448**
379.07	15176.79	**400**
379.27	15179.64	**385**
379.47	15182.55	**423**
379.67	15185.47	**452**
379.86	15188.38	**455**
380.00	15190.34	**526**
380.06	15191.22	**411**
380.20	15193.12	**422**
380.39	15195.81	**481**
380.59	15198.45	**442**
380.78	15201.02	**454**
380.98	15203.54	**427**
381.18	15206.02	**434**
381.37	15208.47	**396**
381.57	15210.88	**401**
381.76	15213.28	**428**
381.96	15215.67	**431**
382.16	15218.05	**413**
382.35	15220.44	**447**
382.55	15222.82	**407**
382.75	15225.21	**433**

Table 0-1—*Continued*

11.03	5550.66	**727**
11.24	5552.63	**707**
11.44	5554.59	**704**
11.63	5556.43	**723**
11.83	5558.33	**797**
12.03	5560.20	**711**
12.23	5562.04	**739**
12.43	5563.85	**775**
12.63	5565.63	**710**
12.84	5567.38	**765**
13.04	5569.12	**737**
13.24	5570.84	**756**
13.44	5572.56	**784**
13.64	5574.26	**724**
13.84	5575.96	**669**
14.04	5577.67	**652**
14.24	5579.38	**635**
14.44	5581.10	**637**
14.65	5582.82	**664**
14.84	5584.45	**646**
15.04	5586.17	**652**
15.24	5587.38	**597**
15.44	5588.24	**593**
15.64	5589.09	**647**
15.84	5589.94	**640**
16.04	5590.79	**657**
16.25	5591.64	**695**
16.45	5592.48	**617**
16.65	5593.31	**621**
16.85	5594.13	**550**
17.05	5594.93	**546**
17.25	5595.72	**506**
17.45	5596.49	**468**
17.60	5597.04	**286**
17.65	5597.23	**753**
17.78	5597.67	**783**
17.95	5598.29	**800**
18.13	5598.89	**770**
18.30	5599.45	**771**
18.48	5599.98	**753**
18.65	5600.45	**730**
18.83	5600.86	**715**
19.00	5601.19	**675**
19.00	5601.19	**957**
19.19	5601.46	**947**
19.39	5601.60	**1002**
19.58	5601.60	**739**
19.77	5601.61	**641**
19.97	5601.61	**672**
20.16	5601.61	**605**
20.35	5601.62	**559**
20.55	5601.62	**589**
20.74	5601.62	**611**
20.93	5601.63	**567**
21.13	5601.63	**546**
21.32	5601.63	**581**
21.51	5601.64	**578**
21.71	5601.64	**627**
21.90	5601.64	**633**

134.39	7212.92	**706**
134.59	7212.92	**676**
134.79	7212.92	**687**
134.98	7212.92	**689**
135.18	7212.92	**748**
135.38	7212.92	**740**
135.57	7212.92	**688**
135.77	7212.93	**675**
135.97	7212.93	**670**
136.16	7212.93	**671**
136.36	7212.93	**719**
136.56	7212.93	**672**
136.75	7212.93	**689**
136.95	7212.93	**695**
137.14	7212.93	**739**
137.34	7212.93	**772**
137.54	7212.93	**768**
137.73	7212.93	**839**
137.93	7212.93	**753**
138.12	7212.94	**800**
138.31	7212.94	**802**
138.51	7212.94	**774**
138.71	7212.94	**805**
138.90	7212.94	**781**
139.10	7212.94	**752**
139.30	7212.94	**732**
139.49	7212.94	**694**
139.69	7212.94	**762**
139.89	7212.94	**740**
140.08	7212.94	**720**
140.28	7212.94	**765**
140.48	7212.95	**778**
140.67	7212.95	**748**
140.87	7212.95	**747**
141.07	7212.95	**731**
141.26	7212.95	**719**
141.46	7212.95	**670**
141.66	7212.95	**743**
141.85	7212.95	**716**
142.05	7212.95	**711**
142.25	7212.95	**667**
142.44	7212.95	**726**
142.64	7212.95	**698**
142.84	7212.96	**677**
143.03	7212.96	**673**
143.23	7212.96	**763**
143.42	7212.96	**797**
143.62	7213.22	**730**
143.82	7213.70	**716**
144.01	7214.42	**650**
144.21	7215.38	**649**
144.41	7216.55	**676**
144.60	7217.94	**683**
144.80	7219.51	**635**
145.00	7221.25	**613**
145.19	7223.14	**564**
145.39	7225.17	**547**
145.59	7227.32	**554**
145.78	7229.56	**538**

258.76	12394.64	**318**
258.95	12399.34	**328**
259.15	12404.03	**324**
259.35	12408.72	**296**
259.55	12413.41	**307**
259.75	12418.09	**338**
259.94	12422.78	**315**
260.14	12427.47	**356**
260.34	12432.18	**291**
260.54	12436.87	**277**
260.73	12441.57	**296**
260.93	12446.25	**363**
261.13	12450.93	**342**
261.33	12455.59	**344**
261.53	12460.24	**305**
261.72	12464.87	**324**
261.92	12469.48	**312**
262.12	12474.04	**309**
262.32	12478.59	**300**
262.51	12483.11	**335**
262.71	12487.61	**317**
262.91	12492.10	**326**
263.11	12496.57	**350**
263.31	12501.03	**364**
263.50	12505.48	**377**
263.70	12509.93	**344**
263.90	12514.39	**352**
264.10	12518.84	**382**
264.29	12523.30	**351**
264.49	12527.77	**351**
264.69	12532.24	**354**
264.89	12536.74	**400**
265.08	12541.24	**394**
265.28	12545.75	**371**
265.48	12550.27	**408**
265.68	12554.81	**350**
265.88	12559.36	**351**
266.07	12563.93	**397**
266.27	12568.52	**368**
266.46	12572.89	**362**
266.66	12577.49	**359**
266.85	12582.11	**359**
267.05	12586.74	**384**
267.25	12591.37	**358**
267.45	12596.00	**368**
267.65	12600.63	**357**
267.84	12605.25	**312**
268.04	12609.88	**363**
268.24	12614.49	**353**
268.44	12619.10	**341**
268.63	12623.70	**390**
268.83	12628.28	**334**
269.03	12632.86	**367**
269.23	12637.43	**359**
269.43	12641.99	**344**
269.62	12646.55	**350**
269.82	12651.08	**373**
270.02	12655.61	**340**
270.22	12660.13	**327**

382.94	15227.60	**446**
383.14	15230.00	**432**
383.33	15232.40	**392**
383.53	15234.81	**435**
383.73	15237.23	**446**
383.92	15239.65	**400**
384.12	15242.10	**424**
384.31	15244.55	**440**
384.51	15247.00	**388**
384.71	15249.47	**391**
384.90	15251.94	**446**
385.10	15254.40	**416**
385.29	15256.87	**411**
385.49	15259.33	**417**
385.69	15261.79	**394**
385.88	15264.24	**464**
386.08	15266.67	**417**
386.28	15269.09	**433**
386.47	15271.51	**399**
386.67	15273.91	**353**
386.86	15276.30	**399**
387.06	15278.70	**412**
387.26	15281.09	**410**
387.45	15283.48	**410**
387.65	15285.87	**349**
387.84	15288.27	**396**
388.04	15290.67	**379**
388.24	15293.08	**385**
388.43	15295.50	**347**
388.63	15297.92	**367**
388.82	15300.35	**383**
389.02	15302.78	**359**
389.22	15305.22	**302**
389.41	15307.66	**268**
389.61	15310.09	**320**
389.80	15312.53	**304**
390.00	15314.96	**329**
390.20	15317.39	**313**
390.39	15319.82	**346**
390.59	15322.25	**344**
390.79	15324.68	**325**
390.98	15327.11	**355**
391.18	15329.54	**331**
391.37	15331.97	**338**
391.57	15334.40	**341**
391.77	15336.84	**311**
391.96	15339.28	**352**
392.16	15341.72	**323**
392.35	15344.16	**377**
392.55	15346.61	**353**
392.75	15349.07	**375**
392.94	15351.53	**348**
393.14	15353.99	**357**
393.33	15356.46	**305**
393.53	15358.94	**326**
393.73	15361.42	**308**
393.92	15363.91	**329**
394.12	15366.40	**312**
394.32	15368.90	**321**

Table 0-1—*Continued*

22.08	5601.65	**600**	145.98	7231.88	**496**	270.41	12664.64	**354**	394.51	15371.41	**362**
22.28	5601.65	**620**	146.17	7234.15	**517**	270.61	12669.14	**397**	394.71	15373.93	**296**
22.47	5601.65	**546**	146.36	7236.58	**535**	270.81	12673.62	**406**	394.90	15376.46	**283**
22.66	5601.66	**624**	146.56	7239.07	**562**	271.01	12678.11	**397**	395.10	15378.99	**312**
22.86	5601.66	**639**	146.76	7241.59	**605**	271.21	12682.58	**390**	395.30	15381.53	**303**
23.05	5601.66	**607**	146.95	7244.15	**629**	271.40	12687.05	**394**	395.49	15384.09	**318**
23.24	5601.67	**656**	147.15	7246.72	**646**	271.60	12691.51	**369**	395.69	15386.65	**321**
23.44	5601.67	**663**	147.35	7249.31	**688**	271.80	12695.98	**341**	395.88	15389.22	**304**
23.63	5601.67	**574**	147.54	7251.91	**618**	272.00	12700.44	**349**	396.08	15391.80	**351**
23.82	5601.94	**579**	147.74	7254.51	**627**	272.19	12704.90	**404**	396.28	15394.39	**319**
24.02	5602.42	**633**	147.94	7257.09	**603**	272.39	12709.36	**377**	396.47	15396.99	**350**
24.21	5603.12	**653**	148.13	7259.67	**534**	272.59	12713.82	**376**	396.67	15399.59	**323**
24.40	5604.02	**728**	148.33	7262.22	**522**	272.79	12718.27	**362**	396.86	15402.19	**319**
24.60	5605.08	**677**	148.53	7264.76	**554**	272.98	12722.74	**382**	397.06	15404.79	**368**
24.79	5606.27	**623**	148.72	7267.29	**638**	273.18	12727.19	**351**	397.26	15407.38	**303**
24.98	5607.57	**554**	148.92	7269.81	**623**	273.38	12731.65	**351**	397.45	15409.97	**366**
25.18	5608.95	**525**	149.12	7272.32	**630**	273.58	12736.11	**327**	397.65	15412.54	**360**
25.37	5610.38	**476**	149.31	7274.82	**579**	273.78	12740.56	**324**	397.84	15415.09	**365**
25.56	5611.83	**433**	149.51	7277.32	**521**	273.97	12745.01	**368**	398.04	15417.63	**337**
25.76	5613.26	**414**	149.70	7279.83	**584**	274.17	12749.47	**392**	398.24	15420.15	**399**
25.95	5614.66	**453**	149.90	7282.34	**586**	274.37	12753.92	**383**	398.43	15422.65	**389**
26.14	5615.99	**457**	150.10	7284.85	**560**	274.57	12758.39	**349**	398.63	15425.13	**405**
26.34	5618.18	**509**	150.29	7287.36	**540**	274.76	12762.85	**410**	398.83	15427.60	**345**
26.53	5620.61	**564**	150.49	7289.89	**535**	274.96	12767.33	**373**	399.02	15430.06	**334**
26.72	5622.96	**515**	150.69	7292.42	**551**	275.16	12771.80	**372**	399.22	15432.50	**337**
26.92	5625.25	**594**	150.88	7294.95	**604**	275.36	12776.30	**318**	399.41	15434.93	**361**
27.11	5627.53	**552**	151.08	7297.49	**549**	275.56	12780.80	**342**	399.61	15437.35	**356**
27.30	5629.81	**559**	151.28	7301.73	**578**	275.75	12785.32	**317**	399.81	15439.77	**325**
27.50	5632.12	**622**	151.47	7306.81	**558**	275.95	12789.86	**361**	400.00	15442.18	**339**
27.68	5634.36	**550**	151.67	7311.89	**571**	276.15	12794.42	**332**	400.20	15444.58	**330**
27.87	5636.80	**618**	151.87	7316.96	**559**	276.35	12798.99	**386**	400.39	15446.98	**352**
28.07	5639.35	**598**	152.06	7322.03	**627**	276.54	12803.58	**360**	400.59	15449.38	**330**
28.26	5642.02	**668**	152.26	7327.08	**614**	276.74	12808.19	**383**	400.79	15451.76	**328**
28.45	5644.79	**659**	152.46	7332.13	**536**	276.94	12812.80	**356**	400.98	15454.13	**309**
28.65	5647.65	**715**	152.65	7337.18	**491**	277.14	12817.42	**381**	401.18	15456.49	**263**
28.84	5650.59	**789**	152.85	7342.23	**489**	277.33	12822.05	**395**	401.37	15458.83	**325**
29.03	5653.57	**680**	153.05	7347.27	**471**	277.53	12826.68	**459**	401.57	15461.16	**306**
29.23	5656.60	**679**	153.24	7352.31	**512**	277.73	12831.31	**410**	401.77	15463.46	**330**
29.42	5659.65	**641**	153.44	7357.34	**541**	277.93	12835.94	**400**	401.96	15465.75	**292**
29.61	5662.70	**596**	153.64	7362.38	**568**	278.13	12840.57	**399**	402.16	15468.01	**344**
29.81	5665.74	**599**	153.83	7367.42	**494**	278.32	12845.20	**363**	402.36	15470.26	**330**
30.00	5668.75	**625**	154.03	7372.46	**531**	278.52	12849.82	**437**	402.55	15472.49	**329**
30.19	5671.73	**643**	154.23	7377.49	**530**	278.72	12854.44	**436**	402.75	15474.71	**291**
30.39	5674.67	**672**	154.41	7382.28	**537**	278.92	12859.05	**416**	402.94	15476.92	**205**
30.58	5677.57	**622**	154.61	7387.32	**553**	279.11	12863.67	**395**	403.14	15479.13	**96**
30.77	5680.46	**603**	154.81	7392.38	**619**	279.31	12868.28	**388**	403.34	15481.34	**54**
30.97	5683.33	**642**	155.00	7397.41	**601**	279.51	12872.90	**339**	403.53	15483.55	**48**
31.16	5686.18	**694**	155.20	7402.45	**701**	279.71	12877.52	**386**	403.73	15485.77	**74**
31.35	5689.03	**794**	155.39	7407.49	**651**	279.91	12882.14	**358**	403.92	15488.01	**113**
31.55	5691.90	**858**	155.59	7412.53	**739**	280.10	12886.77	**343**	404.12	15490.27	**235**
31.74	5694.77	**874**	155.79	7417.56	**730**	280.30	12891.40	**317**	404.32	15492.54	**279**
31.93	5697.66	**853**	155.98	7422.60	**743**	280.50	12896.03	**321**	404.51	15494.82	**323**
32.13	5700.57	**883**	156.18	7427.62	**794**	280.70	12900.67	**315**	404.71	15497.10	**361**
32.32	5703.50	**773**	156.38	7432.65	**758**	280.89	12905.31	**328**	404.90	15499.38	**276**
32.51	5706.46	**758**	156.57	7437.67	**736**	281.09	12909.95	**288**	405.10	15501.66	**295**
32.71	5709.44	**753**	156.77	7442.69	**806**	281.29	12914.58	**273**	405.30	15503.92	**277**
32.90	5712.44	**629**	156.97	7447.71	**816**	281.49	12919.22	**307**	405.49	15506.16	**301**
33.09	5715.45	**666**	157.16	7452.72	**789**	281.69	12923.86	**311**	405.69	15508.38	**310**
33.29	5718.47	**686**	157.36	7457.73	**707**	281.88	12928.48	**299**	405.88	15510.56	**306**

Table 0-1—*Continued*

33.48	5721.50	**672**
33.66	5724.39	**706**
33.86	5727.44	**765**
34.05	5730.49	**760**
34.24	5733.53	**809**
34.44	5736.58	**823**
34.63	5739.63	**794**
34.82	5742.67	**811**
35.02	5745.70	**817**
35.21	5748.72	**815**
35.40	5751.73	**885**
35.60	5754.74	**817**
35.79	5757.72	**955**
35.98	5760.69	**857**
36.18	5763.63	**884**
36.37	5766.57	**883**
36.56	5769.49	**894**
36.76	5772.40	**899**
36.95	5775.29	**857**
37.14	5778.18	**838**
37.34	5781.07	**868**
37.53	5783.95	**780**
37.72	5786.83	**828**
37.92	5789.71	**798**
38.11	5792.58	**829**
38.30	5795.47	**796**
38.50	5798.35	**822**
38.69	5801.23	**713**
38.88	5804.09	**738**
39.08	5806.94	**681**
39.27	5809.78	**601**
39.46	5812.60	**556**
39.66	5815.39	**546**
39.84	5818.03	**588**
40.03	5820.77	**609**
40.23	5823.49	**577**
40.42	5826.18	**630**
40.61	5828.84	**690**
40.81	5831.50	**634**
41.00	5834.16	**650**
41.19	5836.83	**651**
41.39	5839.50	**622**
41.58	5842.19	**610**
41.77	5844.90	**592**
41.97	5847.65	**562**
42.16	5850.43	**543**
42.35	5853.25	**580**
42.55	5856.09	**581**
42.74	5858.95	**578**
42.93	5861.83	**570**
43.13	5864.72	**569**
43.32	5867.61	**574**
43.51	5870.50	**643**
43.71	5873.38	**562**
43.90	5876.23	**547**
44.09	5879.07	**533**
44.29	5881.89	**536**
44.48	5884.70	**602**
44.67	5887.50	**584**

157.56	7462.74	**606**
157.75	7467.74	**668**
157.95	7472.75	**704**
158.15	7477.73	**697**
158.34	7482.74	**707**
158.54	7487.73	**731**
158.74	7492.73	**728**
158.93	7497.73	**756**
159.13	7502.72	**700**
159.33	7507.72	**846**
159.52	7512.74	**814**
159.72	7517.75	**717**
159.92	7522.78	**578**
160.11	7527.81	**600**
160.31	7532.86	**644**
160.51	7537.91	**727**
160.70	7542.97	**777**
160.90	7548.03	**747**
161.09	7553.10	**740**
161.29	7558.16	**747**
161.49	7563.24	**727**
161.68	7568.30	**832**
161.88	7573.36	**881**
162.08	7578.40	**894**
162.27	7583.45	**877**
162.47	7588.49	**850**
162.66	7593.28	**807**
162.85	7598.31	**765**
163.05	7603.33	**829**
163.25	7608.35	**857**
163.44	7613.38	**797**
163.64	7618.40	**815**
163.84	7623.44	**796**
164.03	7628.45	**782**
164.23	7633.49	**741**
164.43	7638.52	**800**
164.62	7643.57	**833**
164.82	7648.61	**751**
165.02	7653.65	**758**
165.21	7658.70	**666**
165.41	7663.77	**601**
165.61	7668.83	**573**
165.80	7673.91	**595**
166.00	7678.97	**601**
166.20	7684.06	**584**
166.39	7689.15	**613**
166.59	7694.25	**625**
166.79	7699.35	**642**
166.98	7704.45	**651**
167.18	7709.55	**695**
167.37	7714.66	**723**
167.57	7719.77	**698**
167.77	7724.88	**728**
167.96	7729.97	**683**
168.16	7735.08	**744**
168.36	7740.17	**738**
168.55	7745.26	**743**
168.75	7750.35	**768**
168.95	7755.44	**708**

282.08	12933.10	**330**
282.28	12937.73	**273**
282.48	12942.34	**288**
282.67	12946.97	**312**
282.87	12951.59	**236**
283.07	12956.22	**248**
283.27	12960.84	**307**
283.47	12965.48	**238**
283.66	12970.12	**261**
283.86	12974.78	**265**
284.06	12979.44	**260**
284.26	12984.13	**268**
284.45	12988.81	**315**
284.65	12993.52	**289**
284.85	12998.24	**270**
285.05	13002.97	**301**
285.24	13007.70	**311**
285.44	13012.44	**330**
285.64	13017.19	**313**
285.84	13021.94	**274**
286.04	13026.71	**327**
286.23	13031.48	**316**
286.43	13036.25	**272**
286.63	13041.02	**272**
286.83	13045.81	**247**
287.02	13050.58	**256**
287.22	13055.37	**271**
287.42	13060.15	**273**
287.62	13064.94	**281**
287.82	13069.72	**270**
288.01	13074.51	**287**
288.21	13079.30	**294**
288.40	13083.85	**277**
288.61	13088.86	**263**
288.80	13093.65	**283**
289.00	13098.42	**294**
289.20	13103.20	**289**
289.39	13107.73	**293**
289.59	13112.50	**308**
289.78	13117.27	**291**
289.98	13122.03	**286**
290.18	13126.78	**248**
290.38	13131.54	**298**
290.57	13136.29	**295**
290.77	13141.03	**282**
290.97	13145.76	**248**
291.17	13150.49	**283**
291.36	13155.21	**269**
291.56	13159.93	**190**
291.76	13164.63	**192**
291.96	13169.32	**161**
292.16	13174.01	**236**
292.35	13178.68	**247**
292.55	13183.35	**268**
292.75	13188.00	**264**
292.95	13192.66	**282**
293.14	13197.32	**334**
293.34	13201.97	**307**
293.54	13206.61	**340**

406.08	15512.71	**306**
406.28	15514.83	**307**
406.47	15516.91	**279**
406.67	15518.96	**334**
406.87	15520.99	**327**
407.06	15523.00	**302**
407.26	15524.99	**286**
407.45	15526.98	**294**
407.65	15528.95	**283**
407.85	15530.92	**308**
408.04	15532.90	**309**
408.24	15534.88	**325**
408.43	15536.86	**319**
408.63	15538.84	**349**
408.83	15540.81	**405**
409.02	15542.78	**336**
409.22	15544.74	**328**
409.41	15546.68	**356**
409.61	15548.60	**315**
409.81	15550.51	**327**
410.00	15552.40	**336**
410.20	15554.25	**327**
410.40	15556.09	**329**
410.59	15557.91	**383**
410.79	15559.72	**302**
410.98	15561.51	**297**
411.18	15563.30	**340**
411.38	15565.09	**325**
411.57	15566.88	**356**
411.77	15568.68	**323**
411.96	15570.49	**299**
412.16	15572.31	**331**
412.36	15574.14	**297**
412.55	15575.98	**344**
412.75	15577.84	**339**
412.94	15579.69	**372**
413.14	15581.55	**364**
413.34	15583.40	**293**
413.53	15585.26	**310**
413.73	15587.10	**330**
413.92	15588.93	**343**
414.12	15590.76	**326**
414.32	15592.57	**354**
414.51	15594.37	**344**
414.71	15596.16	**350**
414.91	15597.95	**329**
415.10	15599.74	**389**
415.30	15601.53	**362**
415.49	15603.33	**397**
415.69	15605.13	**314**
415.89	15606.95	**347**
416.08	15608.78	**327**
416.28	15610.62	**331**
416.47	15612.47	**355**
416.67	15614.32	**329**
416.87	15616.19	**359**
417.06	15618.05	**373**
417.26	15619.90	**414**
417.45	15621.75	**420**

Table 0-1—*Continued*

44.87	5890.31	**615**
45.06	5893.12	**566**
45.25	5895.95	**543**
45.44	5898.67	**583**
45.63	5901.58	**606**
45.82	5904.52	**615**
46.02	5907.52	**646**
46.21	5910.58	**665**
46.40	5913.68	**563**
46.60	5916.83	**562**
46.79	5920.01	**500**
46.98	5923.21	**504**
47.18	5926.43	**500**
47.37	5929.65	**536**
47.56	5932.86	**572**
47.76	5936.06	**512**
47.95	5939.23	**554**
48.14	5942.37	**602**
48.34	5945.49	**579**
48.53	5948.58	**657**
48.72	5951.67	**582**
48.92	5954.75	**686**
49.11	5957.85	**658**
49.30	5960.98	**560**
49.50	5964.13	**602**
49.69	5967.32	**634**
49.88	5970.56	**667**
50.08	5973.87	**772**
50.27	5977.25	**716**
50.46	5980.68	**772**
50.66	5984.16	**812**
50.85	5987.70	**846**
51.03	5991.09	**773**
51.23	5994.71	**678**
51.42	5998.36	**682**
51.61	6002.03	**679**
51.81	6005.72	**614**
52.00	6009.44	**673**
52.19	6013.15	**641**
52.39	6016.88	**665**
52.58	6020.61	**690**
52.78	6024.34	**701**
52.97	6028.07	**665**
53.16	6031.78	**716**
53.36	6035.47	**680**
53.55	6039.14	**705**
53.74	6042.80	**719**
53.94	6046.42	**610**
54.13	6050.02	**647**
54.32	6053.58	**625**
54.51	6057.10	**706**
54.71	6060.60	**609**
54.90	6064.07	**640**
55.10	6067.51	**612**
55.29	6070.92	**583**
55.48	6074.29	**639**
55.67	6077.65	**628**
55.87	6080.99	**600**
56.06	6084.29	**571**

169.14	7760.52	**691**
169.34	7765.62	**691**
169.54	7770.70	**770**
169.73	7775.80	**698**
169.93	7780.89	**738**
170.13	7785.99	**704**
170.32	7791.09	**730**
170.52	7796.20	**662**
170.72	7801.31	**686**
170.90	7806.17	**681**
171.10	7811.28	**686**
171.30	7816.42	**597**
171.49	7821.54	**659**
171.69	7826.67	**706**
171.89	7831.79	**624**
172.08	7836.93	**639**
172.28	7842.06	**622**
172.48	7847.21	**597**
172.67	7852.35	**694**
172.87	7857.49	**683**
173.06	7862.64	**634**
173.26	7867.80	**708**
173.46	7872.95	**710**
173.65	7878.12	**636**
173.85	7883.27	**656**
174.00	7887.19	**635**
174.05	7888.44	**519**
174.20	7892.48	**517**
174.40	7897.76	**520**
174.60	7903.06	**557**
174.80	7908.35	**624**
175.00	7913.64	**676**
175.21	7918.94	**653**
175.41	7924.22	**652**
175.61	7929.51	**608**
175.81	7934.78	**645**
176.01	7940.05	**693**
176.21	7945.32	**676**
176.41	7950.58	**610**
176.61	7955.82	**564**
176.81	7961.07	**609**
177.01	7966.31	**581**
177.21	7971.56	**575**
177.42	7976.79	**573**
177.62	7982.02	**669**
177.82	7987.25	**725**
178.02	7992.48	**655**
178.22	7997.70	**633**
178.42	8002.92	**677**
178.62	8008.15	**668**
178.82	8013.36	**657**
179.02	8018.58	**646**
179.22	8023.79	**635**
179.42	8028.99	**663**
179.61	8033.93	**721**
179.82	8039.11	**664**
180.02	8044.29	**618**
180.22	8049.47	**715**
180.42	8054.62	**729**

293.74	13211.27	**351**
293.94	13215.92	**351**
294.13	13220.58	**316**
294.33	13225.24	**384**
294.53	13229.90	**370**
294.73	13234.55	**420**
294.92	13239.19	**419**
295.12	13243.82	**354**
295.32	13248.43	**382**
295.50	13252.61	**388**
295.52	13253.01	**387**
295.66	13256.24	**454**
295.81	13259.85	**396**
295.97	13263.45	**453**
296.13	13267.02	**379**
296.29	13270.57	**355**
296.44	13274.11	**426**
296.60	13277.63	**407**
296.76	13281.15	**369**
296.91	13284.66	**420**
297.07	13288.17	**445**
297.23	13291.69	**367**
297.39	13295.21	**412**
297.54	13298.74	**388**
297.70	13302.29	**402**
297.86	13305.85	**441**
298.01	13309.44	**446**
298.17	13313.04	**432**
298.33	13316.67	**438**
298.49	13320.30	**442**
298.64	13323.92	**438**
298.80	13327.53	**421**
298.96	13331.13	**466**
299.11	13334.69	**451**
299.27	13338.21	**492**
299.43	13341.69	**503**
299.59	13345.10	**476**
299.74	13348.46	**474**
299.90	13351.73	**477**
300.06	13354.92	**397**
300.21	13358.03	**388**
300.37	13361.04	**385**
300.53	13363.97	**314**
300.69	13366.82	**314**
300.84	13369.58	**200**
301.00	13372.26	**112**
302.00	13387.56	**510**
302.20	13390.26	**519**
302.40	13392.88	**548**
302.60	13395.43	**492**
302.80	13397.94	**404**
303.00	13400.42	**343**
303.19	13402.90	**358**
303.39	13405.40	**352**
303.59	13407.94	**345**
303.79	13410.54	**419**
303.99	13413.23	**371**
304.19	13416.00	**325**
304.39	13418.87	**393**

417.65	15623.59	**457**
417.85	15625.41	**472**
418.04	15627.22	**456**
418.24	15629.01	**455**
418.44	15630.78	**496**
418.63	15632.55	**486**
418.83	15634.31	**498**
419.02	15636.00	**435**
419.22	15636.89	**434**
419.42	15637.79	**435**
419.61	15638.70	**422**
419.81	15639.62	**488**
420.00	15640.53	**456**
420.00	15640.55	**486**
420.20	15641.49	**469**
420.39	15642.46	**457**
420.59	15643.44	**402**
420.78	15644.44	**395**
420.98	15645.44	**391**
421.18	15646.45	**407**
421.37	15647.46	**405**
421.57	15648.47	**432**
421.77	15649.47	**474**
421.96	15650.48	**532**
422.16	15651.47	**519**
422.35	15652.46	**529**
422.55	15653.44	**497**
422.75	15654.41	**461**
422.94	15655.37	**489**
423.14	15656.32	**539**
423.34	15657.27	**478**
423.53	15658.21	**499**
423.73	15659.15	**489**
423.92	15660.07	**486**
424.12	15660.99	**486**
424.32	15661.90	**482**
424.51	15662.79	**515**
424.71	15663.65	**498**
424.90	15664.47	**535**
425.10	15665.24	**503**
425.30	15665.95	**516**
425.49	15666.61	**539**
425.69	15667.18	**473**
425.89	15667.68	**515**
426.08	15668.08	**432**
426.28	15668.39	**487**
426.47	15668.62	**553**
426.67	15668.77	**532**
426.87	15668.87	**516**
427.06	15668.91	**466**
427.26	15668.91	**475**
427.45	15668.91	**458**
427.65	15668.91	**510**
427.85	15668.91	**454**
428.04	15668.91	**415**
428.24	15668.91	**426**
428.44	15668.91	**428**
428.63	15668.91	**421**
428.83	15668.91	**407**

Table 0-1—*Continued*

56.25	6087.57	**651**
56.45	6090.84	**623**
56.64	6094.08	**666**
56.83	6097.30	**682**
57.03	6100.51	**650**
57.21	6103.55	**600**
57.41	6106.73	**648**
57.60	6109.91	**597**
57.79	6113.08	**600**
57.98	6116.24	**617**
58.18	6119.40	**619**
58.37	6122.56	**634**
58.50	6124.65	**634**
58.57	6125.71	**613**
58.70	6127.83	**635**
58.89	6131.00	**633**
59.08	6134.17	**653**
59.28	6137.35	**689**
59.47	6140.51	**729**
59.67	6143.68	**723**
59.86	6146.85	**680**
60.06	6150.01	**668**
60.25	6153.18	**623**
60.45	6156.35	**569**
60.64	6159.51	**491**
60.84	6162.68	**439**
61.03	6165.84	**388**
61.23	6169.00	**477**
61.41	6172.01	**474**
61.61	6175.16	**631**
61.80	6178.33	**676**
62.00	6181.49	**751**
62.19	6184.65	**727**
62.39	6187.81	**664**
62.58	6190.97	**652**
62.78	6194.12	**618**
62.97	6197.28	**686**
63.17	6200.42	**638**
63.36	6203.56	**578**
63.56	6206.69	**574**
63.75	6209.82	**566**
63.95	6212.95	**574**
64.14	6216.06	**562**
64.34	6219.17	**551**
64.53	6222.27	**554**
64.73	6225.36	**577**
64.92	6228.45	**560**
65.12	6231.53	**553**
65.31	6234.61	**506**
65.51	6237.68	**523**
65.70	6240.75	**519**
65.90	6243.82	**567**
66.09	6246.88	**612**
66.28	6249.94	**563**
66.48	6253.01	**539**
66.67	6255.92	**554**
66.86	6258.99	**570**
67.06	6262.05	**658**
67.25	6265.12	**609**

180.62	8059.79	**687**
180.82	8064.95	**613**
181.02	8070.12	**594**
181.22	8075.29	**546**
181.42	8080.48	**579**
181.62	8085.67	**505**
181.82	8090.89	**586**
182.03	8096.13	**568**
182.23	8101.38	**614**
182.43	8106.64	**607**
182.63	8111.90	**571**
182.83	8117.16	**609**
183.03	8122.39	**614**
183.23	8127.58	**647**
183.43	8132.74	**611**
183.63	8137.84	**588**
183.83	8142.89	**571**
184.03	8147.85	**566**
184.24	8152.74	**610**
184.44	8157.58	**567**
184.64	8162.41	**558**
184.84	8167.25	**546**
185.04	8172.14	**556**
185.24	8177.12	**551**
185.44	8182.18	**633**
185.64	8187.41	**579**
185.84	8192.80	**584**
186.04	8198.38	**540**
186.24	8204.17	**568**
186.45	8210.02	**520**
186.65	8215.82	**503**
186.85	8221.46	**434**
187.05	8226.78	**408**
187.25	8231.69	**496**
187.45	8236.04	**535**
187.65	8239.71	**593**
187.85	8242.58	**601**
188.05	8244.53	**605**
188.25	8245.63	**649**
188.45	8246.34	**600**
188.65	8247.18	**580**
188.86	8248.63	**522**
189.06	8251.22	**526**
189.26	8255.45	**546**
189.46	8261.81	**534**
189.66	8270.83	**502**
189.86	8282.98	**452**
190.05	8297.90	**489**
190.25	8317.32	**473**
190.45	8339.93	**447**
190.65	8365.28	**428**
190.85	8392.65	**481**
191.06	8421.48	**487**
191.26	8451.19	**504**
191.46	8481.17	**495**
191.66	8510.87	**470**
191.86	8539.64	**534**
192.06	8566.82	**465**
192.26	8592.27	**452**

304.59	13421.82	**400**
304.79	13424.84	**392**
304.99	13427.90	**403**
305.18	13431.00	**407**
305.38	13434.13	**403**
305.58	13437.26	**394**
305.78	13440.39	**383**
305.98	13443.51	**449**
306.18	13446.60	**447**
306.38	13449.66	**423**
306.58	13452.71	**393**
306.78	13455.73	**414**
306.98	13458.75	**381**
307.17	13461.76	**407**
307.37	13464.77	**373**
307.57	13467.80	**290**
307.77	13470.83	**297**
307.97	13473.88	**342**
308.17	13476.95	**374**
308.37	13480.05	**376**
308.57	13483.15	**403**
308.77	13486.27	**362**
308.97	13489.39	**278**
309.17	13492.52	**273**
309.36	13495.63	**353**
309.56	13498.74	**352**
309.76	13501.83	**388**
309.96	13504.91	**342**
310.16	13507.96	**326**
310.36	13510.99	**357**
310.56	13514.00	**333**
310.76	13517.00	**389**
310.96	13520.00	**391**
311.16	13523.00	**332**
311.35	13526.00	**369**
311.55	13529.02	**387**
311.75	13532.05	**337**
311.95	13535.10	**350**
312.15	13538.18	**367**
312.35	13541.29	**314**
312.55	13544.41	**341**
312.75	13547.54	**348**
312.95	13550.68	**324**
313.15	13553.82	**338**
313.35	13556.95	**316**
313.54	13560.06	**336**
313.74	13563.16	**356**
313.94	13566.24	**358**
314.14	13569.28	**333**
314.34	13572.30	**286**
314.54	13575.29	**277**
314.74	13578.25	**300**
314.94	13581.20	**309**
315.14	13584.14	**301**
315.34	13587.07	**270**
315.53	13589.99	**352**
315.73	13592.92	**301**
315.93	13595.84	**339**
316.13	13598.78	**335**

429.02	15668.91	**358**
429.22	15668.91	**398**
429.42	15668.91	**417**
429.61	15668.91	**448**
429.81	15668.91	**443**
430.01	15668.91	**417**
430.20	15668.91	**421**
430.40	15668.91	**444**
430.59	15668.91	**395**
430.79	15668.91	**430**
430.99	15668.91	**408**
431.18	15668.91	**346**
431.38	15668.91	**347**
431.57	15668.91	**353**
431.77	15669.23	**326**
431.97	15669.62	**397**
432.16	15670.10	**440**
432.36	15670.66	**420**
432.56	15671.28	**421**
432.75	15671.96	**414**
432.95	15672.67	**466**
433.14	15673.41	**422**
433.34	15674.17	**393**
433.54	15674.92	**440**
433.73	15675.67	**383**
433.93	15676.39	**424**
434.13	15677.07	**456**
434.32	15677.72	**439**
434.52	15678.35	**402**
434.71	15678.99	**424**
434.91	15679.64	**400**
435.11	15680.31	**434**
435.30	15681.04	**413**
435.50	15681.83	**360**
435.69	15682.70	**445**
435.89	15683.66	**388**
436.09	15684.73	**414**
436.28	15685.89	**363**
436.48	15687.11	**430**
436.68	15688.32	**440**
436.86	15689.44	**457**
437.06	15690.53	**499**
437.26	15691.52	**469**
437.46	15692.27	**538**
437.66	15692.79	**558**
437.84	15693.01	**618**
438.04	15693.02	**548**
438.23	15693.02	**551**
438.43	15693.02	**574**
438.63	15693.02	**596**
438.82	15693.02	**529**
439.02	15693.02	**574**
439.22	15693.02	**577**
439.41	15693.03	**505**
439.61	15693.03	**590**
439.80	15693.03	**557**
440.00	15693.03	**577**
440.20	15693.03	**536**
440.39	15693.03	**574**

Table 0-1—*Continued*

67.44	6268.19	**605**
67.64	6271.26	**570**
67.83	6274.34	**532**
68.03	6277.43	**568**
68.22	6280.51	**611**
68.42	6283.61	**641**
68.61	6286.71	**629**
68.81	6289.81	**679**
69.00	6292.92	**695**
69.20	6296.01	**704**
69.39	6299.11	**681**
69.59	6302.20	**650**
69.78	6305.29	**621**
69.98	6308.38	**628**
70.17	6311.45	**620**
70.37	6314.52	**579**
70.56	6317.58	**636**
70.76	6320.64	**679**
70.95	6323.69	**734**
71.15	6326.72	**788**
71.34	6329.76	**802**
71.54	6332.79	**785**
71.73	6335.82	**795**
71.92	6338.70	**742**
72.11	6341.72	**649**
72.31	6344.74	**604**
72.50	6347.76	**551**
72.70	6350.77	**561**
72.89	6353.79	**505**
73.09	6356.80	**419**
73.28	6359.81	**359**
73.48	6362.82	**366**
73.67	6365.83	**540**
73.87	6368.84	**613**
74.06	6371.85	**635**
74.25	6374.86	**579**
74.45	6377.87	**572**
74.64	6380.88	**507**
74.84	6383.89	**501**
75.03	6386.90	**516**
75.23	6389.91	**582**
75.42	6392.92	**601**
75.62	6395.92	**644**
75.81	6398.93	**629**
76.01	6401.94	**629**
76.20	6404.93	**634**
76.40	6407.94	**633**
76.59	6410.94	**598**
76.79	6413.94	**653**
76.98	6416.94	**629**
77.17	6419.79	**606**
77.36	6422.78	**638**
77.56	6425.77	**668**
77.75	6428.77	**723**
77.95	6431.77	**613**
78.14	6434.76	**604**
78.34	6437.76	**644**
78.53	6440.76	**694**
78.73	6443.76	**772**

192.46	8616.05	**464**
192.66	8638.47	**374**
192.86	8659.79	**349**
193.06	8680.21	**298**
193.27	8699.98	**392**
193.47	8719.38	**499**
193.67	8738.66	**527**
193.87	8757.99	**555**
194.07	8777.74	**565**
194.27	8797.89	**627**
194.47	8818.58	**634**
194.67	8839.56	**696**
194.87	8860.85	**615**
195.07	8882.37	**574**
195.27	8904.10	**621**
195.47	8925.90	**625**
195.68	8947.75	**615**
195.88	8969.62	**570**
196.08	8991.33	**617**
196.28	9013.00	**576**
196.48	9034.54	**504**
196.68	9055.99	**514**
196.88	9077.38	**444**
197.08	9098.72	**584**
197.28	9120.03	**592**
197.48	9141.39	**610**
197.68	9162.65	**644**
197.89	9183.99	**679**
198.09	9205.34	**675**
198.29	9226.73	**608**
198.49	9248.19	**587**
198.69	9269.62	**575**
198.89	9291.14	**613**
199.09	9312.66	**647**
199.29	9334.19	**568**
199.49	9355.77	**548**
199.69	9377.34	**504**
199.89	9398.91	**477**
200.10	9420.48	**516**
200.30	9442.06	**602**
200.49	9462.59	**631**
200.69	9484.18	**628**
200.89	9505.78	**704**
201.09	9527.39	**747**
201.29	9549.05	**681**
201.49	9570.66	**652**
201.69	9592.36	**681**
201.89	9614.08	**659**
202.09	9635.76	**743**
202.30	9657.54	**636**
202.50	9679.34	**737**
202.70	9701.09	**664**
202.90	9722.92	**768**
203.10	9744.73	**669**
203.30	9766.54	**726**
203.50	9788.39	**730**
203.70	9810.17	**713**
203.90	9832.01	**728**
204.10	9853.80	**683**

316.33	13601.72	**351**
316.53	13604.67	**337**
316.73	13607.63	**395**
316.93	13610.59	**394**
317.13	13613.56	**351**
317.33	13616.52	**383**
317.52	13619.49	**316**
317.72	13622.45	**347**
317.92	13625.42	**353**
318.12	13628.37	**373**
318.32	13631.33	**364**
318.52	13634.28	**321**
318.72	13637.23	**313**
318.92	13640.17	**337**
319.12	13643.12	**339**
319.32	13646.06	**414**
319.52	13649.00	**385**
319.71	13651.95	**393**
319.91	13654.89	**411**
320.11	13657.83	**435**
320.31	13660.78	**414**
320.51	13663.73	**403**
320.71	13666.67	**381**
320.91	13669.62	**417**
321.11	13672.56	**404**
321.31	13675.50	**433**
321.51	13678.44	**414**
321.70	13681.37	**360**
321.90	13684.29	**487**
322.10	13687.21	**424**
322.30	13690.13	**468**
322.50	13693.03	**434**
322.70	13695.94	**444**
322.90	13698.83	**460**
323.10	13701.73	**455**
323.30	13704.63	**463**
323.50	13707.52	**452**
323.69	13710.41	**426**
323.89	13713.30	**436**
324.09	13716.20	**434**
324.29	13719.09	**462**
324.49	13721.99	**441**
324.69	13724.89	**388**
324.89	13727.79	**394**
325.09	13730.70	**415**
325.29	13733.61	**375**
325.49	13736.51	**342**
325.69	13739.42	**357**
325.88	13742.34	**398**
326.08	13745.26	**411**
326.28	13748.18	**436**
326.48	13751.10	**413**
326.68	13754.02	**407**
326.88	13756.95	**353**
327.08	13759.88	**403**
327.28	13762.82	**419**
327.48	13765.76	**396**
327.68	13768.70	**409**
327.87	13771.65	**430**

440.59	15693.03	**547**
440.79	15693.04	**590**
440.98	15693.04	**584**
441.18	15693.04	**576**
441.37	15693.04	**578**
441.57	15693.04	**529**
441.77	15693.04	**530**
441.96	15693.05	**545**
442.16	15693.05	**530**
442.35	15693.05	**529**
442.55	15693.05	**531**
442.75	15693.05	**527**
442.94	15693.05	**546**
443.14	15693.05	**536**
443.34	15693.06	**506**
443.53	15693.06	**524**
443.73	15693.06	**536**
443.92	15693.06	**532**
444.12	15693.50	**479**
444.32	15694.33	**528**
444.51	15695.53	**546**
444.71	15697.09	**471**
444.91	15698.98	**473**
445.10	15701.19	**491**
445.30	15703.70	**530**
445.49	15706.49	**510**
445.69	15709.53	**485**
445.89	15712.82	**522**
446.08	15716.33	**529**
446.28	15720.04	**478**
446.47	15723.93	**547**
446.67	15727.96	**493**
446.87	15732.12	**466**
447.06	15736.39	**560**
447.26	15740.73	**561**
447.46	15745.12	**517**
447.65	15749.54	**504**
447.85	15757.83	**611**
448.04	15766.62	**594**
448.24	15775.36	**634**
448.44	15784.01	**576**
448.63	15792.61	**545**
448.83	15801.16	**530**
449.03	15809.67	**509**
449.22	15818.16	**491**
449.42	15826.64	**510**
449.61	15835.11	**477**
449.81	15843.60	**494**
450.01	15852.10	**530**
450.20	15860.64	**504**
450.40	15869.20	**523**
450.59	15877.79	**439**
450.79	15886.39	**470**
450.99	15895.01	**460**
451.18	15903.63	**456**
451.38	15912.25	**457**
451.58	15920.87	**489**
451.77	15929.51	**440**
451.97	15938.12	**440**

Table 0-1—*Continued*

78.92	6446.76	**800**
79.12	6449.76	**964**
79.31	6452.75	**812**
79.51	6455.75	**864**
79.70	6458.76	**807**
79.90	6461.77	**723**
80.09	6464.78	**731**
80.29	6467.79	**740**
80.48	6470.80	**763**
80.68	6473.82	**759**
80.87	6476.84	**748**
81.07	6479.86	**762**
81.26	6482.88	**709**
81.46	6485.90	**768**
81.65	6488.92	**780**
81.85	6491.94	**709**
82.04	6494.97	**667**
82.23	6497.99	**682**
82.42	6500.86	**681**
82.62	6503.89	**694**
82.81	6506.92	**657**
83.01	6509.95	**664**
83.20	6512.99	**682**
83.39	6516.02	**685**
83.59	6519.05	**742**
83.78	6522.10	**767**
83.98	6525.15	**748**
84.17	6528.21	**743**
84.37	6531.26	**691**
84.56	6534.33	**731**
84.76	6537.39	**772**
84.95	6540.46	**752**
85.15	6543.53	**738**
85.34	6546.60	**672**
85.54	6549.67	**728**
85.73	6552.74	**655**
85.93	6555.81	**555**
86.12	6558.87	**482**
86.32	6561.93	**493**
86.51	6564.99	**468**
86.71	6568.05	**502**
86.90	6571.11	**507**
87.10	6574.17	**572**
87.29	6577.23	**679**
87.49	6580.28	**636**
87.67	6583.20	**648**
87.87	6586.26	**632**
88.06	6589.34	**617**
88.26	6592.41	**573**
88.45	6595.48	**591**
88.65	6598.57	**629**
88.84	6601.65	**645**
89.04	6604.73	**637**
89.23	6607.81	**587**
89.43	6610.87	**617**
89.62	6613.95	**633**
89.82	6617.02	**681**
90.01	6620.08	**710**
90.21	6623.14	**645**

204.30	9875.59	**619**
204.50	9897.37	**636**
204.71	9919.18	**625**
204.91	9940.92	**585**
205.11	9962.77	**608**
205.31	9984.52	**580**
205.51	10006.35	**668**
205.71	10028.16	**634**
205.91	10049.99	**605**
206.11	10071.84	**620**
206.31	10093.75	**548**
206.51	10115.65	**547**
206.71	10137.59	**561**
206.92	10159.60	**655**
207.12	10181.59	**590**
207.32	10203.70	**555**
207.52	10225.83	**549**
207.72	10248.01	**541**
207.92	10270.26	**548**
208.12	10292.61	**543**
208.32	10314.98	**503**
208.52	10337.40	**524**
208.72	10359.73	**527**
208.92	10382.08	**541**
209.13	10404.36	**466**
209.33	10426.44	**487**
209.53	10448.46	**427**
209.73	10470.25	**414**
209.93	10491.84	**415**
210.13	10513.21	**454**
210.33	10534.22	**446**
210.53	10554.94	**452**
210.73	10575.31	**493**
210.92	10594.20	**498**
211.12	10613.71	**400**
211.32	10632.65	**440**
211.53	10651.01	**444**
211.73	10668.76	**429**
211.93	10685.88	**419**
212.13	10702.26	**407**
212.33	10717.93	**409**
212.53	10732.88	**393**
212.73	10747.14	**386**
212.93	10760.73	**409**
213.13	10773.62	**413**
213.33	10785.84	**403**
213.53	10797.42	**398**
213.74	10808.32	**371**
213.94	10818.60	**374**
214.14	10828.28	**420**
214.34	10837.35	**387**
214.50	10844.33	**343**
214.54	10845.97	**388**
214.70	10852.39	**340**
214.89	10860.15	**399**
215.09	10867.67	**353**
215.28	10875.06	**366**
215.48	10882.39	**411**
215.67	10889.73	**410**

328.07	13774.60	**376**
328.27	13777.56	**392**
328.47	13780.52	**392**
328.67	13783.48	**395**
328.87	13786.45	**356**
329.07	13789.42	**348**
329.27	13792.38	**324**
329.47	13795.35	**342**
329.67	13798.32	**340**
329.87	13801.28	**306**
330.06	13804.25	**312**
330.26	13807.21	**300**
330.46	13810.17	**325**
330.66	13813.12	**331**
330.86	13816.07	**321**
331.06	13819.01	**321**
331.26	13821.94	**302**
331.46	13824.87	**320**
331.66	13827.78	**306**
331.86	13830.69	**325**
332.05	13833.58	**306**
332.25	13836.46	**312**
332.45	13839.34	**312**
332.65	13842.21	**275**
332.85	13845.07	**305**
333.05	13847.93	**256**
333.24	13850.65	**296**
333.45	13853.67	**315**
333.65	13856.54	**307**
333.85	13859.43	**347**
334.04	13862.33	**375**
334.23	13865.10	**400**
334.43	13868.02	**396**
334.64	13871.09	**315**
334.84	13874.01	**346**
335.04	13876.92	**315**
335.23	13879.67	**283**
335.43	13882.55	**306**
335.63	13885.40	**316**
335.84	13888.36	**269**
336.03	13891.15	**294**
336.22	13893.76	**309**
336.42	13896.46	**303**
336.62	13899.14	**286**
336.82	13901.79	**280**
337.02	13904.42	**314**
337.22	13907.02	**279**
337.42	13909.61	**344**
337.62	13912.20	**276**
337.82	13914.78	**264**
338.02	13917.35	**365**
338.21	13919.94	**297**
338.41	13922.52	**278**
338.61	13925.11	**311**
338.81	13927.71	**286**
339.01	13930.31	**262**
339.21	13932.93	**336**
339.41	13935.56	**357**
339.61	13938.19	**367**

452.16	15946.72	**448**
452.36	15955.31	**471**
452.56	15963.89	**484**
452.75	15972.45	**428**
452.95	15981.01	**393**
453.14	15989.54	**407**
453.34	15998.07	**423**
453.54	16006.59	**393**
453.73	16015.09	**453**
453.93	16023.58	**475**
454.13	16032.09	**449**
454.32	16040.57	**482**
454.52	16049.05	**426**
454.71	16057.53	**455**
454.91	16066.01	**472**
455.11	16074.48	**449**
455.30	16082.97	**432**
455.50	16091.45	**406**
455.70	16099.95	**333**
455.89	16108.46	**391**
456.09	16116.97	**363**
456.28	16125.49	**342**
456.48	16134.04	**402**
456.68	16142.57	**356**
456.87	16151.11	**370**
457.07	16159.63	**380**
457.26	16168.16	**351**
457.46	16176.66	**336**
457.66	16185.16	**376**
457.85	16193.62	**387**
458.05	16202.07	**407**
458.25	16210.49	**390**
458.44	16218.87	**343**
458.64	16227.25	**371**
458.83	16235.62	**326**
459.03	16243.97	**336**
459.23	16252.34	**317**
459.42	16260.71	**352**
459.62	16269.09	**319**
459.82	16277.48	**342**
460.00	16285.42	**347**
460.01	16285.91	**388**
460.19	16293.66	**372**
460.38	16301.92	**351**
460.57	16310.19	**321**
460.77	16318.48	**315**
460.96	16326.78	**411**
461.15	16335.08	**403**
461.34	16343.39	**457**
461.53	16351.69	**455**
461.72	16359.98	**547**
461.91	16368.28	**490**
462.11	16376.54	**547**
462.30	16384.80	**543**
462.49	16393.02	**566**
462.68	16401.24	**574**
462.87	16409.43	**572**
463.06	16417.60	**514**
463.25	16425.75	**548**

Table 0-1—*Continued*

90.40	6626.19	**663**
90.59	6629.24	**658**
90.79	6632.29	**728**
90.98	6635.34	**677**
91.18	6638.39	**656**
91.37	6641.44	**624**
91.57	6644.50	**611**
91.76	6647.56	**591**
91.96	6650.64	**621**
92.15	6653.72	**565**
92.35	6656.81	**556**
92.54	6659.91	**505**
92.74	6663.02	**555**
92.92	6665.98	**632**
93.12	6669.09	**583**
93.31	6672.19	**639**
93.51	6675.30	**647**
93.70	6678.41	**742**
93.90	6681.51	**685**
94.09	6684.60	**778**
94.29	6687.68	**686**
94.48	6690.77	**695**
94.68	6693.84	**653**
94.87	6696.92	**639**
95.00	6698.93	**650**
95.07	6699.99	**655**
95.20	6702.12	**571**
95.41	6705.32	**623**
95.61	6708.51	**625**
95.81	6711.72	**589**
96.01	6714.92	**595**
96.21	6718.13	**590**
96.42	6721.36	**512**
96.62	6724.58	**490**
96.82	6727.81	**505**
97.03	6731.04	**558**
97.23	6734.27	**551**
97.43	6737.48	**601**
97.63	6740.70	**561**
97.83	6743.91	**560**
98.04	6747.11	**568**
98.24	6750.31	**548**
98.44	6753.49	**614**
98.64	6756.67	**599**
98.85	6759.85	**704**
99.05	6763.03	**692**
99.25	6766.21	**684**
99.45	6769.40	**652**
99.66	6772.60	**685**
99.86	6775.82	**661**
100.06	6779.05	**586**
100.26	6782.30	**617**
100.46	6785.40	**629**
100.66	6788.67	**625**
100.86	6791.96	**549**
101.06	6795.25	**555**
101.27	6798.56	**554**
101.47	6801.87	**550**
101.67	6805.18	**603**

215.87	10897.15	**395**
216.06	10904.77	**413**
216.26	10912.58	**398**
216.45	10920.55	**425**
216.65	10928.62	**367**
216.84	10936.70	**441**
217.04	10944.77	**463**
217.23	10952.74	**404**
217.43	10960.58	**392**
217.62	10968.20	**327**
217.82	10975.55	**342**
218.01	10982.57	**337**
218.21	10989.24	**343**
218.40	10995.60	**371**
218.59	11001.46	**388**
218.78	11007.44	**290**
218.98	11013.37	**327**
219.17	11019.30	**322**
219.37	11025.32	**322**
219.56	11031.47	**330**
219.76	11037.89	**325**
219.96	11044.62	**333**
220.15	11051.71	**356**
220.35	11059.19	**338**
220.54	11066.97	**398**
220.74	11075.04	**347**
220.93	11083.33	**323**
221.13	11091.78	**362**
221.32	11100.35	**371**
221.52	11108.98	**335**
221.71	11117.64	**393**
221.91	11126.30	**400**
222.10	11134.85	**418**
222.30	11143.33	**473**
222.49	11151.69	**448**
222.69	11160.00	**430**
222.88	11168.26	**398**
223.08	11176.48	**402**
223.27	11184.64	**392**
223.47	11192.82	**354**
223.66	11200.98	**358**
223.86	11209.17	**385**
224.05	11217.37	**426**
224.25	11225.60	**372**
224.44	11233.85	**404**
224.64	11242.12	**354**
224.84	11250.41	**340**
225.03	11258.68	**303**
225.23	11266.94	**287**
225.42	11275.18	**307**
225.62	11283.41	**299**
225.81	11291.59	**313**
226.01	11299.74	**341**
226.20	11307.82	**321**
226.40	11315.90	**308**
226.59	11323.96	**274**
226.78	11331.67	**289**
226.97	11339.78	**284**
227.17	11347.99	**294**

339.81	13940.85	**385**
340.00	13943.43	**428**
340.01	13943.51	**386**
340.20	13946.09	**392**
340.40	13948.77	**410**
340.59	13951.47	**356**
340.79	13954.19	**406**
340.99	13956.94	**373**
341.19	13959.72	**420**
341.38	13962.52	**455**
341.58	13965.37	**395**
341.78	13968.25	**387**
341.98	13971.16	**389**
342.17	13974.12	**320**
342.37	13977.11	**339**
342.57	13980.11	**321**
342.77	13983.14	**327**
342.96	13986.16	**316**
343.16	13989.17	**303**
343.36	13992.16	**321**
343.55	13994.98	**311**
343.75	13997.91	**305**
343.94	14000.78	**336**
344.14	14003.60	**343**
344.34	14006.37	**314**
344.54	14009.11	**293**
344.73	14011.85	**289**
344.93	14014.60	**343**
345.13	14017.38	**334**
345.33	14020.22	**294**
345.52	14023.13	**317**
345.72	14026.14	**276**
345.92	14029.26	**254**
346.12	14032.52	**333**
346.31	14035.89	**315**
346.51	14039.35	**318**
346.71	14042.84	**250**
346.91	14046.33	**275**
347.11	14049.78	**296**
347.30	14053.14	**270**
347.50	14056.37	**293**
347.70	14059.43	**337**
347.90	14062.28	**382**
348.09	14064.88	**341**
348.29	14067.24	**319**
348.49	14069.39	**349**
348.69	14071.38	**367**
348.88	14073.27	**346**
349.08	14075.10	**395**
349.28	14076.92	**334**
349.48	14078.78	**318**
349.67	14080.73	**361**
349.86	14082.70	**400**
350.06	14084.96	**401**
350.26	14087.42	**364**
350.46	14090.06	**427**
350.65	14092.85	**425**
350.85	14095.77	**362**
351.05	14098.79	**371**

463.44	16433.88	**601**
463.64	16441.98	**587**
463.83	16450.07	**588**
464.02	16458.13	**544**
464.21	16466.17	**536**
464.40	16474.19	**561**
464.59	16482.20	**594**
464.78	16490.19	**526**
464.98	16498.21	**536**
465.17	16506.21	**563**
465.36	16514.22	**515**
465.55	16522.25	**495**
465.74	16530.30	**496**
465.93	16538.37	**549**
466.12	16546.48	**621**
466.32	16554.61	**603**
466.51	16562.80	**575**
466.70	16571.03	**572**
466.89	16579.32	**567**
467.08	16587.66	**575**
467.27	16596.08	**585**
467.46	16604.56	**610**
467.66	16613.12	**567**
467.85	16621.76	**555**
468.04	16630.51	**521**
468.23	16639.31	**429**
468.42	16648.17	**450**
468.61	16657.02	**510**
468.80	16665.85	**461**
469.00	16674.59	**440**
469.19	16683.23	**463**
469.38	16691.69	**510**
469.57	16699.97	**504**
469.76	16708.00	**477**
469.95	16715.76	**483**
470.14	16723.20	**423**
470.33	16730.36	**458**
470.53	16737.30	**442**
470.72	16744.08	**423**
470.91	16750.76	**405**
471.10	16757.41	**478**
471.29	16764.08	**410**
471.48	16770.84	**383**
471.67	16777.74	**443**
471.87	16784.86	**422**
472.05	16791.87	**487**
472.24	16799.61	**470**
472.43	16807.88	**503**
472.62	16816.85	**492**
472.82	16827.20	**496**
473.00	16837.57	**465**
473.20	16849.66	**465**
473.39	16863.14	**387**
473.58	16878.17	**417**
473.77	16894.94	**401**
473.96	16913.58	**391**
474.15	16934.31	**422**
474.34	16957.17	**425**
474.54	16982.33	**437**

Table 0-1—*Continued*

101.87	6808.49	**617**
102.08	6811.80	**623**
102.28	6815.10	**524**
102.48	6818.40	**534**
102.68	6821.70	**417**
102.89	6825.00	**457**
103.09	6828.31	**515**
103.29	6831.62	**540**
103.49	6834.94	**596**
103.70	6838.26	**537**
103.90	6841.59	**491**
104.10	6844.93	**459**
104.30	6848.29	**469**
104.51	6851.65	**427**
104.71	6855.03	**492**
104.91	6858.40	**485**
105.11	6861.79	**491**
105.32	6865.18	**500**
105.52	6868.58	**466**
105.72	6871.97	**479**
105.92	6875.37	**468**
106.13	6878.77	**499**
106.33	6882.18	**499**
106.53	6885.58	**538**
106.73	6888.99	**549**
106.94	6892.41	**481**
107.14	6895.83	**499**
107.34	6899.25	**507**
107.54	6902.69	**549**
107.75	6906.14	**543**
107.95	6909.60	**487**
108.15	6913.08	**485**
108.35	6916.56	**535**
108.56	6920.06	**558**
108.76	6923.55	**651**
108.96	6927.04	**611**
109.16	6930.53	**639**
109.37	6934.02	**667**
109.57	6937.49	**669**
109.77	6940.95	**677**
109.96	6944.22	**678**
110.17	6947.64	**633**
110.37	6951.04	**610**
110.57	6954.42	**645**
110.77	6957.79	**631**
110.98	6961.15	**631**
111.18	6964.50	**632**
111.38	6967.84	**609**
111.58	6971.18	**590**
111.79	6974.52	**585**
111.99	6977.86	**602**
112.19	6981.20	**599**
112.39	6984.55	**674**
112.60	6987.91	**736**
112.80	6991.27	**716**
113.00	6994.63	**780**
113.20	6997.99	**766**
113.41	7001.35	**767**
113.61	7004.72	**714**

227.36	11356.28	**331**
227.56	11364.71	**323**
227.75	11373.26	**347**
227.95	11381.98	**347**
228.14	11390.88	**334**
228.34	11399.94	**337**
228.53	11409.06	**361**
228.73	11418.14	**387**
228.92	11427.12	**280**
229.12	11435.94	**353**
229.31	11444.48	**292**
229.51	11452.70	**269**
229.70	11460.47	**269**
229.90	11467.77	**292**
230.10	11474.50	**265**
230.29	11480.76	**305**
230.49	11486.85	**279**
230.68	11493.09	**279**
230.88	11499.77	**296**
231.07	11507.23	**283**
231.27	11515.73	**241**
231.46	11525.61	**257**
231.66	11537.13	**261**
231.85	11550.66	**277**
232.05	11566.46	**239**
232.24	11584.61	**295**
232.44	11604.56	**298**
232.63	11625.91	**249**
232.83	11648.03	**260**
233.02	11670.50	**231**
233.22	11692.66	**252**
233.41	11714.02	**260**
233.61	11734.09	**246**
233.80	11752.35	**302**
234.00	11768.24	**259**
234.19	11781.36	**238**
234.39	11791.93	**256**
234.58	11800.31	**290**
234.77	11806.55	**332**
234.97	11811.62	**290**
235.16	11815.51	**304**
235.36	11818.58	**326**
235.55	11821.15	**266**
235.75	11823.58	**268**
235.94	11826.23	**302**
236.14	11829.39	**261**
236.33	11833.16	**259**
236.53	11837.43	**273**
236.72	11842.15	**294**
236.92	11847.20	**284**
237.11	11852.52	**267**
237.31	11858.02	**293**
237.50	11863.62	**294**
237.70	11869.23	**334**
237.89	11874.77	**320**
238.09	11880.14	**285**
238.28	11885.35	**283**
238.48	11890.38	**282**
238.67	11895.29	**285**

351.25	14101.88	**378**
351.44	14105.02	**353**
351.64	14108.17	**363**
351.84	14111.32	**397**
352.04	14114.43	**361**
352.23	14117.49	**364**
352.43	14120.49	**345**
352.63	14123.46	**416**
352.83	14126.39	**368**
353.02	14129.29	**376**
353.22	14132.17	**341**
353.42	14135.04	**301**
353.62	14137.91	**318**
353.82	14140.78	**312**
354.01	14143.65	**356**
354.21	14146.54	**305**
354.41	14149.44	**313**
354.61	14152.36	**362**
354.80	14155.28	**362**
355.00	14158.21	**336**
355.20	14161.15	**355**
355.40	14164.10	**397**
355.59	14167.04	**449**
355.79	14169.98	**391**
355.99	14172.91	**381**
356.18	14175.70	**362**
356.37	14178.62	**357**
356.57	14181.55	**353**
356.77	14184.47	**373**
356.97	14187.39	**347**
357.16	14190.31	**349**
357.36	14193.23	**364**
357.56	14196.15	**323**
357.76	14199.08	**344**
357.96	14202.01	**360**
358.15	14204.95	**417**
358.35	14207.90	**429**
358.55	14210.85	**392**
358.75	14213.79	**404**
358.94	14216.73	**387**
359.14	14219.67	**361**
359.34	14222.60	**354**
359.54	14225.51	**259**
359.73	14228.41	**229**
359.93	14231.30	**281**
360.13	14234.16	**277**
360.33	14237.01	**311**
360.52	14239.86	**275**
360.72	14242.71	**307**
360.92	14245.58	**275**
361.12	14248.47	**300**
361.32	14251.39	**299**
361.51	14254.35	**326**
361.71	14257.36	**309**
361.91	14260.44	**278**
362.11	14263.59	**269**
362.30	14266.78	**280**
362.49	14269.84	**284**
362.69	14273.04	**282**

474.73	17009.74	**451**
474.92	17039.57	**437**
475.11	17071.81	**399**
475.30	17106.63	**396**
475.49	17144.00	**406**
475.68	17184.10	**423**
475.88	17226.90	**443**
476.07	17272.58	**468**
476.26	17320.87	**470**
476.45	17371.41	**434**
476.64	17423.56	**481**
476.83	17476.95	**459**
477.02	17530.92	**524**
477.21	17585.12	**393**
477.41	17638.88	**470**
477.60	17691.91	**469**
477.79	17743.42	**450**
477.98	17793.10	**394**
478.17	17840.41	**373**
478.36	17885.60	**344**
478.55	17928.85	**399**
478.75	17970.56	**477**
478.94	18010.94	**413**
479.13	18050.38	**421**
479.32	18089.08	**448**
479.51	18127.44	**430**
479.70	18165.67	**480**
479.89	18204.15	**452**
480.09	18243.09	**467**
480.28	18282.70	**454**
480.47	18322.79	**410**
480.66	18363.45	**396**
480.85	18404.34	**413**
481.04	18445.56	**408**
481.23	18486.88	**412**
481.43	18528.33	**398**
481.62	18569.70	**414**
481.81	18611.02	**419**
482.00	18652.08	**468**
482.19	18692.91	**389**
482.38	18733.44	**450**
482.57	18773.82	**451**
482.77	18813.98	**479**
482.96	18854.10	**513**
483.15	18894.10	**518**
483.34	18934.14	**506**
483.53	18974.16	**501**
483.72	19014.39	**487**
483.91	19054.63	**446**
484.11	19095.11	**416**
484.30	19135.72	**447**
484.49	19176.56	**461**
484.68	19217.50	**424**
484.87	19258.63	**435**
485.06	19299.83	**447**
485.25	19341.17	**459**
485.44	19382.54	**401**
485.64	19424.02	**400**
485.83	19465.49	**406**

Table 0-1—*Continued*

113.81	7008.07	**694**
114.01	7011.44	**753**
114.22	7014.79	**828**
114.42	7018.15	**798**
114.62	7021.51	**735**
114.82	7024.87	**699**
115.03	7028.22	**705**
115.23	7031.58	**751**
115.43	7034.93	**716**
115.63	7038.30	**686**
115.84	7041.66	**698**
116.04	7045.03	**739**
116.24	7048.41	**688**
116.44	7051.78	**741**
116.65	7055.17	**705**
116.85	7058.55	**642**
117.05	7061.93	**673**
117.25	7065.32	**650**
117.46	7068.71	**690**
117.66	7072.11	**656**
117.86	7075.51	**651**
118.06	7078.90	**720**
118.27	7082.30	**666**
118.47	7085.70	**694**
118.67	7089.09	**608**
118.87	7092.49	**665**
119.08	7095.89	**588**
119.28	7099.28	**484**
119.48	7102.67	**383**
119.68	7106.05	**365**
119.89	7109.43	**426**
120.09	7112.81	**416**
120.29	7116.17	**517**
120.48	7119.36	**450**
120.69	7122.72	**541**
120.89	7126.07	**488**
121.09	7128.47	**596**
121.29	7130.14	**497**
121.50	7131.81	**509**
121.70	7133.48	**522**
121.90	7135.15	**532**
122.10	7136.82	**498**
122.31	7138.48	**525**
122.51	7140.15	**585**
122.71	7141.81	**588**
122.91	7143.48	**533**
123.12	7145.14	**522**
123.32	7146.80	**463**

238.87	11900.09	**298**
239.06	11904.82	**308**
239.26	11909.52	**276**
239.45	11914.19	**280**
239.65	11918.88	**288**
239.84	11923.60	**296**
240.04	11928.41	**274**
240.23	11933.30	**245**
240.43	11938.28	**285**
240.63	11943.33	**301**
240.82	11948.45	**273**
241.02	11953.63	**284**
241.21	11958.88	**329**
241.41	11964.16	**290**
241.60	11969.48	**311**
241.80	11974.81	**283**
241.99	11980.18	**321**
242.19	11985.56	**356**
242.38	11990.93	**376**
242.58	11996.29	**317**
242.76	12001.38	**322**
242.96	12006.72	**348**
243.15	12012.03	**354**
243.35	12017.29	**346**
243.54	12022.50	**372**
243.74	12027.67	**332**
243.93	12032.76	**336**
244.13	12037.81	**326**
244.32	12042.76	**333**
244.52	12047.66	**322**
244.71	12052.50	**346**
244.91	12057.31	**292**
245.10	12062.07	**280**
245.30	12066.80	**307**
245.49	12071.51	**319**
245.69	12076.22	**312**
245.89	12080.91	**316**
246.08	12085.63	**339**
246.28	12090.32	**327**
246.47	12095.04	**298**
246.67	12099.76	**298**
246.86	12104.47	**303**
247.06	12109.18	**250**
247.25	12113.88	**284**
247.45	12118.58	**336**
247.64	12123.26	**302**
247.84	12127.93	**336**
248.03	12132.57	**323**

362.89	14276.20	**237**
363.08	14279.28	**323**
363.28	14282.24	**360**
363.48	14285.05	**331**
363.68	14287.68	**293**
363.87	14290.09	**291**
364.07	14292.26	**300**
364.27	14294.20	**323**
364.47	14296.04	**338**
364.67	14297.77	**349**
364.86	14298.79	**336**
365.06	14299.95	**342**
365.26	14301.31	**366**
365.46	14302.95	**297**
365.65	14304.92	**281**
365.85	14307.28	**328**
366.05	14310.11	**326**
366.25	14313.37	**307**
366.44	14316.85	**311**
366.64	14320.29	**300**
366.84	14323.47	**363**
367.04	14326.15	**329**
367.23	14328.09	**360**
367.43	14329.04	**371**
367.63	14329.32	**374**
367.83	14329.61	**350**
368.03	14329.89	**347**
368.22	14330.18	**377**
368.42	14330.46	**346**
368.62	14330.75	**340**
368.81	14331.02	**272**
369.00	14331.30	**283**
369.20	14331.59	**265**
369.40	14331.87	**270**
369.60	14339.15	**308**
369.79	14351.78	**268**
369.99	14380.85	**255**
370.19	14432.19	**197**
370.39	14495.21	**201**
370.58	14566.99	**182**
370.78	14644.77	**251**
370.98	14725.61	**292**
371.18	14806.72	**281**
371.37	14885.26	**251**
371.57	14958.45	**267**
371.77	15023.33	**279**
371.97	15077.28	**279**
372.17	15110.01	**270**

486.02	19507.03	**399**
486.21	19548.52	**440**
486.40	19590.05	**493**
486.59	19631.49	**534**
486.78	19672.99	**512**
486.98	19714.31	**505**
487.17	19755.60	**434**
487.36	19796.73	**386**
487.55	19837.80	**420**
487.74	19878.67	**390**
487.93	19919.44	**456**
488.12	19959.97	**450**
488.32	20000.41	**491**
488.51	20040.67	**438**
488.70	20080.88	**475**
488.89	20120.99	**459**
489.08	20161.13	**423**
489.27	20201.22	**442**
489.46	20241.41	**446**
489.65	20281.62	**426**
489.85	20322.05	**473**
490.04	20362.52	**435**
490.23	20403.21	**388**
490.42	20443.98	**413**
490.61	20484.93	**425**
490.80	20525.92	**398**
490.99	20567.04	**398**
491.19	20608.15	**467**
491.38	20649.34	**397**
491.57	20690.48	**425**
491.76	20731.65	**396**
491.95	20772.72	**416**
492.14	20813.78	**426**
492.33	20854.71	**339**
492.53	20895.65	**399**
492.72	20936.48	**387**
492.91	20977.32	**414**
493.10	21018.09	**408**
493.29	21058.94	**362**
493.48	21099.67	**349**
493.67	21140.47	**336**
493.87	21181.21	**327**
494.06	21222.03	**353**
494.25	21262.82	**343**
494.44	21303.70	**341**
494.63	21344.53	**357**
494.82	21385.45	**307**
495.01	21426.33	**272**

Table 0-2 Sr count results for CCC-003

Depth (mm)	Age (yr BP)	Sr
0.00	3770.32	**2465**
0.20	3805.30	**2432**
0.40	3840.18	**1841**
0.60	3875.10	**1605**
0.80	3909.89	**1582**
1.00	3944.74	**1510**
1.20	3979.58	**1849**
1.40	4014.28	**1769**
1.60	4049.08	**1829**
1.80	4083.83	**1861**
2.00	4118.56	**1901**
2.20	4153.30	**1926**
2.40	4188.03	**1914**
2.60	4222.77	**1897**
2.81	4257.57	**1844**
3.01	4292.32	**1934**
3.21	4327.13	**1918**
3.41	4361.90	**1861**
3.61	4396.67	**1997**
3.81	4431.46	**1835**
4.01	4466.25	**1940**
4.21	4501.11	**1927**
4.41	4535.94	**1978**
4.61	4570.77	**1936**
4.81	4605.61	**1902**
5.01	4640.47	**1937**
5.20	4673.60	**1913**
5.40	4708.53	**2069**
5.60	4743.43	**1995**
5.80	4778.39	**1980**
6.00	4813.31	**1968**
6.20	4848.24	**1936**
6.40	4883.18	**1865**
6.60	4918.19	**1829**
6.80	4953.15	**1794**
7.00	4988.12	**1706**
7.20	5023.10	**1716**
7.40	5058.02	**1762**
7.60	5093.11	**1739**
7.80	5128.04	**1643**
8.00	5163.02	**1748**
8.21	5198.12	**1871**
8.41	5233.05	**1902**
8.61	5268.03	**1762**
8.81	5303.08	**1819**
9.01	5338.09	**1909**
9.21	5373.10	**1835**
9.41	5408.13	**1879**
9.61	5443.17	**2004**
9.81	5478.29	**2129**
10.01	5513.37	**2106**
10.21	5548.53	**2147**
10.41	5583.60	**1950**
10.61	5618.78	**1961**
10.81	5653.98	**2010**

Depth (mm)	Age (yr BP)	Sr
144.13	14576.50	**410**
144.31	14580.24	**442**
144.50	14583.99	**471**
144.69	14587.73	**462**
144.87	14591.49	**484**
145.06	14595.24	**490**
145.24	14599.01	**463**
145.43	14602.77	**481**
145.62	14606.53	**505**
145.80	14610.30	**546**
145.99	14614.08	**549**
146.17	14617.86	**492**
146.36	14621.65	**565**
146.55	14625.44	**564**
146.73	14629.23	**541**
146.92	14633.03	**506**
147.10	14636.83	**566**
147.29	14640.63	**549**
147.47	14644.45	**517**
147.66	14648.26	**495**
147.85	14652.09	**479**
148.03	14655.91	**597**
148.22	14659.75	**455**
148.40	14663.59	**547**
148.59	14667.44	**544**
148.78	14671.28	**541**
148.96	14675.13	**480**
149.15	14678.99	**479**
149.33	14682.85	**503**
149.52	14686.71	**458**
149.71	14690.57	**470**
149.89	14694.42	**457**
150.08	14698.29	**521**
150.26	14702.15	**495**
150.45	14706.01	**470**
150.64	14709.86	**485**
150.82	14713.72	**472**
151.01	14717.57	**510**
151.19	14721.42	**479**
151.38	14725.27	**601**
151.57	14729.12	**580**
151.75	14732.96	**589**
151.94	14736.81	**570**
152.12	14740.65	**591**
152.31	14744.48	**505**
152.50	14748.31	**478**
152.68	14752.14	**535**
152.87	14755.96	**556**
153.05	14759.78	**594**
153.24	14763.59	**646**
153.43	14767.40	**604**
153.61	14771.20	**594**
153.80	14775.00	**644**
153.98	14778.79	**589**
154.17	14782.58	**612**

Depth (mm)	Age (yr BP)	Sr
286.48	17525.32	**714**
286.67	17529.84	**695**
286.87	17534.41	**704**
287.07	17539.01	**676**
287.26	17543.63	**715**
287.46	17548.24	**662**
287.65	17552.83	**676**
287.85	17557.38	**651**
288.05	17561.87	**574**
288.24	17566.29	**631**
288.44	17570.66	**626**
288.64	17574.98	**631**
288.83	17579.26	**631**
289.03	17583.50	**584**
289.22	17587.71	**612**
289.42	17591.91	**617**
289.62	17596.10	**599**
289.80	17600.07	**627**
290.00	17604.27	**630**
290.20	17608.48	**641**
290.39	17612.70	**692**
290.59	17616.93	**585**
290.79	17621.17	**623**
290.98	17625.40	**565**
291.18	17629.62	**571**
291.37	17633.83	**628**
291.57	17638.03	**610**
291.77	17642.20	**565**
291.96	17646.36	**601**
292.16	17650.47	**580**
292.36	17654.57	**555**
292.55	17658.64	**579**
292.75	17662.70	**563**
292.94	17666.75	**588**
293.14	17670.79	**552**
293.34	17674.82	**577**
293.53	17678.87	**610**
293.73	17682.92	**600**
293.93	17687.00	**600**
294.12	17691.08	**597**
294.32	17695.19	**509**
294.51	17699.32	**625**
294.71	17703.47	**554**
294.91	17707.63	**592**
295.10	17711.82	**601**
295.30	17716.00	**624**
295.50	17720.20	**608**
295.69	17724.39	**605**
295.89	17728.60	**576**
296.08	17732.82	**625**
296.28	17737.02	**524**
296.48	17741.24	**589**
296.67	17745.45	**604**
296.87	17749.68	**572**
297.07	17753.90	**573**

Depth (mm)	Age (yr BP)	Sr
430.55	20472.36	**674**
430.75	20472.46	**615**
430.94	20472.55	**673**
431.14	20472.64	**665**
431.34	20472.73	**711**
431.54	20472.82	**644**
431.73	20472.92	**637**
431.93	20473.01	**549**
432.13	20473.10	**449**
432.31	20473.19	**420**
432.51	20473.28	**441**
432.71	20473.37	**466**
432.90	20476.39	**433**
433.10	20480.58	**444**
433.30	20485.62	**442**
433.49	20491.20	**417**
433.69	20497.03	**447**
433.89	20502.81	**404**
434.08	20508.21	**466**
434.28	20513.13	**425**
434.48	20517.61	**436**
434.67	20521.72	**433**
434.87	20525.55	**408**
435.00	20527.92	**347**
435.07	20529.15	**371**
435.20	20531.38	**356**
435.39	20534.74	**393**
435.59	20538.06	**385**
435.78	20541.42	**428**
435.98	20544.88	**429**
436.17	20548.50	**447**
436.37	20552.27	**389**
436.56	20556.19	**364**
436.76	20560.24	**387**
436.95	20564.38	**400**
437.15	20568.59	**404**
437.34	20572.86	**371**
437.54	20577.17	**363**
437.74	20581.50	**384**
437.93	20588.18	**414**
438.13	20596.77	**424**
438.32	20605.30	**428**
438.52	20613.79	**431**
438.71	20622.22	**425**
438.91	20630.63	**402**
439.10	20639.03	**421**
439.30	20647.43	**360**
439.49	20655.82	**357**
439.69	20664.24	**375**
439.89	20672.69	**351**
440.08	20681.18	**383**
440.28	20689.69	**438**
440.47	20698.27	**431**
440.67	20706.87	**427**
440.86	20715.49	**504**

Table 0-2—*Continued*

11.01	5689.06	**1949**	154.35	14786.36	**629**	297.26	17758.13	**606**	441.06	20724.12	**487**
11.21	5724.24	**1939**	154.54	14790.14	**642**	297.46	17762.37	**648**	441.25	20732.77	**446**
11.41	5759.31	**1849**	154.73	14793.91	**601**	297.65	17766.61	**598**	441.44	20741.00	**506**
11.61	5794.46	**1725**	154.91	14797.68	**558**	297.85	17770.86	**571**	441.63	20749.65	**470**
11.81	5829.59	**1833**	155.10	14801.44	**579**	298.05	17775.12	**577**	441.83	20758.28	**445**
12.01	5864.58	**1822**	155.28	14805.21	**570**	298.24	17779.39	**607**	442.03	20766.90	**486**
12.21	5899.60	**1953**	155.47	14808.96	**599**	298.44	17783.66	**594**	442.22	20775.51	**405**
12.41	5934.68	**1959**	155.66	14812.71	**562**	298.64	17787.94	**587**	442.42	20784.10	**477**
12.61	5969.58	**1933**	155.84	14816.46	**582**	298.83	17792.22	**598**	442.61	20792.66	**497**
12.81	6004.55	**1813**	156.03	14820.22	**596**	299.03	17796.50	**622**	442.81	20801.23	**500**
13.01	6039.46	**1831**	156.21	14823.96	**628**	299.22	17800.78	**626**	443.00	20809.79	**528**
13.21	6074.33	**1792**	156.40	14827.72	**610**	299.42	17805.05	**685**	443.20	20818.34	**542**
13.42	6109.25	**1931**	156.59	14831.46	**587**	299.62	17809.32	**588**	443.39	20826.88	**556**
13.62	6144.04	**1948**	156.77	14835.20	**559**	299.81	17813.58	**570**	443.59	20835.45	**551**
13.82	6178.93	**1977**	156.96	14838.94	**566**	300.01	17817.84	**548**	443.78	20844.02	**555**
14.02	6213.75	**1862**	157.14	14842.67	**543**	300.21	17822.08	**514**	443.98	20852.60	**569**
14.22	6248.57	**1899**	157.33	14846.40	**552**	300.40	17826.32	**536**	444.17	20861.18	**601**
14.42	6283.39	**1809**	157.52	14850.13	**493**	300.60	17830.54	**528**	444.37	20869.80	**595**
14.62	6318.25	**1699**	157.70	14853.84	**457**	300.80	17834.76	**624**	444.57	20878.42	**517**
14.82	6353.01	**1643**	157.89	14857.56	**478**	300.99	17838.96	**576**	444.76	20887.05	**537**
15.02	6387.88	**1708**	158.07	14861.26	**502**	301.19	17843.17	**627**	444.96	20895.69	**480**
15.22	6422.65	**1743**	158.26	14864.97	**519**	301.38	17847.36	**647**	445.15	20904.30	**467**
15.42	6457.53	**1569**	158.45	14868.66	**489**	301.58	17851.55	**594**	445.35	20912.93	**445**
15.62	6492.43	**1539**	158.63	14872.35	**537**	301.78	17855.73	**587**	445.54	20921.56	**478**
15.82	6527.28	**1558**	158.82	14876.04	**571**	301.97	17859.91	**620**	445.74	20930.18	**524**
16.02	6562.10	**1566**	159.00	14879.73	**538**	302.17	17864.07	**612**	445.93	20938.76	**553**
16.21	6595.29	**1612**	159.19	14883.41	**566**	302.37	17868.25	**585**	446.13	20947.34	**483**
16.41	6630.25	**1689**	159.37	14887.09	**543**	302.56	17872.41	**662**	446.32	20955.90	**506**
16.61	6665.11	**1792**	159.56	14890.78	**530**	302.76	17876.56	**605**	446.52	20964.43	**486**
16.81	6700.08	**1584**	159.75	14894.46	**508**	302.95	17880.69	**650**	446.71	20972.90	**474**
17.01	6735.01	**1555**	159.93	14898.15	**494**	303.15	17884.82	**680**	446.91	20981.34	**461**
17.21	6769.90	**1558**	160.12	14901.84	**518**	303.35	17888.92	**676**	447.11	20989.72	**473**
17.41	6804.94	**1577**	160.30	14905.54	**512**	303.54	17893.01	**607**	447.30	20998.03	**444**
17.61	6839.88	**1586**	160.49	14909.24	**526**	303.74	17897.06	**631**	447.50	21006.25	**481**
17.81	6874.81	**1636**	160.68	14912.94	**447**	303.94	17901.10	**625**	447.69	21014.40	**466**
18.01	6909.74	**1522**	160.86	14916.64	**522**	304.13	17905.11	**635**	447.89	21022.46	**399**
18.21	6944.72	**1557**	161.05	14920.34	**535**	304.33	17909.11	**599**	448.08	21030.42	**450**
18.41	6979.64	**1618**	161.23	14924.04	**526**	304.52	17913.06	**600**	448.28	21038.26	**431**
18.61	7014.55	**1609**	161.42	14927.74	**474**	304.72	17916.99	**634**	448.47	21046.03	**429**
18.82	7049.52	**1602**	161.61	14931.45	**327**	304.92	17920.89	**585**	448.67	21053.74	**426**
19.02	7084.39	**1546**	161.79	14935.15	**324**	305.11	17924.77	**632**	448.86	21061.39	**481**
19.22	7119.36	**1597**	161.98	14938.85	**417**	305.31	17928.61	**590**	449.06	21069.00	**455**
19.42	7154.28	**1647**	162.16	14942.54	**590**	305.51	17932.44	**577**	449.26	21076.60	**436**
19.62	7189.16	**1856**	162.35	14946.24	**614**	305.70	17936.23	**664**	449.45	21084.20	**441**
19.82	7224.16	**1802**	162.54	14949.93	**521**	305.90	17940.00	**603**	449.65	21091.82	**502**
20.02	7259.12	**1743**	162.72	14953.62	**475**	306.09	17943.74	**683**	449.84	21099.45	**467**
20.22	7294.09	**1760**	162.90	14957.12	**523**	306.29	17947.46	**641**	450.04	21107.15	**382**
20.42	7329.17	**1838**	163.09	14961.00	**521**	306.49	17951.16	**621**	450.23	21114.90	**383**
20.62	7364.08	**1718**	163.28	14964.69	**523**	306.68	17954.84	**619**	450.43	21122.71	**407**
20.82	7399.09	**1600**	163.47	14968.39	**521**	306.88	17958.52	**603**	450.62	21130.52	**388**
21.02	7433.97	**1498**	163.65	14972.08	**527**	307.08	17962.19	**597**	450.82	21138.37	**407**
21.22	7468.93	**1465**	163.83	14975.59	**524**	307.27	17965.87	**630**	451.01	21146.22	**434**
21.42	7503.84	**1512**	164.00	14979.01	**551**	307.47	17969.54	**695**	451.21	21154.07	**489**
21.62	7538.60	**1543**	164.01	14979.29	**567**	307.66	17973.24	**649**	451.40	21161.87	**425**
21.82	7573.41	**1495**	164.20	14982.94	**540**	307.86	17976.94	**621**	451.60	21169.65	**458**
22.02	7608.10	**1477**	164.39	14986.88	**510**	308.06	17980.67	**644**	451.80	21177.38	**441**
22.22	7642.72	**1493**	164.59	14990.81	**498**	308.25	17984.41	**635**	451.99	21185.05	**386**
22.42	7677.28	**1471**	164.79	14994.75	**521**	308.45	17988.18	**600**	452.19	21192.62	**404**
22.62	7711.80	**1408**	164.99	14998.69	**548**	308.65	17991.96	**619**	452.38	21200.15	**432**

Table 0-2—*Continued*

22.82	7746.30	**1418**	165.18	15002.63	**494**	308.83	17995.57	**623**	452.58	21207.64	**485**
23.02	7780.89	**1469**	165.38	15006.57	**530**	309.03	17999.37	**634**	452.77	21215.12	**477**
23.22	7815.34	**1383**	165.58	15010.52	**565**	309.23	18003.37	**596**	452.97	21222.58	**550**
23.42	7849.92	**1398**	165.77	15014.46	**479**	309.43	18007.18	**647**	453.16	21230.09	**555**
23.62	7884.50	**1362**	165.97	15018.40	**522**	309.63	18010.99	**617**	453.36	21237.64	**503**
23.82	7919.13	**1367**	166.17	15022.34	**507**	309.81	18014.60	**570**	453.55	21245.26	**480**
24.03	7953.89	**1394**	166.37	15026.28	**563**	310.01	18018.39	**573**	453.75	21252.95	**483**
24.23	7988.64	**1362**	166.56	15030.21	**571**	310.21	18022.17	**583**	453.95	21260.77	**565**
24.43	8023.57	**1430**	166.76	15034.15	**630**	310.40	18025.94	**588**	454.14	21268.72	**585**
24.63	8058.45	**1334**	166.96	15038.09	**586**	310.60	18029.70	**583**	454.34	21276.79	**518**
24.83	8093.49	**1173**	167.16	15042.03	**588**	310.80	18033.45	**639**	454.52	21284.58	**540**
25.03	8128.52	**1108**	167.35	15045.98	**595**	310.99	18037.20	**604**	454.72	21292.86	**582**
25.23	8163.56	**1130**	167.55	15049.93	**518**	311.19	18040.95	**604**	454.91	21301.26	**548**
25.43	8198.62	**1131**	167.75	15053.88	**492**	311.38	18044.69	**581**	455.11	21309.74	**515**
25.63	8233.72	**1152**	167.94	15057.85	**508**	311.58	18048.44	**621**	455.30	21318.28	**554**
25.83	8268.69	**1220**	168.14	15061.81	**502**	311.78	18052.19	**561**	455.50	21326.90	**536**
26.03	8303.79	**1233**	168.34	15065.79	**401**	311.97	18055.96	**586**	455.69	21335.57	**593**
26.23	8338.74	**1290**	168.54	15069.77	**450**	312.17	18059.72	**590**	455.89	21344.28	**571**
26.43	8373.65	**1297**	168.73	15073.76	**459**	312.37	18063.50	**566**	456.09	21353.01	**550**
26.63	8408.53	**1305**	168.93	15077.75	**473**	312.56	18067.28	**660**	456.28	21361.78	**582**
26.82	8441.70	**1383**	169.13	15081.76	**457**	312.76	18071.08	**632**	456.48	21370.57	**585**
27.02	8476.53	**1326**	169.32	15085.76	**496**	312.95	18074.88	**591**	456.67	21379.38	**576**
27.22	8511.36	**1303**	169.52	15089.78	**507**	313.15	18078.69	**589**	456.87	21388.22	**564**
27.42	8546.17	**1220**	169.72	15093.79	**467**	313.35	18082.51	**624**	457.06	21397.06	**577**
27.62	8580.94	**1177**	169.92	15097.80	**471**	313.54	18086.35	**593**	457.26	21405.94	**548**
27.82	8615.87	**1151**	170.11	15101.82	**502**	313.74	18090.19	**614**	457.45	21414.84	**568**
28.02	8650.65	**1174**	170.31	15105.84	**500**	313.94	18094.05	**545**	457.65	21423.76	**611**
28.22	8685.50	**1214**	170.51	15109.86	**499**	314.13	18097.90	**570**	457.84	21432.68	**606**
28.42	8720.37	**1123**	170.71	15113.89	**517**	314.33	18101.78	**642**	458.04	21441.64	**620**
28.62	8755.31	**1128**	170.90	15117.91	**491**	314.52	18105.66	**594**	458.23	21450.61	**629**
28.82	8790.21	**1021**	171.10	15121.94	**529**	314.72	18109.55	**594**	458.43	21459.60	**651**
29.02	8825.18	**1187**	171.30	15125.96	**451**	314.92	18113.45	**587**	458.63	21468.58	**650**
29.22	8860.11	**1338**	171.49	15129.98	**515**	315.11	18117.35	**588**	458.82	21477.59	**692**
29.42	8895.04	**1321**	171.69	15133.99	**473**	315.31	18121.27	**572**	459.02	21486.60	**634**
29.63	8929.99	**1266**	171.89	15138.01	**501**	315.51	18125.18	**598**	459.21	21495.62	**643**
29.83	8965.00	**1294**	172.09	15142.02	**519**	315.70	18129.11	**628**	459.41	21504.62	**564**
30.03	8999.91	**1203**	172.28	15146.03	**496**	315.90	18133.03	**600**	459.60	21513.63	**604**
30.23	9034.93	**1242**	172.48	15150.03	**508**	316.09	18136.96	**637**	459.80	21522.63	**583**
30.43	9069.91	**1248**	172.68	15154.02	**498**	316.29	18140.90	**637**	459.99	21531.62	**516**
30.63	9104.93	**1266**	172.87	15158.01	**512**	316.49	18144.84	**628**	460.19	21540.58	**532**
30.83	9139.91	**1480**	173.07	15162.00	**518**	316.68	18148.78	**632**	460.38	21549.54	**469**
31.03	9174.93	**1334**	173.27	15165.97	**493**	316.88	18152.73	**646**	460.58	21558.50	**437**
31.23	9209.84	**1485**	173.47	15169.95	**527**	317.08	18156.68	**616**	460.78	21567.45	**448**
31.43	9244.85	**1333**	173.66	15173.91	**542**	317.27	18160.65	**666**	460.97	21576.37	**392**
31.63	9279.79	**1286**	173.86	15177.87	**494**	317.47	18164.61	**638**	461.17	21585.32	**412**
31.83	9314.72	**1244**	174.06	15181.82	**480**	317.66	18168.58	**656**	461.36	21594.26	**372**
32.03	9349.69	**1300**	174.26	15185.77	**467**	317.86	18172.55	**657**	461.56	21603.21	**350**
32.23	9384.54	**1394**	174.45	15189.71	**441**	318.06	18176.54	**683**	461.75	21612.15	**371**
32.43	9419.48	**1422**	174.65	15193.65	**453**	318.25	18180.53	**645**	461.95	21621.11	**416**
32.63	9454.35	**1239**	174.85	15197.57	**480**	318.45	18184.53	**573**	462.14	21630.08	**417**
32.83	9489.22	**1147**	175.04	15201.50	**476**	318.65	18188.52	**587**	462.34	21639.06	**457**
33.03	9524.09	**1054**	175.24	15205.41	**488**	318.84	18192.54	**624**	462.53	21648.02	**421**
33.23	9558.95	**1149**	175.44	15209.33	**552**	319.04	18196.54	**589**	462.73	21657.01	**394**
33.43	9593.82	**1037**	175.64	15213.23	**504**	319.24	18200.57	**633**	462.92	21666.00	**384**
33.63	9628.81	**932**	175.83	15217.14	**495**	319.43	18204.58	**619**	463.12	21674.98	**375**
33.83	9663.64	**976**	176.02	15220.84	**473**	319.63	18208.60	**597**	463.32	21683.94	**389**
34.03	9698.60	**946**	176.22	15224.73	**508**	319.82	18212.62	**614**	463.51	21692.91	**406**
34.23	9733.52	**940**	176.42	15228.81	**495**	320.00	18216.23	**598**	463.71	21701.86	**392**
34.43	9768.47	**906**	176.62	15232.70	**504**	320.02	18216.64	**560**	463.90	21710.79	**413**

Table 0-2—*Continued*

34.64	9803.50	**993**	176.82	15236.57	**501**	320.20	18220.28	**628**	464.10	21719.69	**396**
34.84	9838.46	**944**	177.01	15240.25	**471**	320.39	18224.31	**648**	464.29	21728.58	**428**
35.04	9873.51	**996**	177.20	15244.12	**444**	320.59	18228.35	**611**	464.49	21737.45	**490**
35.24	9908.67	**983**	177.40	15247.99	**502**	320.79	18232.39	**663**	464.68	21746.32	**432**
35.44	9943.83	**979**	177.60	15251.85	**475**	320.99	18236.42	**614**	464.88	21755.16	**425**
35.64	9978.99	**947**	177.80	15255.71	**506**	321.18	18240.46	**622**	465.07	21764.01	**432**
35.84	10014.37	**990**	177.99	15259.56	**565**	321.38	18244.49	**641**	465.27	21772.86	**476**
36.04	10049.67	**985**	178.19	15263.41	**508**	321.58	18248.51	**671**	465.47	21781.72	**440**
36.24	10085.08	**998**	178.39	15267.25	**501**	321.78	18252.53	**605**	465.66	21790.57	**478**
36.44	10120.55	**1014**	178.58	15271.09	**495**	321.97	18256.55	**576**	465.86	21799.45	**435**
36.64	10155.99	**873**	178.78	15274.93	**506**	322.17	18260.56	**595**	466.05	21808.35	**455**
36.84	10191.23	**1008**	178.98	15278.78	**494**	322.37	18264.56	**624**	466.25	21817.27	**464**
37.04	10226.44	**990**	179.18	15282.61	**482**	322.56	18268.57	**616**	466.44	21826.21	**484**
37.23	10259.66	**987**	179.37	15286.44	**451**	322.76	18272.56	**612**	466.63	21834.70	**518**
37.43	10294.39	**888**	179.57	15290.27	**340**	322.96	18276.56	**643**	466.82	21843.67	**517**
37.63	10328.88	**926**	179.77	15294.11	**452**	323.16	18280.56	**645**	467.02	21852.65	**540**
37.83	10362.97	**878**	179.96	15297.94	**453**	323.35	18284.55	**553**	467.21	21861.65	**506**
38.03	10396.66	**896**	180.16	15301.78	**438**	323.55	18288.56	**604**	467.41	21870.65	**515**
38.23	10429.97	**868**	180.36	15305.61	**512**	323.75	18292.56	**648**	467.60	21879.67	**417**
38.43	10463.14	**859**	180.56	15309.45	**450**	323.94	18296.57	**600**	467.80	21888.70	**389**
38.63	10496.24	**924**	180.75	15313.28	**457**	324.14	18300.59	**568**	468.00	21897.74	**377**
38.83	10529.67	**974**	180.95	15317.11	**513**	324.34	18304.61	**625**	468.19	21906.77	**328**
39.03	10563.56	**989**	181.15	15320.94	**471**	324.54	18308.63	**637**	468.39	21915.82	**300**
39.23	10598.02	**951**	181.35	15324.77	**440**	324.73	18312.67	**568**	468.58	21924.86	**306**
39.43	10633.47	**940**	181.54	15328.59	**479**	324.93	18316.70	**595**	468.78	21933.91	**326**
39.63	10669.96	**949**	181.74	15332.42	**500**	325.13	18320.74	**537**	468.97	21942.93	**340**
39.83	10707.71	**944**	181.94	15336.24	**480**	325.33	18324.78	**542**	469.17	21951.96	**336**
40.04	10747.18	**935**	182.13	15340.06	**484**	325.52	18328.81	**671**	469.36	21960.99	**322**
40.24	10787.98	**972**	182.33	15343.87	**532**	325.72	18332.86	**643**	469.56	21970.00	**405**
40.44	10829.53	**971**	182.53	15347.68	**483**	325.92	18336.90	**636**	469.75	21978.98	**405**
40.64	10871.04	**1018**	182.73	15351.48	**493**	326.11	18340.94	**637**	469.95	21987.95	**439**
40.84	10911.49	**970**	182.92	15355.28	**503**	326.31	18344.98	**626**	470.15	21996.91	**415**
41.04	10950.31	**958**	183.12	15359.07	**571**	326.51	18349.02	**606**	470.34	22005.84	**427**
41.24	10986.42	**967**	183.32	15362.86	**616**	326.71	18353.05	**535**	470.54	22014.75	**448**
41.44	11019.22	**958**	183.51	15366.64	**578**	326.90	18357.08	**605**	470.73	22023.66	**462**
41.64	11047.76	**959**	183.71	15370.42	**566**	327.10	18361.11	**640**	470.93	22032.57	**407**
41.84	11071.13	**914**	183.91	15374.20	**514**	327.30	18365.13	**579**	471.12	22041.49	**393**
42.04	11084.76	**933**	184.11	15377.97	**559**	327.50	18369.16	**637**	471.32	22050.40	**383**
42.24	11090.40	**976**	184.30	15381.74	**553**	327.69	18373.18	**587**	471.51	22059.33	**378**
42.44	11093.35	**913**	184.50	15385.50	**611**	327.89	18377.19	**636**	471.71	22068.29	**396**
42.64	11094.11	**955**	184.70	15389.26	**522**	328.09	18381.20	**625**	471.90	22077.27	**394**
42.84	11094.21	**936**	184.90	15393.03	**576**	328.28	18385.20	**626**	472.10	22086.26	**366**
43.04	11094.30	**915**	185.09	15396.79	**596**	328.48	18389.20	**604**	472.29	22095.30	**368**
43.19	11094.37	**898**	185.29	15400.56	**505**	328.68	18393.20	**614**	472.49	22104.36	**425**
43.38	11094.47	**873**	185.49	15404.32	**561**	328.88	18397.20	**657**	472.69	22113.44	**417**
43.58	11094.56	**877**	185.68	15408.10	**564**	329.07	18401.20	**651**	472.88	22122.52	**415**
43.78	11094.65	**833**	185.88	15411.87	**575**	329.26	18405.00	**642**	473.08	22131.63	**444**
43.97	11094.75	**890**	186.08	15415.65	**516**	329.46	18409.02	**656**	473.27	22140.75	**398**
44.17	11094.84	**848**	186.28	15419.44	**620**	329.66	18413.03	**580**	473.47	22149.87	**377**
44.36	11097.07	**804**	186.47	15423.23	**593**	329.85	18417.05	**521**	473.66	22158.97	**418**
44.56	11100.60	**858**	186.67	15427.02	**603**	330.05	18421.08	**530**	473.86	22168.09	**421**
44.76	11105.21	**834**	186.87	15430.81	**576**	330.25	18425.12	**510**	474.05	22177.19	**481**
44.95	11114.03	**804**	187.06	15434.60	**557**	330.44	18429.17	**538**	474.25	22186.28	**421**
45.15	11126.33	**829**	187.26	15438.39	**533**	330.64	18433.23	**441**	474.44	22195.33	**425**
45.35	11139.53	**848**	187.46	15442.18	**575**	330.84	18437.28	**499**	474.64	22204.40	**396**
45.54	11153.20	**806**	187.66	15445.96	**511**	331.04	18441.34	**507**	474.84	22213.44	**423**
45.74	11166.94	**761**	187.85	15449.74	**476**	331.23	18445.39	**484**	475.00	22221.05	**387**
45.93	11180.29	**809**	188.05	15453.51	**558**	331.43	18449.44	**503**	475.03	22222.48	**388**
46.13	11192.88	**832**	188.25	15457.27	**647**	331.63	18453.49	**530**	475.20	22230.26	**401**

Table 0-2—*Continued*

46.33	11204.62	**798**	188.45	15461.02	**601**	331.83	18457.52	**534**	475.40	22239.46	**420**
46.52	11215.62	**867**	188.64	15464.76	**575**	332.02	18461.54	**581**	475.60	22248.64	**389**
46.72	11226.00	**854**	188.84	15468.51	**619**	332.22	18465.55	**583**	475.80	22257.79	**425**
46.91	11235.88	**835**	189.04	15472.23	**601**	332.42	18469.54	**555**	476.00	22266.95	**423**
47.11	11245.36	**872**	189.23	15475.95	**616**	332.61	18473.53	**591**	476.20	22276.10	**392**
47.31	11254.57	**818**	189.43	15479.66	**577**	332.81	18477.52	**561**	476.40	22285.25	**475**
47.50	11263.62	**810**	189.63	15483.37	**593**	333.01	18481.49	**607**	476.60	22294.39	**423**
47.70	11272.65	**842**	189.83	15487.07	**618**	333.21	18485.48	**533**	476.79	22303.52	**455**
47.89	11281.75	**826**	190.02	15490.76	**624**	333.40	18489.46	**549**	476.99	22312.64	**474**
48.09	11291.06	**865**	190.22	15494.45	**673**	333.60	18493.45	**596**	477.19	22321.78	**480**
48.29	11300.60	**803**	190.42	15498.13	**691**	333.80	18497.45	**538**	477.39	22330.94	**515**
48.48	11310.34	**858**	190.61	15501.79	**643**	333.99	18501.46	**484**	477.59	22340.10	**464**
48.68	11320.27	**765**	190.81	15505.45	**590**	334.19	18505.47	**484**	477.79	22349.28	**495**
48.88	11330.35	**780**	191.01	15509.09	**625**	334.39	18509.51	**500**	477.99	22358.47	**486**
49.07	11340.53	**888**	191.21	15512.72	**622**	334.59	18513.55	**524**	478.19	22367.68	**505**
49.27	11350.79	**915**	191.40	15516.33	**650**	334.78	18517.60	**469**	478.39	22376.90	**550**
49.46	11361.09	**869**	191.60	15519.92	**671**	334.98	18521.66	**492**	478.59	22386.15	**487**
49.66	11371.41	**891**	191.80	15523.49	**757**	335.18	18525.72	**423**	478.79	22395.40	**601**
49.86	11381.70	**837**	192.00	15527.05	**722**	335.38	18529.78	**465**	478.99	22404.67	**520**
50.05	11391.95	**813**	192.19	15530.58	**684**	335.57	18533.85	**493**	479.19	22413.94	**523**
50.25	11402.11	**837**	192.39	15534.09	**706**	335.77	18537.92	**431**	479.39	22423.21	**590**
50.44	11412.21	**848**	192.59	15537.58	**612**	335.97	18541.98	**400**	479.59	22432.47	**570**
50.64	11422.26	**873**	192.78	15541.07	**643**	336.16	18546.04	**423**	479.79	22441.74	**566**
50.84	11432.26	**845**	192.98	15544.53	**621**	336.36	18550.10	**439**	479.98	22450.99	**535**
51.03	11442.23	**871**	193.18	15547.99	**622**	336.56	18554.15	**537**	480.18	22460.24	**564**
51.23	11452.19	**877**	193.38	15551.44	**606**	336.76	18558.21	**504**	480.38	22469.48	**582**
51.42	11462.14	**840**	193.57	15554.89	**587**	336.95	18562.26	**550**	480.58	22478.71	**587**
51.62	11472.11	**884**	193.77	15558.33	**647**	337.15	18566.31	**492**	480.77	22487.48	**553**
51.82	11482.08	**900**	193.97	15561.78	**638**	337.35	18570.37	**555**	480.97	22496.68	**565**
52.01	11492.11	**910**	194.16	15565.23	**684**	337.55	18574.42	**568**	481.17	22505.89	**557**
52.21	11502.15	**861**	194.36	15568.69	**671**	337.74	18578.48	**511**	481.37	22515.10	**558**
52.40	11512.22	**831**	194.56	15572.14	**640**	337.94	18582.54	**545**	481.57	22524.30	**579**
52.60	11522.29	**749**	194.76	15575.60	**704**	338.14	18586.60	**519**	481.77	22533.51	**601**
52.80	11532.34	**850**	194.95	15579.06	**646**	338.33	18590.66	**512**	481.97	22542.71	**606**
52.99	11542.36	**821**	195.15	15582.52	**684**	338.53	18594.73	**528**	482.17	22551.90	**635**
53.19	11552.30	**849**	195.35	15585.97	**606**	338.73	18598.80	**521**	482.37	22561.10	**589**
53.39	11562.16	**860**	195.55	15589.42	**665**	338.93	18602.87	**505**	482.57	22570.32	**608**
53.58	11571.92	**753**	195.74	15592.86	**659**	339.12	18606.95	**547**	482.77	22579.53	**612**
53.78	11581.54	**760**	195.94	15596.29	**734**	339.32	18611.02	**508**	482.97	22588.75	**629**
53.97	11591.02	**670**	196.14	15599.71	**776**	339.52	18615.08	**533**	483.16	22597.98	**634**
54.17	11600.34	**702**	196.33	15603.13	**743**	339.72	18619.15	**535**	483.36	22607.21	**613**
54.37	11609.52	**737**	196.53	15606.53	**745**	339.91	18623.22	**513**	483.56	22616.46	**596**
54.56	11618.59	**708**	196.73	15609.94	**723**	340.11	18627.28	**463**	483.76	22625.72	**595**
54.76	11627.57	**686**	196.93	15613.33	**664**	340.31	18631.34	**505**	483.96	22635.00	**652**
54.95	11636.53	**614**	197.12	15616.72	**732**	340.50	18635.39	**475**	484.16	22644.29	**663**
55.15	11645.47	**573**	197.32	15620.11	**668**	340.70	18639.45	**490**	484.36	22653.59	**712**
55.35	11654.43	**587**	197.52	15623.50	**662**	340.90	18643.50	**491**	484.56	22662.90	**628**
55.54	11663.47	**515**	197.71	15626.89	**655**	341.10	18647.55	**502**	484.76	22672.18	**625**
55.74	11672.58	**487**	197.91	15630.28	**671**	341.29	18651.61	**501**	484.96	22681.49	**648**
55.93	11681.81	**409**	198.11	15633.67	**764**	341.49	18655.67	**480**	485.16	22690.79	**692**
56.13	11691.20	**307**	198.31	15637.07	**659**	341.69	18659.72	**549**	485.36	22700.07	**659**
56.33	11700.72	**255**	198.50	15640.46	**657**	341.88	18663.79	**491**	485.56	22709.33	**669**
56.52	11710.28	**252**	198.70	15643.87	**689**	342.08	18667.85	**592**	485.76	22718.57	**646**
56.72	11719.80	**221**	198.90	15647.27	**674**	342.28	18671.92	**594**	485.96	22727.77	**716**
56.92	11729.21	**196**	199.10	15650.67	**628**	342.48	18676.00	**584**	486.16	22736.94	**718**
57.11	11738.43	**198**	199.29	15654.07	**630**	342.67	18680.08	**649**	486.35	22746.09	**748**
57.31	11747.39	**262**	199.49	15657.48	**565**	342.87	18684.16	**604**	486.55	22755.20	**712**
57.50	11756.03	**321**	199.69	15660.88	**602**	343.07	18688.25	**644**	486.75	22764.28	**773**
57.70	11764.23	**206**	199.88	15664.28	**667**	343.27	18692.34	**699**	486.95	22773.33	**766**

Table 0-2—*Continued*

57.90	11771.96	**197**	200.08	15667.68	**592**	343.46	18696.42	**659**	487.15	22782.35	**778**
58.09	11779.11	**206**	200.28	15671.07	**542**	343.66	18700.52	**682**	487.35	22791.32	**796**
58.29	11785.75	**223**	200.48	15674.47	**550**	343.86	18704.62	**689**	487.55	22800.29	**764**
58.48	11792.04	**246**	200.67	15677.86	**578**	344.05	18708.71	**672**	487.75	22809.22	**748**
58.68	11798.16	**218**	200.87	15681.24	**532**	344.25	18712.82	**688**	487.95	22818.13	**783**
58.88	11804.29	**190**	201.06	15684.46	**591**	344.45	18716.92	**643**	488.15	22827.02	**742**
59.07	11810.62	**190**	201.26	15688.00	**536**	344.65	18721.02	**668**	488.35	22835.88	**743**
59.27	11817.31	**238**	201.46	15691.38	**516**	344.84	18725.12	**597**	488.55	22844.69	**716**
59.46	11824.55	**181**	201.66	15694.74	**530**	345.04	18729.22	**603**	488.75	22853.49	**649**
59.66	11832.50	**218**	201.86	15698.10	**538**	345.24	18733.32	**594**	488.95	22862.25	**680**
59.85	11840.90	**239**	202.04	15701.29	**580**	345.44	18737.42	**572**	489.15	22870.97	**635**
60.05	11851.30	**237**	202.24	15704.64	**531**	345.63	18741.52	**614**	489.35	22879.66	**644**
60.25	11862.39	**227**	202.44	15707.98	**582**	345.83	18745.60	**578**	489.55	22888.30	**603**
60.45	11874.48	**240**	202.64	15711.31	**536**	346.03	18749.69	**620**	489.74	22896.87	**669**
60.64	11887.41	**230**	202.83	15714.63	**559**	346.22	18753.77	**618**	489.94	22905.41	**648**
60.83	11900.32	**240**	203.03	15717.94	**633**	346.42	18757.85	**611**	490.14	22913.90	**569**
61.02	11914.43	**214**	203.23	15721.23	**679**	346.62	18761.93	**622**	490.34	22922.35	**541**
61.22	11928.89	**251**	203.42	15724.52	**642**	346.82	18766.01	**588**	490.54	22930.77	**534**
61.42	11943.58	**265**	203.62	15727.79	**620**	347.01	18770.08	**616**	490.74	22939.16	**510**
61.62	11959.03	**313**	203.82	15731.06	**661**	347.21	18774.15	**618**	490.94	22947.56	**522**
61.81	11972.91	**296**	204.02	15734.30	**606**	347.40	18778.01	**551**	491.14	22955.94	**519**
62.00	11987.22	**311**	204.20	15737.32	**582**	347.59	18782.09	**573**	491.34	22964.37	**541**
62.20	12001.13	**292**	204.40	15740.55	**638**	347.79	18786.16	**572**	491.54	22972.83	**517**
62.40	12014.70	**295**	204.59	15743.75	**610**	347.99	18790.23	**625**	491.73	22980.91	**500**
62.59	12027.99	**320**	204.79	15746.95	**573**	348.19	18794.31	**620**	491.93	22989.48	**524**
62.79	12041.06	**297**	204.99	15750.14	**570**	348.38	18798.39	**661**	492.13	22998.13	**485**
62.98	12054.04	**265**	205.19	15753.33	**621**	348.58	18802.46	**650**	492.33	23006.84	**514**
63.18	12066.97	**279**	205.38	15756.52	**643**	348.78	18806.54	**636**	492.53	23015.65	**503**
63.38	12079.95	**280**	205.58	15759.70	**633**	348.98	18810.63	**543**	492.73	23024.54	**437**
63.57	12093.04	**305**	205.78	15762.88	**675**	349.17	18814.71	**575**	492.92	23033.51	**420**
63.77	12106.37	**321**	205.97	15766.08	**698**	349.37	18818.80	**596**	493.12	23042.56	**464**
63.97	12119.96	**260**	206.17	15769.27	**631**	349.57	18822.90	**588**	493.32	23051.70	**568**
64.16	12133.91	**215**	206.37	15772.47	**665**	349.76	18826.99	**614**	493.52	23060.93	**492**
64.36	12148.23	**214**	206.57	15775.68	**645**	349.96	18831.09	**642**	493.72	23070.21	**526**
64.55	12162.89	**203**	206.76	15778.89	**563**	350.16	18835.19	**601**	493.92	23079.61	**580**
64.75	12177.86	**227**	206.96	15782.10	**622**	350.36	18839.29	**702**	494.12	23089.09	**558**
64.95	12193.12	**172**	207.16	15785.32	**598**	350.55	18843.40	**648**	494.32	23098.65	**519**
65.14	12208.65	**206**	207.35	15788.54	**569**	350.75	18847.51	**633**	494.52	23108.30	**501**
65.34	12224.45	**215**	207.55	15791.77	**512**	350.95	18851.62	**592**	494.72	23118.03	**521**
65.53	12240.46	**178**	207.75	15794.99	**493**	351.15	18855.74	**584**	494.92	23127.82	**495**
65.73	12256.71	**174**	207.95	15798.22	**581**	351.34	18859.86	**582**	495.12	23137.70	**451**
65.93	12273.11	**226**	208.14	15801.45	**513**	351.54	18863.98	**555**	495.32	23147.67	**480**
66.12	12289.68	**263**	208.33	15804.52	**509**	351.74	18868.11	**545**	495.52	23157.71	**463**
66.32	12306.41	**233**	208.53	15807.75	**533**	351.93	18872.24	**605**	495.72	23167.82	**445**
66.51	12323.25	**300**	208.72	15810.99	**520**	352.13	18876.37	**560**	495.92	23178.00	**469**
66.71	12340.19	**263**	208.92	15814.23	**552**	352.33	18880.51	**565**	496.11	23188.23	**437**
66.91	12357.21	**247**	209.12	15817.48	**481**	352.53	18884.65	**602**	496.31	23198.55	**435**
67.10	12374.27	**248**	209.32	15820.72	**509**	352.72	18888.79	**617**	496.51	23208.94	**429**
67.30	12391.37	**383**	209.51	15823.98	**486**	352.92	18892.94	**662**	496.71	23219.38	**441**
67.50	12408.48	**617**	209.71	15827.24	**487**	353.12	18897.09	**548**	496.91	23229.88	**426**
67.69	12425.58	**628**	209.91	15830.52	**511**	353.32	18901.23	**610**	497.11	23240.43	**362**
67.89	12442.64	**526**	210.11	15833.80	**589**	353.51	18905.39	**554**	497.31	23251.04	**366**
68.08	12459.66	**535**	210.30	15837.09	**558**	353.71	18909.54	**558**	497.51	23261.67	**341**
68.28	12476.61	**505**	210.50	15840.39	**557**	353.91	18913.70	**584**	497.71	23272.36	**356**
68.48	12493.48	**615**	210.70	15843.70	**558**	354.10	18917.86	**568**	497.91	23283.10	**348**
68.67	12510.28	**709**	210.89	15847.01	**529**	354.30	18922.02	**609**	498.11	23293.87	**324**
68.87	12527.01	**783**	211.09	15850.32	**581**	354.50	18926.18	**563**	498.31	23304.68	**322**
69.06	12543.64	**710**	211.29	15853.65	**631**	354.70	18930.35	**552**	498.51	23315.52	**325**
69.26	12560.21	**778**	211.48	15856.98	**650**	354.89	18934.51	**609**	498.71	23326.38	**347**

Table 0-2—*Continued*

69.46	12576.66	**763**	211.68	15860.32	**601**	355.09	18938.68	**571**	498.91	23337.30	**366**
69.65	12593.02	**751**	211.88	15863.66	**591**	355.29	18942.85	**567**	499.11	23348.26	**349**
69.85	12609.28	**713**	212.08	15867.00	**588**	355.48	18947.01	**573**	499.30	23359.25	**427**
70.04	12625.45	**664**	212.27	15870.36	**544**	355.68	18951.17	**585**	499.50	23370.29	**431**
70.24	12641.54	**557**	212.47	15873.71	**609**	355.88	18955.34	**573**	499.70	23381.36	**516**
70.44	12657.61	**533**	212.67	15877.06	**610**	356.08	18959.50	**610**	499.90	23392.48	**501**
70.63	12673.74	**490**	212.86	15880.42	**642**	356.27	18963.66	**612**	500.10	23403.61	**516**
70.83	12689.99	**439**	213.06	15883.78	**677**	356.47	18967.82	**595**	500.30	23414.81	**511**
71.02	12706.41	**477**	213.26	15887.14	**688**	356.67	18971.98	**609**	500.50	23426.05	**554**
71.22	12723.12	**532**	213.46	15890.49	**594**	356.87	18976.13	**597**	500.70	23437.35	**643**
71.42	12740.14	**579**	213.65	15893.85	**597**	357.06	18980.29	**571**	500.90	23448.71	**653**
71.61	12757.60	**627**	213.85	15897.21	**581**	357.26	18984.44	**575**	501.10	23460.12	**652**
71.81	12775.51	**687**	214.05	15900.56	**563**	357.46	18988.59	**673**	501.30	23471.58	**661**
72.01	12793.97	**626**	214.24	15903.91	**584**	357.65	18992.74	**594**	501.50	23483.13	**644**
72.20	12813.00	**502**	214.44	15907.26	**584**	357.85	18996.89	**649**	501.70	23494.75	**634**
72.40	12832.46	**529**	214.64	15910.61	**575**	358.05	19001.03	**604**	501.90	23506.45	**722**
72.59	12852.23	**629**	214.84	15913.96	**539**	358.25	19005.18	**589**	502.10	23518.24	**690**
72.79	12872.13	**822**	215.03	15917.30	**509**	358.44	19009.32	**629**	502.29	23529.52	**788**
72.99	12891.96	**827**	215.23	15920.65	**532**	358.64	19013.46	**652**	502.49	23541.48	**735**
73.18	12911.62	**789**	215.43	15923.99	**525**	358.84	19017.61	**732**	502.68	23553.52	**749**
73.38	12930.89	**824**	215.63	15927.34	**555**	359.04	19021.74	**687**	502.88	23565.69	**807**
73.57	12949.64	**829**	215.82	15930.68	**599**	359.23	19025.89	**682**	503.08	23577.97	**778**
73.77	12967.68	**819**	216.02	15934.02	**592**	359.43	19030.03	**625**	503.28	23590.37	**771**
73.97	12984.89	**850**	216.22	15937.36	**579**	359.63	19034.17	**653**	503.48	23602.89	**809**
74.16	13001.10	**790**	216.40	15940.54	**587**	359.82	19038.31	**659**	503.68	23615.55	**787**
74.36	13016.29	**919**	216.60	15943.88	**563**	360.00	19042.00	**610**	503.88	23628.31	**818**
74.55	13030.49	**876**	216.80	15947.22	**564**	360.02	19042.46	**693**	504.08	23641.24	**793**
74.75	13043.73	**929**	217.00	15950.57	**545**	360.20	19046.15	**675**	504.28	23654.32	**839**
74.95	13056.06	**875**	217.19	15953.90	**556**	360.39	19050.29	**710**	504.48	23667.52	**847**
75.14	13067.52	**965**	217.39	15957.24	**511**	360.59	19054.44	**674**	504.68	23680.86	**819**
75.34	13078.10	**904**	217.59	15960.58	**543**	360.79	19058.58	**680**	504.88	23694.30	**779**
75.54	13087.88	**955**	217.78	15963.91	**570**	360.99	19062.72	**635**	505.08	23707.86	**751**
75.73	13096.86	**1015**	217.98	15967.25	**584**	361.18	19066.85	**661**	505.28	23721.48	**752**
75.93	13105.09	**941**	218.18	15970.58	**550**	361.38	19070.98	**638**	505.48	23735.22	**768**
76.12	13112.59	**983**	218.38	15973.90	**545**	361.58	19075.11	**654**	505.68	23749.04	**817**
76.32	13119.42	**941**	218.57	15977.24	**450**	361.78	19079.22	**731**	505.87	23762.93	**867**
76.52	13125.67	**856**	218.77	15980.57	**415**	361.97	19083.33	**672**	506.07	23776.89	**867**
76.71	13131.40	**923**	218.97	15983.89	**458**	362.17	19087.42	**671**	506.27	23790.90	**783**
76.91	13136.69	**969**	219.16	15987.22	**446**	362.37	19091.51	**729**	506.47	23804.92	**765**
77.10	13141.63	**958**	219.36	15990.55	**408**	362.56	19095.59	**677**	506.67	23819.00	**761**
77.30	13146.26	**930**	219.56	15993.88	**422**	362.76	19099.68	**685**	506.87	23833.10	**746**
77.50	13150.68	**940**	219.76	15997.20	**496**	362.96	19103.75	**654**	507.07	23847.22	**737**
77.69	13154.96	**980**	219.95	16000.53	**406**	363.16	19107.83	**634**	507.27	23861.34	**747**
77.89	13159.18	**1007**	220.15	16003.86	**408**	363.35	19111.91	**631**	507.47	23875.46	**763**
78.08	13163.40	**953**	220.35	16007.19	**419**	363.55	19116.00	**643**	507.67	23889.55	**683**
78.28	13167.68	**946**	220.54	16010.52	**438**	363.75	19120.09	**721**	507.87	23903.59	**666**
78.48	13172.01	**992**	220.74	16013.86	**434**	363.95	19124.20	**715**	508.07	23917.63	**658**
78.67	13176.39	**987**	220.94	16017.20	**427**	364.14	19128.31	**759**	508.27	23931.61	**685**
78.87	13180.84	**984**	221.14	16020.54	**404**	364.34	19132.44	**720**	508.47	23945.55	**677**
79.07	13185.35	**887**	221.33	16023.87	**438**	364.54	19136.57	**704**	508.67	23959.44	**717**
79.26	13189.93	**968**	221.53	16027.22	**419**	364.74	19140.71	**726**	508.87	23973.28	**697**
79.46	13194.58	**959**	221.73	16030.56	**441**	364.93	19144.85	**639**	509.06	23987.02	**669**
79.65	13199.30	**959**	221.92	16033.91	**440**	365.13	19148.99	**628**	509.26	24000.74	**725**
79.85	13204.09	**912**	222.12	16037.25	**492**	365.33	19153.13	**658**	509.46	24014.39	**728**
80.05	13208.97	**936**	222.32	16040.59	**477**	365.52	19157.27	**695**	509.66	24027.97	**781**
80.24	13213.93	**934**	222.52	16043.95	**448**	365.72	19161.40	**743**	509.86	24041.48	**707**
80.44	13218.99	**949**	222.71	16047.30	**436**	365.92	19165.52	**672**	510.06	24054.92	**800**
80.63	13224.18	**927**	222.91	16050.63	**469**	366.12	19169.63	**708**	510.26	24068.25	**809**
80.83	13229.50	**906**	223.11	16053.98	**522**	366.31	19173.73	**703**	510.46	24081.53	**816**

Table 0-2—*Continued*

81.03	13234.98	**862**	223.30	16057.33	**584**	366.51	19177.82	**739**	510.66	24094.75	**729**
81.22	13240.64	**890**	223.50	16060.67	**606**	366.71	19181.91	**675**	510.86	24107.91	**765**
81.42	13246.50	**823**	223.70	16064.01	**536**	366.91	19185.99	**682**	511.06	24121.00	**682**
81.61	13252.57	**961**	223.90	16067.34	**477**	367.10	19190.08	**688**	511.26	24134.03	**694**
81.81	13258.88	**905**	224.09	16070.67	**466**	367.30	19194.17	**678**	511.46	24147.01	**782**
82.00	13265.16	**899**	224.29	16074.01	**480**	367.50	19198.26	**615**	511.66	24159.91	**745**
82.20	13272.05	**908**	224.49	16077.33	**490**	367.69	19202.36	**684**	511.86	24172.79	**727**
82.39	13279.19	**853**	224.67	16080.49	**462**	367.89	19206.47	**644**	512.06	24185.63	**611**
82.59	13286.57	**933**	224.87	16083.82	**446**	368.09	19210.59	**660**	512.25	24198.43	**591**
82.79	13294.13	**871**	225.07	16087.14	**448**	368.29	19214.73	**657**	512.45	24211.19	**559**
82.99	13301.86	**920**	225.27	16090.45	**433**	368.48	19218.87	**735**	512.65	24223.92	**562**
83.19	13309.73	**848**	225.46	16093.77	**420**	368.68	19223.03	**602**	512.85	24236.60	**467**
83.39	13317.72	**818**	225.66	16097.10	**459**	368.88	19227.18	**605**	513.05	24249.28	**435**
83.58	13325.79	**800**	225.86	16100.43	**430**	369.08	19231.35	**570**	513.25	24261.93	**517**
83.78	13333.94	**735**	226.05	16103.74	**441**	369.27	19235.51	**566**	513.45	24274.57	**513**
83.98	13342.10	**803**	226.25	16107.07	**455**	369.47	19239.67	**570**	513.64	24286.57	**574**
84.18	13350.27	**848**	226.45	16110.40	**415**	369.67	19243.82	**509**	513.84	24299.18	**540**
84.38	13358.40	**890**	226.65	16113.72	**410**	369.87	19247.97	**504**	514.04	24311.78	**539**
84.58	13366.45	**881**	226.84	16117.03	**431**	370.06	19252.10	**386**	514.24	24324.36	**566**
84.77	13374.38	**865**	227.04	16120.33	**422**	370.26	19256.22	**396**	514.44	24336.96	**607**
84.97	13382.16	**807**	227.24	16123.62	**445**	370.46	19260.33	**362**	514.64	24349.55	**641**
85.17	13389.73	**793**	227.43	16126.88	**457**	370.65	19264.44	**337**	514.84	24362.15	**618**
85.37	13397.06	**794**	227.63	16130.13	**457**	370.85	19268.53	**372**	515.00	24372.44	**660**
85.57	13404.10	**742**	227.83	16133.35	**493**	371.05	19272.62	**376**	515.04	24374.74	**681**
85.77	13410.82	**843**	228.03	16136.54	**470**	371.25	19276.70	**368**	515.20	24384.79	**657**
85.96	13417.16	**896**	228.22	16139.71	**434**	371.44	19280.78	**359**	515.39	24397.16	**679**
86.16	13423.11	**923**	228.42	16142.85	**472**	371.64	19284.86	**409**	515.59	24409.52	**648**
86.36	13428.67	**869**	228.62	16145.96	**496**	371.84	19288.95	**389**	515.78	24421.88	**685**
86.56	13433.90	**881**	228.81	16149.06	**471**	372.04	19293.03	**387**	515.98	24434.25	**674**
86.76	13438.83	**915**	229.01	16152.15	**560**	372.23	19297.12	**354**	516.17	24446.63	**689**
86.96	13443.51	**943**	229.21	16155.22	**598**	372.43	19301.20	**360**	516.37	24459.01	**714**
87.15	13447.97	**975**	229.41	16158.30	**534**	372.63	19305.29	**326**	516.57	24471.41	**757**
87.35	13452.29	**840**	229.60	16161.37	**470**	372.82	19309.38	**372**	516.76	24483.81	**711**
87.55	13456.47	**869**	229.80	16164.45	**492**	373.02	19313.48	**416**	516.96	24496.22	**738**
87.75	13460.58	**899**	230.00	16167.53	**504**	373.22	19317.58	**324**	517.15	24508.64	**672**
87.95	13464.64	**818**	230.19	16170.62	**549**	373.42	19321.67	**409**	517.35	24521.07	**711**
88.15	13468.72	**857**	230.39	16173.73	**476**	373.61	19325.77	**386**	517.54	24533.51	**689**
88.34	13472.81	**893**	230.59	16176.84	**524**	373.81	19329.87	**353**	517.74	24545.97	**680**
88.54	13476.91	**935**	230.79	16179.94	**488**	374.01	19333.97	**377**	517.94	24558.43	**568**
88.74	13481.01	**840**	230.98	16183.06	**528**	374.21	19338.06	**350**	518.13	24570.92	**570**
88.94	13485.13	**851**	231.18	16186.16	**516**	374.40	19342.15	**390**	518.33	24583.42	**509**
89.14	13489.23	**782**	231.38	16189.26	**479**	374.60	19346.25	**367**	518.52	24595.94	**522**
89.34	13493.33	**765**	231.57	16192.34	**495**	374.80	19350.34	**405**	518.71	24607.87	**581**
89.53	13497.41	**889**	231.77	16195.41	**521**	375.00	19354.43	**347**	518.90	24620.47	**611**
89.73	13501.49	**902**	231.97	16198.47	**494**	375.19	19358.52	**322**	519.10	24633.09	**648**
89.93	13505.53	**955**	232.17	16201.50	**506**	375.39	19362.60	**340**	519.30	24645.78	**609**
90.13	13509.56	**824**	232.36	16204.50	**486**	375.59	19366.68	**340**	519.49	24658.50	**575**
90.33	13513.55	**929**	232.56	16207.49	**488**	375.78	19370.75	**365**	519.69	24671.29	**558**
90.53	13517.53	**862**	232.76	16210.47	**540**	375.98	19374.82	**320**	519.88	24684.14	**468**
90.72	13521.49	**808**	232.95	16213.27	**598**	376.18	19378.89	**298**	520.08	24697.07	**430**
90.92	13525.44	**849**	233.14	16216.20	**558**	376.38	19382.95	**302**	520.27	24710.06	**465**
91.12	13529.39	**839**	233.34	16219.12	**620**	376.57	19387.00	**344**	520.47	24723.15	**433**
91.32	13533.33	**847**	233.54	16222.03	**522**	376.77	19391.05	**333**	520.66	24736.31	**397**
91.52	13537.28	**825**	233.73	16224.91	**496**	376.97	19395.10	**355**	520.86	24749.59	**376**
91.72	13541.23	**884**	233.93	16227.79	**475**	377.17	19399.14	**354**	521.06	24762.95	**421**
91.91	13545.20	**877**	234.13	16230.66	**456**	377.36	19403.19	**338**	521.25	24776.42	**478**
92.11	13549.18	**853**	234.33	16233.51	**483**	377.56	19407.22	**386**	521.45	24790.00	**476**
92.31	13553.18	**920**	234.52	16236.37	**498**	377.76	19411.26	**363**	521.64	24803.72	**515**
92.51	13557.20	**867**	234.72	16239.22	**605**	377.96	19415.29	**348**	521.84	24817.55	**461**

Table 0-2—*Continued*

92.71	13561.23	**836**	234.92	16242.07	**585**	378.15	19419.31	**351**	522.03	24831.53	**502**
92.91	13565.27	**895**	235.11	16244.94	**627**	378.35	19423.34	**375**	522.23	24845.61	**491**
93.10	13569.31	**872**	235.31	16247.82	**585**	378.55	19427.37	**356**	522.43	24859.76	**511**
93.29	13573.16	**847**	235.51	16250.70	**605**	378.74	19431.39	**389**	522.62	24873.87	**569**
93.49	13577.22	**780**	235.71	16253.62	**588**	378.94	19435.42	**412**	522.82	24887.97	**557**
93.69	13581.27	**845**	235.90	16256.56	**588**	379.14	19439.44	**425**	523.01	24901.95	**639**
93.90	13585.52	**837**	236.10	16259.52	**605**	379.34	19443.47	**357**	523.21	24915.68	**620**
94.10	13589.58	**825**	236.30	16262.51	**613**	379.53	19447.49	**353**	523.40	24929.18	**660**
94.28	13593.41	**827**	236.49	16265.53	**573**	379.73	19451.53	**364**	523.60	24942.35	**538**
94.48	13597.46	**830**	236.69	16268.57	**510**	379.93	19455.56	**353**	523.80	24955.14	**609**
94.68	13601.50	**857**	236.89	16271.62	**576**	380.13	19459.60	**303**	523.99	24967.48	**489**
94.88	13605.56	**884**	237.09	16274.68	**501**	380.32	19463.63	**370**	524.19	24979.31	**559**
95.08	13609.63	**905**	237.28	16277.76	**573**	380.52	19467.68	**325**	524.38	24990.70	**544**
95.28	13613.72	**929**	237.48	16280.84	**559**	380.72	19471.71	**323**	524.58	25001.70	**548**
95.47	13617.83	**937**	237.68	16283.91	**531**	380.91	19475.75	**336**	524.77	25012.37	**575**
95.67	13621.97	**921**	237.87	16286.98	**508**	381.11	19479.79	**328**	524.97	25022.79	**593**
95.87	13626.15	**866**	238.07	16290.04	**540**	381.31	19483.83	**328**	525.17	25033.03	**581**
96.07	13630.36	**879**	238.27	16293.09	**517**	381.51	19487.86	**360**	525.36	25043.15	**596**
96.27	13634.61	**877**	238.47	16296.13	**521**	381.70	19491.89	**292**	525.56	25053.22	**554**
96.47	13638.87	**905**	238.66	16299.14	**528**	381.90	19495.91	**355**	525.75	25063.30	**522**
96.66	13643.12	**923**	238.86	16302.13	**544**	382.10	19499.93	**313**	525.94	25072.97	**452**
96.86	13647.35	**938**	239.06	16305.10	**608**	382.30	19503.94	**334**	526.13	25083.27	**408**
97.06	13651.53	**945**	239.25	16308.03	**595**	382.49	19507.94	**302**	526.33	25093.69	**458**
97.26	13655.65	**930**	239.45	16310.93	**627**	382.69	19511.94	**343**	526.53	25104.15	**549**
97.46	13659.68	**891**	239.65	16313.80	**609**	382.89	19515.95	**332**	526.72	25114.58	**564**
97.66	13663.62	**925**	239.85	16316.62	**579**	383.09	19519.95	**306**	526.92	25124.87	**573**
97.85	13667.42	**868**	240.00	16318.80	**615**	383.28	19523.95	**323**	527.11	25134.98	**636**
98.05	13671.08	**832**	240.04	16319.40	**592**	383.48	19527.96	**322**	527.31	25144.80	**563**
98.25	13674.58	**843**	240.19	16321.51	**661**	383.68	19531.98	**366**	527.50	25154.27	**596**
98.45	13677.97	**856**	240.39	16324.16	**610**	383.87	19536.01	**347**	527.70	25163.30	**550**
98.65	13681.26	**873**	240.58	16326.77	**625**	384.07	19540.05	**329**	527.89	25171.82	**599**
98.85	13684.49	**788**	240.78	16329.33	**620**	384.27	19544.09	**295**	528.09	25179.74	**560**
99.04	13687.68	**796**	240.97	16331.83	**621**	384.47	19548.15	**316**	528.29	25187.09	**599**
99.24	13690.87	**821**	241.17	16334.28	**614**	384.66	19552.21	**323**	528.48	25193.95	**561**
99.44	13694.08	**819**	241.36	16336.67	**631**	384.86	19556.29	**321**	528.68	25200.44	**638**
99.64	13697.34	**917**	241.56	16339.00	**586**	385.06	19560.36	**296**	528.87	25206.65	**553**
99.84	13700.67	**800**	241.75	16341.27	**621**	385.26	19564.44	**343**	529.07	25212.68	**559**
100.04	13704.12	**893**	241.94	16343.48	**598**	385.45	19568.52	**338**	529.26	25218.64	**567**
100.23	13707.69	**888**	242.14	16345.61	**583**	385.65	19572.61	**359**	529.46	25224.65	**612**
100.43	13711.38	**861**	242.33	16347.70	**564**	385.85	19576.69	**375**	529.66	25230.79	**635**
100.63	13715.15	**809**	242.53	16349.74	**591**	386.04	19580.77	**433**	529.85	25237.18	**592**
100.83	13719.02	**860**	242.72	16351.76	**583**	386.24	19584.84	**452**	530.05	25243.91	**615**
101.03	13722.93	**853**	242.92	16353.76	**564**	386.44	19588.92	**451**	530.24	25251.04	**576**
101.23	13726.91	**800**	243.11	16355.78	**589**	386.64	19592.99	**422**	530.44	25258.53	**559**
101.42	13730.90	**866**	243.31	16357.80	**577**	386.83	19597.06	**410**	530.63	25266.34	**597**
101.62	13734.92	**868**	243.50	16359.85	**576**	387.03	19601.13	**444**	530.83	25274.39	**599**
101.82	13738.92	**809**	243.69	16361.95	**577**	387.23	19605.21	**397**	531.03	25282.64	**573**
102.02	13742.90	**865**	243.89	16364.11	**592**	387.43	19609.29	**484**	531.22	25291.03	**547**
102.22	13746.85	**928**	244.08	16366.33	**592**	387.62	19613.38	**465**	531.42	25299.52	**553**
102.42	13750.76	**881**	244.28	16368.64	**628**	387.82	19617.47	**514**	531.61	25308.04	**439**
102.61	13754.65	**833**	244.47	16371.03	**600**	388.02	19621.57	**632**	531.81	25316.56	**400**
102.81	13758.52	**795**	244.67	16373.48	**620**	388.22	19625.68	**776**	532.00	25325.00	**384**
103.01	13762.36	**859**	244.86	16375.99	**561**	388.41	19629.80	**654**	532.20	25333.33	**439**
103.21	13766.20	**872**	245.06	16378.56	**558**	388.61	19633.92	**617**	532.40	25341.56	**440**
103.41	13770.01	**855**	245.25	16381.18	**499**	388.81	19638.04	**686**	532.59	25349.71	**472**
103.61	13773.83	**944**	245.45	16383.85	**555**	389.00	19642.17	**640**	532.79	25357.78	**443**
103.80	13777.64	**856**	245.64	16386.55	**482**	389.20	19646.29		532.98	25365.82	**456**
104.00	13781.46	**890**	245.83	16389.29	**555**	389.40	19650.42		533.17	25373.42	**444**
104.20	13785.27	**906**	246.03	16392.06	**507**	389.60	19654.55		533.36	25381.41	**470**

Table 0-2—*Continued*

104.40	13789.10	**885**	246.21	16394.71	**497**	389.79	19658.67		533.56	25389.40	**461**
104.60	13792.93	**818**	246.41	16397.53	**512**	389.99	19662.78		533.76	25397.41	**410**
104.80	13796.76	**854**	246.60	16400.36	**481**	390.19	19666.89		533.95	25405.47	**429**
104.99	13800.59	**872**	246.80	16403.22	**522**	390.39	19671.00		534.15	25413.57	**447**
105.19	13804.42	**831**	246.99	16406.10	**503**	390.58	19675.10		534.34	25421.74	**381**
105.39	13808.25	**884**	247.19	16408.99	**601**	390.78	19679.19		534.54	25429.96	**359**
105.59	13812.07	**801**	247.38	16411.90	**561**	390.98	19683.29		534.73	25438.21	**383**
105.79	13815.89	**814**	247.57	16414.82	**533**	391.17	19687.38		534.93	25446.51	**396**
105.99	13819.71	**830**	247.77	16417.77	**540**	391.37	19691.47		535.13	25454.83	**386**
106.18	13823.52	**701**	247.96	16420.73	**526**	391.57	19695.57		535.32	25463.17	**385**
106.38	13827.32	**781**	248.16	16423.70	**554**	391.77	19699.67		535.52	25471.52	**450**
106.58	13831.11	**695**	248.35	16426.68	**565**	391.96	19703.77		535.71	25479.88	**378**
106.78	13834.90	**763**	248.55	16429.68	**496**	392.16	19707.87		535.91	25488.23	**397**
106.98	13838.68	**705**	248.74	16432.70	**500**	392.36	19711.99		536.10	25496.58	**348**
107.18	13842.46	**744**	248.94	16435.73	**549**	392.55	19716.10		536.30	25504.91	**377**
107.37	13846.23	**753**	249.13	16438.77	**506**	392.75	19720.22		536.50	25513.24	**394**
107.57	13849.99	**792**	249.33	16441.83	**526**	392.95	19724.34		536.69	25521.55	**423**
107.77	13853.75	**720**	249.52	16444.91	**547**	393.15	19728.46		536.89	25529.86	**372**
107.97	13857.51	**667**	249.71	16448.01	**546**	393.34	19732.59		537.08	25538.16	**407**
108.17	13861.25	**656**	249.91	16451.12	**583**	393.54	19736.72		537.28	25546.47	**306**
108.37	13865.00	**738**	250.10	16454.25	**641**	393.74	19740.84		537.47	25554.77	**341**
108.56	13868.73	**707**	250.30	16457.41	**566**	393.94	19744.97		537.67	25563.08	**323**
108.76	13872.48	**705**	250.49	16460.58	**591**	394.00	19746.31	**616**	537.87	25571.39	**322**
108.96	13876.21	**770**	250.69	16463.79	**594**	394.20	19750.43	**614**	538.06	25579.69	**284**
109.16	13879.96	**778**	250.88	16467.04	**549**	394.39	19754.55	**692**	538.26	25588.02	**309**
109.36	13883.71	**805**	251.08	16470.31	**562**	394.59	19758.66	**637**	538.45	25596.36	**343**
109.56	13887.46	**769**	251.27	16473.64	**579**	394.79	19762.77	**605**	538.65	25604.71	**314**
109.75	13891.23	**777**	251.46	16477.00	**587**	394.98	19766.89	**628**	538.84	25613.07	**288**
109.95	13895.00	**812**	251.66	16480.42	**589**	395.18	19771.02	**582**	539.04	25621.44	**281**
110.15	13898.79	**709**	251.85	16483.90	**568**	395.38	19775.14	**509**	539.23	25629.82	**319**
110.35	13902.59	**760**	252.05	16487.43	**583**	395.57	19779.27	**539**	539.43	25638.21	**309**
110.55	13906.39	**762**	252.24	16491.02	**544**	395.77	19783.41	**498**	539.63	25646.63	**310**
110.75	13910.21	**774**	252.44	16494.67	**547**	395.97	19787.54	**515**	539.82	25655.05	**310**
110.94	13914.03	**728**	252.63	16498.36	**524**	396.17	19791.69	**519**	540.02	25663.49	**302**
111.14	13917.87	**753**	252.83	16502.10	**533**	396.36	19795.84	**532**	540.20	25671.52	**243**
111.34	13921.70	**744**	253.02	16505.86	**534**	396.56	19800.00	**486**	540.40	25679.98	**311**
111.54	13925.53	**716**	253.21	16509.66	**585**	396.76	19804.16	**488**	540.59	25688.46	**296**
111.74	13929.37	**694**	253.41	16513.47	**574**	396.94	19808.12	**490**	540.79	25696.96	**275**
111.94	13933.20	**707**	253.60	16517.30	**536**	397.14	19812.28	**454**	540.99	25705.47	**287**
112.13	13937.03	**737**	253.80	16521.13	**554**	397.34	19816.43	**459**	541.18	25714.00	**245**
112.33	13940.86	**630**	253.99	16524.95	**512**	397.53	19820.60	**380**	541.38	25722.53	**263**
112.53	13944.68	**706**	254.19	16528.78	**473**	397.73	19824.76	**393**	541.57	25731.09	**254**
112.73	13948.51	**674**	254.38	16532.62	**538**	397.93	19828.92	**384**	541.77	25739.66	**230**
112.93	13952.33	**698**	254.58	16536.53	**539**	398.12	19833.06	**389**	541.96	25748.24	**207**
113.13	13956.15	**707**	254.77	16540.55	**550**	398.32	19837.21	**499**	542.16	25756.83	**249**
113.32	13959.97	**709**	254.96	16544.68	**603**	398.52	19841.34	**439**	542.36	25765.44	**241**
113.52	13963.80	**683**	255.16	16548.99	**491**	398.71	19845.48	**477**	542.55	25774.06	**247**
113.72	13967.63	**714**	255.35	16553.50	**573**	398.91	19849.62	**458**	542.75	25782.69	**266**
113.92	13971.46	**706**	255.55	16558.26	**595**	399.11	19853.75	**454**	542.94	25791.33	**323**
114.12	13975.29	**694**	255.74	16563.29	**587**	399.30	19857.89	**543**	543.14	25799.97	**412**
114.32	13979.12	**716**	255.94	16568.63	**626**	399.50	19862.03	**513**	543.33	25808.61	**358**
114.51	13982.96	**688**	256.13	16574.31	**567**	399.70	19866.16	**533**	543.53	25817.27	**370**
114.71	13986.81	**718**	256.33	16580.33	**604**	399.90	19870.31	**579**	543.73	25825.92	**435**
114.91	13990.66	**716**	256.52	16586.62	**587**	400.09	19874.46	**529**	543.92	25834.58	**435**
115.11	13994.52	**711**	256.72	16593.16	**629**	400.29	19878.62	**617**	544.12	25843.23	**425**
115.31	13998.38	**696**	256.91	16599.87	**592**	400.49	19882.79	**633**	544.31	25851.88	**425**
115.51	14002.25	**716**	257.10	16606.73	**578**	400.68	19886.96	**605**	544.51	25860.52	**414**
115.70	14006.13	**741**	257.29	16613.31	**613**	400.88	19891.13	**613**	544.70	25869.15	**416**
115.90	14010.02	**735**	257.48	16620.32	**607**	401.08	19895.30	**637**	544.90	25877.76	**366**

Table 0-2—*Continued*

116.10	14013.91	**632**	257.68	16627.29	**546**	401.27	19899.49	**715**	545.10	25886.37	**356**
116.30	14017.82	**553**	257.87	16634.24	**615**	401.47	19903.68	**645**	545.29	25894.94	**355**
116.49	14021.53	**549**	258.07	16641.07	**539**	401.67	19907.87	**755**	545.49	25903.49	**342**
116.70	14025.65	**503**	258.26	16647.79	**636**	401.86	19912.06	**752**	545.68	25912.01	**410**
116.89	14029.57	**628**	258.46	16654.38	**561**	402.06	19916.25	**672**	545.88	25920.49	**390**
117.09	14033.49	**645**	258.65	16660.88	**568**	402.26	19920.44	**788**	546.07	25928.93	**384**
117.29	14037.42	**650**	258.84	16667.23	**561**	402.45	19924.64	**738**	546.27	25937.35	**405**
117.48	14041.16	**623**	259.04	16673.50	**554**	402.65	19928.84	**676**	546.46	25945.72	**415**
117.68	14045.08	**624**	259.23	16679.64	**554**	402.85	19933.04	**649**	546.66	25954.07	**383**
117.88	14049.01	**536**	259.43	16685.70	**580**	403.03	19937.04	**627**	546.86	25962.39	**355**
118.07	14052.93	**656**	259.62	16691.65	**562**	403.23	19941.26	**640**	547.05	25970.69	**325**
118.27	14056.86	**651**	259.82	16697.52	**520**	403.43	19945.48	**618**	547.24	25978.56	**294**
118.47	14060.78	**665**	260.01	16703.28	**497**	403.62	19949.69	**610**	547.43	25986.83	**338**
118.67	14064.70	**716**	260.21	16708.98	**532**	403.82	19953.93	**580**	547.63	25995.08	**327**
118.87	14068.61	**664**	260.40	16714.60	**536**	404.02	19958.18	**588**	547.82	26003.34	**342**
119.07	14072.53	**711**	260.60	16720.17	**598**	404.22	19962.44	**583**	548.02	26011.59	**351**
119.26	14076.44	**651**	260.79	16725.66	**585**	404.41	19966.70	**589**	548.22	26019.84	**369**
119.46	14080.36	**669**	260.98	16731.13	**559**	404.61	19970.96	**624**	548.41	26028.09	**352**
119.66	14084.27	**707**	261.18	16736.54	**527**	404.81	19975.22	**644**	548.61	26036.34	**426**
119.86	14088.19	**634**	261.37	16741.95	**523**	405.00	19979.49	**597**	548.80	26044.59	**409**
120.06	14092.11	**663**	261.57	16747.32	**436**	405.20	19983.76	**586**	549.00	26052.84	**530**
120.26	14096.04	**622**	261.76	16752.70	**560**	405.40	19988.01	**652**	549.19	26061.08	**546**
120.45	14099.96	**639**	261.96	16758.08	**558**	405.59	19992.27	**706**	549.39	26069.31	**552**
120.65	14103.89	**685**	262.15	16763.47	**617**	405.79	19996.51	**730**	549.59	26077.53	**587**
120.85	14107.82	**698**	262.35	16768.87	**602**	405.99	20000.74	**715**	549.78	26085.75	**580**
121.05	14111.76	**680**	262.54	16774.31	**609**	406.18	20004.95	**700**	549.98	26093.95	**686**
121.25	14115.69	**693**	262.73	16779.73	**575**	406.38	20009.14	**808**	550.17	26102.14	**656**
121.45	14119.63	**667**	262.93	16785.18	**564**	406.58	20013.33	**609**	550.37	26110.31	**717**
121.64	14123.57	**711**	263.12	16790.62	**533**	406.77	20017.51	**614**	550.56	26118.47	**711**
121.84	14127.51	**679**	263.32	16796.09	**542**	406.97	20021.67	**593**	550.76	26126.60	**771**
122.04	14131.45	**746**	263.51	16801.55	**611**	407.17	20025.82	**525**	550.96	26134.71	**641**
122.24	14135.40	**727**	263.71	16807.03	**583**	407.36	20029.97	**416**	551.15	26142.78	**639**
122.44	14139.34	**691**	263.90	16812.49	**574**	407.56	20034.11	**423**	551.35	26150.83	**600**
122.64	14143.28	**679**	264.10	16817.98	**630**	407.76	20038.25	**420**	551.54	26158.83	**603**
122.83	14147.22	**652**	264.29	16823.45	**609**	407.96	20042.39	**430**	551.74	26166.81	**610**
123.03	14151.17	**653**	264.48	16828.94	**599**	408.15	20046.52	**426**	551.93	26174.73	**577**
123.23	14155.11	**714**	264.68	16834.42	**603**	408.35	20050.66	**500**	552.13	26182.60	**513**
123.43	14159.06	**658**	264.87	16839.91	**642**	408.55	20054.79	**507**	552.33	26190.43	**529**
123.63	14163.00	**624**	265.07	16845.38	**578**	408.74	20058.92	**468**	552.52	26198.22	**490**
123.83	14166.95	**606**	265.26	16850.87	**565**	408.93	20062.84	**423**	552.72	26205.97	**514**
124.02	14170.90	**561**	265.46	16856.35	**633**	409.13	20066.97	**458**	552.91	26213.70	**530**
124.22	14174.85	**707**	265.65	16861.83	**632**	409.32	20071.10	**524**	553.11	26221.40	**510**
124.42	14178.79	**683**	265.85	16867.30	**627**	409.52	20075.22	**519**	553.30	26229.07	**488**
124.62	14182.74	**636**	266.04	16872.79	**651**	409.72	20079.35	**580**	553.50	26236.73	**442**
124.80	14186.33	**603**	266.23	16878.26	**617**	409.91	20083.47	**577**	553.69	26244.39	**439**
124.82	14186.69	**628**	266.43	16883.74	**568**	410.11	20087.58	**568**	553.89	26252.04	**429**
124.99	14190.03	**689**	266.62	16889.21	**568**	410.31	20091.70	**550**	554.09	26259.69	**394**
125.17	14193.74	**682**	266.82	16894.68	**550**	410.50	20095.82	**600**	554.27	26266.97	**401**
125.36	14197.45	**656**	267.01	16900.13	**589**	410.70	20099.94	**617**	554.47	26274.64	**365**
125.54	14201.16	**637**	267.21	16905.59	**646**	410.90	20104.05	**645**	554.66	26282.31	**352**
125.73	14204.87	**643**	267.40	16911.04	**635**	411.09	20108.17	**647**	554.86	26290.00	**373**
125.92	14208.58	**651**	267.60	16916.49	**608**	411.29	20112.28	**678**	555.00	26295.55	**306**
126.10	14212.29	**694**	267.79	16921.92	**715**	411.49	20116.40	**711**	555.05	26297.70	**308**
126.29	14216.02	**623**	267.99	16927.35	**707**	411.69	20120.53	**766**	555.20	26303.37	**313**
126.47	14219.74	**682**	268.18	16932.76	**729**	411.88	20124.65	**677**	555.40	26311.22	**316**
126.66	14223.47	**717**	268.37	16938.19	**721**	412.08	20128.79	**721**	555.59	26319.07	**316**
126.85	14227.19	**655**	268.57	16943.59	**675**	412.28	20132.92	**754**	555.79	26326.98	**331**
127.03	14230.93	**593**	268.76	16949.01	**611**	412.47	20137.07	**663**	555.99	26334.91	**357**
127.22	14234.67	**640**	268.96	16954.40	**601**	412.67	20141.20	**660**	556.19	26342.88	**311**

Table 0-2—*Continued*

127.40	14238.42	**652**	269.15	16959.81	**616**	412.87	20145.35	**678**	556.39	26350.86	**367**
127.59	14242.17	**718**	269.34	16964.94	**640**	413.06	20149.51	**642**	556.59	26358.88	**377**
127.77	14245.93	**628**	269.53	16970.34	**570**	413.26	20153.67	**688**	556.78	26366.92	**379**
127.96	14249.69	**662**	269.73	16975.75	**612**	413.46	20157.83	**602**	556.98	26374.97	**395**
128.15	14253.47	**675**	269.92	16981.15	**624**	413.65	20161.99	**633**	557.18	26383.02	**389**
128.33	14257.25	**637**	270.11	16986.57	**644**	413.85	20166.15	**579**	557.38	26391.05	**327**
128.52	14261.04	**706**	270.31	16992.00	**629**	414.05	20170.32	**655**	557.58	26399.09	**304**
128.70	14264.83	**635**	270.50	16997.41	**620**	414.24	20174.50	**610**	557.77	26407.11	**313**
128.89	14268.63	**624**	270.70	17002.85	**642**	414.44	20178.67	**535**	557.97	26415.11	**303**
129.08	14272.43	**533**	270.89	17008.28	**620**	414.63	20182.64	**571**	558.17	26423.06	**277**
129.26	14276.24	**553**	271.09	17013.72	**664**	414.82	20186.82	**559**	558.37	26431.00	**294**
129.45	14280.05	**546**	271.28	17019.16	**808**	415.02	20191.00	**564**	558.57	26438.91	**284**
129.63	14283.86	**529**	271.48	17024.61	**710**	415.22	20195.20	**567**	558.76	26446.81	**319**
129.82	14287.68	**576**	271.67	17030.05	**742**	415.41	20199.38	**578**	558.96	26454.69	**310**
130.01	14291.49	**586**	271.86	17035.50	**724**	415.61	20203.58	**535**	559.16	26462.54	**260**
130.19	14295.31	**607**	272.06	17040.94	**734**	415.81	20207.79	**593**	559.36	26470.40	**313**
130.38	14299.13	**660**	272.25	17046.39	**698**	416.01	20211.99	**555**	559.56	26478.25	**288**
130.56	14302.94	**686**	272.45	17051.83	**694**	416.20	20216.21	**594**	559.76	26486.11	**270**
130.75	14306.76	**692**	272.64	17057.29	**566**	416.40	20220.41	**588**	559.95	26493.96	**244**
130.94	14310.57	**703**	272.84	17062.73	**607**	416.60	20224.64	**568**	560.15	26501.83	**263**
131.12	14314.39	**701**	273.03	17068.18	**644**	416.79	20228.88	**643**	560.35	26509.70	**245**
131.31	14318.20	**651**	273.23	17073.62	**628**	416.99	20233.13	**627**	560.55	26517.58	**263**
131.49	14322.01	**637**	273.42	17079.08	**663**	417.19	20237.39	**615**	560.75	26525.45	**240**
131.68	14325.81	**579**	273.62	17084.53	**694**	417.38	20241.67	**595**	560.94	26533.29	**268**
131.87	14329.62	**624**	273.81	17089.98	**666**	417.58	20245.97	**593**	561.14	26541.14	**257**
132.05	14333.41	**606**	274.00	17095.44	**707**	417.78	20250.30	**573**	561.34	26548.97	**256**
132.24	14337.21	**524**	274.20	17100.90	**618**	417.97	20254.65	**578**	561.54	26556.77	**244**
132.42	14341.00	**583**	274.39	17106.35	**685**	418.17	20259.02	**616**	561.73	26564.13	**266**
132.61	14344.79	**594**	274.59	17111.82	**688**	418.37	20263.43	**586**	561.93	26571.87	**251**
132.80	14348.57	**570**	274.78	17117.26	**660**	418.56	20267.85	**630**	562.12	26579.56	**283**
132.98	14352.36	**672**	274.98	17122.72	**623**	418.76	20272.31	**601**	562.32	26587.21	**298**
133.17	14356.13	**691**	275.17	17128.15	**634**	418.96	20276.76	**682**	562.52	26594.81	**298**
133.35	14359.91	**625**	275.37	17133.59	**674**	419.15	20281.26	**585**	562.72	26602.35	**318**
133.54	14363.68	**644**	275.56	17139.02	**673**	419.35	20285.77	**615**	562.92	26609.86	**300**
133.73	14367.46	**629**	275.75	17144.43	**655**	419.55	20290.30	**546**	563.11	26617.31	**294**
133.91	14371.23	**657**	275.95	17149.83	**699**	419.75	20294.85	**538**	563.31	26624.70	**304**
134.10	14374.99	**676**	276.14	17155.21	**665**	419.94	20299.40	**564**	563.51	26632.02	**262**
134.28	14378.75	**700**	276.34	17160.58	**701**	420.14	20303.98	**570**	563.71	26639.30	**342**
134.47	14382.52	**671**	276.53	17165.98	**711**	420.34	20308.62	**567**	563.91	26646.51	**302**
134.65	14386.28	**653**	276.73	17171.37	**634**	420.53	20313.38	**510**	564.11	26653.66	**326**
134.84	14390.04	**633**	276.92	17176.82	**648**	420.72	20318.09	**505**	564.30	26660.75	**294**
135.03	14393.79	**652**	277.12	17182.29	**644**	420.92	20323.27	**458**	564.50	26667.78	**248**
135.21	14397.55	**605**	277.31	17187.83	**628**	421.11	20328.78	**506**	564.70	26674.79	**280**
135.40	14401.30	**555**	277.50	17193.44	**674**	421.31	20334.67	**464**	564.90	26681.78	**290**
135.58	14405.05	**467**	277.70	17199.14	**625**	421.51	20341.00	**515**	565.10	26688.76	**333**
135.77	14408.79	**514**	277.89	17204.93	**690**	421.70	20347.83	**477**	565.29	26695.73	**315**
135.96	14412.54	**506**	278.09	17210.83	**684**	421.90	20355.26	**492**	565.49	26702.73	**308**
136.14	14416.28	**533**	278.28	17216.83	**618**	422.10	20361.74	**573**	565.69	26709.76	**278**
136.33	14420.03	**531**	278.48	17222.90	**635**	422.29	20366.08	**532**	565.89	26716.84	**250**
136.51	14423.77	**495**	278.67	17228.97	**685**	422.49	20370.66	**483**	566.09	26723.97	**262**
136.70	14427.51	**489**	278.87	17235.04	**595**	422.69	20375.40	**508**	566.28	26731.14	**246**
136.89	14431.24	**521**	279.06	17241.03	**548**	422.88	20380.28	**517**	566.48	26738.39	**222**
137.07	14434.98	**468**	279.26	17246.94	**570**	423.08	20385.21	**578**	566.68	26745.70	**269**
137.26	14438.71	**541**	279.45	17252.69	**519**	423.28	20390.15	**535**	566.88	26753.06	**226**
137.43	14442.25	**460**	279.64	17258.26	**538**	423.48	20395.01	**521**	567.08	26760.46	**231**
137.62	14445.98	**512**	279.84	17263.61	**557**	423.67	20399.74	**498**	567.28	26767.92	**253**
137.81	14449.72	**537**	280.00	17267.86	**579**	423.87	20404.29	**457**	567.47	26775.43	**243**
138.00	14453.63	**605**	280.03	17268.72	**550**	424.07	20408.58	**555**	567.67	26782.99	**221**
138.19	14457.36	**566**	280.20	17272.77	**553**	424.26	20412.58	**499**	567.87	26790.59	**260**

Table 0-2—*Continued*

138.36	14460.90	**554**	280.39	17277.54	**519**	424.46	20416.30	**492**	568.07	26798.21	**241**
138.55	14464.63	**569**	280.59	17282.31	**668**	424.66	20419.75	**472**	568.27	26805.89	**215**
138.74	14468.36	**626**	280.79	17287.24	**638**	424.85	20422.92	**485**	568.46	26813.60	**226**
138.92	14472.09	**603**	280.98	17292.47	**698**	425.05	20425.83	**509**	568.66	26821.33	**189**
139.11	14475.81	**566**	281.18	17298.18	**659**	425.25	20428.48	**543**	568.86	26829.09	**232**
139.29	14479.54	**661**	281.37	17304.48	**658**	425.44	20430.88	**578**	569.06	26836.84	**228**
139.48	14483.27	**667**	281.57	17311.57	**614**	425.64	20433.04	**484**	569.26	26844.62	**228**
139.67	14487.01	**608**	281.77	17319.56	**649**	425.84	20434.97	**566**	569.46	26852.39	**265**
139.85	14490.73	**610**	281.96	17328.64	**704**	426.03	20436.67	**564**	569.65	26860.17	**220**
140.04	14494.47	**654**	282.16	17338.89	**678**	426.23	20438.17	**557**	569.85	26867.92	**243**
140.22	14498.20	**610**	282.36	17350.21	**666**	426.43	20439.52	**630**	570.05	26875.67	**294**
140.41	14501.94	**655**	282.55	17362.33	**655**	426.61	20440.75	**640**	570.25	26883.41	**234**
140.60	14505.67	**601**	282.75	17375.04	**752**	426.81	20442.04	**629**	570.45	26891.12	**215**
140.78	14509.41	**568**	282.94	17388.05	**724**	427.01	20443.40	**610**	570.64	26898.81	**236**
140.97	14513.15	**548**	283.14	17401.18	**838**	427.20	20444.91	**650**	570.84	26906.50	**275**
141.15	14516.88	**529**	283.34	17414.10	**804**	427.40	20446.63	**648**	571.04	26914.18	**278**
141.34	14520.61	**569**	283.53	17426.65	**802**	427.60	20448.64	**639**	571.24	26921.85	**273**
141.52	14524.35	**539**	283.73	17438.52	**778**	427.80	20451.00	**612**	571.44	26929.52	**339**
141.71	14528.08	**499**	283.93	17449.51	**764**	427.99	20453.80	**587**	571.63	26937.17	**326**
141.90	14531.81	**542**	284.12	17459.37	**735**	428.19	20457.04	**566**	571.83	26944.83	**328**
142.08	14535.54	**604**	284.32	17468.09	**776**	428.39	20460.52	**618**	572.03	26952.50	**436**
142.27	14539.26	**598**	284.51	17475.78	**740**	428.58	20463.97	**626**	572.23	26960.16	**472**
142.45	14542.98	**529**	284.71	17482.60	**719**	428.78	20467.09	**588**	572.43	26967.83	**533**
142.64	14546.70	**471**	284.91	17488.65	**729**	428.98	20469.62	**570**	572.63	26975.49	**648**
142.83	14550.42	**509**	285.10	17494.08	**762**	429.17	20471.29	**593**	572.82	26983.17	**694**
143.01	14554.15	**494**	285.30	17499.02	**698**	429.37	20471.81	**548**	573.02	26990.86	**634**
143.20	14557.86	**442**	285.50	17503.61	**789**	429.57	20471.90	**642**	573.22	26998.56	**635**
143.38	14561.59	**487**	285.69	17507.95	**777**	429.76	20471.99	**617**	573.42	27006.25	**633**
143.57	14565.31	**426**	285.89	17512.20	**762**	429.96	20472.09	**586**	573.62	27013.97	**644**
143.76	14569.04	**442**	286.08	17516.48	**735**	430.16	20472.18	**628**	573.81	27021.70	**630**
143.94	14572.77	**449**	286.28	17520.85	**763**	430.35	20472.27	**654**			

Table 0-3 Sr count results for CCC-007

Depth (mm)	Age (yr BP)	Sr
2.00	9260.96	**240**
2.21	9264.74	**281**
2.41	9268.53	**317**
2.62	9272.33	**298**
2.82	9276.14	**281**
3.03	9279.96	**245**
3.24	9283.77	**294**
3.44	9287.57	**257**
3.65	9291.37	**244**
3.85	9295.16	**223**
4.06	9298.93	**213**
4.27	9302.68	**220**
4.47	9306.43	**236**
4.68	9310.16	**233**
4.88	9313.90	**292**
5.09	9317.64	**227**
5.30	9321.38	**233**
5.49	9324.94	**222**
5.70	9328.70	**211**
5.90	9332.47	**239**
6.11	9336.27	**198**
6.32	9340.09	**235**
6.52	9343.93	**283**
6.73	9347.78	**204**
6.93	9351.65	**197**
7.14	9355.52	**168**
7.35	9359.40	**186**
7.55	9363.27	**232**
7.76	9367.14	**227**
7.96	9371.01	**236**
8.17	9374.87	**243**
8.38	9378.72	**249**
8.58	9382.56	**249**
8.79	9386.41	**206**
9.00	9390.27	**180**
9.20	9394.13	**212**
9.41	9398.00	**224**
9.61	9401.88	**205**
9.82	9405.79	**221**
10.03	9409.72	**191**
10.23	9413.67	**227**
10.44	9417.67	**218**
10.64	9421.70	**231**
10.85	9425.80	**220**
11.06	9429.97	**213**
11.26	9434.21	**201**
11.47	9438.53	**236**
11.67	9442.95	**253**
11.88	9447.46	**288**
12.09	9452.10	**274**
12.29	9456.84	**254**
12.49	9461.44	**261**
12.69	9466.37	**237**
12.90	9471.38	**235**
13.00	9473.84	**231**

Depth (mm)	Age (yr BP)	Sr
108.04	11869.49	**180**
108.24	11877.44	**192**
108.43	11885.41	**167**
108.63	11893.41	**147**
108.83	11901.41	**167**
109.02	11909.45	**195**
109.22	11917.50	**167**
109.42	11925.57	**192**
109.61	11933.66	**177**
109.81	11941.78	**200**
110.00	11949.88	**218**
110.20	11958.03	**216**
110.40	11966.18	**181**
110.59	11974.32	**228**
110.79	11982.49	**172**
110.99	11990.68	**202**
111.18	11998.86	**148**
111.38	12007.04	**186**
111.58	12015.23	**187**
111.77	12023.43	**217**
111.97	12031.60	**147**
112.16	12039.79	**163**
112.36	12047.97	**166**
112.56	12056.13	**171**
112.74	12063.88	**171**
112.94	12072.03	**191**
113.14	12080.13	**165**
113.33	12088.21	**172**
113.53	12096.27	**165**
113.73	12104.29	**199**
113.92	12112.28	**160**
114.12	12120.23	**148**
114.31	12128.12	**214**
114.51	12135.98	**169**
114.71	12143.79	**163**
114.90	12151.54	**228**
115.10	12159.24	**206**
115.30	12166.90	**187**
115.49	12174.49	**219**
115.69	12182.04	**197**
115.89	12189.52	**193**
116.08	12196.93	**176**
116.28	12204.29	**176**
116.48	12211.61	**171**
116.67	12218.84	**200**
116.87	12226.05	**193**
117.06	12233.19	**146**
117.26	12240.29	**152**
117.46	12247.35	**183**
117.65	12254.37	**188**
117.85	12261.33	**140**
118.05	12268.27	**165**
118.24	12275.16	**181**
118.44	12282.01	**161**
118.64	12288.76	**155**

Depth (mm)	Age (yr BP)	Sr
213.85	13965.10	**175**
214.05	13969.92	**147**
214.24	13974.67	**210**
214.43	13979.35	**156**
214.63	13983.99	**232**
214.80	13988.07	**167**
214.82	13988.57	**209**
214.99	13995.99	**186**
215.19	14005.09	**229**
215.38	14014.17	**191**
215.58	14023.26	**215**
215.77	14032.36	**225**
215.96	14041.53	**193**
216.16	14050.74	**250**
216.35	14060.03	**212**
216.54	14069.36	**225**
216.74	14078.77	**197**
216.93	14088.18	**153**
217.13	14097.63	**189**
217.32	14107.08	**174**
217.51	14116.55	**175**
217.71	14126.01	**183**
217.90	14135.46	**192**
218.09	14144.88	**184**
218.29	14154.28	**187**
218.48	14163.66	**206**
218.68	14173.03	**185**
218.87	14182.37	**219**
219.06	14191.73	**234**
219.26	14201.08	**218**
219.45	14210.45	**221**
219.65	14219.82	**220**
219.84	14229.23	**201**
220.03	14238.64	**197**
220.23	14248.10	**213**
220.42	14257.56	**216**
220.61	14267.07	**241**
220.81	14276.57	**221**
221.00	14286.11	**204**
221.20	14295.65	**226**
221.39	14305.20	**263**
221.58	14314.76	**210**
221.78	14324.32	**195**
221.97	14333.87	**180**
222.17	14343.44	**158**
222.36	14352.98	**154**
222.55	14362.53	**174**
222.75	14372.07	**207**
222.94	14381.63	**200**
223.13	14391.16	**215**
223.33	14400.70	**191**
223.52	14410.23	**203**
223.72	14419.77	**196**
223.91	14429.29	**223**
224.10	14438.83	**245**

Depth (mm)	Age (yr BP)	Sr
318.74	19063.35	**184**
318.94	19072.81	**175**
319.13	19082.29	**152**
319.33	19091.79	**201**
319.53	19101.26	**195**
319.72	19110.75	**178**
319.92	19120.24	**214**
320.12	19129.72	**208**
320.31	19139.20	**216**
320.51	19148.69	**221**
320.70	19158.15	**174**
320.90	19167.64	**202**
321.10	19177.12	**193**
321.29	19186.59	**194**
321.49	19196.07	**170**
321.69	19205.56	**194**
321.88	19215.02	**189**
322.08	19224.51	**174**
322.28	19233.99	**203**
322.47	19243.47	**201**
322.67	19252.95	**212**
322.86	19262.44	**199**
323.06	19271.90	**189**
323.26	19281.40	**194**
323.45	19290.88	**207**
323.65	19300.36	**176**
323.85	19309.84	**175**
324.04	19319.33	**177**
324.24	19328.81	**187**
324.43	19337.80	**179**
324.62	19347.28	**181**
324.82	19356.77	**185**
325.01	19366.24	**207**
325.21	19375.73	**179**
325.41	19385.22	**209**
325.60	19394.70	**190**
325.80	19404.19	**188**
326.00	19413.69	**194**
326.19	19423.16	**168**
326.39	19432.67	**167**
326.59	19442.16	**188**
326.78	19451.65	**207**
326.98	19461.15	**167**
327.18	19470.65	**210**
327.37	19480.13	**210**
327.57	19489.63	**210**
327.76	19499.12	**197**
327.96	19508.60	**207**
328.16	19518.08	**187**
328.35	19527.57	**174**
328.55	19537.02	**197**
328.75	19546.51	**154**
328.94	19555.98	**186**
329.14	19565.44	**164**
329.34	19574.91	**157**

Table 0-3—*Continued*

13.11	9476.45	**243**	118.83	12295.43	**157**	224.30	14448.35	**218**	329.53	19584.38	**177**
13.20	9478.71	**179**	119.03	12301.99	**167**	224.49	14457.89	**210**	329.73	19593.83	**160**
13.31	9481.55	**308**	119.22	12308.42	**172**	224.68	14467.41	**203**	329.92	19603.31	**191**
13.39	9483.63	**306**	119.42	12314.71	**167**	224.88	14476.95	**212**	330.12	19612.79	**155**
13.52	9486.70	**243**	119.62	12320.84	**199**	225.07	14486.47	**183**	330.32	19622.26	**166**
13.59	9488.56	**264**	119.81	12326.77	**172**	225.27	14496.00	**228**	330.51	19631.74	**171**
13.79	9493.51	**232**	120.01	12332.52	**181**	225.46	14505.52	**175**	330.71	19641.24	**165**
13.99	9498.46	**209**	120.21	12338.07	**177**	225.65	14515.05	**223**	330.91	19650.70	**143**
14.18	9503.41	**236**	120.40	12343.42	**203**	225.85	14524.56	**207**	331.10	19660.20	**148**
14.38	9508.34	**261**	120.60	12348.64	**198**	226.04	14534.10	**235**	331.30	19669.69	**198**
14.58	9513.26	**226**	120.80	12353.74	**182**	226.24	14543.61	**216**	331.50	19679.19	**172**
14.78	9518.16	**229**	120.99	12358.76	**199**	226.43	14553.13	**160**	331.69	19688.66	**172**
14.97	9523.06	**254**	121.19	12363.74	**191**	226.62	14562.64	**169**	331.89	19698.16	**184**
15.17	9527.94	**256**	121.38	12368.70	**209**	226.81	14571.69	**152**	332.08	19707.64	**213**
15.37	9532.81	**240**	121.58	12373.67	**184**	227.00	14581.20	**164**	332.28	19717.13	**172**
15.57	9537.65	**225**	121.78	12378.71	**207**	227.20	14591.19	**165**	332.48	19726.61	**206**
15.76	9542.48	**222**	121.97	12383.83	**169**	227.40	14601.02		332.67	19736.11	**202**
15.96	9547.28	**245**	122.17	12389.05	**207**	227.60	14610.84		332.87	19745.57	**186**
16.16	9552.08	**226**	122.37	12394.39	**203**	227.80	14620.68		333.07	19755.06	**164**
16.36	9556.83	**245**	122.56	12399.81	**200**	228.00	14630.51		333.26	19764.54	**213**
16.55	9561.56	**248**	122.76	12405.27	**167**	228.20	14640.35		333.46	19774.00	**173**
16.75	9566.23	**219**	122.96	12410.78	**176**	228.40	14650.20		333.66	19783.47	**171**
16.95	9570.87	**198**	123.15	12416.30	**177**	228.60	14660.05		333.85	19792.95	**178**
17.14	9575.43	**195**	123.35	12421.80	**174**	228.80	14669.91		334.05	19802.39	**181**
17.34	9579.94	**254**	123.54	12427.27	**179**	229.00	14679.77		334.24	19811.85	**206**
17.54	9584.36	**230**	123.74	12432.67	**154**	229.20	14689.64		334.44	19821.30	**169**
17.74	9588.70	**231**	123.94	12437.99	**179**	229.40	14699.51		334.64	19830.75	**150**
17.93	9592.95	**195**	124.13	12443.21	**176**	229.60	14709.39		334.80	19838.59	**188**
18.13	9597.09	**218**	124.33	12448.33	**215**	229.80	14719.26		334.83	19840.20	**179**
18.33	9601.14	**245**	124.53	12453.33	**192**	230.00	14729.14		335.00	19848.03	**221**
18.53	9605.10	**236**	124.72	12458.25	**182**	230.20	14739.03		335.19	19857.49	**175**
18.72	9608.96	**265**	124.91	12462.86	**205**	230.40	14748.91		335.39	19866.94	**179**
18.92	9612.75	**213**	125.11	12467.63	**190**	230.60	14758.80		335.58	19876.42	**196**
19.12	9616.47	**236**	125.30	12472.35	**222**	230.80	14768.45	**199**	335.78	19885.90	**223**
19.32	9620.11	**220**	125.50	12477.03	**204**	231.00	14778.11	**222**	335.98	19895.40	**159**
19.51	9623.69	**227**	125.70	12481.66	**194**	231.19	14787.78	**211**	336.17	19904.90	**164**
19.71	9627.22	**240**	125.89	12486.26	**217**	231.39	14797.44	**194**	336.37	19914.44	**201**
19.91	9630.70	**242**	126.09	12490.84	**206**	231.58	14807.11	**248**	336.57	19923.97	**149**
20.11	9634.14	**190**	126.28	12495.41	**217**	231.78	14816.78	**228**	336.76	19933.52	**171**
20.30	9637.54	**215**	126.48	12499.97	**196**	231.97	14826.45	**201**	336.96	19943.06	**163**
20.50	9640.90	**227**	126.68	12504.55	**171**	232.17	14836.12	**194**	337.15	19952.61	**169**
20.70	9644.23	**228**	126.87	12509.14	**149**	232.36	14845.80	**210**	337.35	19962.15	**158**
20.89	9647.55	**204**	127.07	12513.75	**229**	232.56	14855.47	**195**	337.55	19971.69	**176**
21.09	9650.84	**219**	127.27	12518.40	**168**	232.75	14865.16	**232**	337.74	19981.21	**146**
21.29	9654.12	**195**	127.46	12523.09	**192**	232.95	14874.83	**199**	337.94	19990.72	**178**
21.49	9657.38	**220**	127.66	12527.82	**157**	233.14	14884.51	**201**	338.14	20000.21	**202**
21.68	9660.65	**210**	127.86	12532.63	**189**	233.34	14894.18	**212**	338.33	20009.69	**188**
21.88	9663.91	**191**	128.05	12537.51	**205**	233.53	14903.86	**229**	338.53	20019.15	**166**
22.08	9667.17	**207**	128.25	12542.45	**168**	233.73	14913.52	**228**	338.72	20028.61	**168**
22.28	9670.44	**211**	128.44	12547.43	**197**	233.93	14923.19	**220**	338.92	20038.04	**187**
22.47	9673.72	**235**	128.64	12552.44	**208**	234.12	14932.85	**213**	339.12	20047.47	**181**
22.67	9677.00	**221**	128.84	12557.42	**214**	234.32	14942.52	**196**	339.31	20056.90	**160**
22.87	9680.28	**218**	129.03	12562.38	**213**	234.51	14952.18	**183**	339.51	20066.34	**140**
23.07	9683.54	**230**	129.23	12567.26	**186**	234.71	14961.85	**188**	339.70	20075.77	**154**
23.26	9686.81	**213**	129.43	12572.05	**225**	234.90	14971.51	**211**	339.90	20085.22	**165**
23.45	9689.90	**219**	129.62	12576.72	**207**	235.10	14981.19	**198**	340.10	20094.67	**156**
23.65	9693.15	**218**	129.82	12581.24	**192**	235.29	14990.86	**166**	340.29	20104.13	**160**
23.84	9696.38	**178**	130.02	12585.59	**167**	235.49	15000.55	**166**	340.49	20113.59	**138**
24.04	9699.59	**223**	130.21	12589.74	**190**	235.68	15010.24	**210**	340.69	20123.07	**167**

Table 0-3—*Continued*

24.24	9702.79	**203**
24.44	9705.97	**230**
24.63	9709.13	**261**
24.83	9712.29	**227**
25.03	9715.43	**311**
25.23	9718.56	**286**
25.42	9721.68	**271**
25.62	9724.80	**213**
25.82	9727.91	**263**
26.02	9731.01	**260**
26.21	9734.11	**263**
26.41	9737.22	**200**
26.61	9740.31	**193**
26.81	9743.41	**223**
27.00	9746.51	**216**
27.20	9749.62	**239**
27.40	9752.72	**205**
27.59	9755.83	**213**
27.79	9758.93	**218**
27.99	9762.05	**215**
28.19	9765.17	**191**
28.38	9768.30	**201**
28.58	9771.42	**231**
28.78	9774.56	**214**
28.98	9777.68	**217**
29.17	9780.82	**236**
29.37	9783.94	**228**
29.57	9787.08	**232**
29.77	9790.20	**193**
29.96	9793.33	**249**
30.16	9796.44	**216**
30.36	9799.55	**229**
30.55	9802.66	**234**
30.75	9805.77	**254**
30.95	9808.88	**246**
31.15	9812.01	**258**
31.34	9815.14	**248**
31.54	9818.28	**270**
31.74	9821.43	**263**
31.94	9824.61	**225**
32.13	9827.79	**219**
32.33	9831.00	**205**
32.53	9834.22	**224**
32.73	9837.46	**215**
32.92	9840.71	**245**
33.12	9843.96	**187**
33.32	9847.22	**259**
33.52	9850.48	**263**
33.71	9853.73	**237**
33.91	9856.99	**232**
34.11	9860.24	**242**
34.30	9863.48	**246**
34.50	9866.71	**245**
34.70	9869.94	**231**
34.90	9873.15	**258**
35.09	9876.35	**219**
35.29	9879.54	**204**
35.49	9882.72	**177**
35.69	9885.88	

130.41	12593.72	**194**
130.60	12597.54	**179**
130.80	12601.23	**186**
131.00	12604.81	**192**
131.19	12608.29	**199**
131.39	12611.70	**182**
131.59	12615.06	**186**
131.78	12618.39	**210**
131.98	12621.71	**182**
132.18	12625.04	**172**
132.37	12628.37	**201**
132.57	12631.72	**201**
132.76	12635.06	**194**
132.96	12638.40	**152**
133.16	12641.72	**192**
133.35	12645.03	**222**
133.55	12648.31	**229**
133.75	12651.56	**185**
133.94	12654.78	**206**
134.14	12657.96	**180**
134.34	12661.10	**192**
134.50	12663.70	**185**
134.53	12664.20	**142**
134.70	12666.79	**157**
134.90	12669.86	**174**
135.09	12672.88	**196**
135.29	12675.89	**147**
135.49	12678.86	**218**
135.69	12681.81	**189**
135.88	12684.74	**215**
136.08	12687.66	**190**
136.28	12690.55	**194**
136.48	12693.43	**179**
136.68	12696.31	**175**
136.87	12699.20	**175**
137.07	12702.10	**171**
137.27	12705.01	**221**
137.47	12707.94	**170**
137.67	12710.91	**194**
137.86	12713.91	**175**
138.06	12716.96	**212**
138.26	12720.04	**213**
138.46	12723.18	**198**
138.65	12726.34	**186**
138.85	12729.55	**245**
139.05	12732.78	**183**
139.25	12736.06	**167**
139.45	12739.35	**181**
139.64	12742.67	**198**
139.84	12746.01	**235**
140.04	12749.36	**182**
140.24	12752.73	**215**
140.44	12756.12	**189**
140.63	12759.51	**169**
140.83	12762.92	**196**
141.03	12766.34	**217**
141.23	12769.77	**232**
141.41	12773.04	**227**
141.61	12776.50	**230**

235.88	15019.96	**206**
236.07	15029.67	**202**
236.27	15039.41	**209**
236.46	15049.14	**198**
236.66	15058.90	**238**
236.86	15068.65	**225**
237.05	15078.42	**206**
237.25	15088.18	**214**
237.44	15097.96	**225**
237.64	15107.72	**217**
237.83	15117.50	**211**
238.03	15127.26	**210**
238.22	15137.03	**215**
238.42	15146.79	**218**
238.61	15156.56	**232**
238.81	15166.31	**230**
239.00	15176.07	**240**
239.20	15185.82	**200**
239.40	15195.57	**213**
239.59	15205.31	**208**
239.79	15215.06	**215**
239.98	15224.80	**216**
240.18	15234.55	**233**
240.37	15244.28	**233**
240.57	15254.02	**231**
240.76	15263.75	**214**
240.96	15273.49	**199**
241.15	15283.21	**178**
241.35	15292.95	**182**
241.54	15302.67	**167**
241.74	15312.40	**167**
241.93	15322.11	**227**
242.13	15331.83	**191**
242.33	15341.54	**243**
242.52	15351.26	**241**
242.72	15360.97	**228**
242.91	15370.68	**201**
243.11	15380.39	**213**
243.30	15390.12	**188**
243.50	15399.83	**206**
243.69	15409.56	**150**
243.89	15419.28	**166**
244.08	15429.02	**168**
244.28	15438.76	**221**
244.46	15448.02	**206**
244.67	15458.25	**192**
244.86	15468.01	**205**
245.06	15477.75	**191**
245.26	15487.51	**255**
245.44	15496.77	**274**
245.64	15506.52	**277**
245.83	15516.26	**242**
246.03	15526.02	**229**
246.22	15535.74	**260**
246.42	15545.48	**247**
246.61	15555.19	**230**
246.81	15564.92	**246**
247.00	15574.62	**192**
247.20	15584.33	**224**

340.88	20132.53	**153**
341.08	20142.00	**167**
341.27	20151.45	**162**
341.47	20160.90	**168**
341.67	20170.33	**171**
341.86	20179.75	**162**
342.06	20189.15	**131**
342.26	20198.53	**139**
342.45	20207.89	**127**
342.65	20217.25	**158**
342.84	20226.60	**151**
343.04	20235.97	**162**
343.24	20245.33	**182**
343.43	20254.72	**191**
343.63	20264.11	**180**
343.83	20273.55	**165**
344.02	20283.00	**177**
344.22	20292.50	**182**
344.41	20302.02	**183**
344.61	20311.58	**146**
344.81	20321.15	**147**
345.00	20330.74	**142**
345.20	20340.33	**155**
345.39	20349.93	**175**
345.59	20359.52	**132**
345.79	20369.12	**136**
345.98	20378.69	**177**
346.18	20388.25	**197**
346.38	20397.79	**204**
346.57	20407.32	**178**
346.77	20416.83	**190**
346.96	20426.34	**168**
347.16	20435.83	**154**
347.36	20445.32	**169**
347.55	20454.80	**150**
347.75	20464.28	**143**
347.95	20473.76	**173**
348.14	20483.25	**175**
348.34	20492.73	**149**
348.53	20502.23	**131**
348.73	20511.71	**152**
348.93	20521.20	**170**
349.12	20530.68	**136**
349.32	20540.17	**160**
349.51	20549.64	**148**
349.71	20559.12	**156**
349.91	20568.58	**128**
350.10	20578.04	**160**
350.30	20587.49	**158**
350.50	20596.94	**151**
350.69	20606.38	**131**
350.89	20615.83	**122**
351.07	20624.79	**160**
351.28	20634.72	**140**
351.48	20644.16	**137**
351.67	20653.62	**131**
351.87	20663.08	**124**
352.06	20672.08	**178**
352.25	20681.56	**141**

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35.88	9889.03	
36.08	9892.16	
36.28	9895.28	
36.48	9898.39	
36.67	9901.50	
36.87	9904.61	**188**
37.07	9907.72	**210**
37.27	9910.85	**264**
37.46	9913.99	**289**
37.66	9917.15	**281**
37.86	9920.34	**268**
38.05	9923.55	**213**
38.25	9926.81	**233**
38.45	9930.08	**204**
38.65	9933.38	**210**
38.84	9936.68	**194**
39.04	9939.99	**211**
39.24	9943.29	**173**
39.44	9946.59	**199**
39.63	9949.86	**214**
39.83	9953.11	**171**
40.03	9956.33	**182**
40.23	9959.52	**196**
40.42	9962.68	**199**
40.62	9965.81	**178**
40.82	9968.93	**209**
41.02	9972.04	**170**
41.21	9975.15	**192**
41.41	9978.27	**210**
41.61	9981.39	**180**
41.80	9984.54	**193**
42.00	9987.71	**208**
42.20	9990.92	**210**
42.40	9994.15	**196**
42.59	9997.40	**214**
42.79	10000.65	**184**
42.99	10003.91	**227**
43.19	10007.17	**197**
43.37	10010.25	**186**
43.57	10013.47	**187**
43.77	10016.66	**213**
43.97	10019.82	**206**
44.16	10022.93	**202**
44.36	10026.00	**235**
44.56	10029.05	**178**
44.76	10032.06	**179**
44.95	10035.07	**152**
45.15	10038.06	**194**
45.35	10041.06	**194**
45.54	10044.05	**194**
45.74	10047.07	**205**
45.94	10050.11	**211**
46.14	10053.18	**164**
46.33	10056.28	**170**
46.53	10059.40	**134**
46.73	10062.53	**164**
46.93	10065.68	**148**
47.12	10068.84	**161**
47.32	10071.99	**232**

141.81	12779.96	**221**
142.01	12783.44	**230**
142.21	12786.92	**160**
142.40	12790.41	**189**
142.60	12793.91	**174**
142.80	12797.43	**197**
143.00	12800.95	**198**
143.20	12804.50	**192**
143.39	12808.04	**183**
143.59	12811.60	**198**
143.79	12815.17	**187**
143.99	12818.76	**188**
144.18	12822.36	**190**
144.38	12825.98	**185**
144.58	12829.59	**193**
144.78	12833.23	**176**
144.98	12836.87	**210**
145.17	12840.52	**177**
145.37	12844.16	**185**
145.57	12847.82	**161**
145.77	12851.47	**185**
145.97	12855.13	**206**
146.16	12858.78	**190**
146.36	12862.43	**192**
146.56	12866.08	**168**
146.76	12869.74	**169**
146.95	12873.39	**175**
147.15	12877.05	**176**
147.35	12880.71	**185**
147.55	12884.39	**202**
147.75	12888.06	**197**
147.94	12891.76	**193**
148.14	12895.45	**193**
148.34	12899.17	**201**
148.54	12902.88	**205**
148.74	12906.61	**196**
148.93	12910.32	**220**
149.13	12914.05	**191**
149.33	12917.76	**194**
149.53	12921.47	**206**
149.72	12925.16	**195**
149.92	12928.84	**193**
150.12	12932.50	**171**
150.32	12936.15	**201**
150.52	12939.77	**202**
150.71	12943.40	**171**
150.91	12947.01	**210**
151.11	12950.62	**213**
151.31	12954.23	**190**
151.50	12957.85	**226**
151.70	12961.46	**212**
151.90	12965.09	**206**
152.10	12968.73	**188**
152.30	12972.39	**184**
152.49	12976.05	**223**
152.69	12979.74	**189**
152.89	12983.42	**200**
153.09	12987.11	**176**
153.29	12990.79	**256**

247.39	15594.03	**237**
247.59	15603.73	**193**
247.79	15613.42	**211**
247.98	15623.12	**239**
248.18	15632.79	**228**
248.37	15642.48	**200**
248.57	15652.15	**203**
248.76	15661.83	**200**
248.96	15671.49	**210**
249.15	15681.15	**206**
249.35	15690.80	**222**
249.54	15700.45	**256**
249.74	15710.08	**228**
249.93	15719.71	**207**
250.13	15729.33	**188**
250.32	15738.94	**247**
250.52	15748.54	**206**
250.72	15758.14	**251**
250.91	15767.73	**216**
251.11	15777.33	**207**
251.30	15786.91	**188**
251.50	15796.51	**208**
251.69	15806.09	**208**
251.89	15815.69	**209**
252.08	15825.28	**212**
252.28	15834.89	**190**
252.47	15844.49	**268**
252.67	15854.11	**229**
252.86	15863.72	**223**
253.06	15873.34	**210**
253.25	15882.96	**222**
253.45	15892.58	**221**
253.65	15902.20	**210**
253.84	15911.83	**200**
254.04	15921.45	**202**
254.23	15931.08	**230**
254.43	15940.69	**205**
254.62	15950.32	**228**
254.82	15959.93	**233**
255.01	15969.56	**224**
255.20	15978.77	**223**
255.21	15979.16	**195**
255.39	15988.22	**235**
255.58	15997.68	**202**
255.78	16007.13	**185**
255.97	16016.57	**209**
256.16	16026.00	**200**
256.35	16035.43	**200**
256.55	16044.85	**204**
256.74	16054.28	**210**
256.93	16063.69	**202**
257.12	16073.11	**241**
257.32	16082.52	**213**
257.51	16091.95	**211**
257.70	16101.37	**209**
257.89	16110.81	**198**
258.09	16120.24	**179**
258.28	16129.70	**206**
258.47	16139.15	**217**

352.45	20691.05	**150**
352.64	20700.54	**128**
352.85	20710.53	**152**
353.04	20719.55	**157**
353.23	20729.06	**173**
353.43	20738.56	**143**
353.63	20748.07	**189**
353.82	20757.56	**164**
354.02	20767.06	**126**
354.21	20776.54	**160**
354.41	20786.02	**161**
354.61	20795.49	**138**
354.80	20804.96	**141**
355.00	20814.42	**138**
355.20	20823.88	**155**
355.39	20833.33	**171**
355.59	20842.79	**148**
355.78	20852.24	**167**
355.98	20861.68	**147**
356.18	20871.13	**164**
356.37	20880.59	**141**
356.57	20890.04	**139**
356.76	20899.50	**182**
356.96	20908.95	**155**
357.16	20918.41	**125**
357.35	20927.86	**179**
357.55	20937.32	**154**
357.75	20946.77	**156**
357.94	20956.23	**176**
358.14	20965.68	**168**
358.33	20975.14	**145**
358.53	20984.58	**159**
358.73	20994.04	**135**
358.92	21003.48	**148**
359.12	21012.93	**140**
359.32	21022.37	**140**
359.51	21031.82	**138**
359.71	21041.26	**143**
359.90	21050.70	**121**
360.10	21060.13	**159**
360.30	21069.58	**152**
360.49	21079.01	**149**
360.69	21088.45	**149**
360.88	21097.88	**143**
361.08	21107.32	**169**
361.28	21116.75	**120**
361.47	21126.20	**124**
361.67	21135.64	**130**
361.87	21145.10	**122**
362.06	21154.55	**127**
362.26	21164.01	**159**
362.45	21173.47	**160**
362.65	21182.95	**152**
362.85	21192.42	**179**
363.04	21201.90	**170**
363.24	21211.38	**163**
363.44	21220.88	**155**
363.63	21230.37	**153**
363.83	21239.87	**176**

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47.52	10075.14	**226**	153.48	12994.49	**238**	258.66	16148.61	**204**	364.02	21249.37	**175**
47.72	10078.27	**224**	153.68	12998.18	**182**	258.86	16158.07	**215**	364.22	21258.89	**153**
47.91	10081.38	**189**	153.88	13001.87	**213**	259.05	16167.54	**205**	364.42	21268.39	**191**
48.11	10084.48	**200**	154.08	13005.54	**181**	259.24	16177.01	**155**	364.61	21277.90	**192**
48.31	10087.54	**214**	154.27	13009.22	**180**	259.43	16186.48	**161**	364.81	21287.41	**153**
48.51	10090.59	**184**	154.47	13012.89	**187**	259.62	16195.94	**189**	365.01	21296.93	**153**
48.70	10093.62	**166**	154.67	13016.56	**214**	259.82	16205.41	**181**	365.20	21306.44	**165**
48.90	10096.63	**190**	154.87	13020.21	**179**	260.01	16214.86	**186**	365.40	21315.96	**179**
49.10	10099.63	**178**	155.07	13023.88	**217**	260.20	16224.31	**206**	365.59	21325.46	**144**
49.29	10102.63	**173**	155.26	13027.53	**203**	260.39	16233.75	**152**	365.79	21334.97	**143**
49.49	10105.63	**178**	155.46	13031.19	**239**	260.59	16243.20	**203**	365.99	21344.46	**171**
49.69	10108.63	**161**	155.65	13034.66	**227**	260.78	16252.64	**211**	366.18	21353.96	**158**
49.89	10111.63	**218**	155.85	13038.33	**205**	260.97	16262.08	**219**	366.38	21363.45	**162**
50.08	10114.65	**220**	156.05	13041.99	**176**	261.16	16271.51	**198**	366.57	21372.93	**167**
50.28	10117.68	**221**	156.24	13045.66	**214**	261.36	16280.96	**225**	366.77	21382.41	**138**
50.48	10120.71	**229**	156.44	13049.32	**216**	261.55	16290.39	**192**	366.97	21391.90	**132**
50.68	10123.75	**230**	156.64	13052.99	**208**	261.74	16299.84	**166**	367.16	21401.37	**160**
50.87	10126.81	**230**	156.84	13056.65	**224**	261.93	16309.28	**201**	367.36	21410.86	**163**
51.07	10129.86	**214**	157.03	13060.31	**195**	262.13	16318.73	**194**	367.56	21420.34	**182**
51.27	10132.91	**246**	157.23	13063.95	**199**	262.32	16328.18	**208**	367.75	21429.83	**173**
51.47	10135.97	**232**	157.43	13067.59	**202**	262.51	16337.65	**187**	367.95	21439.32	**136**
51.66	10139.02	**265**	157.63	13071.20	**200**	262.70	16347.10	**243**	368.14	21448.83	**173**
51.86	10142.07	**211**	157.83	13074.82	**223**	262.90	16356.57	**185**	368.34	21458.33	**154**
52.06	10145.12	**260**	158.02	13078.40	**234**	263.09	16366.03	**196**	368.54	21467.85	**168**
52.25	10148.16	**236**	158.22	13081.98	**164**	263.28	16375.50	**227**	368.73	21477.36	**120**
52.45	10151.20	**248**	158.42	13085.53	**184**	263.47	16384.95	**225**	368.93	21486.88	**137**
52.65	10154.23	**259**	158.62	13089.08	**201**	263.66	16394.41	**231**	369.13	21496.39	**116**
52.85	10157.26	**223**	158.82	13092.62	**236**	263.86	16403.86	**238**	369.32	21505.92	**171**
53.04	10160.29	**190**	159.01	13096.18	**214**	264.05	16413.32	**207**	369.52	21515.43	**155**
53.24	10163.33	**191**	159.21	13099.73	**189**	264.24	16422.75	**223**	369.71	21524.95	**181**
53.44	10166.37	**210**	159.41	13103.31	**237**	264.43	16432.20	**211**	369.91	21534.46	**140**
53.64	10169.41	**221**	159.61	13106.90	**212**	264.63	16441.63	**210**	370.11	21543.97	**153**
53.83	10172.46	**221**	159.80	13110.52	**191**	264.82	16451.07	**218**	370.30	21553.47	**138**
54.03	10175.52	**238**	160.00	13114.16	**210**	265.01	16460.50	**227**	370.50	21562.97	**140**
54.23	10178.59	**227**	160.20	13117.85	**222**	265.20	16469.95	**233**	370.69	21572.46	**144**
54.43	10181.67	**241**	160.40	13121.56	**244**	265.40	16479.38	**219**	370.89	21581.96	**139**
54.62	10184.75	**211**	160.60	13125.30	**195**	265.59	16488.83	**214**	371.09	21591.45	**134**
54.80	10187.51	**263**	160.79	13129.06	**178**	265.78	16498.27	**160**	371.28	21600.95	**153**
54.82	10187.83	**239**	160.99	13132.84	**200**	265.97	16507.73	**186**	371.48	21610.45	**151**
55.00	10190.55	**236**	161.19	13136.62	**148**	266.17	16517.18	**121**	371.68	21619.96	**140**
55.19	10193.59	**216**	161.39	13140.42	**196**	266.36	16526.65	**215**	371.87	21629.46	**178**
55.39	10196.61	**240**	161.59	13144.21	**202**	266.55	16536.12	**167**	372.07	21638.98	**133**
55.58	10199.62	**234**	161.78	13148.01	**210**	266.74	16545.60	**161**	372.26	21648.49	**149**
55.78	10202.60	**223**	161.98	13151.79	**210**	266.93	16555.08	**167**	372.46	21658.03	**160**
55.98	10205.55	**213**	162.18	13155.56	**168**	267.13	16564.56	**193**	372.66	21667.55	**203**
56.17	10208.48	**246**	162.38	13159.31	**208**	267.32	16574.04	**202**	372.85	21677.09	**153**
56.37	10211.38	**192**	162.57	13163.06	**191**	267.51	16583.53	**199**	373.05	21686.63	**140**
56.56	10214.24	**193**	162.77	13166.79	**192**	267.70	16593.01	**213**	373.25	21696.16	**165**
56.76	10217.08	**123**	162.97	13170.51	**178**	267.90	16602.49	**191**	373.44	21705.69	**149**
56.95	10219.90	**208**	163.17	13174.21	**187**	268.09	16611.97	**210**	373.64	21715.23	**159**
57.15	10222.69	**227**	163.37	13177.91	**253**	268.28	16621.45	**209**	373.83	21724.75	**158**
57.35	10225.46	**229**	163.56	13181.58	**219**	268.47	16630.91	**200**	374.03	21734.29	**159**
57.54	10228.20	**260**	163.76	13185.26	**222**	268.67	16640.38	**201**	374.23	21743.80	**139**
57.74	10230.92	**260**	163.96	13188.91	**219**	268.86	16649.84	**193**	374.42	21753.32	**173**
57.93	10233.61	**251**	164.16	13192.57	**216**	269.05	16659.31	**175**	374.62	21762.82	**188**
58.13	10236.29	**250**	164.36	13196.20	**209**	269.24	16668.76	**186**	374.82	21772.33	**144**
58.33	10238.93	**204**	164.55	13199.84	**208**	269.44	16678.22	**179**	375.00	21781.28	**147**
58.52	10241.50	**173**	164.75	13203.46	**229**	269.63	16687.66	**231**	375.01	21781.82	**170**
58.72	10243.97	**207**	164.95	13207.08	**230**	269.82	16697.11	**230**	375.20	21790.91	**163**

Table 0-3—*Continued*

58.91	10246.32	**205**
59.11	10248.52	**195**
59.30	10250.53	**204**
59.50	10252.34	**244**
59.70	10253.90	**194**
59.89	10255.20	**183**
60.09	10256.19	**200**
60.28	10256.91	**202**
60.48	10257.42	**197**
60.68	10257.78	**183**
60.87	10258.06	**224**
61.07	10258.33	**249**
61.26	10258.66	**249**
61.46	10259.12	**227**
61.64	10259.74	**260**
61.84	10260.65	**196**
62.04	10261.89	**214**
62.23	10263.50	**202**
62.43	10265.47	**269**
62.62	10267.78	**269**
62.82	10270.39	**276**
63.02	10273.31	**244**
63.21	10276.48	**275**
63.41	10279.91	**261**
63.60	10283.54	**243**
63.80	10287.38	**211**
63.99	10291.39	**212**
64.19	10295.56	**196**
64.39	10299.87	**232**
64.58	10304.35	**232**
64.78	10308.98	**232**
64.97	10313.78	**211**
65.17	10318.72	**222**
65.37	10323.85	**215**
65.56	10329.12	**222**
65.76	10334.59	**230**
65.95	10340.20	**172**
66.15	10346.00	**195**
66.34	10351.96	**199**
66.54	10358.11	**202**
66.74	10364.42	**236**
66.93	10370.92	**211**
67.13	10377.59	**223**
67.32	10384.44	**198**
67.52	10391.46	**213**
67.72	10398.68	**203**
67.91	10406.06	**209**
68.11	10413.65	**198**
68.30	10421.37	**155**
68.50	10429.24	**171**
68.70	10437.18	**170**
68.89	10445.20	**178**
69.09	10453.23	**152**
69.28	10461.26	**176**
69.48	10469.23	**206**
69.67	10477.12	**218**
69.87	10484.89	**227**
70.07	10492.49	**198**
70.26	10499.95	**202**

165.15	13210.69	**233**
165.34	13214.30	**179**
165.54	13217.91	**201**
165.74	13221.52	**189**
165.94	13225.12	**187**
166.14	13228.73	**213**
166.33	13232.33	**172**
166.53	13235.94	**209**
166.73	13239.54	**205**
166.93	13243.15	**238**
167.12	13246.75	**208**
167.32	13250.37	**210**
167.52	13253.97	**226**
167.72	13257.59	**211**
167.92	13261.19	**196**
168.11	13264.81	**170**
168.31	13268.42	**193**
168.51	13272.04	**225**
168.71	13275.66	**214**
168.90	13279.10	**216**
169.09	13282.72	**225**
169.29	13286.36	**223**
169.49	13289.98	**206**
169.69	13293.61	**194**
169.88	13297.24	**197**
170.08	13300.89	**194**
170.28	13304.53	**220**
170.48	13308.18	**193**
170.68	13311.83	**243**
170.87	13315.49	**213**
171.07	13319.16	**214**
171.27	13322.84	**183**
171.47	13326.52	**199**
171.67	13330.23	**221**
171.86	13333.93	**209**
172.06	13337.66	**189**
172.26	13341.39	**199**
172.46	13345.15	**218**
172.65	13348.89	**204**
172.85	13352.65	**211**
173.05	13356.39	**220**
173.25	13360.14	**182**
173.45	13363.86	**229**
173.64	13367.58	**189**
173.84	13371.27	**247**
174.04	13374.95	**213**
174.24	13378.60	**264**
174.44	13382.23	**200**
174.63	13385.84	**232**
174.83	13389.45	**211**
175.00	13392.53	**218**
175.03	13393.05	**236**
175.19	13396.05	**250**
175.39	13399.58	**236**
175.58	13403.11	**220**
175.77	13406.66	**218**
175.97	13410.23	**181**
176.16	13413.83	**229**
176.35	13417.44	**177**

270.00	16706.07	**206**
270.20	16715.52	**212**
270.40	16725.42	**179**
270.59	16734.85	**207**
270.78	16744.28	**170**
270.97	16753.24	**185**
271.16	16762.66	**230**
271.35	16772.09	**201**
271.54	16781.51	**217**
271.73	16790.94	**215**
271.93	16800.36	**169**
272.12	16809.80	**195**
272.31	16819.22	**204**
272.50	16828.66	**204**
272.70	16838.09	**154**
272.89	16847.53	**187**
273.08	16856.96	**167**
273.27	16866.41	**190**
273.47	16875.85	**177**
273.66	16885.30	**157**
273.85	16894.74	**198**
274.04	16904.20	**214**
274.24	16913.64	**176**
274.43	16923.10	**189**
274.62	16932.55	**234**
274.81	16942.01	**224**
275.01	16951.46	**184**
275.20	16960.92	**181**
275.39	16970.36	**161**
275.58	16979.81	**181**
275.77	16989.24	**213**
275.97	16998.67	**153**
276.16	17008.09	**191**
276.35	17017.51	**196**
276.54	17026.91	**201**
276.74	17036.32	**167**
276.93	17045.71	**186**
277.12	17055.11	**191**
277.31	17064.50	**183**
277.51	17073.89	**190**
277.70	17083.27	**154**
277.89	17092.66	**219**
278.08	17102.03	**192**
278.28	17111.42	**176**
278.47	17120.80	**221**
278.66	17130.18	**197**
278.85	17139.55	**224**
279.05	17148.92	**190**
279.24	17158.28	**169**
279.43	17167.65	**166**
279.62	17176.99	**200**
279.81	17186.34	**155**
280.01	17195.67	**194**
280.20	17205.00	**154**
280.39	17214.31	**155**
280.58	17223.63	**173**
280.78	17232.93	**164**
280.97	17242.24	**189**
281.16	17251.53	**158**

375.40	21800.54	**185**
375.60	21810.15	**173**
375.80	21819.77	**159**
376.00	21829.37	**150**
376.19	21838.97	**152**
376.39	21848.56	**188**
376.59	21858.15	**137**
376.79	21867.73	**172**
376.99	21877.32	**171**
377.19	21886.90	**153**
377.39	21896.50	**147**
377.59	21906.08	**124**
377.79	21915.68	**147**
377.99	21925.27	**109**
378.19	21934.89	**138**
378.38	21944.50	**141**
378.58	21954.13	**133**
378.78	21963.75	**148**
378.98	21973.38	**170**
379.18	21983.01	**144**
379.38	21992.65	**140**
379.58	22002.27	**156**
379.78	22011.90	**169**
379.98	22021.53	**151**
380.18	22031.16	**123**
380.38	22040.77	**126**
380.58	22050.40	**140**
380.77	22060.01	**120**
380.97	22069.63	**152**
381.17	22079.24	**135**
381.37	22088.84	**143**
381.57	22098.45	**142**
381.77	22108.07	**154**
381.97	22117.68	**163**
382.17	22127.29	**187**
382.37	22136.90	**168**
382.57	22146.52	**158**
382.77	22156.13	**157**
382.96	22165.75	**159**
383.16	22175.35	**152**
383.36	22184.95	**135**
383.56	22194.55	**160**
383.76	22204.15	**137**
383.96	22213.74	**159**
384.16	22223.33	**153**
384.36	22232.91	**160**
384.56	22242.49	**142**
384.76	22252.06	**125**
384.96	22261.63	**147**
385.15	22271.20	**140**
385.35	22280.78	**156**
385.55	22290.35	**174**
385.75	22299.94	**148**
385.95	22309.52	**183**
386.15	22319.11	**134**
386.35	22328.71	**118**
386.55	22338.31	**134**
386.75	22347.91	**172**
386.95	22357.51	**149**

Table 0-3—*Continued*

70.46	10507.25	**209**	176.55	13421.07	**230**	281.35	17260.84	**175**	387.15	22367.11	**169**
70.65	10514.42	**165**	176.74	13424.72	**243**	281.55	17270.14	**150**	387.34	22376.72	**148**
70.85	10521.49	**195**	176.93	13428.37	**206**	281.74	17279.45	**190**	387.54	22386.31	**146**
71.05	10528.48	**194**	177.13	13432.04	**225**	281.93	17288.75	**183**	387.74	22395.91	**140**
71.24	10535.40	**186**	177.32	13435.71	**220**	282.12	17298.07	**191**	387.94	22405.50	**188**
71.44	10542.28	**227**	177.51	13439.37	**227**	282.32	17307.38	**207**	388.14	22415.09	**182**
71.63	10549.14	**207**	177.71	13443.03	**212**	282.51	17316.71	**196**	388.34	22424.67	**149**
71.83	10556.01	**225**	177.90	13446.68	**199**	282.70	17326.04	**176**	388.54	22434.25	**144**
72.02	10562.89	**207**	178.09	13450.31	**205**	282.89	17335.37	**193**	388.74	22443.82	**171**
72.22	10569.81	**186**	178.29	13453.93	**184**	283.08	17344.69	**204**	388.94	22453.40	**169**
72.42	10576.76	**205**	178.48	13457.54	**191**	283.28	17354.03	**216**	389.14	22462.97	**128**
72.61	10583.74	**223**	178.67	13461.14	**227**	283.47	17363.35	**184**	389.34	22472.56	**150**
72.81	10590.75	**213**	178.87	13464.73	**178**	283.66	17372.67	**206**	389.53	22482.14	**166**
73.00	10597.78	**157**	179.06	13468.30	**240**	283.85	17381.99	**164**	389.73	22491.74	**152**
73.20	10604.83	**204**	179.25	13471.87	**202**	284.05	17391.30	**179**	389.93	22501.34	**183**
73.40	10611.89	**194**	179.45	13475.44	**191**	284.24	17400.60	**176**	390.13	22510.96	**159**
73.59	10618.96	**224**	179.64	13478.99	**210**	284.43	17409.90	**147**	390.33	22520.58	**124**
73.79	10626.04	**241**	179.84	13482.54	**196**	284.62	17419.19	**182**	390.53	22530.20	**165**
73.98	10633.11	**223**	180.03	13486.09	**204**	284.82	17428.49	**185**	390.73	22539.84	**144**
74.18	10640.18	**209**	180.22	13489.63	**198**	285.01	17437.77	**178**	390.93	22549.49	**144**
74.37	10647.25	**247**	180.42	13493.18	**144**	285.20	17447.06	**187**	391.13	22559.13	**107**
74.57	10654.32	**247**	180.61	13496.72	**160**	285.39	17456.34	**149**	391.33	22568.78	**161**
74.77	10661.37	**239**	180.80	13500.27	**145**	285.59	17465.63	**195**	391.53	22578.43	**166**
74.96	10668.42	**212**	181.00	13503.82	**145**	285.78	17474.91	**181**	391.73	22588.09	**156**
75.16	10675.46	**232**	181.19	13507.37	**195**	285.97	17484.21	**166**	391.92	22597.73	**151**
75.35	10682.51	**209**	181.38	13510.93	**215**	286.16	17493.49	**167**	392.12	22607.37	**152**
75.55	10689.54	**194**	181.58	13514.49	**239**	286.36	17502.79	**168**	392.32	22617.01	**189**
75.74	10696.22	**190**	181.77	13518.05	**278**	286.55	17512.08	**144**	392.52	22626.66	**150**
75.93	10703.24	**187**	181.96	13521.62	**209**	286.74	17521.39	**171**	392.72	22636.29	**186**
76.13	10710.27	**189**	182.16	13525.19	**197**	286.93	17530.68	**164**	392.92	22645.94	**138**
76.32	10717.29	**238**	182.35	13528.78	**226**	287.12	17539.99	**164**	393.12	22655.58	**130**
76.52	10724.30	**193**	182.54	13532.37	**238**	287.32	17549.29	**168**	393.32	22665.22	**156**
76.72	10731.33	**208**	182.74	13535.96	**219**	287.51	17558.60	**162**	393.52	22674.86	**145**
76.91	10738.33	**220**	182.93	13539.56	**215**	287.70	17567.89	**138**	393.72	22684.52	**129**
77.11	10745.35	**189**	183.12	13543.16	**199**	287.89	17577.20	**183**	393.92	22694.17	**170**
77.30	10752.35	**206**	183.32	13546.76	**226**	288.09	17586.49	**176**	394.11	22703.82	**142**
77.50	10759.36	**197**	183.50	13550.18	**199**	288.28	17595.79	**202**	394.31	22713.48	**169**
77.69	10766.36	**205**	183.69	13553.78	**216**	288.47	17605.08	**190**	394.51	22723.16	**143**
77.89	10773.38	**187**	183.89	13557.37	**227**	288.66	17614.38	**209**	394.71	22732.82	**207**
78.09	10780.37	**205**	184.09	13561.14	**202**	288.86	17623.67	**192**	394.91	22742.49	**179**
78.28	10787.38	**182**	184.28	13564.72	**248**	289.05	17632.97	**178**	395.11	22752.15	**158**
78.48	10794.37	**211**	184.47	13568.13	**188**	289.24	17642.26	**165**	395.31	22761.82	**142**
78.67	10801.38	**208**	184.66	13571.70	**228**	289.43	17651.56	**192**	395.51	22771.47	**150**
78.87	10808.36	**176**	184.85	13575.27	**227**	289.63	17660.85	**185**	395.71	22781.11	**132**
79.07	10815.36	**176**	185.05	13578.85	**224**	289.82	17670.16	**186**	395.91	22790.75	**160**
79.26	10822.34	**175**	185.24	13582.42	**195**	290.01	17679.45	**155**	396.11	22800.37	**142**
79.46	10829.32	**181**	185.43	13585.99	**184**	290.20	17688.76	**176**	396.30	22809.98	**128**
79.65	10836.28	**192**	185.63	13589.56	**205**	290.40	17698.06	**183**	396.50	22819.59	**171**
79.85	10843.25	**185**	185.82	13593.13	**217**	290.59	17707.38	**154**	396.70	22829.19	**146**
80.04	10850.20	**214**	186.01	13596.71	**218**	290.78	17716.68	**199**	396.90	22838.79	**189**
80.24	10857.16	**196**	186.21	13600.29	**187**	290.97	17726.00	**193**	397.10	22848.38	**176**
80.44	10864.09	**175**	186.40	13603.87	**225**	291.16	17735.32	**141**	397.30	22857.98	**131**
80.63	10871.03	**170**	186.59	13607.46	**190**	291.36	17744.64	**185**	397.50	22867.59	**155**
80.83	10877.96	**174**	186.79	13611.05	**158**	291.55	17753.96	**182**	397.70	22877.20	**168**
81.02	10884.90	**208**	186.98	13614.63	**166**	291.74	17763.29	**216**	397.90	22886.82	**184**
81.22	10891.83	**214**	187.17	13618.23	**177**	291.93	17772.62	**148**	398.10	22896.46	**143**
81.42	10898.79	**205**	187.37	13621.82	**182**	292.13	17781.96	**183**	398.30	22906.12	**156**
81.61	10905.74	**168**	187.56	13625.42	**156**	292.32	17791.29	**187**	398.50	22915.79	**177**
81.81	10912.71	**168**	187.75	13629.03	**202**	292.51	17800.63	**171**	398.69	22925.46	**167**

Table 0-3—*Continued*

82.00	10919.69	**208**
82.20	10926.70	**247**
82.39	10933.71	**191**
82.59	10940.75	**192**
82.79	10947.79	**196**
82.98	10954.85	**202**
83.18	10961.89	**171**
83.37	10968.94	**226**
83.57	10975.97	**172**
83.77	10983.01	**188**
83.96	10990.03	**173**
84.16	10997.03	**209**
84.35	11004.02	**183**
84.55	11011.00	**180**
84.74	11017.97	**166**
84.94	11024.93	**192**
85.14	11031.89	**229**
85.33	11038.85	**187**
85.53	11045.82	**206**
85.72	11052.79	**211**
85.92	11059.77	**215**
86.12	11066.76	**199**
86.31	11073.76	**179**
86.51	11080.78	**182**
86.70	11087.82	**173**
86.90	11094.85	**206**
87.10	11101.89	**193**
87.29	11108.94	**174**
87.49	11115.99	**169**
87.68	11123.05	**190**
87.88	11130.11	**192**
88.07	11137.17	**220**
88.27	11144.23	**248**
88.47	11151.29	**221**
88.66	11158.35	**191**
88.86	11165.41	**171**
89.05	11172.48	**161**
89.25	11179.53	**189**
89.45	11186.58	**182**
89.64	11193.63	**193**
89.83	11200.32	**135**
90.02	11207.35	**164**
90.22	11214.38	**164**
90.41	11221.41	**163**
90.61	11228.43	**147**
90.81	11235.44	**217**
91.00	11242.45	**205**
91.20	11249.46	**207**
91.39	11256.45	**182**
91.59	11263.45	**162**
91.79	11270.43	**192**
91.98	11277.43	**182**
92.18	11284.40	**165**
92.37	11291.40	**196**
92.57	11298.37	**178**
92.77	11305.36	**193**
92.96	11312.33	**241**
93.16	11319.33	**193**
93.35	11326.31	**220**

187.95	13632.63	**179**
188.14	13636.24	**197**
188.34	13639.86	**189**
188.53	13643.47	**198**
188.72	13647.08	**194**
188.92	13650.70	**183**
189.11	13654.31	**205**
189.30	13657.92	**176**
189.50	13660.63	**190**
189.69	13662.43	**184**
189.88	13664.23	**228**
190.08	13666.02	**215**
190.27	13667.81	**220**
190.46	13669.60	**264**
190.66	13671.39	**220**
190.85	13673.17	**196**
191.04	13674.96	**222**
191.24	13676.74	**181**
191.43	13678.52	**212**
191.62	13680.30	**187**
191.82	13682.08	**227**
192.01	13683.86	**180**
192.20	13685.65	**164**
192.40	13687.43	**180**
192.59	13689.22	**167**
192.78	13691.00	**159**
192.98	13692.79	**193**
193.17	13694.57	**180**
193.36	13696.35	**195**
193.56	13698.13	**243**
193.75	13699.90	**176**
193.94	13701.67	**200**
194.14	13703.44	**202**
194.33	13705.20	**206**
194.52	13706.96	**188**
194.72	13708.72	**208**
194.91	13710.48	**210**
195.10	13712.24	**251**
195.30	13714.01	**234**
195.49	13715.78	**194**
195.68	13717.57	**223**
195.88	13719.36	**208**
196.07	13721.16	**206**
196.26	13722.97	**157**
196.46	13724.79	**181**
196.65	13726.61	**195**
196.84	13728.44	**163**
197.04	13730.26	**190**
197.23	13732.07	**156**
197.42	13733.87	**181**
197.62	13735.66	**163**
197.81	13737.43	**177**
198.01	13739.18	**151**
198.20	13740.90	**124**
198.39	13742.61	**183**
198.59	13744.32	**183**
198.78	13746.03	**167**
198.97	13747.75	**124**
199.17	13749.50	**140**

292.70	17809.96	**210**
292.90	17819.30	**166**
293.09	17828.64	**201**
293.28	17837.98	**194**
293.47	17847.30	**220**
293.67	17856.64	**196**
293.86	17865.96	**176**
294.05	17875.29	**154**
294.24	17884.60	**152**
294.44	17893.91	**173**
294.63	17903.22	**175**
294.82	17912.53	**202**
295.00	17921.23	**208**
295.01	17921.82	**180**
295.20	17930.72	**183**
295.39	17940.21	**227**
295.59	17949.70	**186**
295.79	17959.20	**166**
295.98	17968.68	**165**
296.18	17978.19	**182**
296.37	17987.69	**181**
296.57	17997.19	**159**
296.77	18006.69	**187**
296.96	18016.20	**174**
297.16	18025.69	**184**
297.36	18035.21	**177**
297.55	18044.71	**174**
297.75	18054.20	**183**
297.95	18063.70	**185**
298.14	18073.21	**174**
298.34	18082.70	**199**
298.53	18092.20	**140**
298.73	18101.70	**193**
298.93	18111.18	**170**
299.12	18120.67	**169**
299.32	18130.16	**191**
299.52	18139.64	**180**
299.71	18149.11	**159**
299.91	18158.58	**207**
300.11	18168.06	**166**
300.30	18177.50	**185**
300.50	18186.97	**184**
300.69	18196.42	**170**
300.89	18205.87	**166**
301.08	18214.85	**175**
301.27	18224.32	**159**
301.47	18233.76	**201**
301.67	18243.23	**171**
301.86	18252.70	**186**
302.06	18262.17	**171**
302.26	18271.65	**154**
302.45	18281.15	**181**
302.65	18290.63	**169**
302.85	18300.13	**153**
303.04	18309.63	**145**
303.24	18319.10	**193**
303.43	18328.59	**219**
303.63	18338.08	**199**
303.83	18347.53	**168**

398.89	22935.15	**125**
399.09	22944.84	**152**
399.29	22954.54	**191**
399.49	22964.22	**169**
399.69	22973.91	**171**
399.89	22983.58	**187**
400.09	22993.26	**190**
400.29	23002.92	**163**
400.48	23012.09	**123**
400.68	23021.74	**139**
400.88	23031.86	**169**
401.08	23041.48	**179**
401.28	23051.10	**158**
401.47	23060.23	**183**
401.67	23069.84	**181**
401.87	23079.44	**192**
402.07	23089.04	**176**
402.28	23099.10	**192**
402.47	23108.21	**172**
402.67	23117.79	**148**
402.87	23127.36	**179**
403.06	23136.93	**159**
403.26	23146.51	**147**
403.46	23156.07	**160**
403.66	23165.64	**200**
403.86	23175.20	**141**
404.06	23184.77	**183**
404.26	23194.33	**167**
404.46	23203.89	**171**
404.66	23213.45	**166**
404.86	23223.01	**169**
405.06	23232.58	**137**
405.25	23242.16	**158**
405.45	23251.74	**155**
405.65	23261.34	**168**
405.85	23270.94	**146**
406.05	23280.56	**181**
406.25	23290.18	**174**
406.45	23299.83	**166**
406.65	23309.47	**146**
406.85	23319.13	**167**
407.05	23328.78	**167**
407.25	23338.45	**170**
407.44	23348.11	**158**
407.64	23357.78	**143**
407.84	23367.43	**137**
408.04	23377.09	**166**
408.24	23386.73	**167**
408.44	23396.37	**146**
408.64	23406.00	**151**
408.84	23415.64	**125**
409.04	23425.26	**141**
409.24	23434.90	**175**
409.44	23444.52	**188**
409.64	23454.16	**158**
409.83	23463.80	**142**
410.03	23473.43	**167**
410.23	23483.08	**196**
410.43	23492.73	**157**

Table 0-3—*Continued*

93.55	11333.32	**182**
93.74	11340.31	**221**
93.94	11347.33	**206**
94.14	11354.35	**185**
94.33	11361.40	**200**
94.50	11367.46	**197**
94.53	11368.43	**207**
94.70	11374.53	**222**
94.89	11381.60	**218**
95.09	11388.68	**215**
95.29	11395.77	**239**
95.48	11402.83	**181**
95.68	11409.92	**193**
95.87	11416.99	**158**
96.07	11424.04	**196**
96.27	11431.09	**193**
96.46	11438.15	**189**
96.66	11445.18	**166**
96.86	11452.22	**169**
97.05	11459.26	**195**
97.25	11466.30	**195**
97.45	11473.34	**180**
97.64	11480.39	**180**
97.84	11487.42	**140**
98.03	11494.48	**186**
98.23	11501.54	**162**
98.43	11508.62	**164**
98.62	11515.68	**146**
98.82	11522.76	**171**
99.02	11529.83	**170**
99.21	11536.90	**188**
99.41	11543.97	**173**
99.61	11551.05	**190**
99.80	11558.10	**156**
100.00	11565.17	**187**
100.20	11572.22	**174**
100.39	11579.26	**193**
100.59	11586.32	**171**
100.77	11593.04	**178**
100.97	11600.11	**177**
101.17	11607.22	**205**
101.36	11614.35	**177**
101.56	11621.51	**210**
101.76	11628.72	**154**
101.95	11635.97	**163**
102.15	11643.26	**219**
102.35	11650.62	**203**
102.54	11658.02	**193**
102.74	11665.44	**183**
102.93	11672.89	**176**
103.13	11680.36	**173**
103.33	11687.82	**195**
103.52	11695.30	**172**
103.72	11702.77	**185**
103.92	11710.21	**191**
104.11	11717.63	**184**
104.31	11725.03	**133**
104.51	11732.40	**178**
104.70	11739.77	**168**

199.36	13751.27	**159**
199.55	13753.09	**112**
199.75	13754.97	**200**
199.94	13756.90	**144**
200.13	13758.90	**181**
200.33	13760.96	**175**
200.52	13763.03	**203**
200.71	13765.10	**159**
200.91	13767.12	**142**
201.10	13769.08	**169**
201.28	13770.84	**154**
201.49	13772.65	**148**
201.68	13774.20	**155**
201.87	13775.55	**165**
202.07	13776.68	**153**
202.25	13777.57	**148**
202.44	13778.40	**187**
202.64	13779.24	**225**
202.83	13780.20	**190**
203.02	13781.40	**192**
203.22	13782.93	**179**
203.41	13784.92	**189**
203.60	13787.47	**185**
203.80	13790.70	**164**
203.99	13794.72	**191**
204.18	13799.57	**204**
204.38	13804.91	**178**
204.57	13810.35	**185**
204.76	13815.44	**185**
204.96	13819.78	**193**
205.15	13822.95	**163**
205.34	13824.51	**186**
205.54	13824.60	**181**
205.73	13824.69	**203**
205.92	13824.77	**179**
206.12	13824.86	**186**
206.31	13824.94	**154**
206.51	13825.03	**203**
206.70	13825.12	**172**
206.89	13825.20	**213**
207.09	13825.29	**219**
207.28	13825.38	**204**
207.47	13825.46	**193**
207.67	13825.55	**176**
207.86	13825.64	**197**
208.05	13825.72	**182**
208.25	13825.81	**217**
208.44	13825.89	**184**
208.63	13825.98	**188**
208.83	13829.70	**225**
209.02	13835.22	**173**
209.21	13842.09	**216**
209.41	13849.86	**170**
209.60	13858.05	**214**
209.79	13866.26	**206**
209.99	13874.00	**191**
210.18	13880.90	**208**
210.37	13886.97	**190**
210.57	13892.32	**220**

304.02	18357.00	**169**
304.22	18366.45	**176**
304.42	18375.89	**188**
304.61	18385.32	**155**
304.81	18394.75	**175**
305.00	18404.15	**195**
305.20	18413.58	**211**
305.40	18422.99	**176**
305.59	18432.39	**213**
305.79	18441.81	**221**
305.99	18451.23	**184**
306.18	18460.64	**184**
306.38	18470.07	**228**
306.58	18479.49	**221**
306.77	18488.91	**205**
306.97	18498.34	**185**
307.17	18507.77	**174**
307.36	18517.18	**179**
307.56	18526.59	**171**
307.75	18535.99	**162**
307.95	18545.39	**180**
308.15	18554.75	**178**
308.34	18564.13	**181**
308.54	18573.49	**185**
308.74	18582.85	**181**
308.93	18592.21	**193**
309.13	18601.58	**187**
309.32	18610.93	**204**
309.52	18620.32	**202**
309.72	18629.70	**156**
309.91	18639.10	**170**
310.11	18648.52	**202**
310.31	18657.96	**202**
310.50	18667.40	**185**
310.70	18676.86	**163**
310.90	18686.32	**150**
311.09	18695.78	**176**
311.29	18705.24	**167**
311.49	18714.70	**187**
311.68	18724.13	**153**
311.88	18733.57	**185**
312.07	18742.99	**173**
312.26	18751.91	**161**
312.46	18761.29	**186**
312.65	18770.68	**217**
312.85	18780.03	**226**
313.05	18789.40	**192**
313.24	18798.77	**215**
313.44	18808.14	**195**
313.64	18817.52	**180**
313.83	18826.91	**186**
314.03	18836.31	**198**
314.22	18845.76	**193**
314.42	18855.21	**173**
314.62	18864.69	**171**
314.81	18874.15	**162**
315.01	18883.64	**188**
315.21	18893.13	**164**
315.40	18902.62	**167**

410.63	23502.39	**175**
410.83	23512.05	**168**
411.03	23521.71	**170**
411.23	23531.38	**169**
411.43	23541.04	**166**
411.63	23550.72	**133**
411.83	23560.38	**151**
412.02	23570.04	**130**
412.22	23579.70	**144**
412.42	23589.37	**148**
412.62	23599.02	**163**
412.82	23608.68	**130**
413.02	23618.34	**170**
413.22	23628.00	**154**
413.42	23637.65	**142**
413.62	23647.31	**149**
413.82	23656.97	**148**
414.02	23666.62	**145**
414.21	23676.27	**141**
414.41	23685.93	**148**
414.61	23695.58	**157**
414.81	23705.24	**138**
415.01	23714.89	**161**
415.21	23724.55	**156**
415.41	23734.20	**142**
415.61	23743.85	**107**
415.80	23753.13	**170**
415.81	23753.49	**153**
416.00	23762.63	**183**
416.19	23772.13	**157**
416.39	23781.63	**151**
416.58	23791.13	**171**
416.78	23800.62	**172**
416.98	23810.11	**142**
417.17	23819.59	**129**
417.37	23829.07	**186**
417.57	23838.54	**144**
417.76	23848.01	**145**
417.96	23857.46	**123**
418.15	23866.91	**130**
418.35	23876.35	**143**
418.55	23885.79	**124**
418.74	23895.22	**122**
418.94	23904.65	**126**
419.14	23914.07	**128**
419.33	23923.49	**145**
419.53	23932.88	**133**
419.72	23942.32	**122**
419.91	23951.26	**122**
420.11	23960.66	**133**
420.30	23970.07	**138**
420.50	23979.49	**139**
420.69	23988.90	**115**
420.89	23998.32	**105**
421.09	24007.74	**97**
421.28	24017.17	**102**
421.48	24026.59	**102**
421.68	24036.02	**129**
421.87	24045.45	**170**

Table 0-3—*Continued*

104.90	11747.14	**164**	210.76	13897.08	**189**	315.60	18912.10	**172**	422.07	24054.88	**162**
105.09	11754.52	**178**	210.95	13901.35	**214**	315.80	18921.60	**184**	422.26	24064.32	**137**
105.29	11761.90	**202**	211.15	13905.25	**222**	315.99	18931.06	**176**	422.46	24073.76	**145**
105.49	11769.33	**174**	211.34	13908.91	**210**	316.19	18940.53	**190**	422.66	24083.20	**120**
105.68	11776.78	**215**	211.53	13912.44	**171**	316.38	18949.99	**192**	422.85	24092.66	**115**
105.88	11784.26	**180**	211.73	13915.95	**205**	316.58	18959.43	**178**	423.05	24102.12	**132**
106.08	11791.79	**181**	211.92	13919.57	**183**	316.78	18968.87	**162**	423.25	24111.59	**112**
106.27	11799.39	**165**	212.11	13923.40	**198**	316.97	18978.31	**165**	423.44	24121.07	**154**
106.47	11807.01	**186**	212.31	13927.48	**174**	317.17	18987.73	**199**	423.64	24130.56	**139**
106.67	11814.70	**176**	212.50	13931.78	**215**	317.37	18997.17	**198**	423.83	24140.07	**141**
106.86	11822.42	**192**	212.69	13936.25	**177**	317.56	19006.61	**203**	424.03	24149.59	**133**
107.06	11830.18	**190**	212.89	13940.89	**198**	317.76	19016.04	**205**	424.23	24159.12	**119**
107.25	11837.98	**206**	213.08	13945.63	**173**	317.96	19025.49	**204**	424.42	24168.66	**137**
107.45	11845.81	**182**	213.27	13950.46	**182**	318.15	19034.95	**195**	424.62	24178.22	**141**
107.65	11853.67	**174**	213.47	13955.34	**195**	318.35	19044.40	**185**	424.81	24187.78	**71**
107.84	11861.57	**187**	213.66	13960.23	**176**	318.54	19053.88	**180**	425.01	24197.34	**86**

Section II

Development and Optimization of Microbeam X-Ray Fluorescence Analysis of Speleothems

Chapter 6

Introduction

Speleothem trace metal abundances and ratios are used to provide invaluable insights into past climates and paleohydrological regimes and aid in the interpretation of stable isotopic results in the same specimens (Banner 1995; Ayalon et al. 1999; Hellstrom and McCulloch 2000; Li et al. 2005; Fairchild et al. 2006; Springer et al. 2008). Speleothems are valuable archives, due to their multi-proxy nature and the ability to accurately date these samples using U-series techniques. Interest in these archives has heightened, as they offer better time-control and, often, higher time resolution than other continental paleoclimate archives, such as those from lacustrine deposits.

Changes in trace metal (Mg, Ba, and Sr) concentrations are reflections of changes in hydrogeochemical processes in the epikarst ((Fairchild et al. 2006; Fairchild and Treble 2009). The concentrations indirectly record surface climate as they are directly affected by the amount of precipitation and moisture present in the soil and epikarst. During periods of low rainfall, trace metal ratios generally increase as a result of the longer residence time of water in the soil and epikarst zones (Roberts et al. 1998; 1999; Hellstrom and McCulloch 2000; Johnson et al. 2006).

Numerous techniques have been employed in the analysis of trace metal concentrations in speleothems: laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) and optical-emission spectroscopy (ICP-OES) (Roberts et al. 1999; Treble et al. 2003); secondary ionization mass spectrometry (SIMS) (Huang et al. 2001; Treble et al. 2007); synchrotron X-ray microprobe (Borsato et al. 2007). These conventional methods of trace metal analysis of speleothems have been shown to produce high-resolution, high-quality data sets. However, these methods can be

expensive, time-consuming in both sample preparation and instrument time, and often require the destruction of speleothem samples, which are of limited availability and size.

X-ray fluorescence spectrometry, which measures the elemental abundances as secondary characteristic X-rays from sample material that has been bombarded with primary X-rays, has been used in a variety of disciplines (Jarvis and Jarvis 1992; Potts and Ellis 1999). We present trace metal results obtained through the rapid and non-destructive method of micro-X-ray fluorescence spectrometry (μ-XRF) using the Bruker ARTAX system as compared to conventional methods. It will be demonstrated that the same high-quality results can be obtained using this instrument and methods.

Chapter 7

Methods

Speleothem samples were cut in half parallel to their growth axes and subsequently polished. A very smooth polish on the cut surface is critical.

A semi-portable microbeam x-ray fluorescence unit (Bruker ARTAX) was utilized to develop down-axis geochemical transects of Ca and Sr in several stalagmite samples from eastern North America and the Yucatan Peninsula of Mexico.

The ARTAX system is comprised of a motor-driven, tripod-supported x-y-z axis and has interchangeable X-ray tubes and a variety of filters. Rhodium and W tubes were utilized in this study in order to determine the most appropriate tube for speleothem trace metal analysis. The Rh microfocus tube has a beam size of 70 microns, while the W tube is equipped with a collimator and has a beam size of 650 microns. The X-ray tubes generate an X-ray beam that penetrates the sample material, and stimulates the emission of characteristic X-rays. The number and energy of the characteristic x-rays are measured by the XRF and allow for the identification and concentration of atoms present in the sample. Therefore the terms “count” and “count time” refer to the number of characteristic X-rays (directly related to the concentration of the element in the sample) of a particular element detected and the amount of time an individual spot measurement was exposed to the incident beam. Because speleothems contain high concentrations of Ca, an Al-Ti-Cu filter, which blocks a large portion of Ca counts, was utilized in all scans.

The x-y-z stage of the system has a minimum step increment of 5 microns, ultimately allowing for resolution down to spot-size overlap. Because the beam is non-contact and non-destructive, scans can be performed at a variety of count-times and spatial resolutions, thereby conserving speleothem material for additional analyses. The maximum long-axis range of an individual transect is 4 cm, requiring that long

speleothem transects be pieced together. The µ-XRF system is controlled by the software program in which the various machine settings and parameters are customizable. Once a scan is programmed and initiated, the µ-XRF is fully-automated and requires no further manipulation. Additionally, the mount is equipped with a camera that records pictures of measurement locations, which aids in piecing together the transects.

The stalagmite samples analyzed as well as their scanning parameters can be found in Table 1. A wide variety of settings was utilized in order to assess the optimal settings to rapidly acquire the most useful data for stalagmites of differing composition.

Table 7-1 Speleothem samples utilized in micro-XRF study

Sample Name	Location	Number of transects	kEv	µA	Count time (s)	Spot distance (mm)
BCC-020	WV, USA	area	50	500	10	0.5
BCC-025	WV, USA	13	50	500	10	0.06
CCC-001	WV, USA	13				0.5
CCC-003	WV, USA	area	40	500	5	0.06
CCC-003	WV, USA	16	50	600	10	0.06
CCC-003	WV, USA	2	50	600	120	0.25
CCC-007	WV, USA	3	50	600	10	0.1
CCC-007	WV, USA	14	50	600	60	0.2
CCC-007	WV, USA	2	50	600	120	0.2
HC2-02	WV, USA					
SAN-5	Yuc, Mex	area	40	500	15	0.03
TN-MOR02-1	TN, USA	3	50	600	120	0.33
VA-HEL-01	VA, USA	9	50	600	10	0.1
VA-HEL-02	VA, USA	12	50	600	60	0.2

Calibration curves were created for the µ-XRF system using weighed mixtures of pure carbonate powders from Alfa Aesar. Mixtures of 99.9999% pure CaCO3 and SrCO3 powders were made, pressed into small cylindrical molds, and scanned at four time settings.

Counting Statistics

Of major concern to the authors was the repeatability of measured values. To test this, a single point on a stalagmite (BCC-026) was analyzed for 30s using the Rh tube and Al-Ti-Cu filter, for 30 individual measurements. The repeatability of the instrument was estimated for Sr and for Sr/Ca based on simulations of the measured values. The counts data are expected to follow a Poisson distribution. In order to test whether this is realistic, a suite of statistical tests was performed. Only the results for the statistical tests of Sr are reported, but all of the tests performed on Sr values were also performed on Ca values with the same conclusions.

From the (n = 30) Sr values, the mean of 7742 and standard deviation of 99.70 were calculated. In the absence of a theoretical distribution for the sampling distribution of the variance from a Poisson distribution, a simulation was conducted using R statistical software. A set of 1000 samples, each (n = 30), were drawn from a Poisson distribution of the mean and standard deviation of the measured Sr values. These values were plotted as a histogram and subsequently redrawn as a probability density with $\lambda = 7742$. A Kolmogorov-Smirnov test was applied and resulted in a p-value of 0.6169. This test indicates that there is no reason to conclude that the data do not follow a Poisson distribution.

In order to test the sample standard deviation of 99.70 against the theoretical standard deviation of 87.99 ($\sqrt{7742}$), an empirical cumulative distribution function was performed. The sample standard deviation falls within the 95% confidence interval, giving no indication that the data do not follow a Poisson distribution.

In order to test for time-dependency errors, a lag test for autocorrelation was performed. In a lag test of 1, the correlation coefficient of -0.3525 suggests that the data are not correlated and the data do not exhibit time dependent behavior.

As a final test as to whether measured Sr values follow a Poisson distribution, a C control chart was produced. All of the points plotted between the upper and lower control limits and there was no occurrence of six consecutive points plotting above or below the central line or displaying monotonicity.

In summary, for measurements involving a single count, there is no evidence that the measurement uncertainty is not simply the variability of a Poisson distribution with the mean equal to counts. Since the variance of a Poisson distribution is equal to its mean, the three sigma limits of a measurement would be given by

$$\lambda \pm 3 \cdot \sqrt{\lambda}$$

where λ is the measured value in counts.

Since the distribution is Poisson, the three sigma limits do not represent the same percentage of the data as if it were normal, however for all reasonable values of counts, more than 99.7% of the data will fall within the three sigma limits.

For results reported as Sr/Ca, the standard deviation of the ratio is approximated by

$$stdev\left(\frac{N}{D}\right) \approx \sqrt{\left(\frac{\lambda_N}{\lambda_D}\right)^2 \cdot \left(\frac{1}{\lambda_N} + \frac{1}{\lambda_D}\right)}$$

The ratio is approximately normally distributed, implying that 99.7% of the values will fall within three standard deviations of the mean.

Chapter 8

Results and Discussion

Analysis of speleothems was undertaken at a tube setting 40-50kV and 500-600□A, with a variable count time from 5 to 120 seconds per measurement. The increment of analysis (step) varied from 0.1 to 1 mm, depending upon the desired temporal and spatial resolution. Growth-axis transects up to 4cm in length were assembled piecewise in order to develop continuous records. A typical spectrum for an individual measurement is shown in Figure 1.

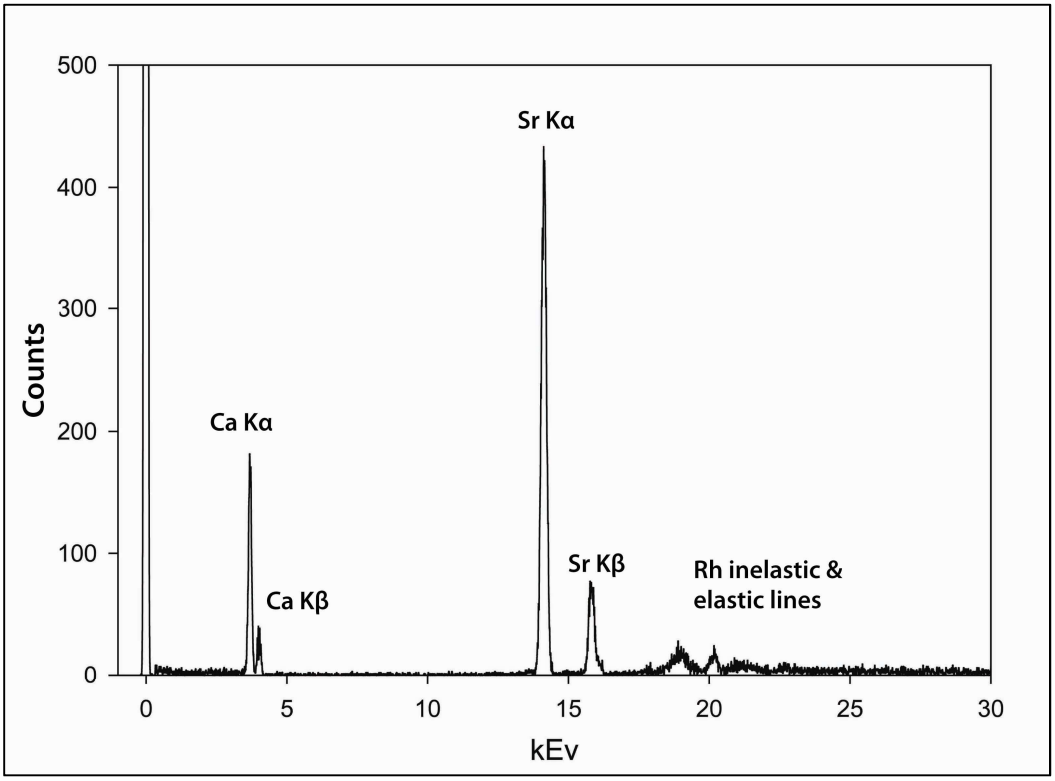

Figure 8-1 Sample spectrum for single spot scan using ARTAX µ-XRF with Al-Ti-Cu filter with Ca and Sr Kα and Kβ peaks and Rh elastic and inelastic peaks

In order to assess the applicability of this method to trace element analysis in speleothems, several questions were posed: 1) How consistent are transect scans? Figure 2 shows the reproducibility of a sample transect that was scanned using the same settings and transect line for three individual scans. While there is some noticeable variation between the three lines, the overall trend of the data is preserved in all three scans.

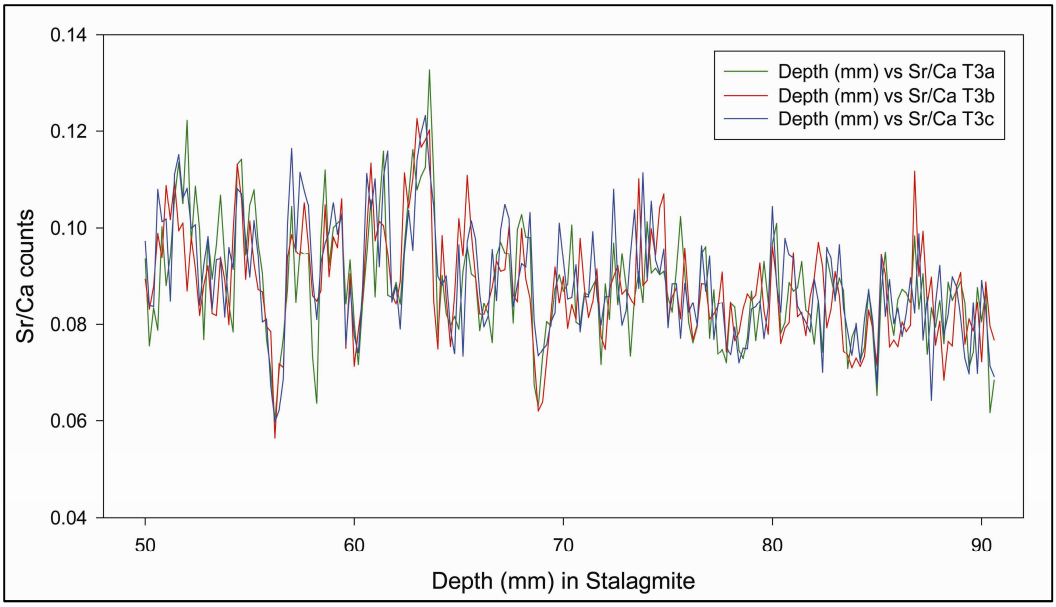

Figure 8-2 The reproducibility of Sr/Ca results for a 40-mm transect of sample CCC-007.

2) To what extent does the count time affect the measured values and ultimately the transects? Figure 3 shows Sr/Ca counts for a 10-mm section of a stalagmite, with identical point measurements taken at three different time settings. This figure illustrates the increased variability of the lower count times compared to higher.

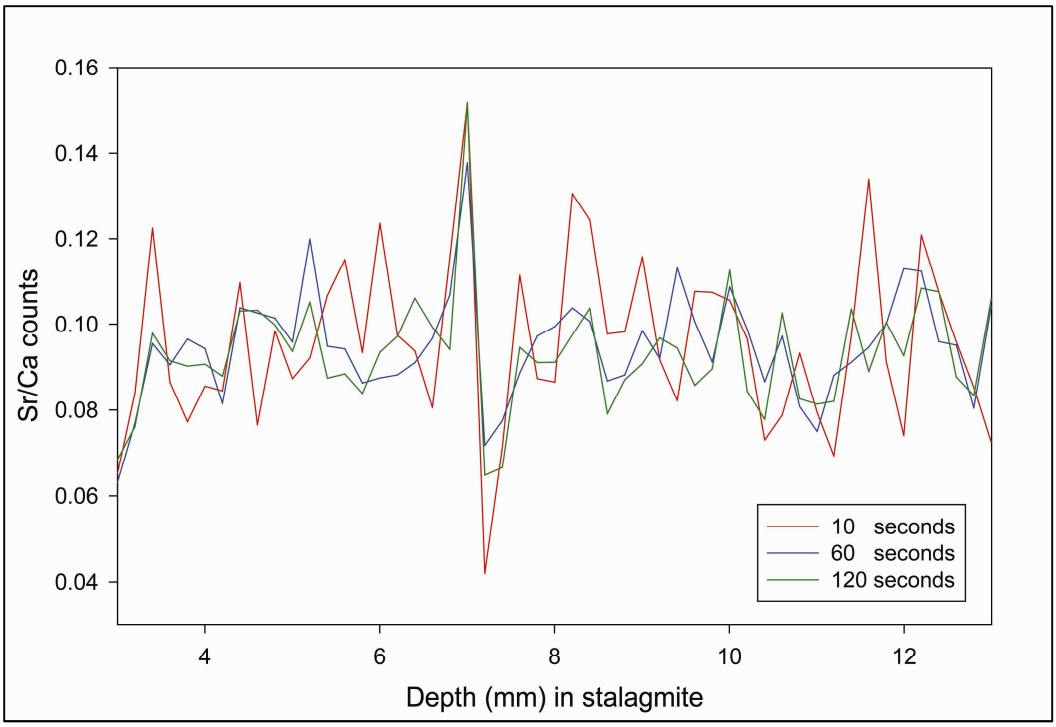

Figure 8-3 Depth comparison of Sr/Ca values and count times of 10, 60, and 120 seconds for a 10 mm transect of sample CCC-007. Note the importance of longer count times to more closely approximate the true value.

3) How does count time influence the consistency of single-spot measurements? Figure 4 shows the results of a 'spot-test', where an individual spot was measured 50 times at settings of 10s, 60s, and 120s. This figure further illustrates that longer count times show less variability in measured values.

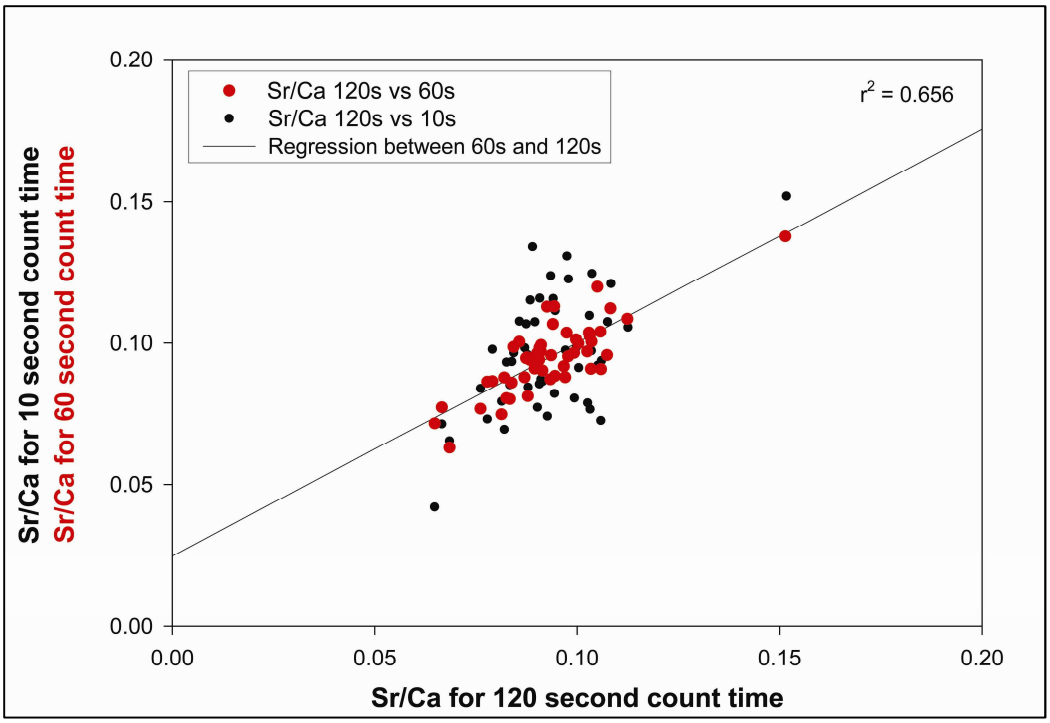

Figure 8-4 Measured Sr/Ca values for count times of 10 and 60 seconds, compared to 120 seconds.

4) How comparable are Sr results obtained through µ-XRF methods to a conventional method? Figure 5 shows Sr/Ca results obtained through ICP-OES as compared to those obtained using µ-XRF. The time series displayed in Figure 5 demonstrates the comparability of both methods. However, at approximately 3800 years, an abrupt spike in the Sr/Ca measured by µ-XRF is not observed in the ICP results. This artificial peak is the result of a crack in the calcite in the speleothem coincident with this depth, which illustrates a potential impact of in-situ analysis.

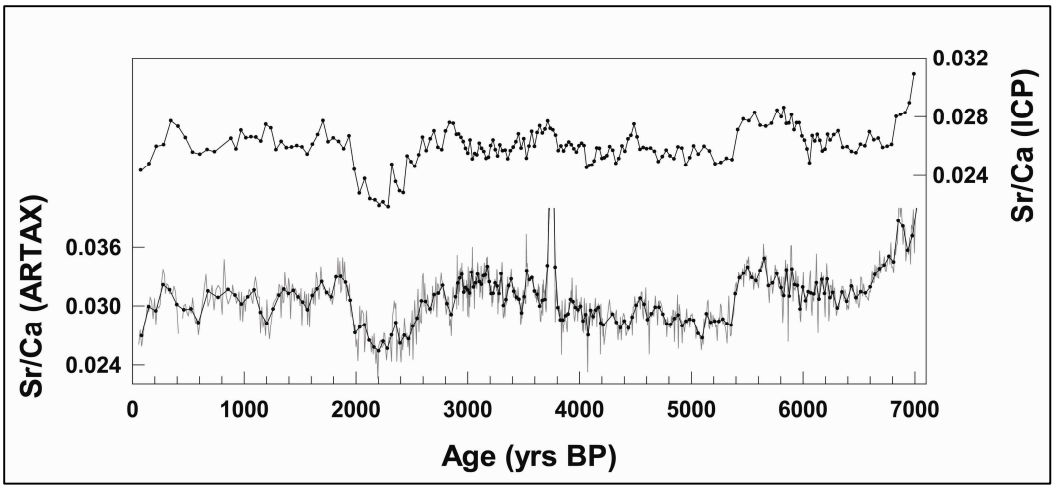

Figure 8-5 ARTAX µ-XRF Sr/Ca results compared to traditional ICP-OES results obtained for the same section of sample BCC-002.

It was determined that any imperfections in the polish of the sample potentially influence the analysis of Ca, presumably because the characteristic x-rays emitted from the lighter elements are generated from the shallowest depths of the sample. Thus, surficial scratches have a definitive and uncorrectable impact on the analysis. In the case of discrete voids within the path of the scan transect, those voids can be ‘side-stepped’ by later taking measurements directly adjacent to the void, down lamina. Due to the different depths at which the Ca and Sr atoms are excited, and because of the potential for microscopic cracks or voids that may influence one element over the other, it is beneficial to report results obtained through µ-XRF as Sr counts instead of Sr/Ca. It is also advisable to carefully note the presence and locations of voids or problematic areas within the sample material so that they may be addressed prior to data compilation. The calibration curves, shown in Figure 6, allow for the direct conversion of counts to concentration (ppm).

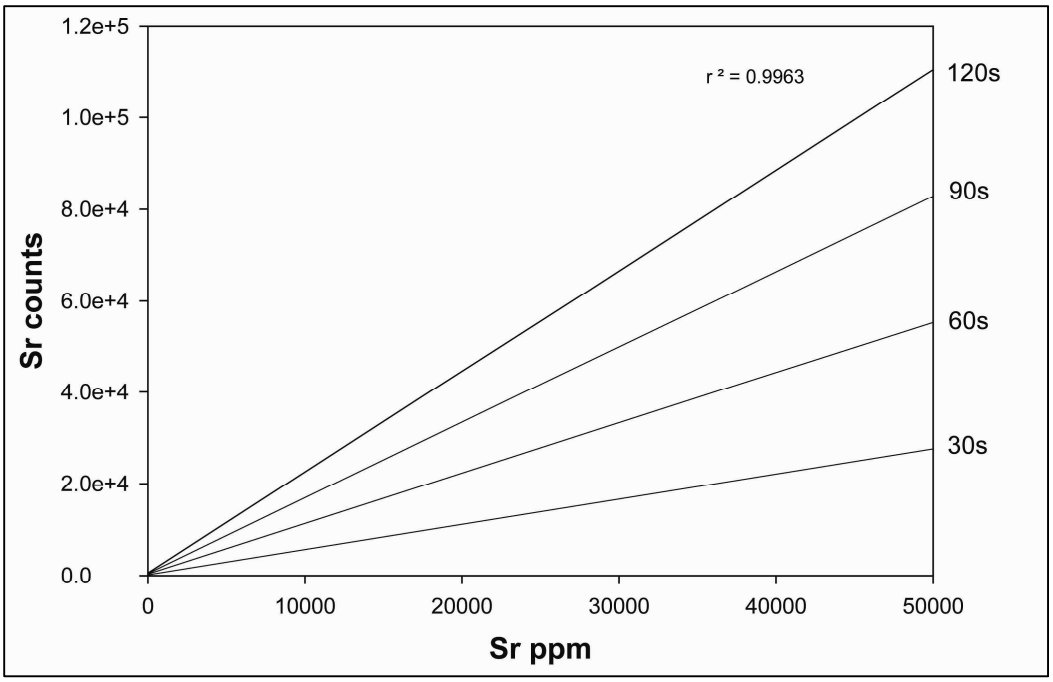

Figure 8-6 Calibration curves for W tube and Al-Ti-Cu filter at settings of 30s, 60s, 90s, and 120s.

Chapter 9

Conclusions

Trace metal analysis has become an integral part of paleoclimate reconstructions based on speleothems. Of the various techniques used in these analyses, μ-XRF has many advantages such as decreased cost per analysis, rapidity, and non-destructiveness. Results obtained through this method are comparable to those obtained through conventional methods. Although μ-XRF results can be influenced by surface effects such as cracks or voids, this problem can be circumvented through the 'side-stepping' of visible voids within the sample and the use of Sr values rather than Sr/Ca.

We propose that this analysis would ultimately allow an investigator to quickly build speleothem chronologies and thereby identify and prioritize the best speleothem samples in order to optimize both time and resources in paleoclimate investigations. Trace element results obtained prior to costly U-Th age dates or stable isotope analysis could be useful in the identification of samples of focus and thereby preserve limited sample material.

Section III

High Frequency Cave Drip Monitoring and Cave Environment Study: Implications for Stalagmite Paleoclimate Studies

Chapter 10

Introduction

Speleothems as paleoclimate archives have been increasingly utilized over the past few decades (Baker et al. 1997; Dorale et al. 1998; Roberts et al. 1998; Hellstrom and McCulloch 2000; Wang et al. 2001; Poore et al. 2003; Dykoski et al. 2005; Cheng et al. 2006; Spötl et al. 2006; Vollweiler et al. 2006; Borsato et al. 2007; Cruz et al. 2007; Mattey et al. 2008; Lambert and Aharon 2010; Stríkis et al. 2011). Stalagmites, the speleothems traditionally utilized in paleoclimate studies, are the product of cave dripwaters which have complex surface-to-cave hydrological pathways, seasonal distributions, and hydrochemical histories. Isotopic and trace element variation between coeval speleothems, as was demonstrated for the Culverson Creek Cave (CCC) record, underscores the importance of an understanding of drip water variability, as speleothem records may represent different aspects of the climate system.

The complexity of cave dripwater evolution from the soil zone and through the vadose (unsaturated) and phreatic (saturated) zones in the epikarst have prohibited a complete understanding of the hydrologic histories of individual cave drips. However, the dripwater frequency and hydrochemistry of dripwaters can give clues as to the hydrologic pathway of the individual drips. Figure 10-1 shows a schematic for the possible pathways that water may take through these zones (Tooth and Fairchild 2003).

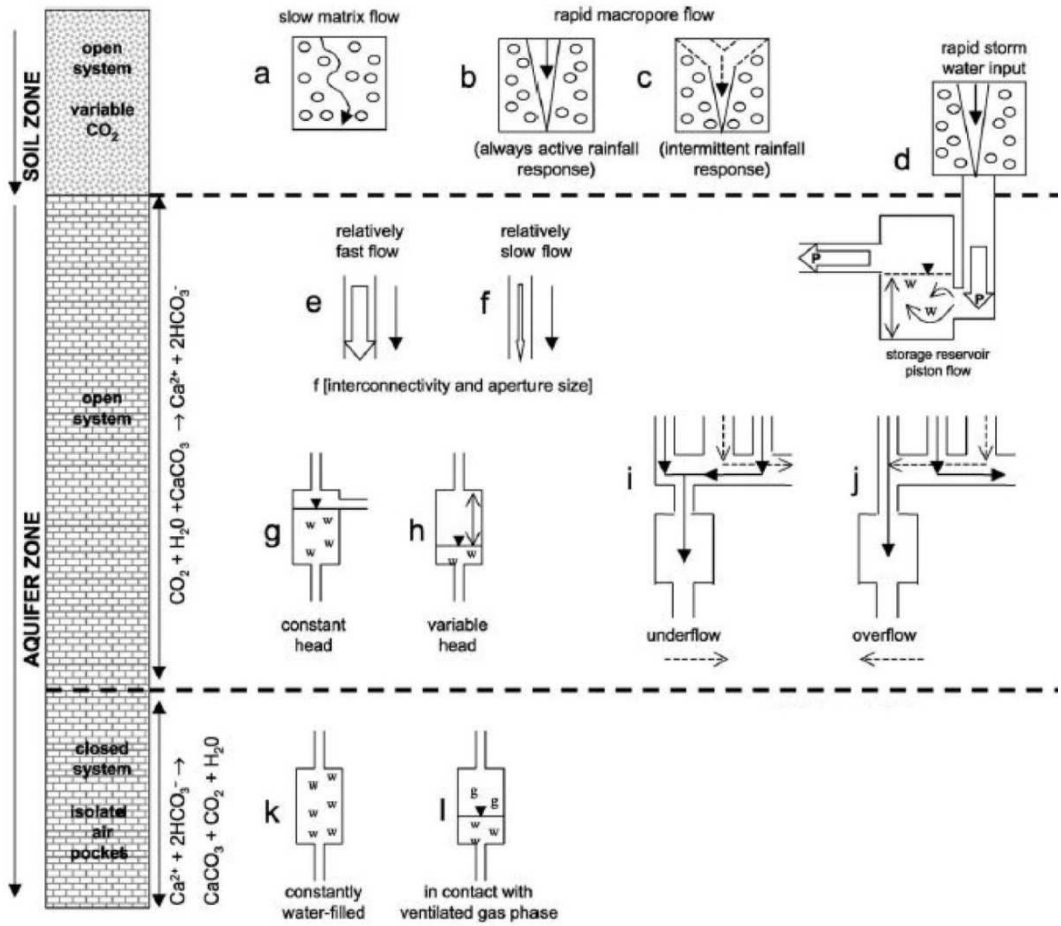

Figure 10-1 Schematic for water infiltration pathways in the soil and aquifer zones, where a) slow matrix flow in the soil zone, rapid macropore flow in the soil zone with b) always active rainfall response and c) intermittent response, d) piston flow modelled as a direct soil macropore inflow to a perched reservoir, and in the vadose zone, e) large aperture and f) small aperture conduits, g) constant head and h) variable head, i) underflow behavior and j) overflow behavior, and in the phreatic zone, k) constantly water-filled and l) partially water-filled voids. Modified from Tooth and Fairchild (2003).

As seen in Figure 10-1 a-c, the soil zone exerts a control on water infiltration, as the saturation of the soil governs the amount of infiltration (i.e. dry soils will retain water in the micropores whereas saturated soils will permit infiltration through macropore

connectivity). Figure 10-1 d demonstrates the mixing and storage of waters, which can lessen the variability of event-specific hydrochemical signatures. ‘Piston flow’ is demonstrated through the influx of waters causing the horizontal movement of waters from the storage reservoir. The interconnectivity and conduit or aperture size exert a control on the rapidity with which waters are able to flow through the vadose zone, as seen in Figure 10-1 e and f. Constant hydrologic head (g) is maintained through the connectivity of vertical and horizontal conduit components whereas (h), variable head, is maintained by vertical infiltration alone. The mechanisms of ‘underflow’ (i) and ‘overflow’ (j) are the products of the geometry of the inter-connected conduit system, where the fluid pathways taken by infiltrating waters are determined based on amount of water/air already in the system. In the phreatic zone, isolated air voids may be present.

Research Objectives

The purpose of this study is to determine the variability of hydrological pathways, dripwater frequency and hydrochemistry, and cave microclimate parameters for three caves in southeastern West Virginia. An understanding of these components is essential in the interpretation of paleoclimate proxies from speleothem calcite.

As a framework for this study, several questions were posed:

1) Do cave temperatures and pCO_2 levels change seasonally?
2) What is the inter-cave and intra-cave variability of dripwater frequency?
3) Can dripwater response to rainfall events demonstrate the type of flow?
4) What is the annual to inter-annual variability in hydrochemistry of dripwaters?

5) Can a regional study of modern cave dripwater geochemistry and microclimate monitoring be used to validate the climatic implications of speleothem geochemical proxies?

Background

Previous work on karst vadose hydrology has focused on three major themes: drip variability and flow regimes (Smart and Friederich 1986; Baker et al. 1997; Baker and Brunsdon 2003) hydrochemical studies of dripwaters (Huang et al. 2001; Tooth and Fairchild 2003; McDonald et al. 2004; 2007; Karmann et al. 2007; Lambert and Aharon 2010; 2011) and experimental/quantitative models of calcite deposition and/or isotopic evolution (Buhmann and Dreybrodt 1985; Dreybrodt 1996; Wackerbarth et al. 2010). Many recent studies have included aspects of the three themes (Baldini et al. 2006; 2008; Verheyden et al. 2008; Sherwin and Baldini 2011).

In a pioneering study of discharge in a karst aquifer in Mendip Hills, UK, Smart and Friederich (1986) determined that for cave drips with low recharge rates, flow within the aquifer is predominantly vertical (seepage), but with increasingly higher drip rates, flow switches recharge to vertical shafts (fracture). This study was one of the first to demonstrate the variability within karst hydrological systems. ‘Overflow’ behavior was observed as rapid responses to rainfall events.

In a study of six actively-growing stalagmite drips in Lower Cave (Bristol, UK) over a two year period, Baker et al. (1997) demonstrated that of the drip sites, all were reduced during dry periods and postulated that during periods of rainfall deficit, drips are fed from storage within the aquifer. Inter-annual variability was greater than intra-annual

variability for these drip sites. This study highlights the importance of multiple years of drip site observation, as a few of the drip sites that were classified as ‘seepage flow’ for one year of the study were reclassified as ‘seasonal drips’ for the next.

Baker and Brunsdon (2003), utilizing automatic drip loggers at six drip sites in Stump Cross Caverns (Yorkshire, UK), demonstrated that drips revealed non-linear and chaotic drip rate variability. Non-linearities of weather and karst features were found to lead to non-linear drip responses and ‘event’ dripwater may have different geochemical compositions than ‘normal’ dripwater. These results have implications for paleoclimate reconstructions utilizing stalagmites, as dripwaters are assumed to respond linearly to climate and drip rate. The authors concluded that “non-linearities in drip-water hydrology, including flow switching between different water sources or flow routes, non-linear responses to surface rainfall, evapotranspiration and/or water table changes, and mixing between event water and pre-event water, could all lead to the interpretation of extreme climate and environmental changes in stalagmite proxies when indeed none have occurred”. This study highlighted the complexities in infiltration of waters into cave systems.

For the hydrochemical studies, chemical aspects of dripwaters were examined. Huang et al. (2001) conducted a study of dripwaters and cave pool waters over a three-year span from Grotta di Ernesto, Italy. The authors demonstrated that annual trace element (Mg/Ca) dripwater cyclicity reflected an increase in prior calcite precipitation (PCP) over the winter months as opposed to the wetter summer months. These findings have implications for seasonally-variable calcite deposition and over or under-representation of certain seasonal geochemical constituents.

Recharge variations and hydrochemical responses of dripwaters were the focus of Tooth and Fairchild (2003), which utilized dripwater samples collected over summer

and winter months from Crag Cave, Ireland. Through an examination of the variation in dripwater responses, four categories of cave drip types were established (in response to rainfall events); 1) rapid response, 2) rapid response with time delay, 3) intermediate response, and 4) no response.

McDonald et al. (2004), in a study of dripwaters from Kooringa Cave in eastern Australia, observed marked periods of lower Ca^{2+} and higher Mg/Ca. These dripwater chemistries were demonstrated to coincide with lower drip rates that were caused by El-Niño related reduction in meteoric precipitation. McDonald et al. (2007) furthered their research into Australian Cave dripwaters by studying the hydrochemistry of dripwaters from Wombeyan Caves in southeastern Australia. In this study, ten cave drips were sampled over a 5.5 year period, with each drip exhibiting a unique chemistry and a variety of responses to meteoric precipitation. Extremely low flow drips were shown to have elevated trace element (Mg, Sr, Ba) concentrations due to higher residence times in the epikarst.

Karmann et al. (2007) conducted two separate 2-year monitoring studies of hydrochemistry and hydrology of the Santana-Pérolas Cave system (southeastern Brazil). Mg/Ca and Sr/Ca were measured in surface, well, and cave drip waters at multiple sampling sites. The authors found a high degree of synchronicity in hydrochemical variations between monitoring sites and concluded that the trace element concentrations in speleothems are capable of recording short-lived climate variations. Groundwater residence times and PCP were determined to be the key control of trace element concentrations in waters in the epikarst and vadose zones.

Lambert and Aharon (2010) measured oxygen and hydrogen isotopes in rainfall and cave dripwaters from DeSoto Caverns (Alabama, U.S.A.) over a three year period. The purpose of this study was to define the relationship between rainfall (frequency,

isotopes, amount) and that of cave dripwaters. They found that a well-mixed epikarst storage compartment served to dampen the large shifts in isotopic values of rainwater. Dripwaters showed weak seasonal variations and recorded only 20% and 51% of the ^{18}O and ^{2}H enrichment over the study period that was measured in rain waters. The authors estimated that the residence times of waters in the epikarst ranged from 1 – 3 months based on the comparison of precipitation events and flow-rate data. Using the same dripwater samples, Lambert and Aharon (2011) explored the relationship between DIC and $\delta^{13}C$ from cave drips in order to better understand the carbon cycle in karst systems. The authors determined that a multi-year trend of decreasing precipitation was not found to influence the carbon in dripwaters, and inferred that rainfall amount is not a significant factor in carbon water chemistry.

In an effort to better understand the chemical processes that occur in karst systems, numerous experimental and modelling studies have been conducted. For example, Buhmann and Dreybrodt (1985) developed a general theory for the kinetics of the dissolution and precipitation reactions of calcite for both open and closed systems and Dreybrodt (1996) developed numerical models of fissure enlargement in limestone. In addition to kinetic and numerical models that describe the physical and chemical processes of calcite dissolution and precipitation, models have also been developed to relate calcite proxies to paleoenvironmental conditions. Wackerbarth et al. (2010) constructed a drip water model to determine how annual temperatures and the amount of precipitation affect the oxygen isotope signal of cave dripwaters. Through the quantified relationship of winter temperatures and winter $\delta^{18}O$ of precipitation, the authors attempted to reconstruct paleotemperatures for stalagmites from Atta and Bunker Caves in western Germany. The temperature curves are highly sensitive to the relationship between winter

precipitation and winter temperatures (which likely differed significantly from modern), however, and those estimates are viewed with substantial uncertainty.

Recent studies have utilized a combination of cave microclimate monitoring, hydrochemistry, and drip water studies. Baldini et al. (2006), in a three year monitoring study of Crag Cave (Ireland), found a high degree of variability in Mg/Ca behavior between drip sites. The authors determined that stalagmites which are fed by very slow drips may be the best speleothems for paleoclimate studies, as their diffuse recharge was found to minimize the influence of discrete meteoric precipitation events and instead represent the long-term climate. Those stalagmites resulting from intermediate flow regimes were determined, through seasonally-variable flow rates, to have a seasonal bias in calcite deposition. High-discharge rates typically resulted in non-deposition due to calcite undersaturated waters. Flow rerouting and blocking were found to occur in high-discharge sites and though non-deposition is typical, any stalagmite forming through these drips were determined to be unsuitable for paleoclimate studies.

Using Crag Cave monitoring data in conjunction with a nearby cave, Baldini et al. (2008) studied of the variability of cave air pCO_2 on daily to seasonal timescales and its influence on modern calcite precipitation. Two major types of variability of cave air pCO_2 were determined: long-term (seasonal) variation likely due to soil-respired CO_2 responses to temperature and short-term (daily to weekly) variation due to cave ventilation. More calcite was found to be deposited in the winter months, when low cave pCO2 occurs due to the greater influx of external air, in contrast to summer months, where pCO2 levels are typically elevated in cave systems due to higher soil respiration rates and decreased ventilation. However, those drips with seasonally-variable hydrochemistry may have greater summer growth rates. Different drip sites have the capability to be biased towards

different seasons, which may account for differences in isotopic and trace element values in coeval speleothems.

Verheyden et al. (2008) conducted a study of cave climate, hydrochemistry, and geochemistry of modern calcite from Père Noël Cave (Belgium). Highly seasonal drip rates were observed, along with a covariation in $\delta^{18}O$, $\delta^{13}C$, Sr/Ca, and Mg/Ca of the modern calcite thought to be the result of kinetic disequilibrium effects of calcite deposition.

Sherwin and Baldini (2011) conducted hourly cave air pCO_2 (Crag Cave) and Ca^{2+} concentration measurements and determined that even on very short time scales, PCP could affect calcite deposition. The authors concluded that cave air pCO_2 controls drip water hydrochemistry in the winter months, but that drip water dilution (observed as sudden Ca^{2+} decreases) may play a larger role in the summer months.

Setting

Culverson Creek Cave (CCC), Buckeye Creek Cave (BCC), and Lost World Caverns (LWC) are located in southeastern West Virginia. These three caves were ideal for a long-term monitoring study for several reasons: 1) stalagmites from CCC and BCC have been utilized in this and other paleoclimate studies ((Springer et al. 2008; Gilbert 2010; Hardt 2010), 2) the caves are located in the same region, and 3) the caves exhibit a wide range of morphologies and drip sites.

Figure 10-2 shows a regional map with the caves labeled with blue star location markers.

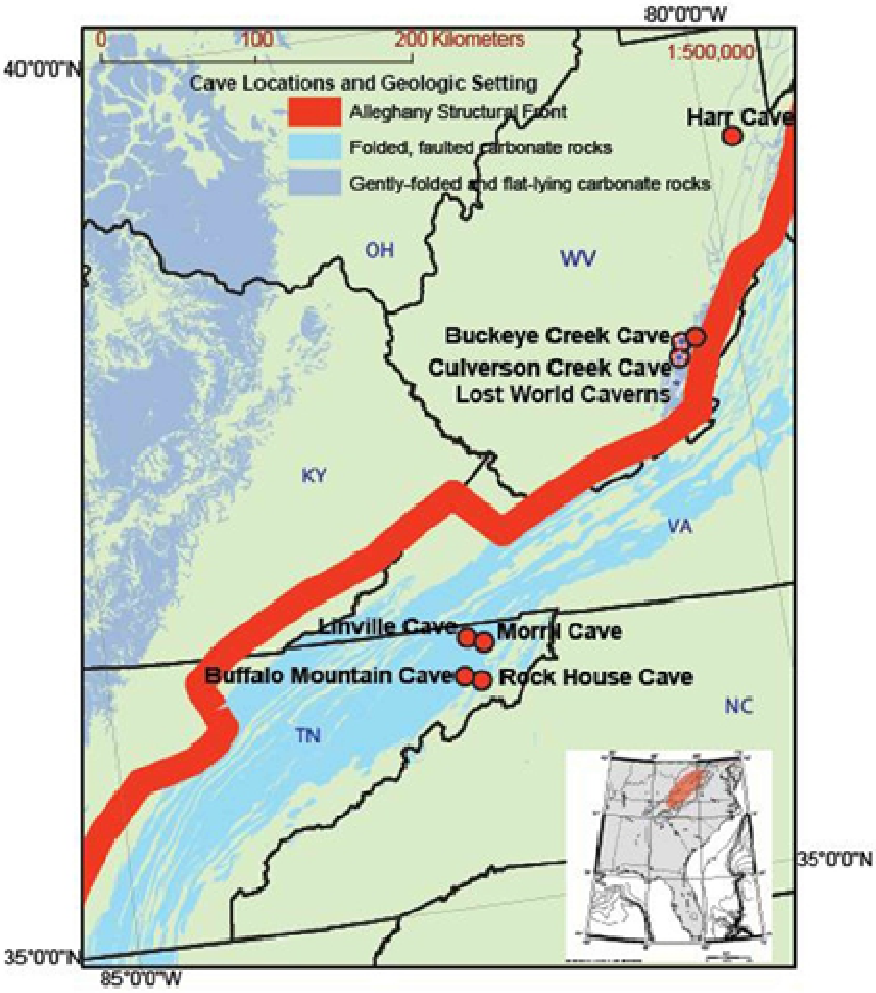

Figure 10-2 Regional map showing cave locations and geologic setting for Buckeye Creek Cave, Culverson Creek Cave, and Lost World Caverns in southeastern West Virginia.

These three caves are formed within the Union Limestone Member of the Greenbrier Group, which is Mississippian in age and consists primarily of interbedded limestone, shales, and sandstone. The Union Limestone is composed of variable white-to-gray, massive limestone and contains chert and abundant marine fossils (see X for a

stratigraphic column). CCC (37º49’56.94”N/80º26’49.38”W) is a large, shallow cave system with multiple entrances. The nearest entrance to the study site is called the ‘SSS entrance’, which is a small stream passage that is prone to flooding during periods of extended precipitation or snowmelt. This portion of the cave is a network of passages developed over a slot canyon, which is a steep, narrow stream passage. Figure 10-3 shows a map of the SSS-entrance section of CCC, with ‘Station 1’ being the chamber in which the monitoring equipment was deployed and water samples were obtained.

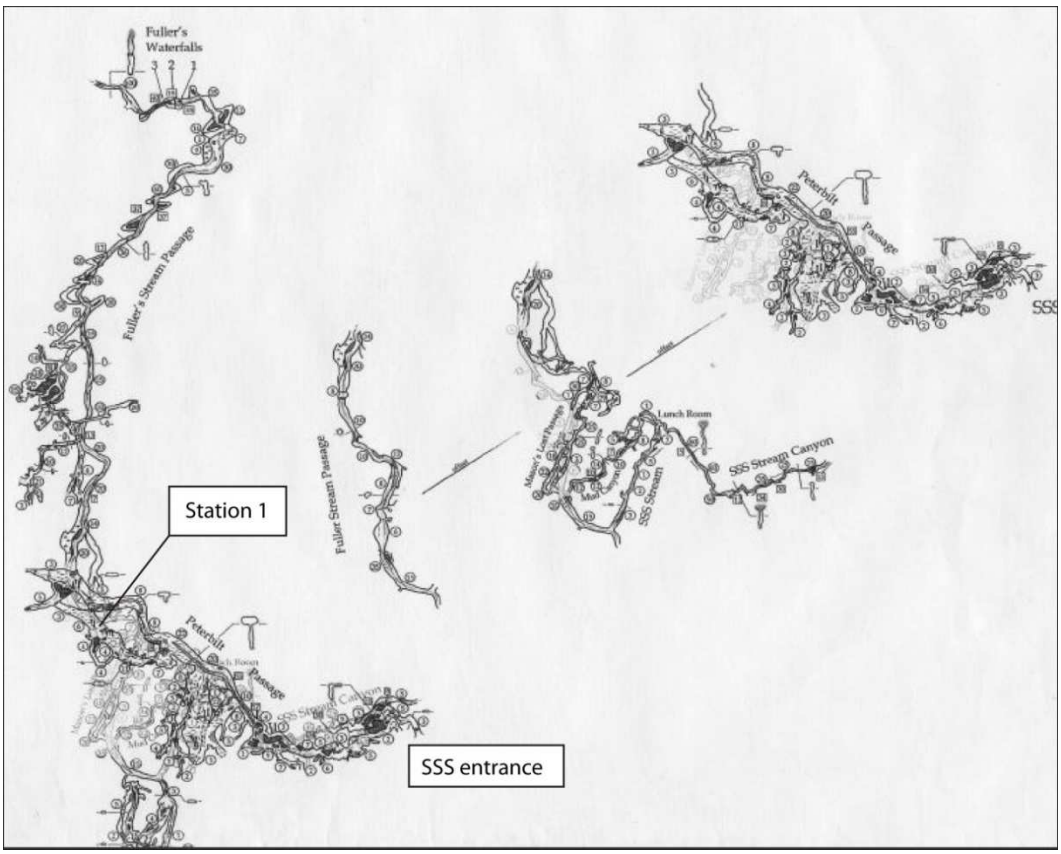

Figure 10-3 Culverson Creek Map for the SSS-entrance section with monitoring and water sample location

BCC (37º58’33.37”N/80º23’58.66”W) is a large cave system with multiple horizontal networks above the basal Buckeye Creek stream passage and is accessed through the Buckeye Creek entrance. This cave system is also prone to flooding, with the narrow canyon (located approximately 800 feet from the entrance) and the near-siphon ‘Watergate Sump’ being especially sensitive to rises in water-level.

Figure 10-5 shows a map for the section of Buckeye Creek Cave in this study, in two panels (Dasher and Balfour 1994). Two monitoring stations were established, ‘Station 1’ was located in the basal stream passage to the east of the canyon and ‘Station 2’ further back in the cave, at the distal end of the ‘Berry Rutzen Trail’ passage on the secondary level. Periodic flooding of the Watergate Sump proved to be a significant barrier to accessing Station 2 regularly.

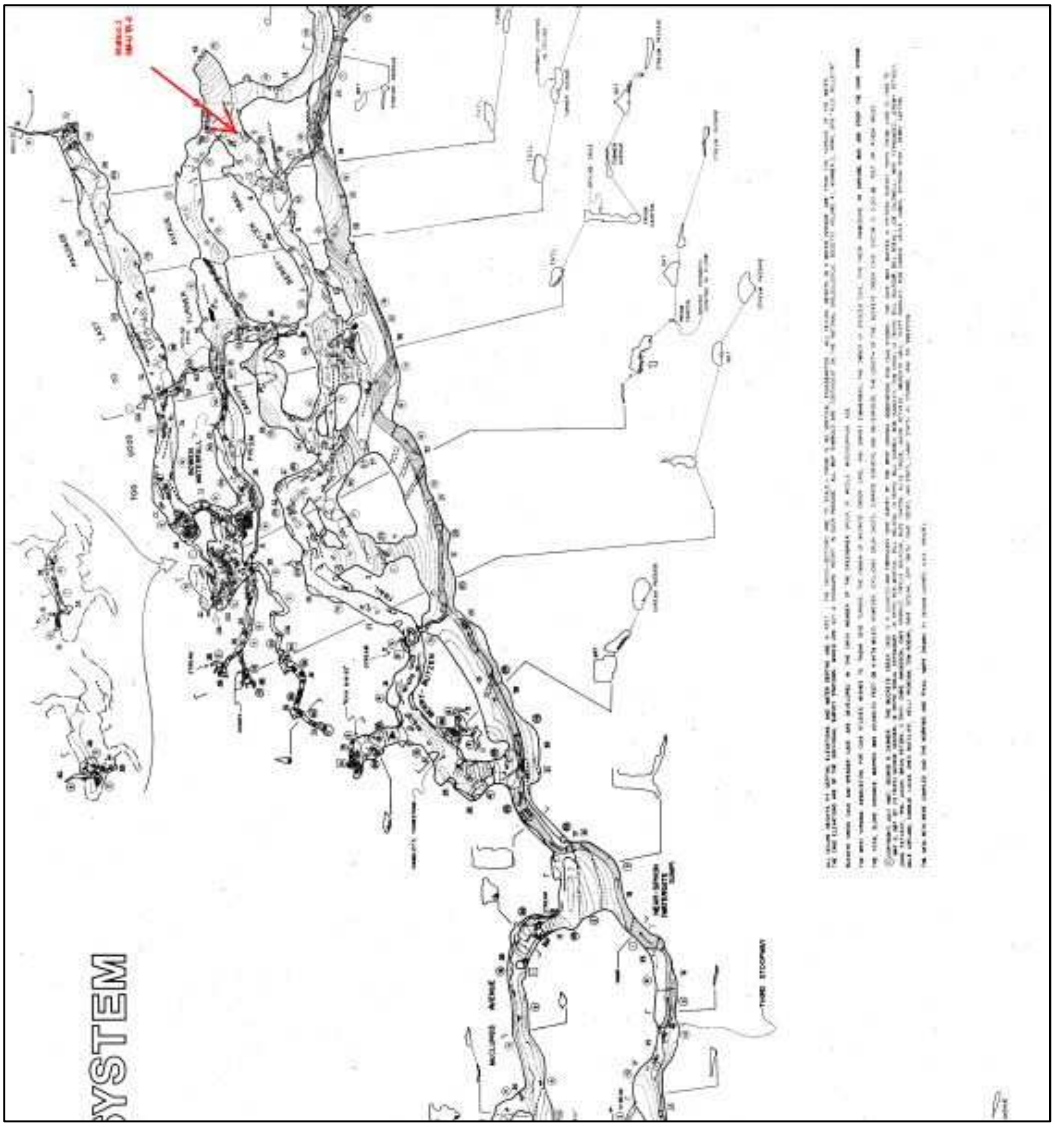

Figure 10-4 Map for Buckeye Creek Cave showing monitoring and water sampling locations, Panel 2 (modified from Dasher and Balfour, 1994)

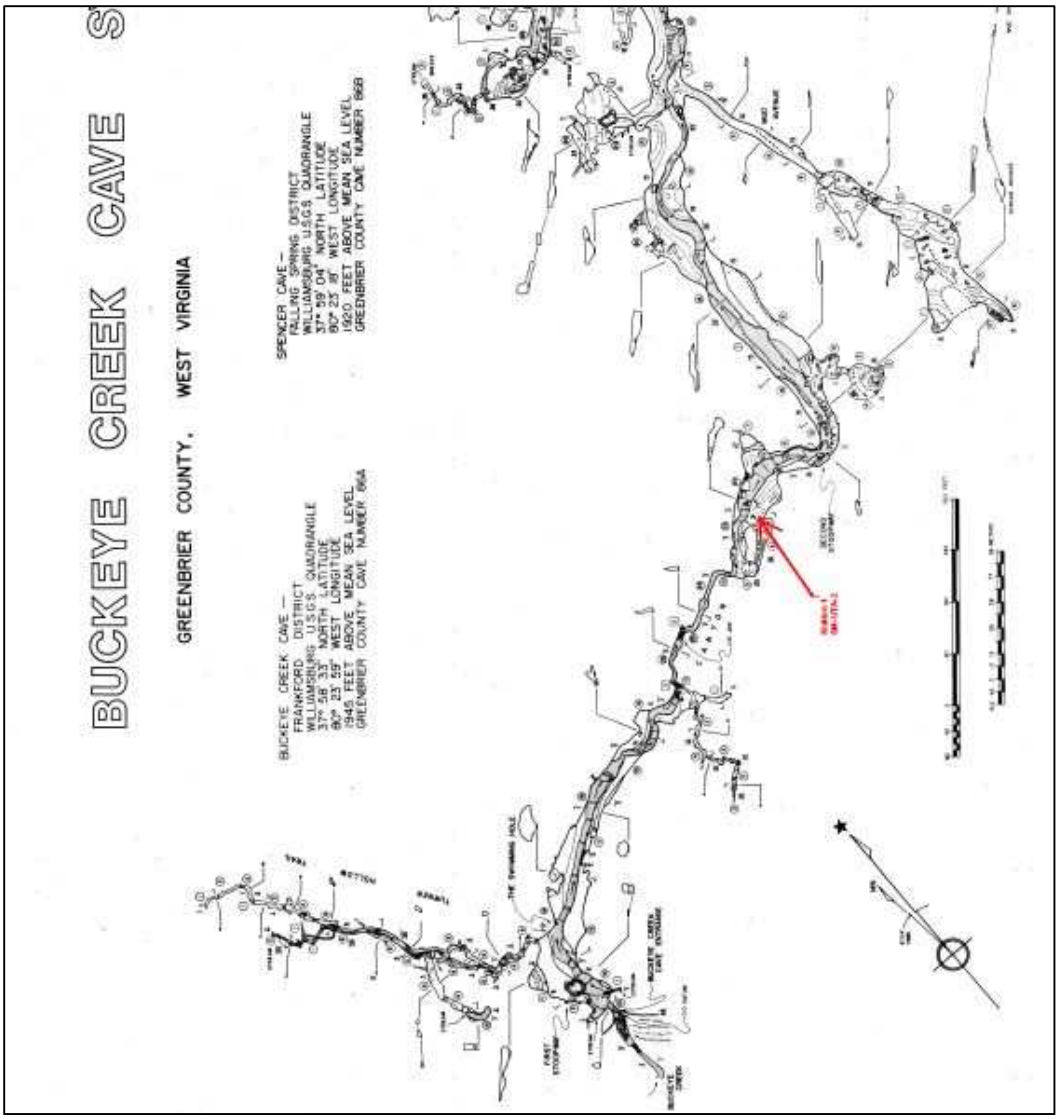

Figure 10-5 Map for Buckeye Creek Cave showing monitoring and water sampling locations, Panel 1 (modified from Dasher and Balfour, 1994)

Lost World Caverns (37º49’56.94”N/80º26’49.38”W), formerly Grapevine Cave, is a relatively small cave located 10.22 miles from the entrance to BCC. The original entrance is a ~120 foot vertical shaft, though an artificial entrance tunnel was built to connect the northeastern section of the cave with the surface. LWC has two main

sections- the ‘commercial section’, which has high ceilings and is highly decorated in speleothem formations, and the ‘wild section’, the non-commercialized section. These two sections are separated by a narrow passage of breakdown (ceiling fall) rubble called simply the “Connection”. LWC receives tourists year-round and the commercial section is is frequented by visitors daily. The ‘wild section’ is utilized for cave tours, though on a less-frequent basis. Figure 10-6 shows a map for LWC, with the monitoring and dripwater sampling locations labeled. LWC was ideal for an examination of the intra-cave variability in dripwater frequency and hydrochemistry for this monitoring study because it is accessible year-round, not prone to flooding, and has a wide variety of speleothem formations and drips. However, the caveat to studying the environment of a commercialized cave is the anthropogenic influence. CO_2 measurements were recorded for the commercialized and wild cave sections, as for BCC and CCC, though anthropogenic CO_2 undoubtedly influenced these results.

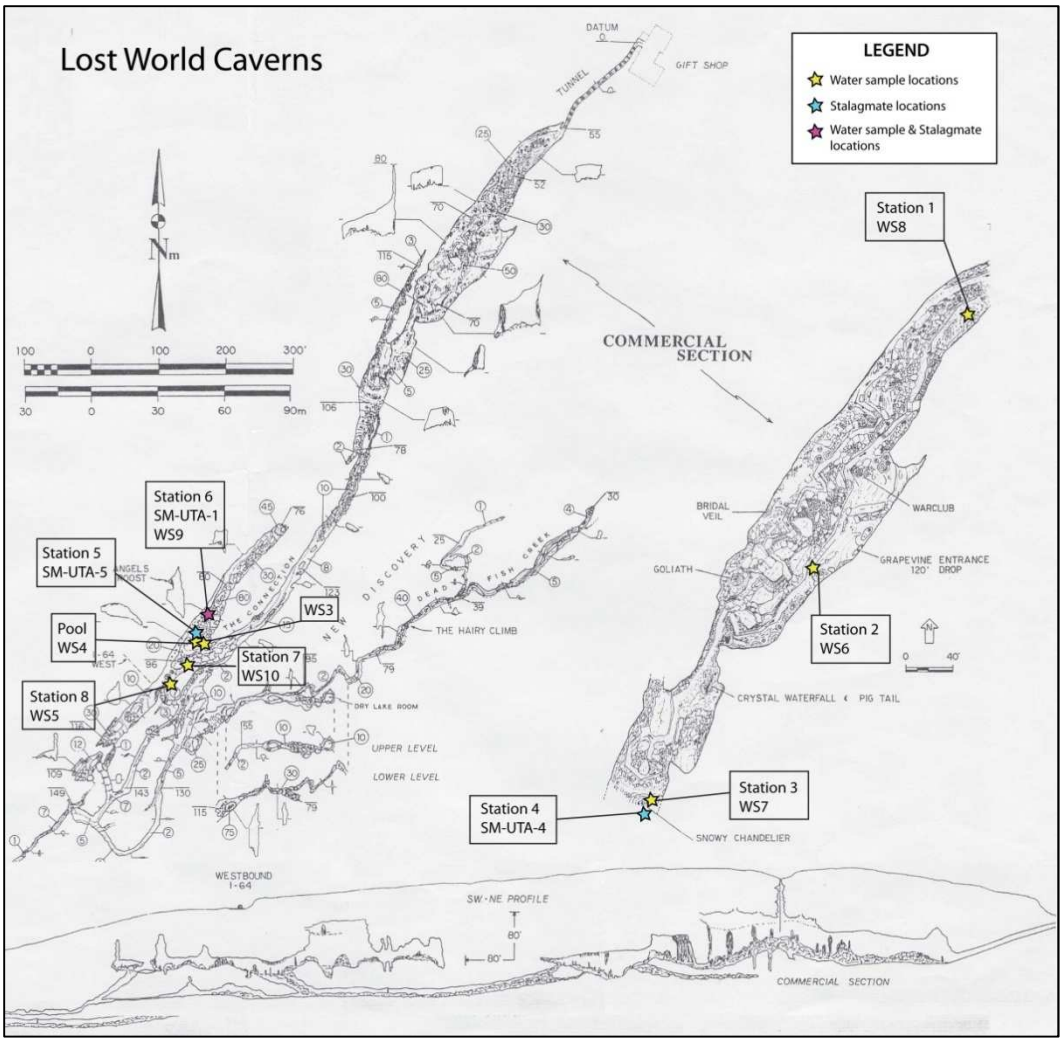

Figure 10-6 Map for Lost World Caverns showing monitoring and water sample locations

Regional Climate

Southeastern West Virginia has a temperate climate with an average annual temperature of 50.36ºF and an average annual precipitation of 1276.35 mm (ncdc.noaa.gov). Figure 10-7 shows the average monthly surface temperatures and precipitation amounts for Lewisburg, WV, for the study interval. The highest temperatures

typically occur during the month of July while the maximum precipitation is received during the month of May.

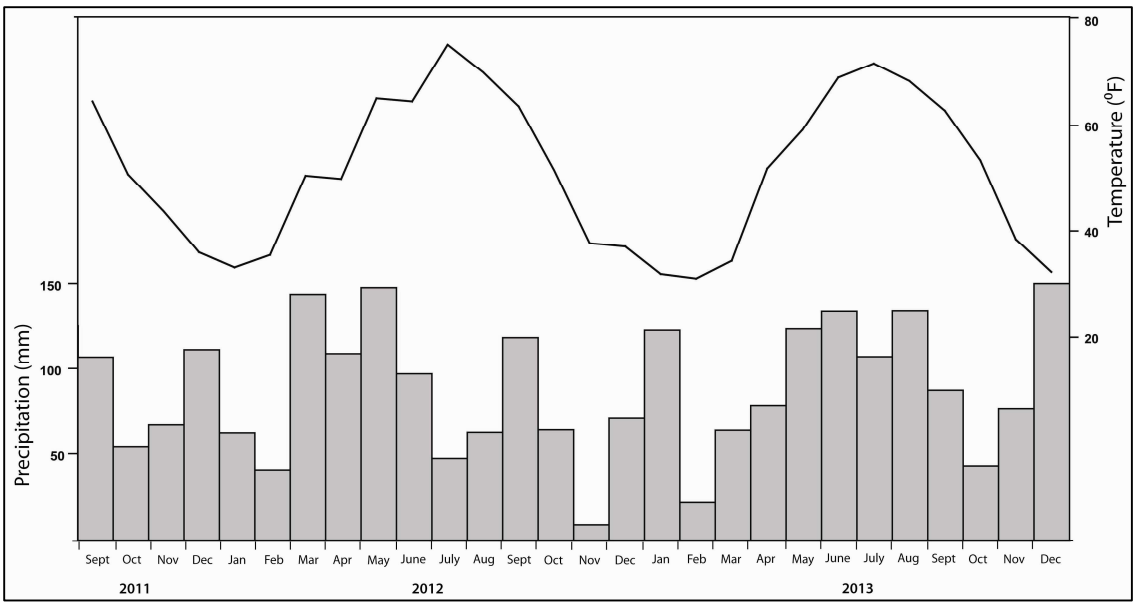

Figure 10-7 Mean monthly surface temperature and precipitation totals for Lewisburg, WV

The seasonal distribution of rainfall is an important consideration in paleoclimate studies, as speleothems could be biased toward a particular season. Figure 10-8 (Hardt 2010) shows a comparison of July and August precipitation in southeastern WV and the SNAO, which is defined as the “first empirical orthogonal function of observed summertime extratropical North Atlantic pressure at mean sea level” (Folland et al. 2009). The SNAO modulates the amount of precipitation that is received by the study region in the summer months.

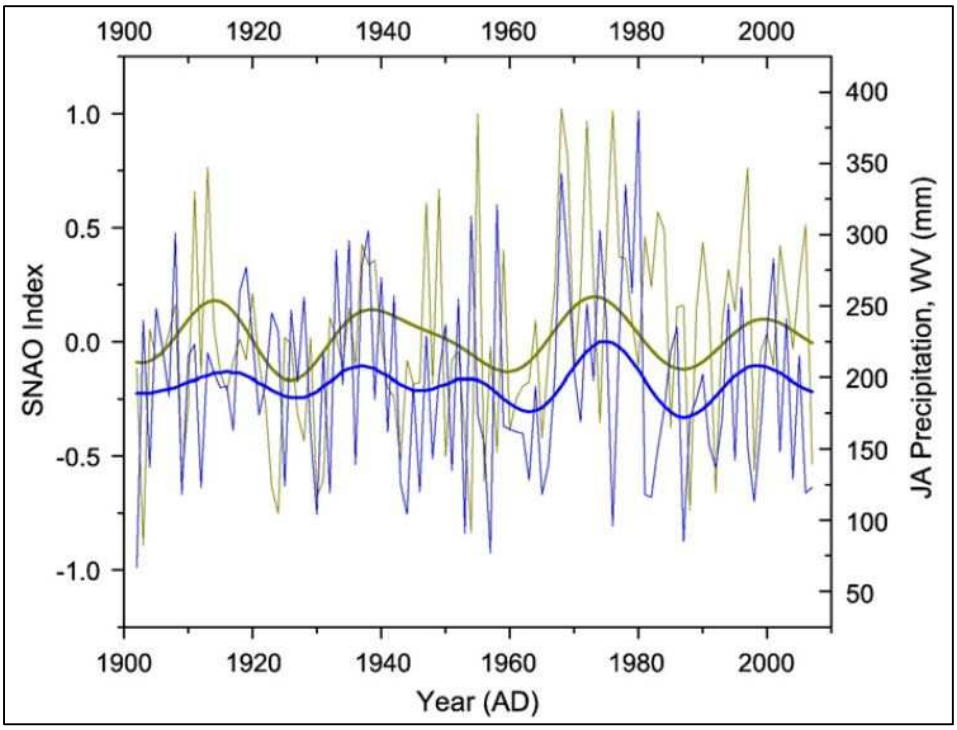

Figure 10-8 Comparison of July and August Precipitation in WV and the SNAO index

Chapter 11

Methods

A variety of monitoring equipment was utilized in this study of intra-to-inter cave variability in dripwater frequency, cave microclimate, and hydrochemistry.

In August 2011, monitoring equipment was deployed to each of the three caves as well as well as the surface above the caves. Trips to the study caves were undertaken approximately every three months during the 2.5 year period (Aug 2011 – Dec 2013) to retrieve data from the continuous data loggers, obtain discrete CO_2 measurements, and obtain water samples for hydrochemical (isotopic, ionic, and trace metal) analysis.

Temperature and Relative Humidity

Cave temperature and relative humidity were measured continuously in each of the caves over the study period using EasyLogger USB RH/Temp loggers manufactured by Lascar Electronics UK. Temperature and relative humidity measurements were recorded every 30 minutes for the study duration. Cave air pCO_2 concentrations were measured during each of the cave trips using a 0 – 10,000 ppm K33-ELG data logger manufactured by Dataq Instruments.

Dripwater Sample Collection

During each of the trips to the study region, two visits to each of the study caves were required in order to obtain enough drip water for multiple analyses. During the first of the set of cave visits, water catchment cups were deployed under drip sites and allowed to accumulate over the course of 24 to 48 hours. Water samples were then collected on the second of the set of trips, though occasionally some of the water samples, especially during the dry seasons, did not result in enough water to allow all of

the analyses to be performed. Water samples were stored in VWR high-density polyethylene 60-ml or 120-ml bottles. Twelve water samples were collected during sampling trips and are labeled (WS = 'water sample') in Table 11-1.

Table 11-1 Water Sample ID and Location Description

Water Sample ID	Location Descriptions	Cave
WS 1	Shared with Station 1 (SM-UTA-2) Stalactite-fed	BCC
WS2	Shared with Station 2 (SM-UTA-3) Stalactite-fed	BCC
WS3	High-rate drip on side of large flowstone	LWC
WS4	Pool Water	LWC
WS5	Very slow drip rate- inactive most of study period	LWC
WS6	Stalactite-fed	LWC
WS7	Fed by large stalactite	LWC
WS8	High flow rate on side of large stalagmite	LWC
WS9	Fed by soda straw (~12 inches)	LWC
WS10	Stalactite-fed	LWC
WS11	Collection of stalactites over conglomeration of stalagmites	CCC
WS12	Fed by dense collection of soda straws	CCC

Hydrochemical Analysis

Isotopic and ionic analyses were conducted at Texas State University at San Marcos by B. Schwartz at the Schwartz Isotope Lab. The instrument used is a Model 908-0008, Los Gatos Research, Liquid Water Stable Isotope Analyzer. It uses Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS) laser technology to simultaneously measure hydrogen and oxygen stable isotopic ratios from liquid water samples. All data are reported relative to V-SMOW.

Surface Precipitation Frequency

For surface precipitation monitoring, one Driptych Pluvimate drip frequency logger was installed near the entrances to each of the study caves (labelled PM-UTA-1 for BCC, PM-UTA-3 for LWC, and PM-UTA-2 for CCC). Each of these data loggers were contained within a rain-gauge cylinder and were placed in areas unobstructed by trees or buildings. These data loggers recorded the drip frequency of precipitation at 10 minute intervals during the study period.

Cave Dripwater Frequency

Driptych Stalagmate drip frequency loggers, which were specifically designed for cave drip measurements, were installed on actively-growing stalagmites in the three study caves. Measurements were recorded at the same interval as the Pluvimate loggers, every 10 minutes over the study period. Two Stalagmates were installed in BCC (labelled SM-UTA-2 and SM-UTA-3), three in LWC (SM-UTA-1, SM-UTA-4, and SM-UTA-5), and one in CCC (SM-UTA-6). These drip loggers were deployed under drip sites exhibiting different behaviors, in an effort to document the variety of dripwater responses to surface precipitation events.

Chapter 12

Results

Results for temperature and relative humidity, pCO_2 concentrations, Pluvimates, Stalagmates, and hydrochemistry are plotted as time-series from August 25th, 2011 to December 31st, 2013. Gaps in data are indicated in each of the results and are the product of occasional equipment failure, battery failure, or inaccessible cave entrances/sections.

Cave Microclimate

Temperature and Relative Humidity

Temperature and relatively humidity in the study caves were measured continuously during the study period.

Figure 12-1 shows the temperature and relative humidity for BCC (gaps due to equipment failure between Oct 2012 and Jan 2013 and Oct 2013 – Dec 2013). Average temperature and relative humidity for BCC for the duration of the study period were 50.8ºF and 99.99%.

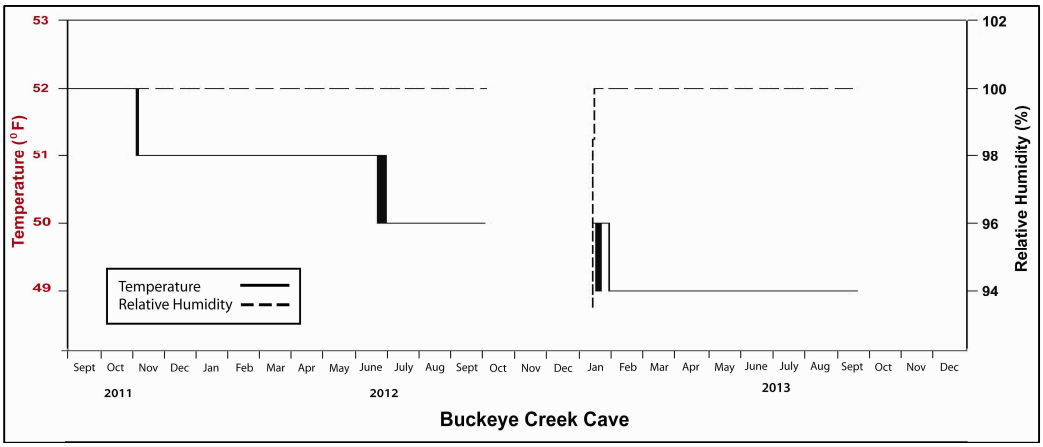

Figure 12-1 Temperature (ºF) and relative humidity (%) for Buckeye Creek Cave

Temperature and relative humidity measurements were obtained for LWC throughout the study period (except for a six-month gap from July 2012 – Jan 2013), as seen in Figure 12-2. Average temperature and relative humidity for LWC for the duration of the study period were 53.0ºF and 99.70%.

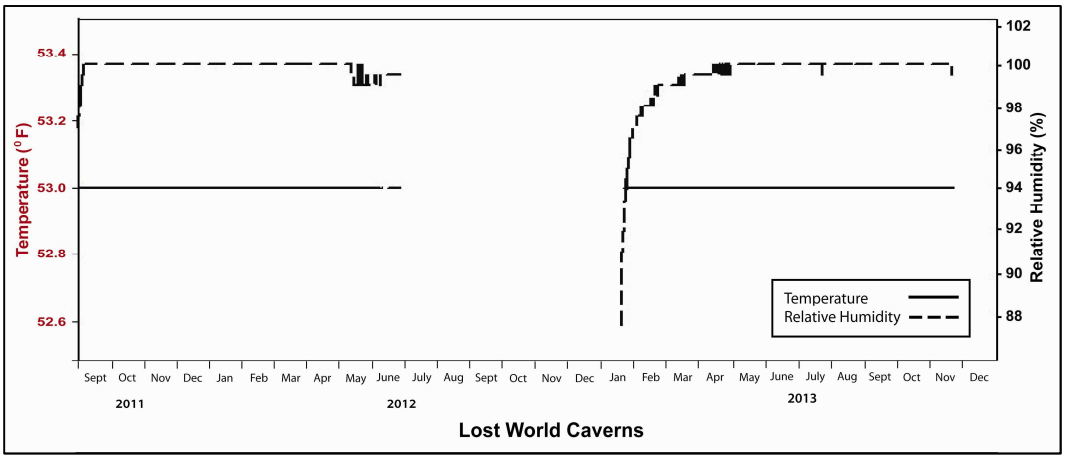

Figure 12-2 Temperature (ºF) and relative humidity (%) for Lost World Caverns

Temperature and relative humidity measurements were obtained for CCC throughout the study period (except for a six-month gap from July 2012 – Jan 2013), as seen in Figure 12-3. This record is punctuated with equipment failures, as seen by gaps from May – June 2012, Oct 2012 – Jan 2013, Apr – Aug 2013, and Nov – Dec 2013. Average temperature and relative humidity for BCC for the duration of the study period were 53.0ºF and 99.81%.

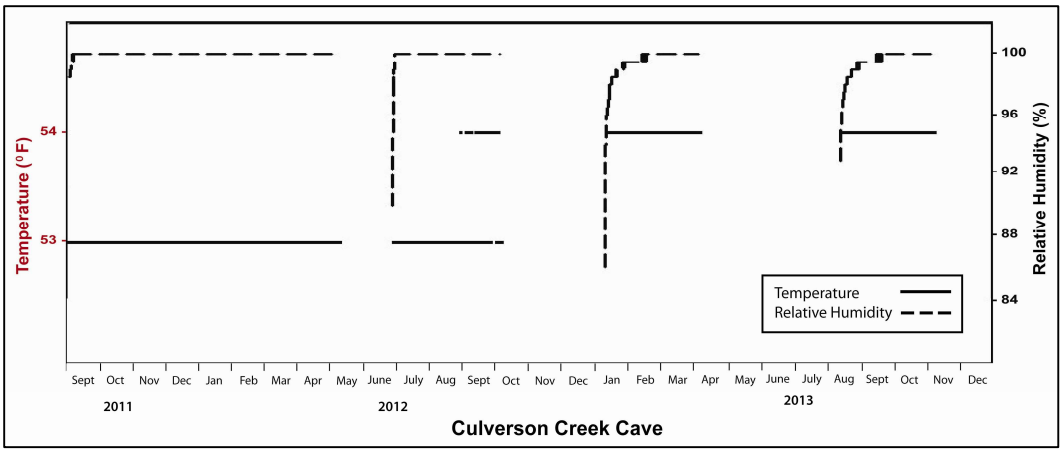

Figure 12-3 Temperature (ºF) and relative humidity (%) for Culverson Creek Cave

Cave air CO_2 (ppm)

CO_2 measurements were obtained during each of the cave trips. Results are shown in Figure 12-4 through

Figure 12-6 for BCC, LWC, and CCC, respectively. No measurements for BCC or CCC were obtained for the final trip, Dec 2013, due to the flooding of the cave entrances. Results for BCC show a gradual increase in pCO2 (ppm) for both stations throughout the study period. More measurements were obtained for LWC due to year-round access. Though this cave received tourists year-round and has an artificial entrance, general seasonal trends in pCO2 (ppm) are observed as relatively higher values during the summer months than during the winter months. Results for CCC have a similar trend, though the maximum values in 2012 occurred during the early spring rather than the summer months.

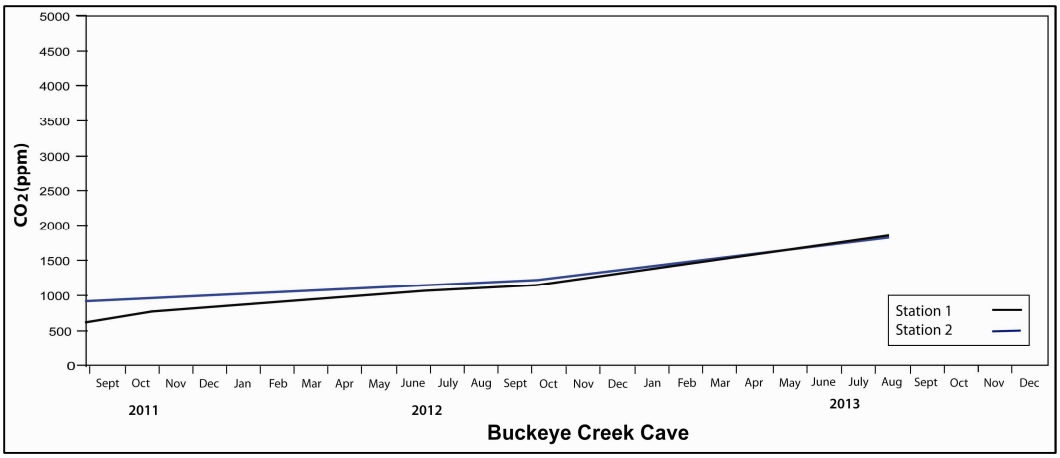

Figure 12-4 Cave air pCO_2 (ppm) results for Station 1 and Station 2 in Buckeye Creek Cave

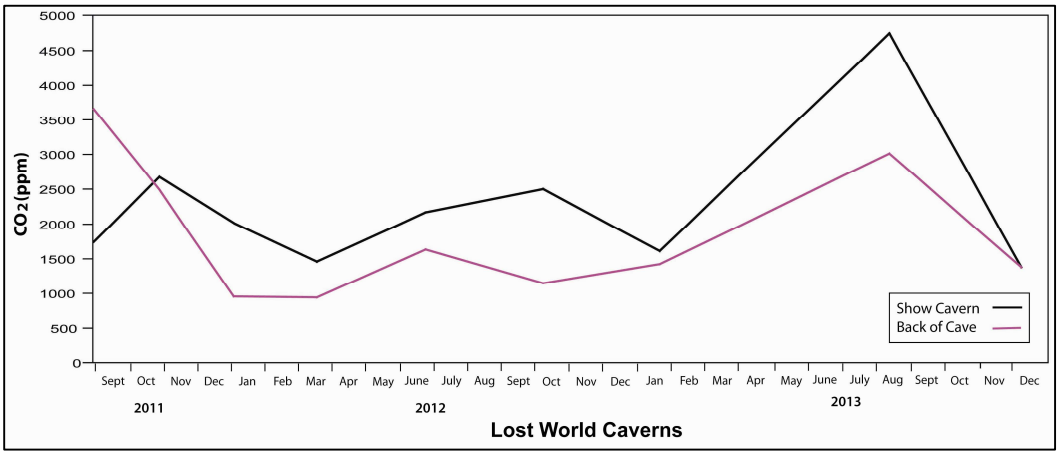

Figure 12-5 Cave air CO_2 (ppm) results for Show Cavern and Back of Cave in Lost World Caverns

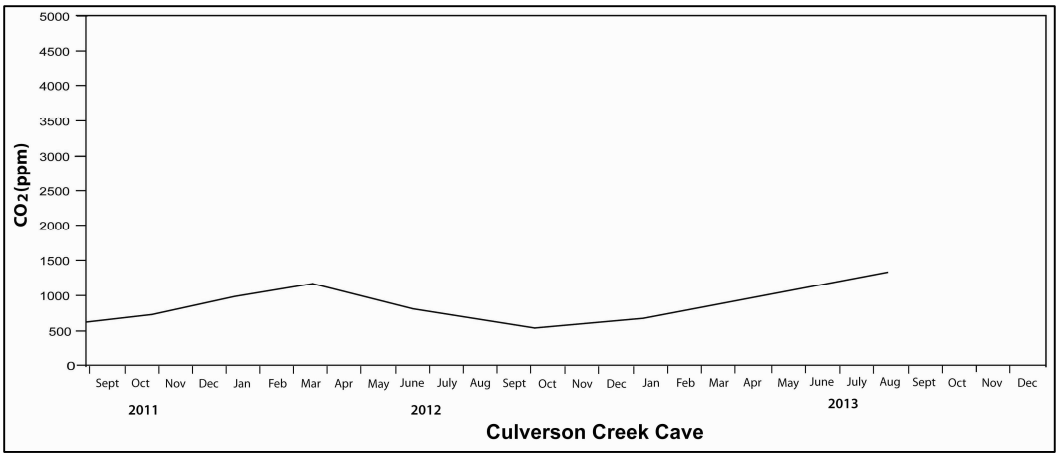

Figure 12-6 Cave air CO_2 (ppm) results for Station 1 in Culverson Creek Cave

Surface Precipitation Drip Frequency

Figure 12-7 through Figure 12-9 show the surface precipitation frequency for Pluvimate driploggers located near BCC, LWC, and CCC, respectively. In conjunction, monthly precipitation totals and average surface temperatures are shown for Lewisburg, West Virginia (climate data were obtained from ncdc.noaa.gov). Gaps in Pluvimate data are indicated by yellow bars.

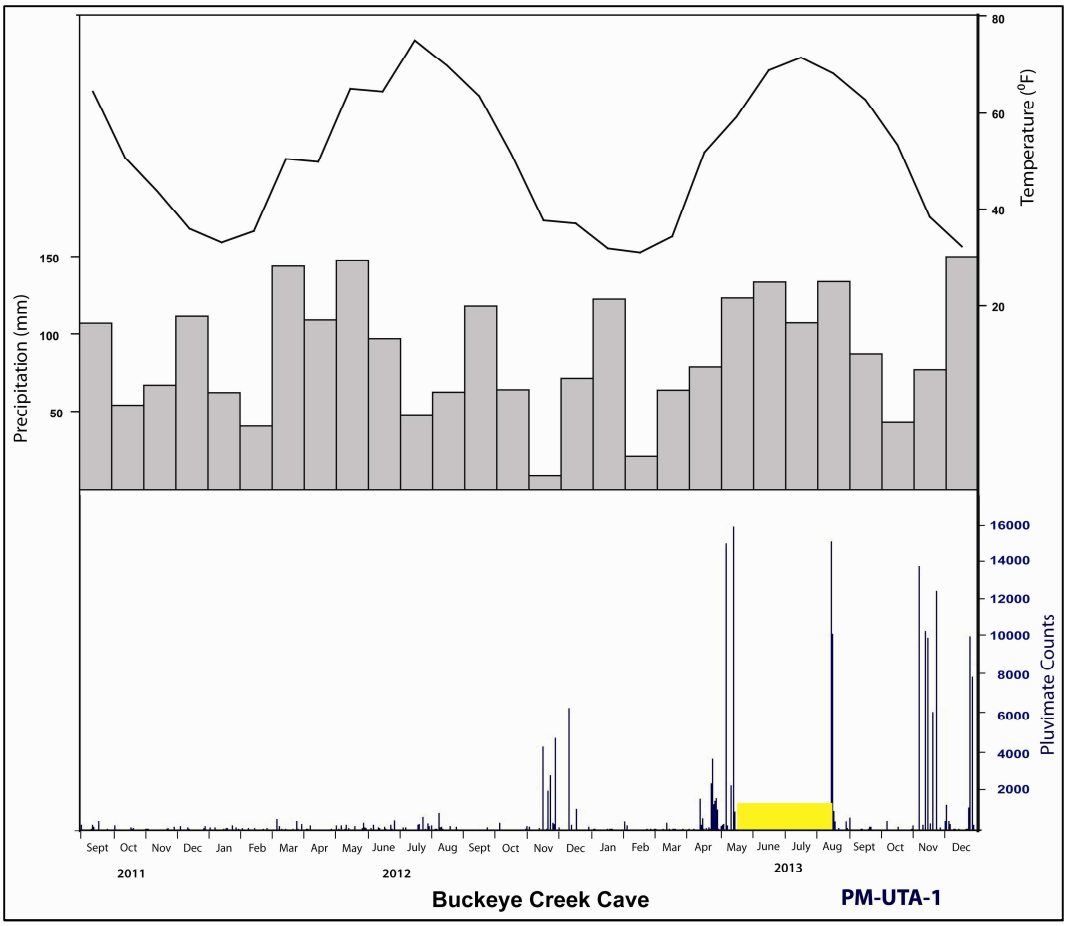

Figure 12-7 BCC Pluvimate surface precipitation drip frequency compared to monthly precipitation (mm) totals and average surface temperature (ºF) for Lewisburg, WV

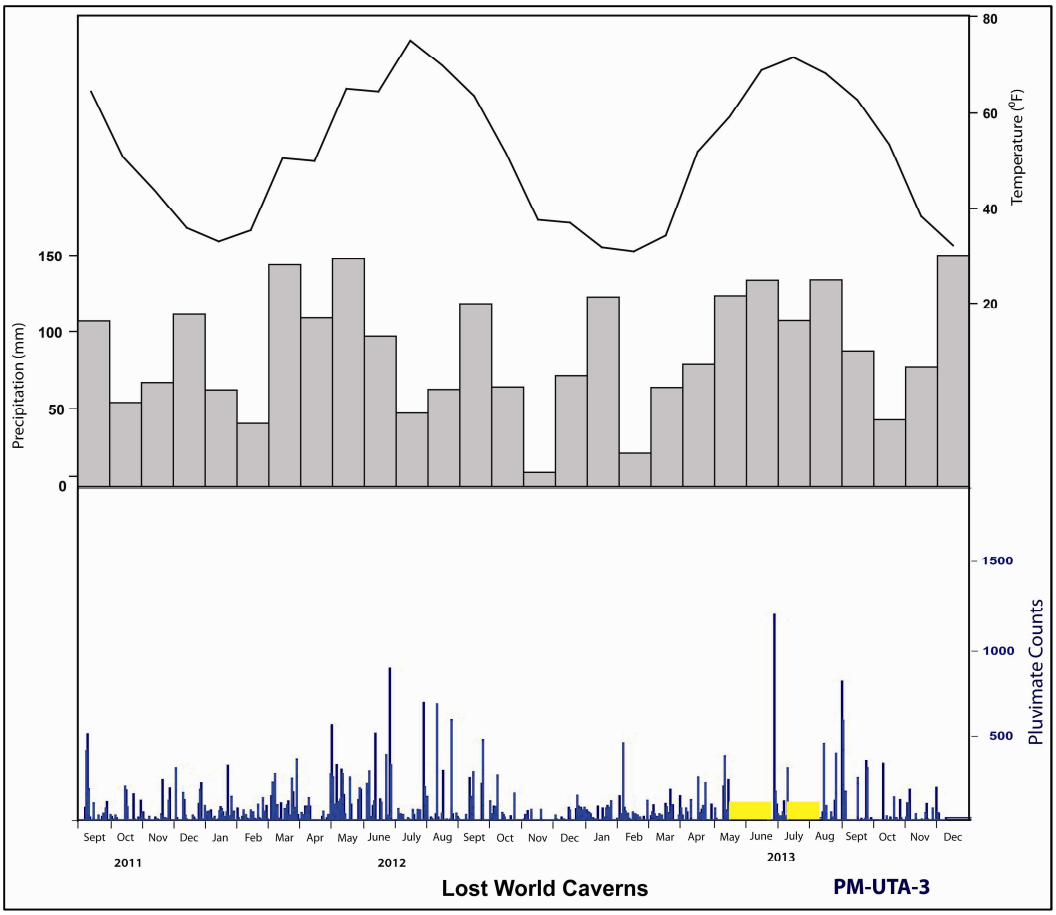

Figure 12-8 LWC Pluvimate surface precipitation drip frequency compared to monthly precipitation (mm) totals and average surface temperature (ºF) for Lewisburg, WV

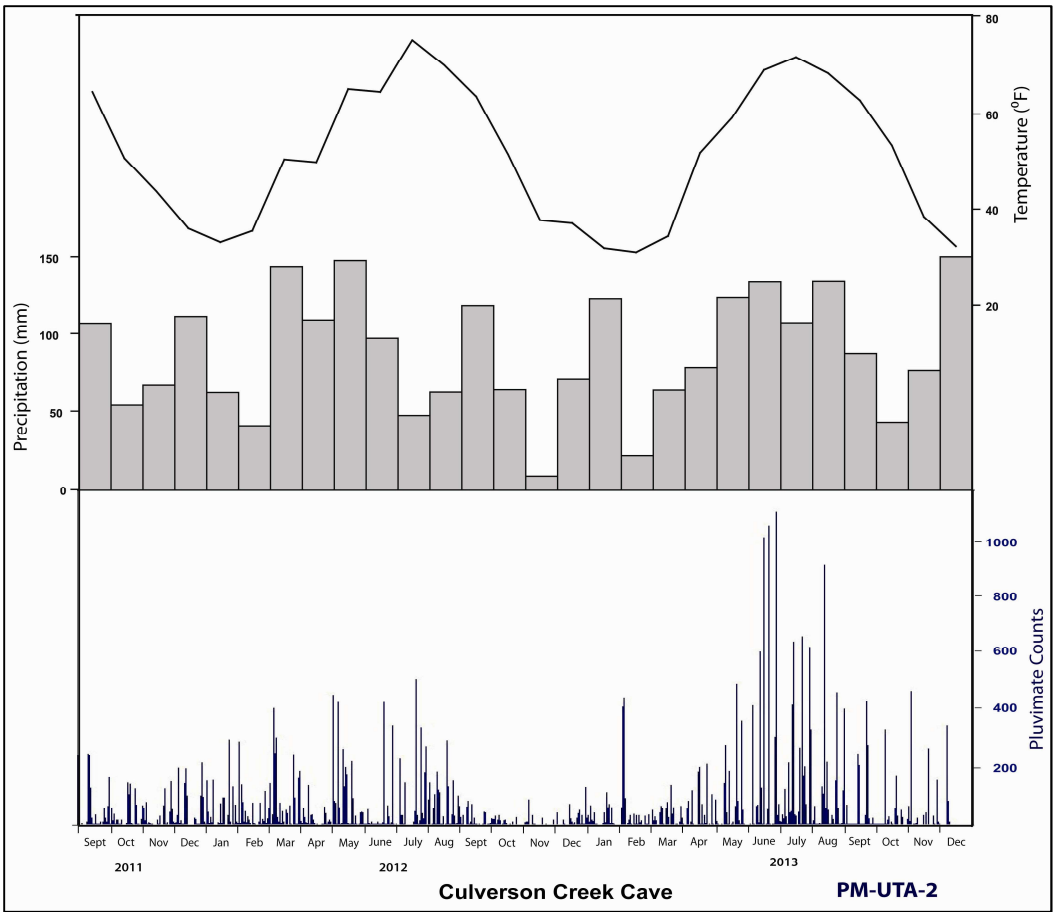

Figure 12-9 CCC Pluvimate surface precipitation drip frequency compared to monthly precipitation (mm) totals and average surface temperature (ºF) for Lewisburg, WV

Surface precipitation drip frequency data recorded by the Pluvimates are largely reflected in the monthly precipitation totals for LWC and CCC. In contrast, the Pluvimate data for BCC for Sept 2011 – Oct 2012 show a substantially lessened response. Differences in the Pluvimate data and the monthly precipitation totals highlight the importance of drip frequency monitoring. Figure 12-9, for example, shows a meteoric precipitation event of ~400 counts in early February 2013. But because the rest of the

month had very little precipitation, this large pulse of precipitation is not reflected in the monthly totals. Another example from this record is the three extreme precipitation events that occurred in June 2013. These are the three instances of greatest precipitation amounts as discrete events during the study record, but the monthly precipitation total for that month is relatively unremarkable.

These data are important because they allow the timing and magnitude of precipitation events to be identified and Pluvimates were ideal for monitoring high-resolution drip frequency. However, the response of the equipment to precipitation events in cold winter months may be lessened due to the possible formation of ice on the logger or in the catchment.

Cave Drip Frequency

Cave drip frequency was monitored for six drip sites. Figure 12-10through Figure 12-15 show the Stalagmate drip logger results compared to the cave-respective Pluvimate results. Gaps in data are indicated with yellow bars.

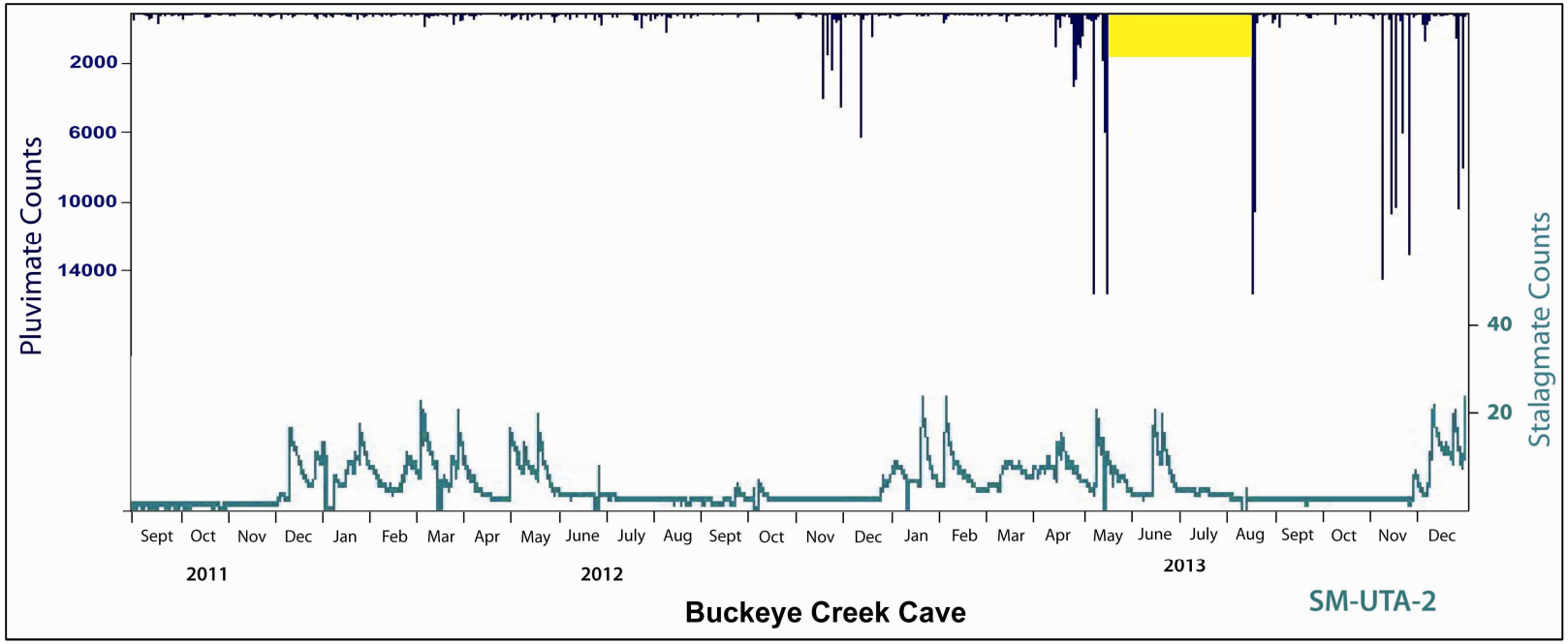

Figure 12-10 BCC Stalagmate SM-UTA-2 cave drip frequency *versus* Pluvimate surface drip frequency

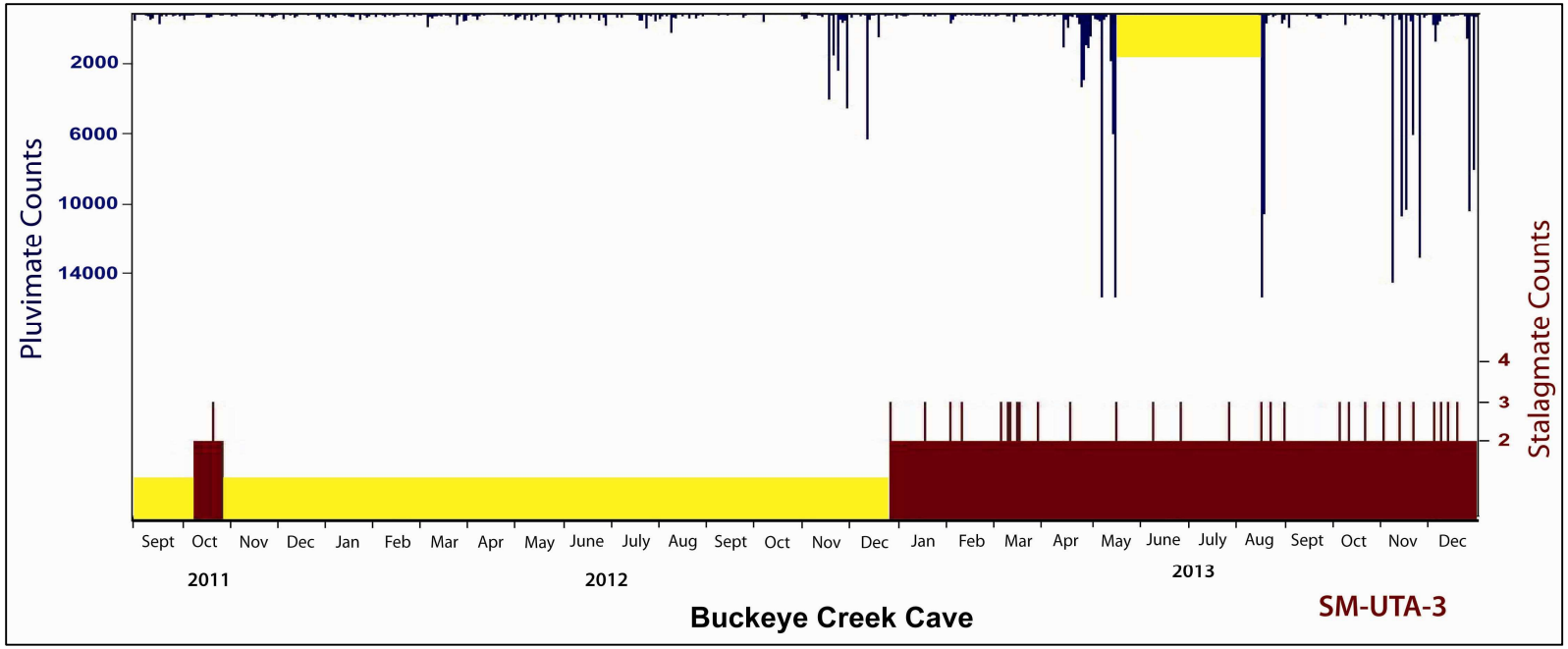

Figure 12-11 BCC Stalagmate SM-UTA-3 cave drip frequency *versus* Pluvimate surface drip frequency

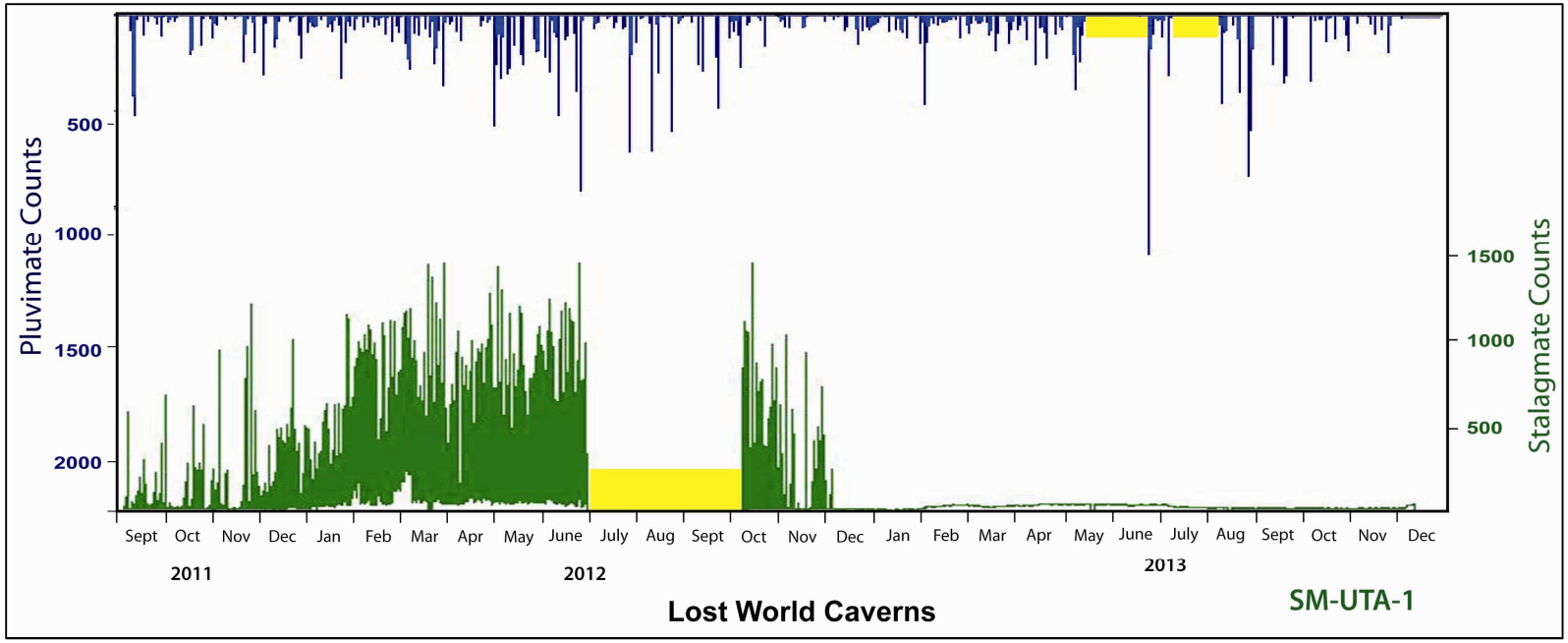

Figure 12-12 LWC Stalagmate SM-UTA-1 cave drip frequency *versus* Pluvimate surface drip frequency

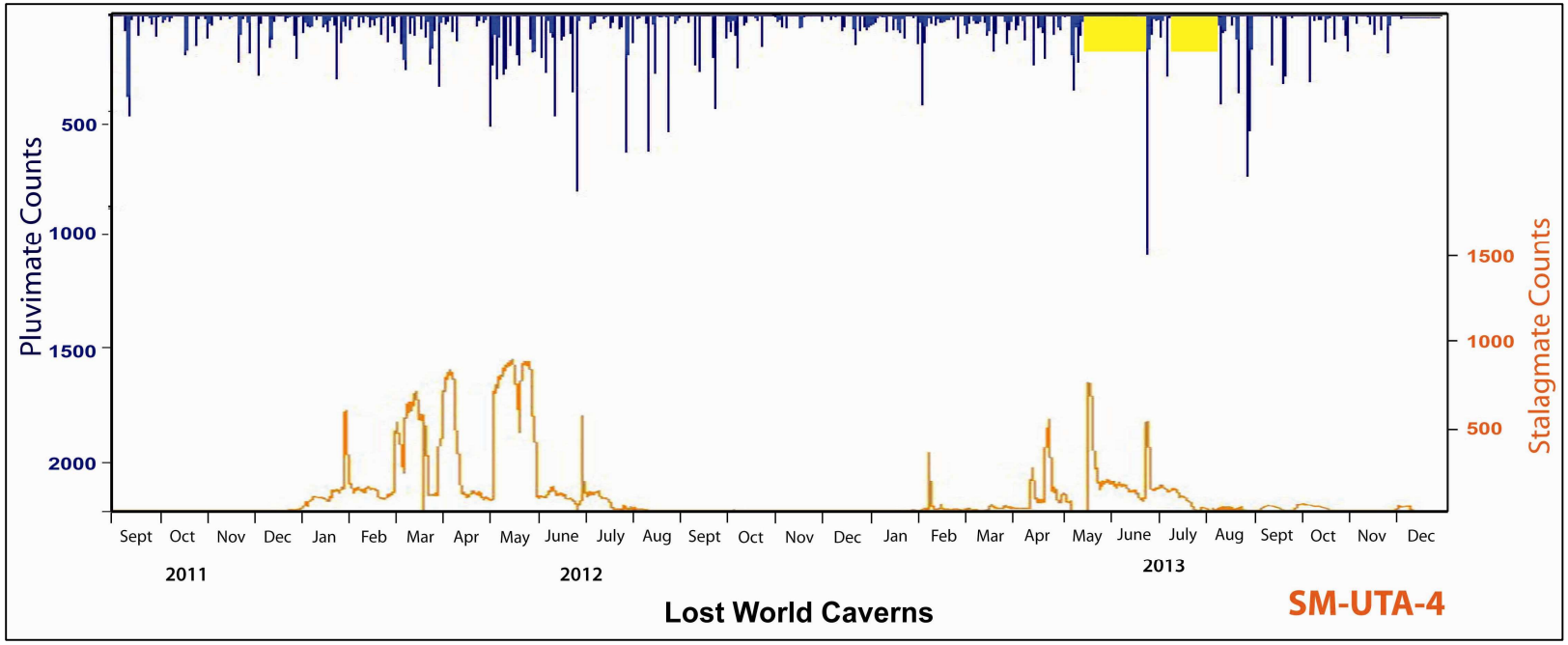

Figure 12-13 LWC Stalagmate SM-UTA-4 cave drip frequency *versus* Pluvimate surface drip frequency

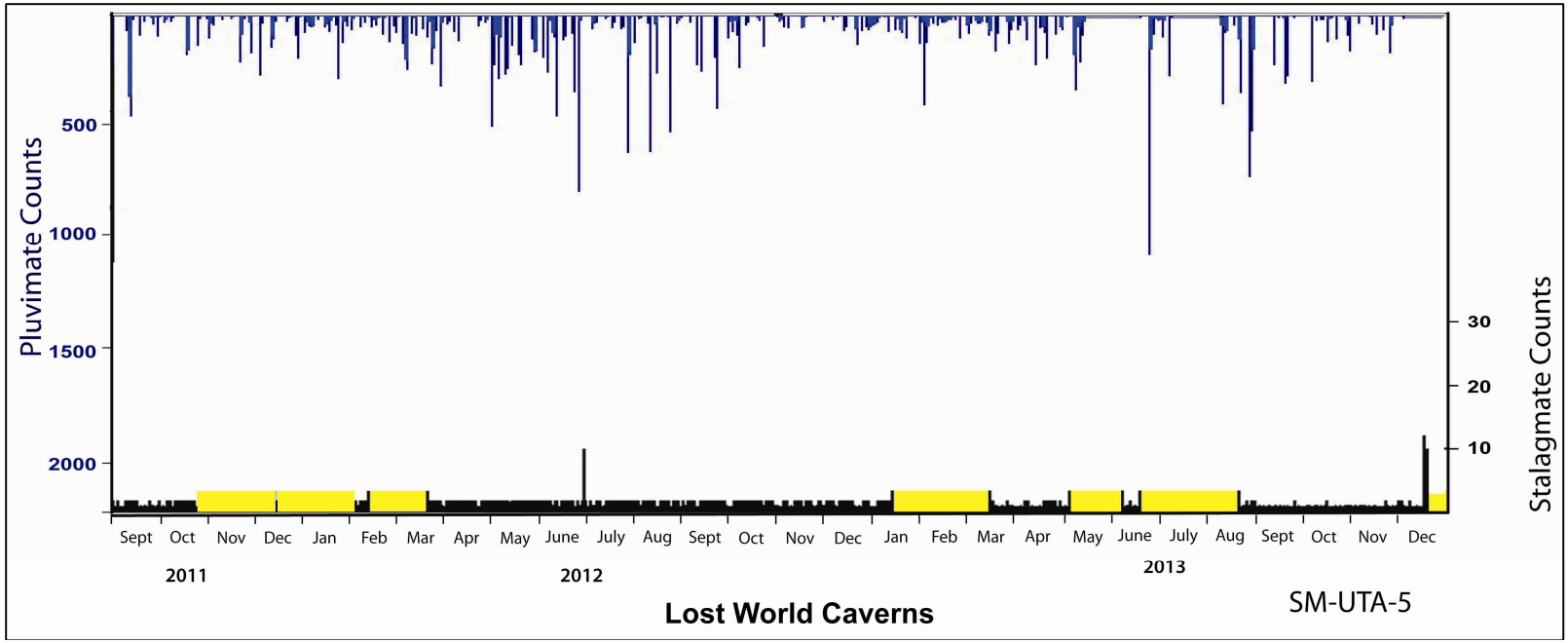

Figure 12-14 LWC Stalagmate SM-UTA-5 cave drip frequency *versus* Pluvimate surface drip frequency

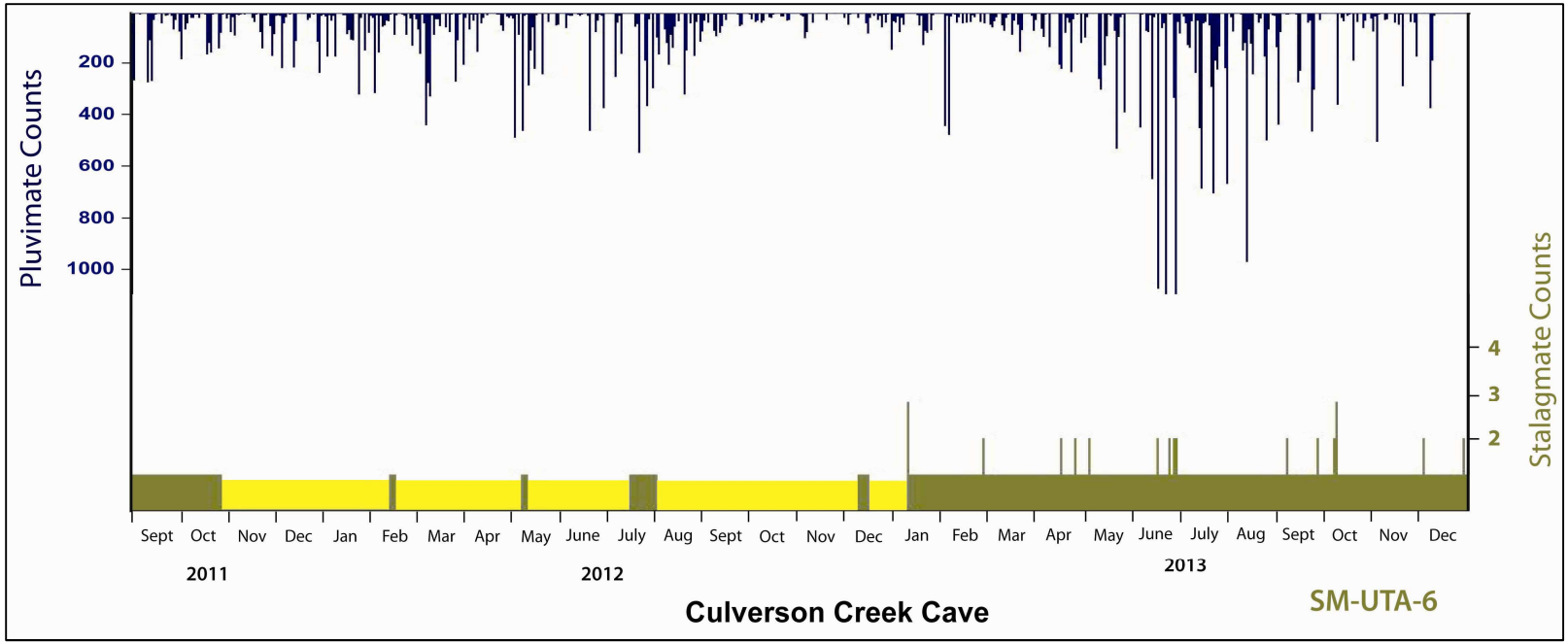

Figure 12-15 CCC Stalagmate SM-UTA-6 cave drip frequency *versus* Pluvimate surface drip frequency

Hydrochemistry

Dripwater samples were analyzed for $\delta^{18}O$, δD (2H), anions Cl^-, NO_3^-, SO_4^{2-}, and cations Na^+, K^+, Mg^{2+}, Ca^{2+}, Sr^{2+}, and Ba^{2+}. Table 12-1 shows the combined results of these analyses. 'NA' denotes no sample available.

Table 12-1 Hydrochemical results for dripwater samples

				Anions			Cations					
	Sample ID	**$\delta^{18}O$**	**δD**	**Cl^-**	**NO_3^{2-}**	**SO_4^{2-}**	**Na^+**	**K^+**	**Mg^+**	**Ca^{2+}**	**Sr^{2+}**	**Ba^{2+}**
Aug-11	**WS1**	-8.66	-54.01	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS2	-8.72	-55.27	0.7362	1.6093	23.4032	2.5961	0.748	9.5396	50.5376	1.6085	0.0118
	WS3	-8.75	-49.81	1.3201	2.3417	3.7217	2.5567	0.7008	2.7409	53.1011	0.6395	0.0615
	WS4	-8.37	-49.81	1.5847	2.8151	4.7747	3.3575	0.876	3.3248	43.2357	0.5761	0
	WS5	-8.5	-51.39	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS6	-7.6	-48.68	2.5888	30.3731	11.5591	3.0515	1.1276	4.9252	52.401	0	0.0386
	WS7	-8.31	-52.1	2.3138	1.8959	12.0584	3.2577	0.8425	4.1394	53.0038	0	0
	WS8	-8.62	-52.7	0.8668	1.8063	5.3475	2.8756	0.5217	2.6425	33.3692	0	0
	WS9	-8.21	-52.32	2.9516	2.4636	12.8734	3.1668	1.1125	5.0261	49.3744	0	0
	WS10	-8.54	-52.21	33.9824	3.2311	11.9534	10.0626	1.1154	8.7136	55.8622	1.4859	0
	WS11	-7.55	-45.81	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS12	-7.15	-43.66	NA	NA	NA	NA	NA	NA	NA	NA	NA
Oct-11	**WS1**	-8.5	-53.25	0.6929	1.1231	28.0193	2.5744	0.7034	10.2854	51.0699	1.6539	0.012
	WS2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS3	-6.95	-48.38	1.2828	2.6742	3.9968	2.2547	0.6043	2.7523	50.0394	0.6552	0.0322
	WS4	-7.86	-51.24	1.4652	2.8457	4.8884	2.4864	0.7266	3.3509	51.3567	0.7119	0.0718
	WS5	-5.78	-43.27	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS6	-7.66	-45.73	2.568	29.9631	11.6471	3.2144	1.1092	4.7477	51.7465	0	0.0344
	WS7	-7.04	-49.61	2.2036	3.8973	10.321	3.2527	0.8285	3.9767	55.1498	0	0
	WS8	-6.51	-47.92	0.9333	2.0956	5.3093	2.3292	0.6597	2.8804	45.7207	0	0
	WS9	-7.72	-52.8	2.8738	2.4725	12.2744	2.626	1.0098	5.3257	49.3634	0	0.053

Table 12-1—*Continued*

	WS10	-6.39	-48.48	30.0761	3.2883	11.4213	8.6069	1.0515	9.1022	55.8276	1.5466	0
	WS11	-5.53	-43.39	117.1342	0.5256	36.3569	12.1013	1.4268	20.1385	55.0847	0.7546	0.0159
	WS12	-6.2	-42.04	0.776	0	23.7495	7.7289	1.3846	25.1763	19.791	0.8777	0
Dec-11	**WS1**	-8.77	-48.72	0.7973	1.0042	20.7409	0.8162	0.377	10.1889	53.6386	1.6761	0.0188
	WS2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS3	-8.48	-46.22	1.0864	1.9884	4.3175	0.9382	0.4193	2.2577	49.8831	0	0.0519
	WS4	-8.78	-50.62	1.1684	1.6491	4.6229	0.9499	0.4441	2.3452	50.2764	0	0.0436
	WS5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS6	-8.25	-49.26	2.6553	32.2391	12.1934	1.4961	0.6719	4.7192	41.8187	0	0.0271
	WS7	-9.08	-45.87	1.9871	3.9614	9.0801	1.3267	0.5227	3.8616	50.7288	0	0.0337
	WS8	-8.24	-49.67	0.8415	2.0559	4.8961	0.9754	0.4742	2.2288	50.7288	0	0.0642
	WS9	-8.69	-49.67	2.8897	2.5424	12.3819	1.2734	0.8169	5.5166	49.0018	0	0.0921
	WS10	-8.81	-48.12	51.0093	2.7675	12.7516	9.5405	0.8031	9.4152	47.5956	1.4992	0.0111
	WS11	-8.5	-49.35	141.1551	0.2415	44.0177	11.2386	0.9896	21.5854	62.3072	0.8276	0.0341
	WS12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mar-12	**WS1**	-3.13	-32.59	0.7955	0.6557	15.0763	0.7171	0.3433	10.0511	23.641	1.5564	0.0046
	WS2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS3	-0.92	-27.64	1.3993	1.5879	4.6393	0.8967	0.4178	1.7818	24.6478	0.3771	0
	WS4	-6.84	-44.96	1.5052	1.6176	5.0548	0.9335	0.4338	1.9254	25.5148	0.3492	0
	WS5	-3.26	-36.11	278.986	19.6632	21.2248	29.6047	1.7522	12.1949	93.1696	2.2066	0.3534
	WS6	-6.87	-44.5	3.0686	18.8499	13.7724	1.5716	0.7848	4.5509	30.3207	0	0
	WS7	-4.37	-39.23	2.2056	0.559	13.2411	1.4588	0.5728	4.4919	24.5986	0	0
	WS8	-5.75	-43.44	1.0013	2.309	5.0967	1.0268	0.4083	2.2186	24.5666	0	0.0197
	WS9	-5.94	-44.21	2.8567	1.6672	12.9433	1.2518	0.793	5.2526	25.6379	0.6181	0.0314
	WS10	-4.72	-40.48	56.6112	2.8082	13.7564	13.255	0.8726	9.0889	31.5857	1.5553	0

Table 12-1—*Continued*

	WS11	-3.18	-34.51	146.288	0.3285	42.4067	12.133	1.0326	22.6425	52.9514	1.3661	0.2378
	WS12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Jun-12	**WS1**	-7.63	-47.12	0.5883	0.7598	17.4452	0.7602	0.3354	9.8995	65.4105	2.3454	0.2835
	WS2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS3	-8.09	-49.95	1.3931	1.8473	3.7859	0.683	0.4654	2.1363	43.9904	0	0
	WS4	-8.15	-49.68	1.5763	1.846	4.2625	0.724	0.5043	2.2694	45.0752	0	0
	WS5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS6	-7.6	-47.37	2.7325	19.6991	13.1076	1.3808	0.8095	4.5782	53.4517	0	0
	WS7	-8.1	-51.38	2.6654	0.5077	14.0633	1.2578	0.578	4.3821	51.3772	0	0
	WS8	-8.31	-52.29	0.9447	0	5.1537	0.8116	0.1531	2.48	41.9518	0	0
	WS9	-8.16	-51.86	2.909	1.772	12.7845	0.9975	0.8026	4.9182	44.021	0	0
	WS10	-7.97	-52	46.4764	2.7992	13.4743	10.9847	0.8499	8.4593	50.5446	1.7002	0
	WS11	-7.05	-45.52	135.551	0.4454	39.756	10.7158	1.0335	21.6794	66.4481	0	0.0365
	WS12	-7.48	-46.42	0.7488	0	22.1973	3.9904	0.8971	25.5431	24.0555	1.0587	0
Oct-12	**WS1**	-11.14	-54.85	0.6584	1.2428	23.9916	0.8336	0.4672	9.7197	49.2367	2.197	0.1508
	WS2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	WS3	-11.2	-58.1	1.2688	2.1836	3.6486	0.918	0.4957	2.9858	56.1592	0	0
	WS4	-11.48	-59.73	1.4585	2.0749	4.4645	0.9871	0.558	3.2208	52.3208	0	0
	WS5	-11.39	-59.91	242.814	19.2513	14.9248	23.363	1.7193	15.2579	97.3543	1.8741	0
	WS6	-11.02	-55.66	2.3873	25.967	10.9395	1.4859	0.9221	4.9722	53.2454	0	0
	WS7	-11.54	-57.99	2.2143	2.5948	10.2155	1.325	0.5879	3.9938	49.0011	0	0
	WS8	-11.45	-60.25	1.0444	2.0579	5.0235	1.0115	0.4541	2.8271	46.3432	0	0
	WS9	-11.32	-58.62	2.859	2.2445	11.4101	1.271	0.854	5.419	48.97	0	0.1089
	WS10	-11.86	-61.17	42.3379	2.9378	12.2403	9.7001	0.8632	8.6499	55.7969	1.8404	0.0924
	WS11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12-1—*Continued*

	WS12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Hydrochemistry plots

Hydrochemical time-series are shown in Figure 12-16 through Figure 12-26 for the period of Aug 2011 – Oct 2012.

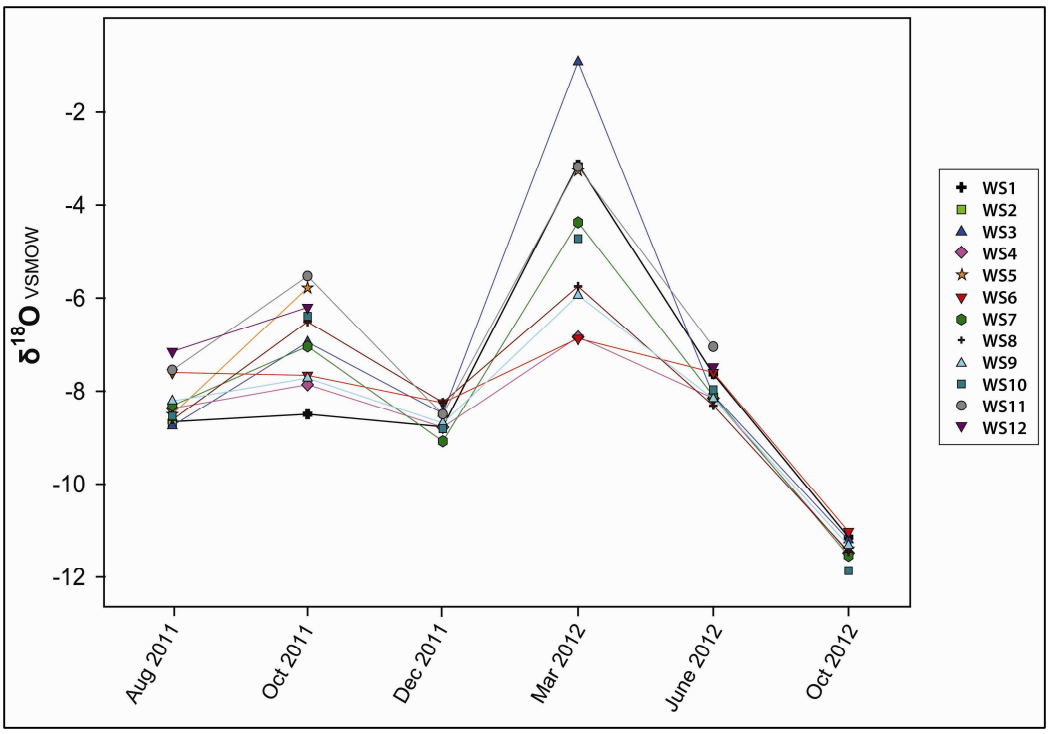

Figure 12-16 $\delta^{18}O$ for dripwater samples from Aug 2011 – Oct 2012.

The $\delta^{18}O$ values of the dripwater samples display a range from -12 to -1‰ V-SMOW. The maximum values occur in Oct 2011 and March 2012 whereas the minimum values occur in Aug 2011, Dec 2011, and Oct 2012., Dec 2011, and Oct 2012.

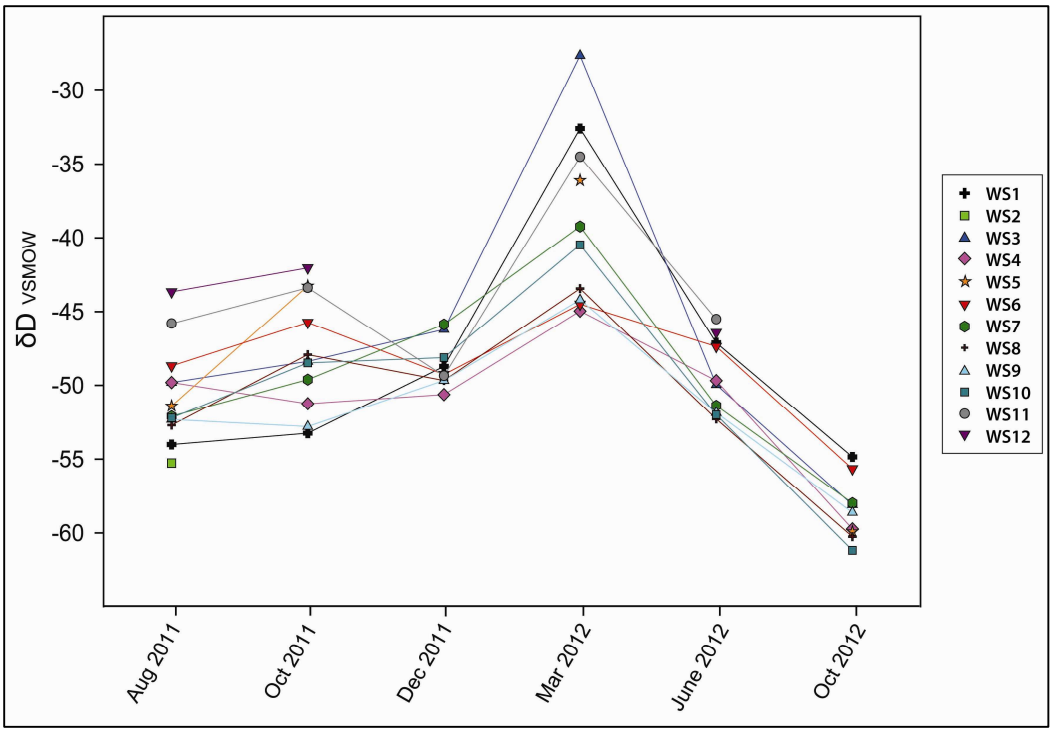

Figure 12-17 δD for dripwater samples from Aug 2011 – Oct 2012

The δD values of the dripwater samples display a range from -60 to -30‰ V-SMOW. Like $\delta^{18}O$, the maximum values occur in Oct 2011 and March 2012.

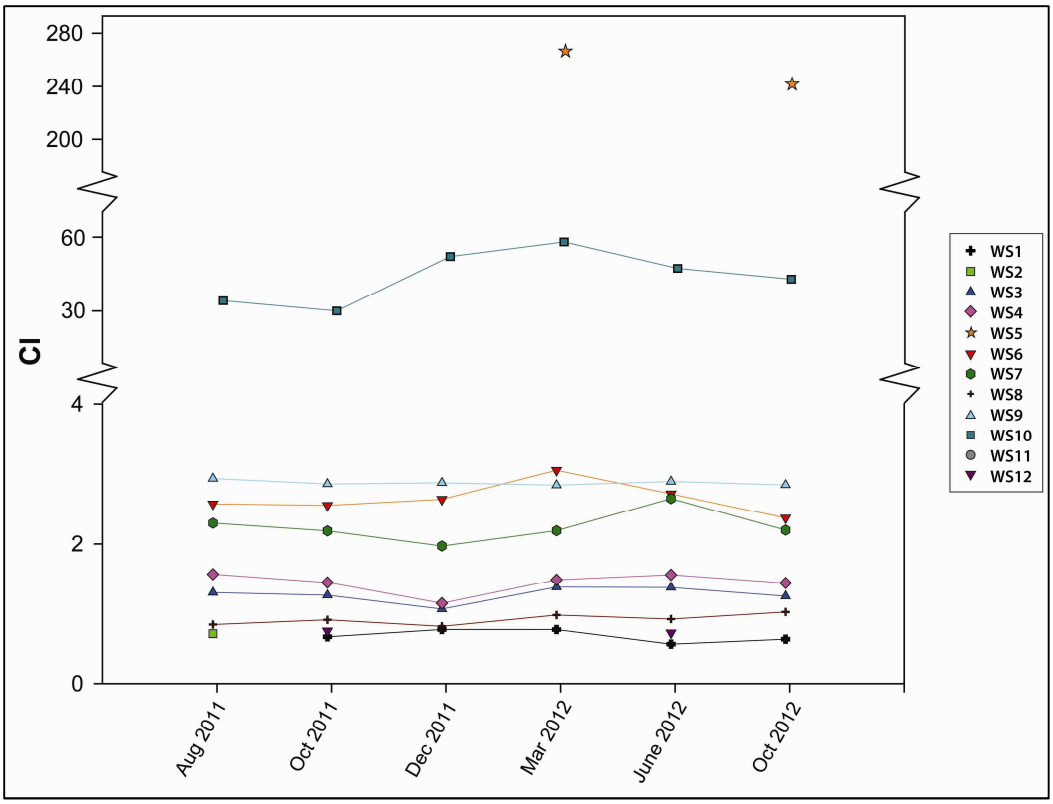

Figure 12-18 Cl^- (ppm) for dripwater samples from Aug 2011 – Oct 2012

Dripwater Cl^- values for the majority of the water samples are generally low and relatively invariant throughout the year. However, sample WS10, from LWC, had values an order of magnitude higher than most of the samples. Larger still, by two order of magnitude were the WS5 values obtained in Mar and Oct 2012.

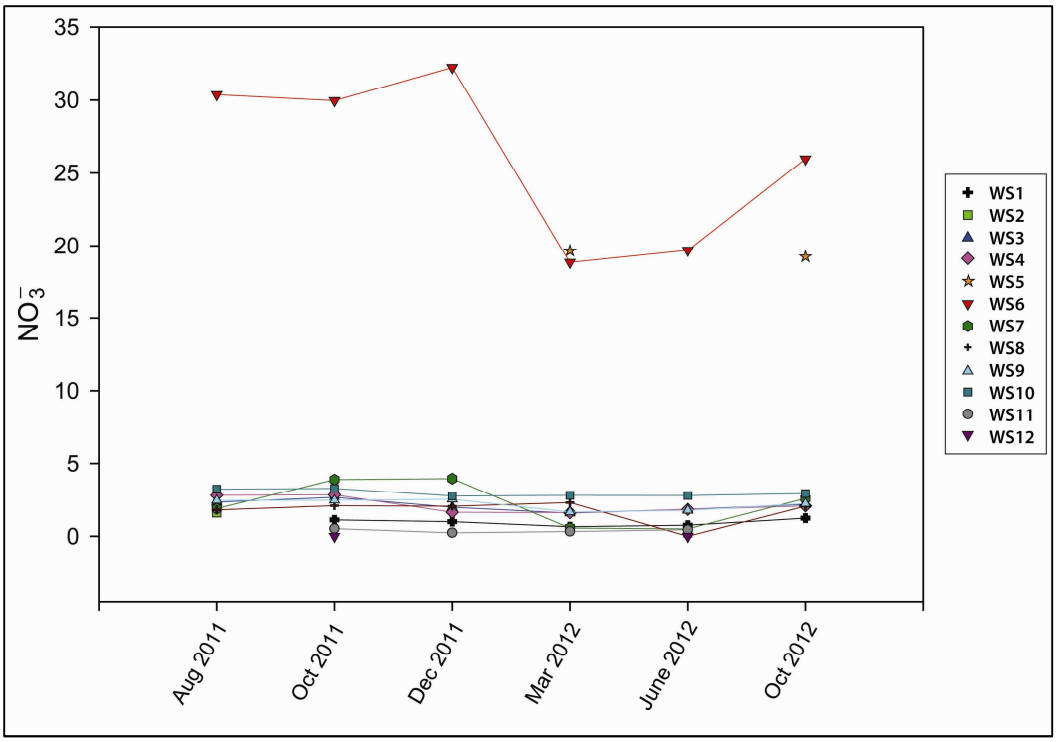

Figure 12-19 NO_3^{2-} (ppm) for dripwater samples from Aug 2011 – Oct 2012

Nitrate values for the dripwater samples were overall low and largely invariant over the year. However, WS5 and WS6, from LWC, have much higher values.

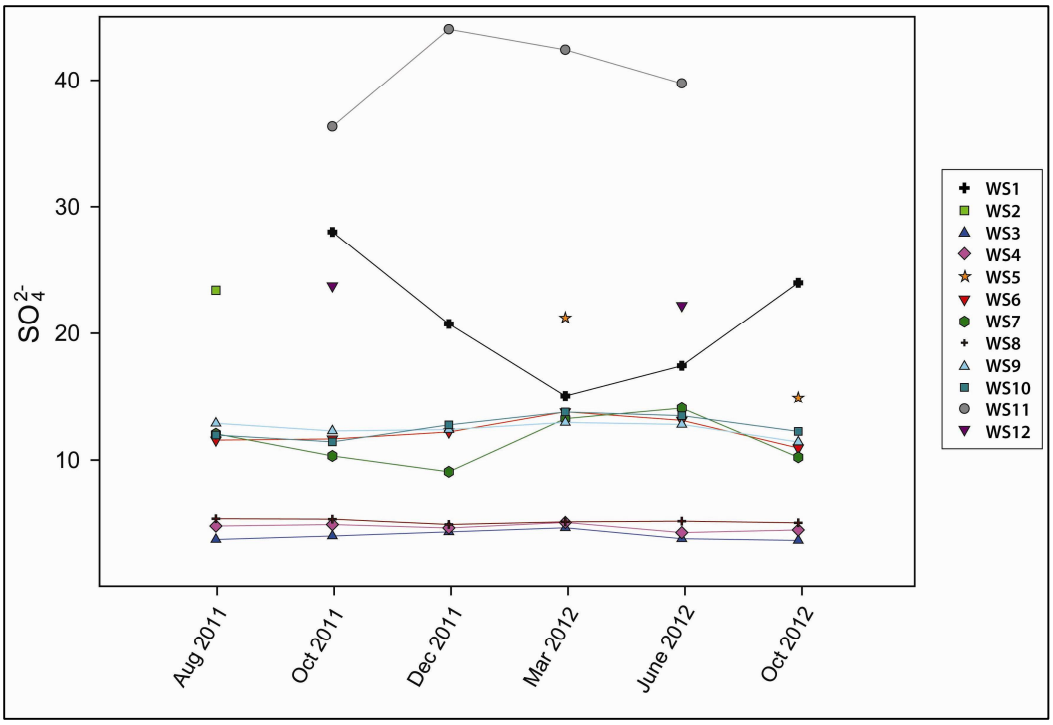

Figure 12-20 SO_4^{2-} (ppm) for dripwater samples from Aug 2011 – Oct 2012

Sulfate values ranged from a minimum of ~4 ppm with no substantial annual variability to higher, more variable values.

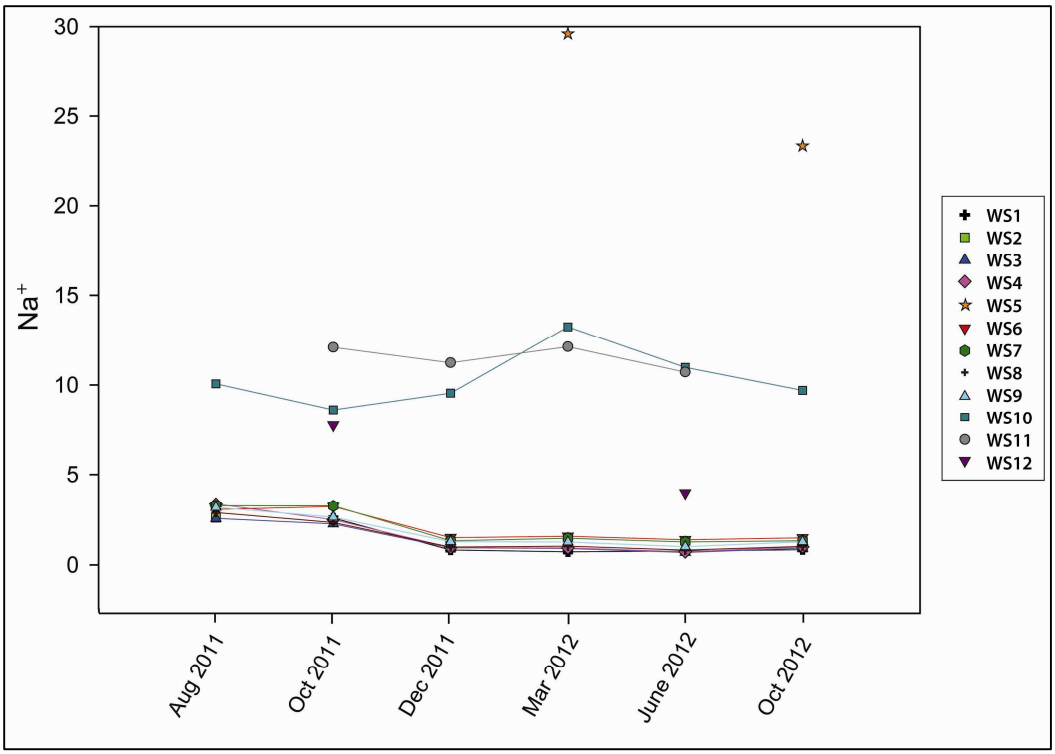

Figure 12-21 Na^+ (ppm) for dripwater samples from Aug 2011 – Oct 2012

Sodium cation values were remarkably similar for the majority of dripwaters. WS5, WS10 from LWC and WS11 from CCC were deviations from the majority.

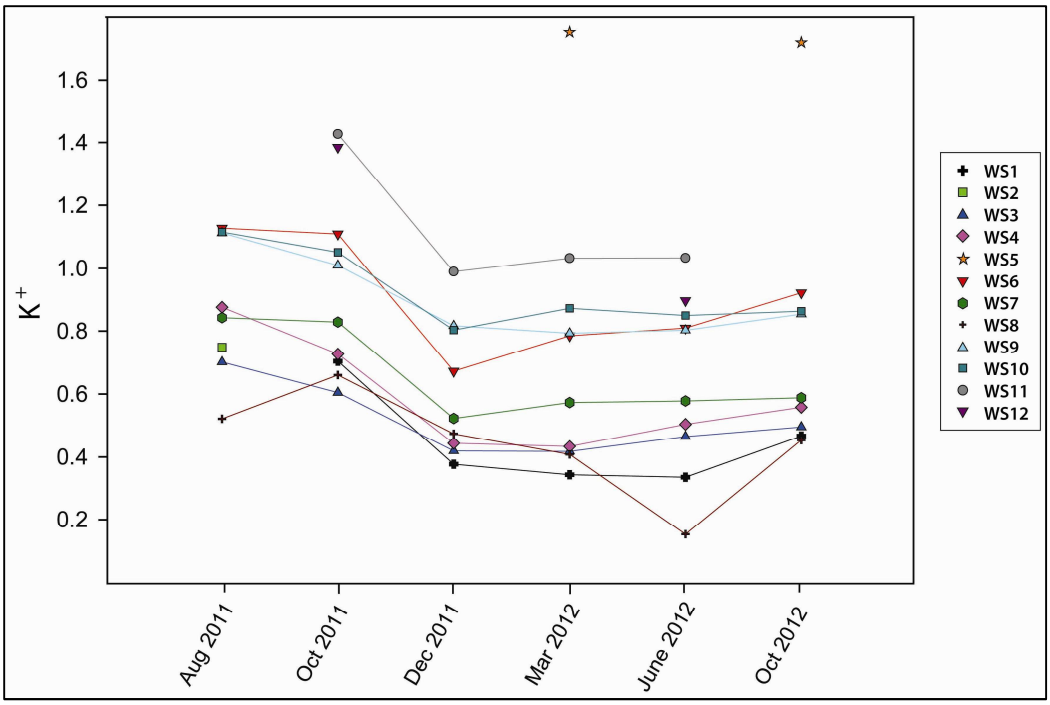

Figure 12-22 K^+ (ppm) for dripwater samples from Aug 2011 – Oct 2012

Potassium cation values were overall low, with a general trend of higher values in Oct 2011 and low values in March and June 2012.

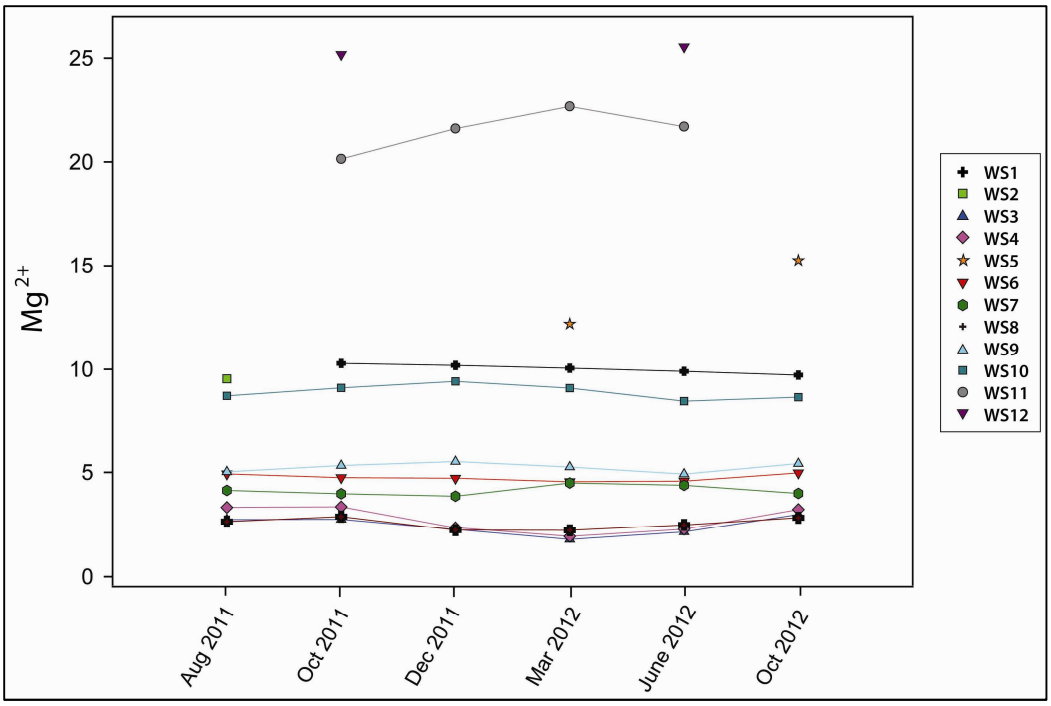

Figure 12-23 Mg^{2+} for dripwater samples from Aug 2011 – Oct 2012

Magnesium cations for most of the samples ranged between 3 – 10 ppm. WS11 and WS12, from CCC, had substantially higher values.

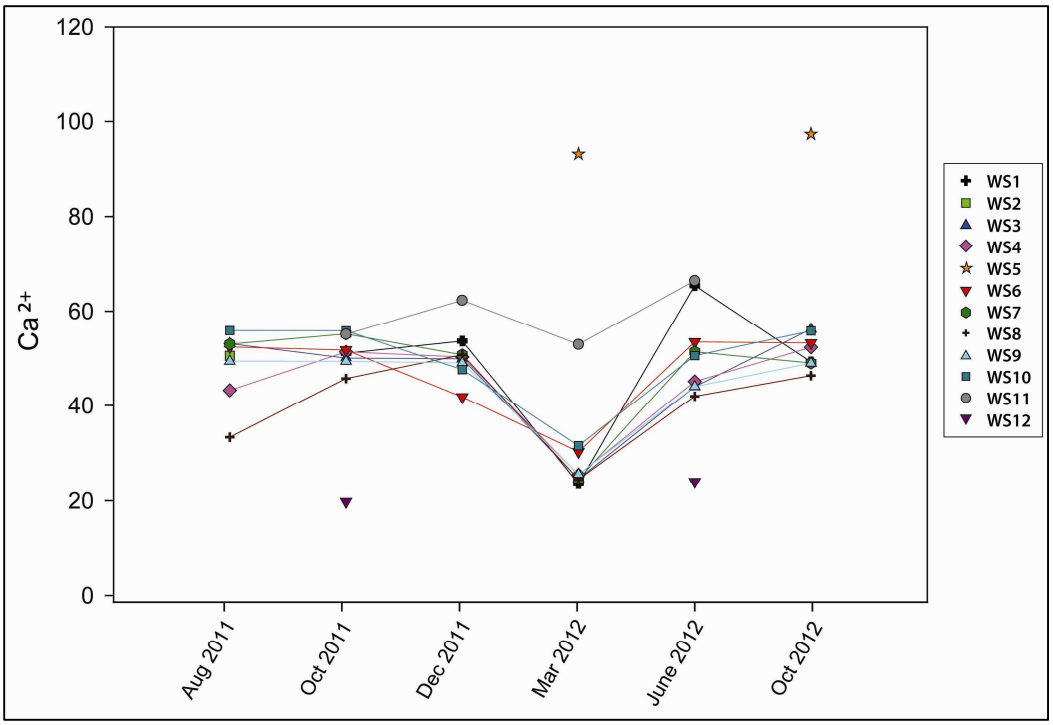

Figure 12-24 Ca^{2+} for dripwater samples from Aug 2011 – Oct 2012

Calcium cation values ranged from 20 – 95 ppm, with the majority of the samples following a trend of values between 40 – 60 ppm, with a substantial decrease in March 2012, followed by a return to previous values.

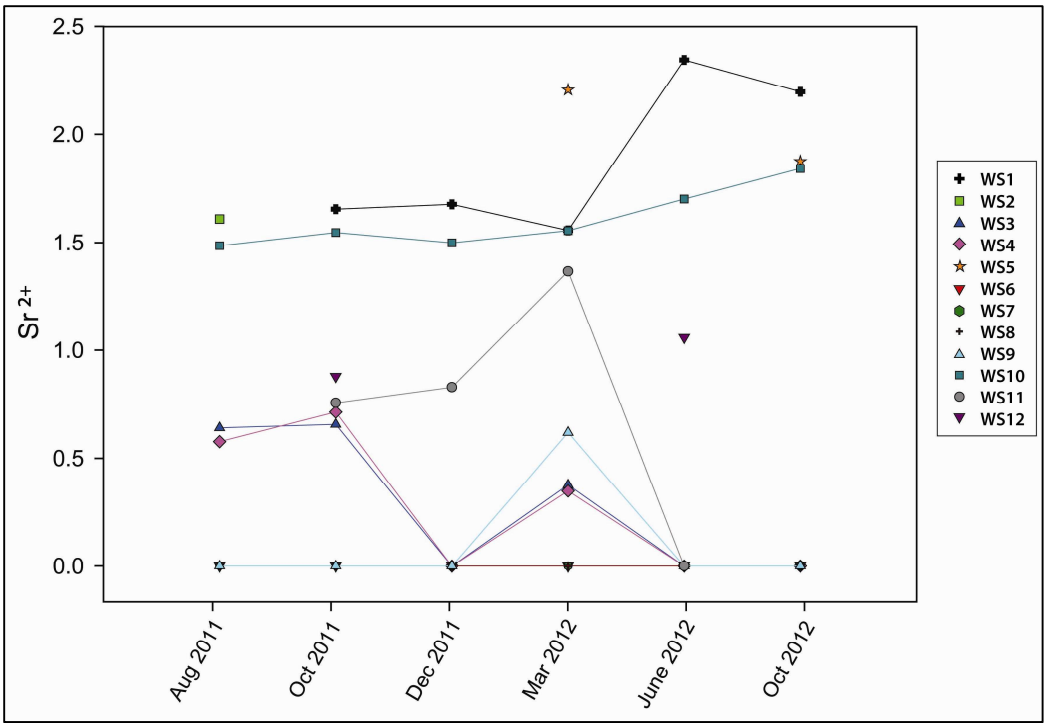

Figure 12-25 Sr^{2+} for dripwater samples from Aug 2011 – Oct 2012

Strontium cation values for the dripwaters display the greatest amount of variability, though all values were below 2.5 ppm.

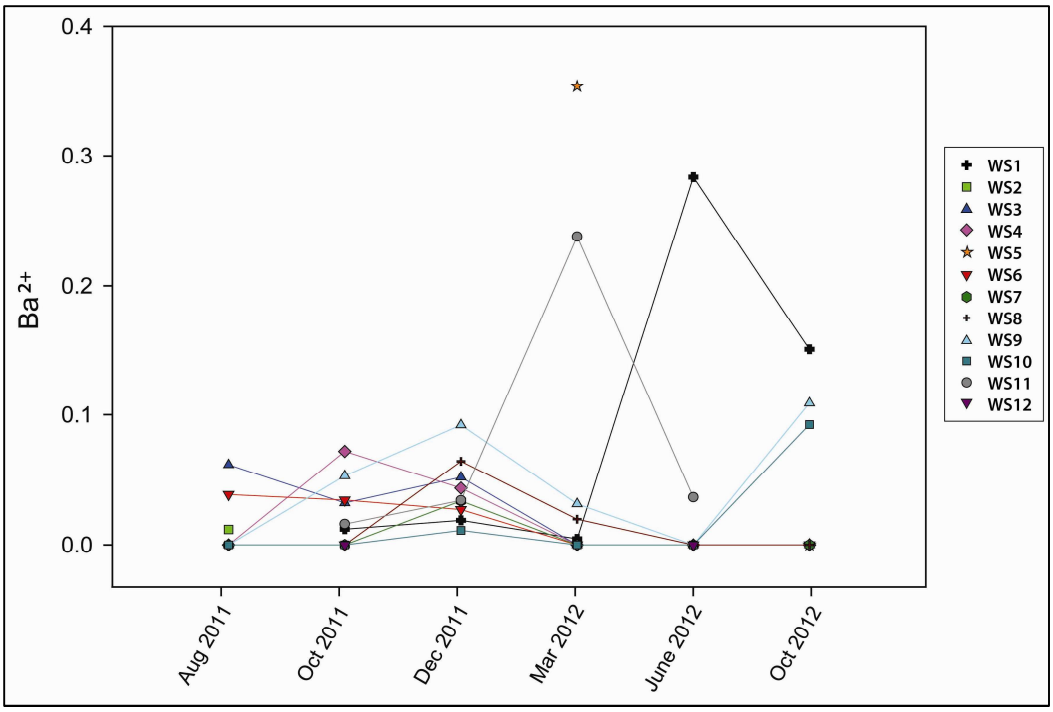

Figure 12-26 Ba^{2+} for dripwater samples from Aug 2011 – Oct 2012

Barium cation values were very low for the dripwaters and will not be considered in the discussion section.

Chapter 13

Discussion

Cave Microclimate

The average temperatures recorded in BCC (50.8ºF), LWC (53.0ºF), and CCC (53.4ºF) revealed stable temperatures near the average surface temperature of the region (50.4ºF). The high relative humidity of the caves hindered the collection of data, as the loggers were prone to battery and logger failure. The advantages of using these loggers were that they were relatively inexpensive, downloadable directly through a USB, and the batteries were easily changed. The disadvantages were that the temperature values recorded were only to the nearest whole number (which is a problem if you are investigating slight temperature differences), and were prone to failure.

The pCO_2 measurements obtained in this study allow insight into the seasonal variability in concentrations, which effectively controls the amount of calcite precipitation in caves. However, continuous monitoring of non-anthropogenic-influenced caves would be more useful for future studies, as higher-frequency analysis would allow for the examination of daily and weekly fluctuations.

Characterization of Cave Drip Sites

The variability in drip frequency of cave drips and the response to surface precipitation events lends insight into the flow path of the water through the epikarst. Using the general classification scheme of Tooth and Fairchild (2003), the cave drips are classified as 1) rapid response, 2) rapid response with time delay, 3) seasonal response, or 4) no response, where “response” is the response of the cave drip to surface precipitation events.

For the BCC Stalagmates, Driplogger SM-UTA-2 (Figure 12-10) is characterized as having a seasonal response to precipitation events. The drip is only active between Dec – May or June months and does not drip during the rest of the year. This drip is likely fed by piston flow of a perched reservoir, which is only active during infiltration surplus. SM-UTA-3 (Figure 12-11) demonstrates no increased response to precipitation events. This drip is very slow and highly stable and is likely fed through diffuse flow through the epikarst.

For the LWC Stalagmates, Driplogger SM-UTA-1 (Figure 12-12) is characterized as having a 'rapid response' for the first half of the study period, where very high drip rates in direct response to precipitation events are observed. In early Dec of 2012, drip rates dropped to very low values that persisted throughout the rest of the study period. The drip route likely became partially blocked and rerouted to another outlet. Baldini et al. (2006) suggested that for very high flow drips, flow switching or stoppage is common, and makes any stalagmite formed under such a drip unsuitable for paleoclimate studies. Stalagmate SM-UTA-4 (Figure 12-13) displays highly seasonal drip behavior, as it is only active during the months of Jan or Feb – July. Stalagmate SM-UTA-5 (Figure 12-14) is generally non-responsive to precipitation events except for the occasional increase in drip rate to large precipitation events.

The CCC Stalagmate, SM-UTA-6 (Figure 12-15) displays generally no response to precipitation events, aside from a few isolated increases due to precipitation events.

Hydrochemical Characterizations

The water samples displayed a wide range of values for many of the measured isotopes and ions, though most dripwaters behaved in a similar manner over the study interval. Significant deviations from the general behavior include WS6 nitrate values,

which may be the result of farmland directly over that particular section of the cave. The most striking feature of the hydrochemical results is the values for March 2012, when average values of $\delta^{18}O$ increased from -7 to -3‰ VSMOW, δD increased from -50 to -30‰ VSMOW, Ca2+ values decreased from approximately 50 ppm to 30 ppm. This period coincided with a substantial increase in precipitation, where monthly totals increased from ~50 to 150mm from February to March. Sustained precipitation for this period is also observed in the Pluvimate data for LWC and CCC (Figure 12-8 and Figure 12-9. This abrupt increase in precipitation resulted in the dilution of cations, particularly Ca^{2+}.

Chapter 14

Conclusions

Cave environments are highly stable throughout the year. Cave temperatures approach the mean surface temperature of the cave region and relative humidity levels were consistently near 100% throughout the study period. Measurements for pCO_2 revealed seasonally-variable values, though continuous logging would likely reveal higher-frequency variability.

Surface precipitation events can be recorded using Pluvimate drip frequency loggers, and largely reflect monthly totals of precipitation obtained elsewhere. Drip frequency logging is advantageous in that it allows for the identification of extreme precipitation events that may not be reflected in monthly totals.

Stalagmates were shown to record cave drip frequency over time. However, these instruments had a higher failure rate than did their surface counterparts, possibly due to the high humidity levels in the caves. The cave drips monitored with the Stalagmate drip loggers revealed a wide variety of behaviors in response to surface precipitation events. One (SM-UTA-1) was categorized as ‘highly responsive’ though it changed behavior during the middle of the study period. Two Stalagmates (SM-UTA-2 and -4) were categorized as having a ‘seasonal response’. Stalagmites formed under such drips would be biased towards their particular ‘growing season’ and not reflective of the overall climate. Of the six drips studied, three of them (SM-UTA-3, -5, and -6) displayed ‘no response’ to precipitation events, as their slow, consistent drips throughout the study period remained largely unresponsive. Stalagmites forming under such drips would be the best candidates for paleoclimate studies, as they reflect long-term climate changes rather than a seasonal or ‘flashy’ response to precipitation events.

The hydrochemical analyses revealed several deviations from overall trends, which may indicate unique flowpaths that are unconnected to the other drip flowpaths. Dilution of dripwaters was observed for samples obtained in March 2012 and is evidenced by abrupt changes in $\delta^{18}O$, δD, and Ca^{2+} values.

The variability observed in cave drip frequency highlights the benefits of conducting cave monitoring studies prior to stalagmite collection, as half of the drips monitored in this study were demonstrated to be poor candidates for paleoclimate studies.

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Biography

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