UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

A study of *Bacillus cereus* distributions and ten water extractable ions from soils on St. John, U.S. Virgin Islands

By

R.E. Tucker*, J.B. McHugh*, and H.V. Alminas*

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*U.S. Geological Survey, DFC, Box 25046, MS 973, Denver, CO 80225

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Abstract

A biogeochemical survey using Bacillus cereus and examination of ten water-extractable ions was conducted on A-horizon soil samples collected from St. John, U.S. Virgin Islands. The biogeochemical data showed a large natural population variability and no correlations with water-extractable Cu, Ag, and Zn. B. cereus population variability depends on a set of complex factors which need to be more fully examined before population variability can be successfully utilized as a mineralization predictor in this region.

The distribution of water-extractable Ag, Cl, Cu, SO_4, and Ca ions clearly depict areas of mineralization previously detailed in soil and rock samples. The data suggest that considerable transport of dissolved ions is occurring. The distribution of Cl suggests a significant seawater component to the extensive hydrothermal alteration. A water extraction of soils is an effective method for delineating areas of hydrothermal alteration.

Introduction

The U.S. Geological Survey began multidisciplinary studies of the U.S. Virgin Islands in 1983. These studies are being conducted to assist the Territorial Government of the Virgin Islands by providing necessary information for future planning and resource appraisal. The initial phase of this geochemical study was designed to examine the regional geochemical characteristics of the islands and to identify possible minerals potential. The mineralized areas may also represent environmental hazards due to elevated concentrations of heavy metals.

The search for metals often incorporates new techniques or technologies that utilize a variety of subtle chemical or physical characteristics associated with the mineralization process. The distribution of metal tolerant plant and fungal species has been utilized in mineral exploration with some success, although there are numerous environmental and physiological characteristics that are not well understood (Cannon, 1960; Brooks, 1972; and Kovalevskii, 1979). One of the newest assay techniques developed for geochemical exploration is the use of bacterial populations to indicate mineralization. A biogeochemical study was, therefore, conducted in conjunction with the other geochemical studies of St. John.

The use of bacteria as a mineral exploration tool has been investigated near sulfur, gold, and copper mineralized areas and indicates that increased populations of Bacillus cereus may occur over mineralized areas compared to adjacent, less mineralized areas (Miller, 1983; Watterson and others, 1983, 1986; Parduhn and Watterson, 1984; and Parduhn, 1987).

The use of B. cereus population densities in metals exploration depends on the microbial ecology and the physiological responses caused by heavy metals in the environment. Geomicrobiological investigations over mineralized areas have focused on the genus Bacillus because: (1) the bacteria form spores that are long lived in the soil and geochemial samples, and (2) B. cereus is easy to culture and to identify using an egg yolk agar.

The focus of this report is an examination of the data for ten water-extractable ions from A- and B-horizon soils and the distribution of the bacteria Bacillus cereus from A-horizon soils on St. John.

Study Area

The U.S. Virgin Islands are located in the Greater Antilles Island arc some 40 miles east of Puerto Rico (fig. 1). The major islands include St. Croix, St. John, and St. Thomas. There are about 40 smaller islands in the study area concentrated near St. Thomas and St. John. The British Virgin Islands are within a few miles of St. John Island.

St. Croix is the largest of the U.S. Virgin Islands, containing 84 square miles and is located 35 miles south of St. Thomas. St. John Island contains 19 square miles and St. Thomas Island contains 30 square miles. The topography of the islands is mountainous. The coastline of St. Croix is regular. The coastlines of St. John and St. Thomas are irregular with numerous bays. Small fringing coral reefs are common in shallow water.

The climate in the Virgin Islands is maritime tropical. The average annual rainfall is 50-60 inches per year in the higher elevations and 20-30 inches per year in the lower elevations. The East End and most of the coastal regions are characterized by cacti and (or) drought resistant plants. There is no well-defined wet or dry season. The temperature is generally constant between 80 and 85°F.

The vegetation is generally not native to the islands and consists of thorny brush and Hurricane grass in the formerly cleared areas. The uncleared portions of the more mountainous areas are covered by dense tropical forest with a few large trees and a dense undergrowth of brushes and vines. There are only a few free-flowing streams and these are frequently intermittent.

General Geology

The natural history and geology of the Virgin Islands have been studied by many naturalists and scientists over the years (Shomburgk, 1837; Cleve, 1881; Quin, 1907; Meyerhoff, 1926; Cederstrom, 1941, 1950; Donnelly, 1959, 1966; Helsley, 1960; Whetten, 1966; Alminas and Tucker, 1987; Tucker, 1987). Most of these studies have focused on the stratigraphic sequences and rock types.

St. Thomas and St. John are composed predominantly of volcanic rocks. The southern portions of both islands are composed of felsic flows, mafic dikes and thin beds of radiolarites, collectively called the Water Island Formation (Donnelly, 1966). Uncomformably overlying the Water Island Formation is the Louisenhoj Formation. The Louisenhoj Formation is a thick sequence of andesitic ejecta and coarse tuff beds.

The Outer Brass Limestone overlies the Louisenhoj Formation. This unit is predominantly siliceous limestone with about 10 percent interbedded crystal tuffs.

The Outer Brass Limestone is overlain by the Tutu Formation. The Tutu Formation is composed of fine- to coarse-grained volcanic wackes made up of weathered Louisenhoj rocks. Thin limestone beds are interlayered with the wackes. The Tutu Formation on Grass Cay, Mingo Cay, Lovango Cay, and Mary Point is a garnetiferous skarn. Numerous iron veins cut the skarn.

The Coki Point megabreccia lithofaces of the Tutu Formation are composed of large fossileferous limestone blocks. The fossil evidence suggests an Albian age (113-93.5 Ma). The Congo Cay Limestone Member is coarsely crystalline limestone that is exposed only on Congo Cay in the U.S. Virgin Islands.

The Hans Lollik Formation crops out on the two Hans Lollik Islands. This unit is very similar mineralogically and texturally to the Louisenhoj Formation. It should be noted that the geology of the British Virgin Islands

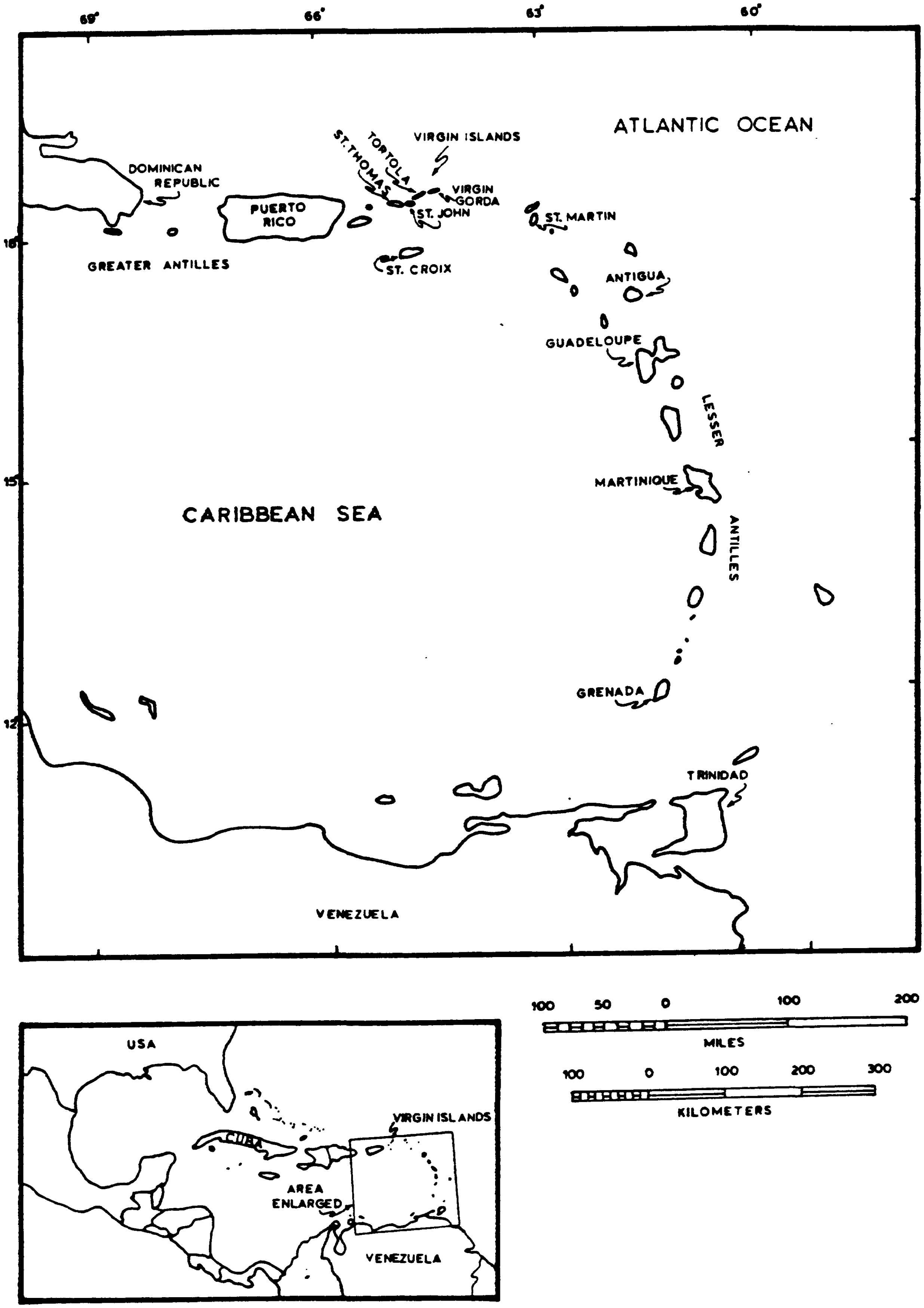


Figure 1.--Index map of the Virgin Islands and vicinity.

as described by Helsley (1960) is not a simple continuum of the layered sequence set forward by Donnelly (1966). A generalized geologic map is given on figure 2.

In conjunction with the geochemical study, five rocks from the Water Island Formation and two rocks from the Louisenhoj Formation were dated. The felsic rocks range in age from 30.9 to 65.8 MA. The andesitic rocks were dated at 38.6 and 42.1 MA (fig. 2). The Water Island and Louisenhoj Formations were dated at approximately 100 MA, based on one K-Ar whole rock date and the age of fossils in the Coki Point Megabreccia (Donnelly, 1966). The new dates indicate these formations are much younger than previously believed. Accretionary processes are undoubtedly responsible for the addition of the older sedimentary rocks onto an existing felsic platform. Felsic activity has continued over an extended period.

Interpretations of the data from stream-sediment concentrates, rocks, and soils indicate extensive mineralization occurs throughout the study area (Tucker and others, 1985; Alminas and Tucker, 1987; Tucker, 1987). The mineralization consists of precious-and-base metals associated with sulfide-rich igneous bodies and zones of hydrothermal alteration. Throughout the study area, the mineralization transects the major rock units. The geochemical anomalies identified on St. John are given on figure 3.

Sample Collection

Geochemical sampling was conducted from 1983 to 1988 on the three main islands of St. Croix, St. John, and St. Thomas, and numerous smaller islands in the region. Over 1,500 rock, soil, and stream-sediment samples were collected and analyzed for 31 elements by 6-step D.C.-arc emission spectrography (Hopkins and others, 1986; McHugh and others, 1989a). Gold analysis by atomic absorption spectroscopy is presented in McHugh and others (1989). Data for ten water-extractable ions from St. Croix and St. Thomas are presented in McHugh and others (1989b).

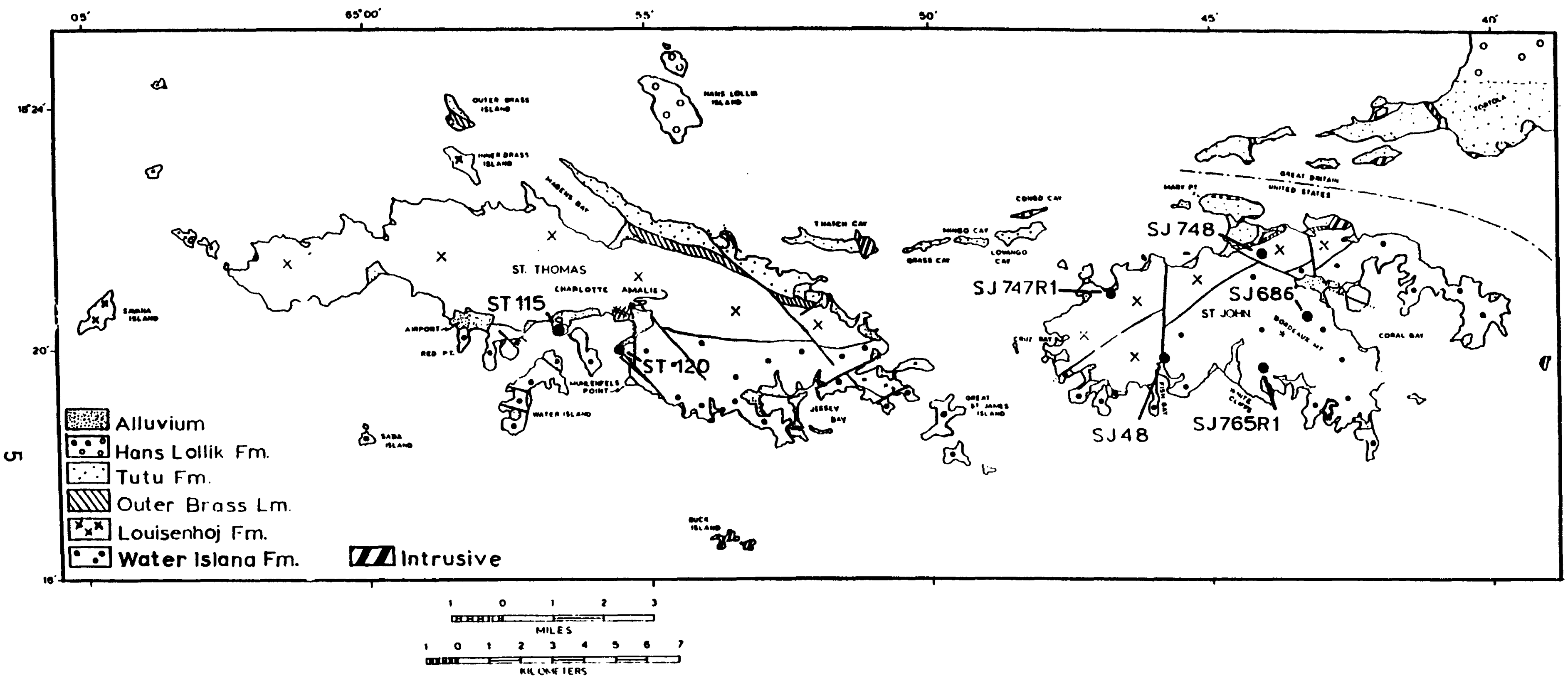
Sample collection was conducted by H.V. Alminas and R.E. Tucker. B-horizon soil samples were collected throughout the study area in conjunction with stream-sediment and rock-chip sampling. The B horizon or a zone of rather distinct reddening generally occurred at a depth of between 12 to 18 inches. In cases where no distinct B-horizon soil was present, such as in the graben infilling, on St. Croix or Bordeaux Mountain on St. John, a sample was collected at a depth of approximately 18 inches. A-horizon soils were collected on St. John as part of an extensive follow-up study. The leaf litter was cleared from an area approximately 12 inches in diameter. The top 4 inches of soil was loosened, hand mixed, placed in a cloth bag, and allowed to air dry. Approximately 1.5 pounds of soil were collected at all sample localities. The sample locality maps for St. John, is given on figure 4.

Duplicate site samples were collected at eight sites to examine the site variation. The duplicate samples were collected approximately 40 feet apart. One sample was designated as the site duplicate sample and analyzed two times.

Analytical Procedures

A. Geomicrobiology

The culture plate tests for <u>Bacillus</u> <u>cereus</u> were conducted using a nearly species specific egg yolk agar culture medium (table 1, Watterson, 1985). The culture method is summarized in table 2. All water blanks, agar medium, and



ST115	40.7 ± 1.1 Ma	SJ48	50.2 ± 5.7 Ma	SJ747R1	42.1 ± 0.6
ST120	65.8 ± 2.9 Ma	SJ685	37.7 ± 1.1 Ma	SJ748	38.6 ± 0.8 Ma
SJ765R1	30.9 ± 0.3 Ma				

Figure 2 Generalized geologic map of St. Thomas and St. John, U.S. Virgin Islands, with site localities of samples collected for K-Ar whole rock dating.

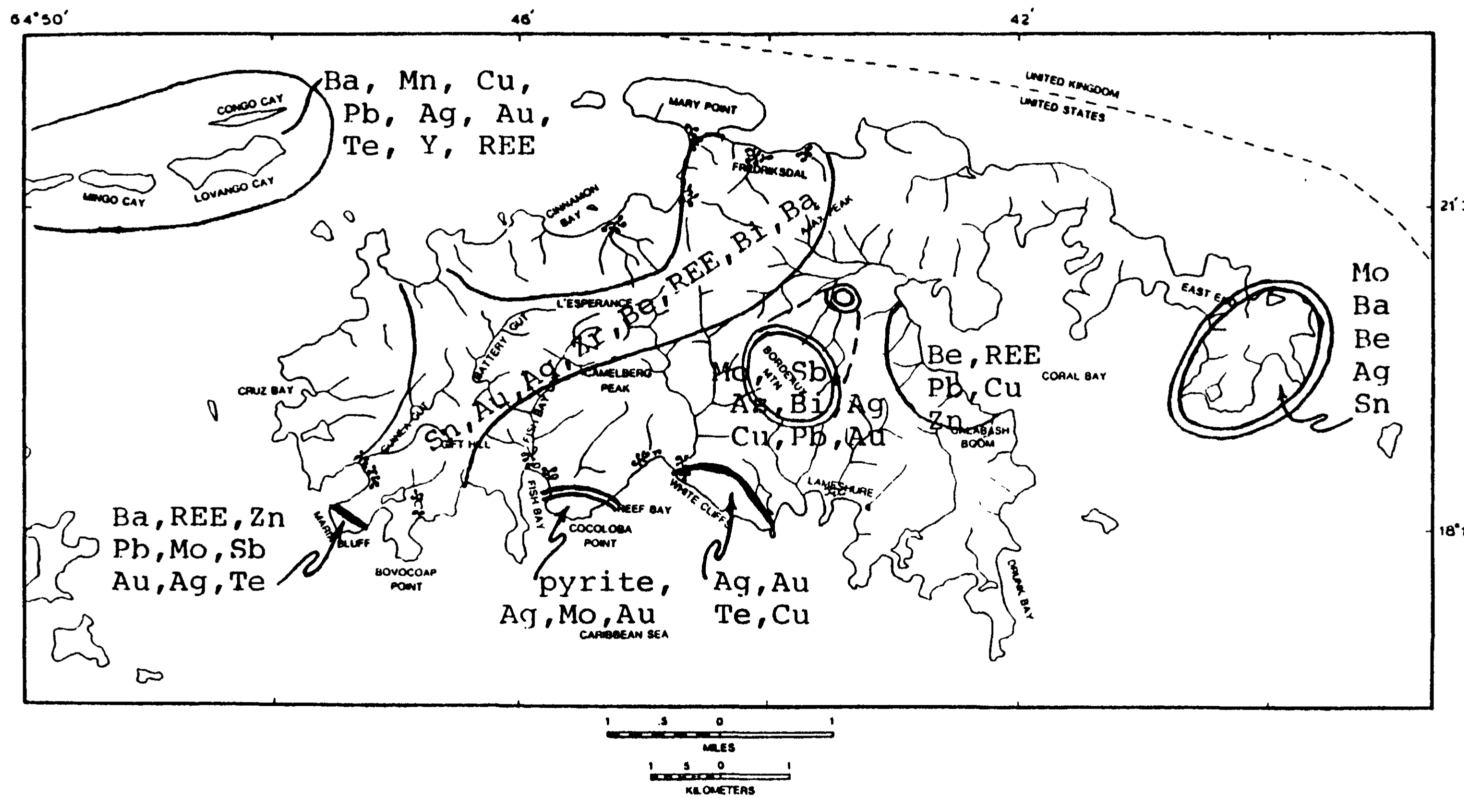


Figure 3 Geochemical anomalies identified on St. john, U.S. Virgin Islands.

= metal sulfide rich intrusives
— metallized hydrothermal cells and zones

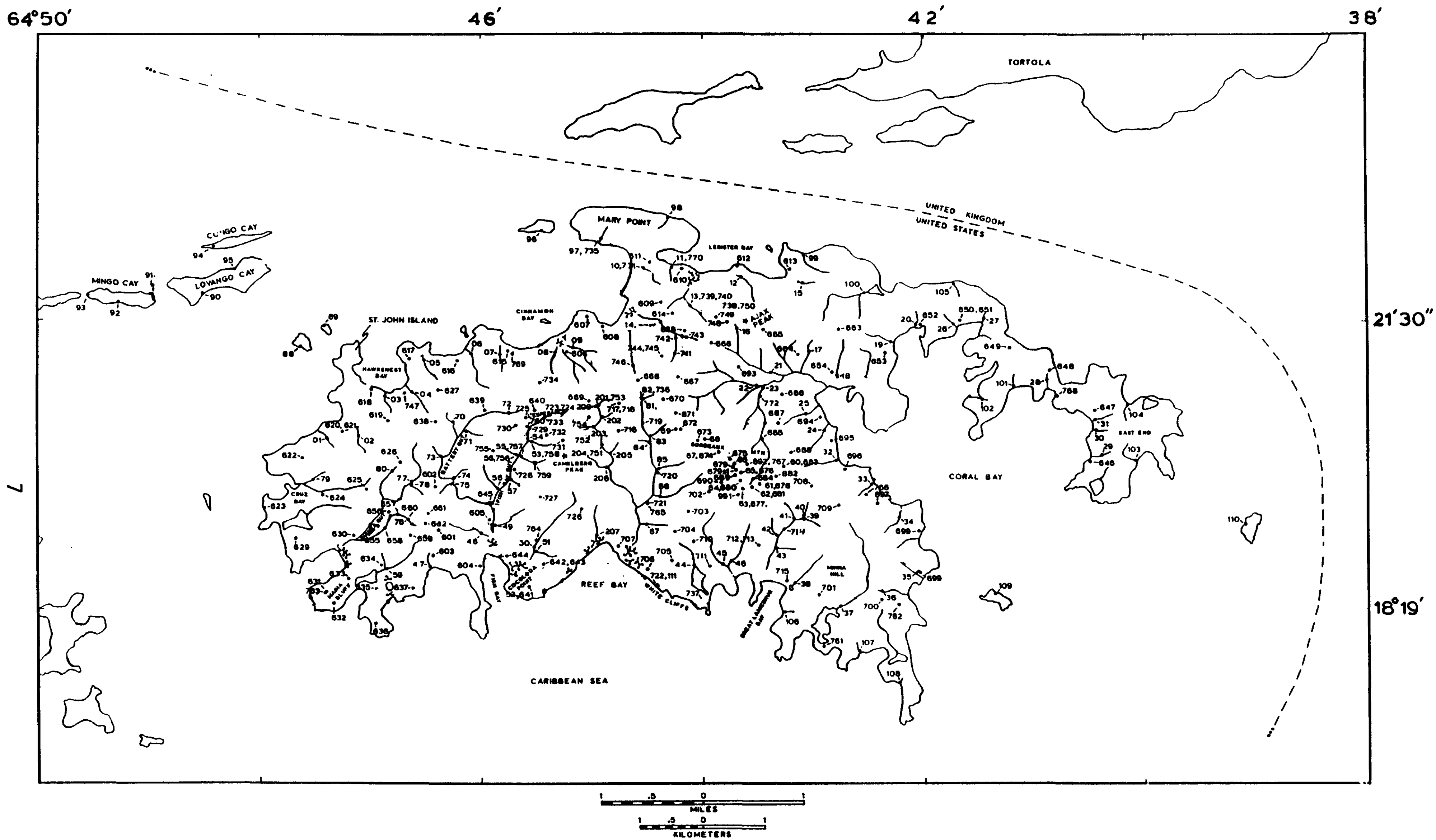


Figure 4. Sample site locality map for St. John, U.S. Virgin Islands.

Table 1.--Selective egg yolk agar used for *B. cereus* population studies

1.0 g K_2HPO_4	All ingredients added to 1 liter of deionized water, stirred well, then divided equally into 250 ml glass bottles containing agar.
0.2 g $MgSO_4$ $7H_2O$	
0.01 g Fe_2SO_4 $7H_2O$	
0.01 g $CaCl_2$	
1.0 g glucose	
1.0 g NH_4Cl	
0.1 g yeast extract	
5.0 g trisodium citrate	
Add 3 g agar to each of 4, 250 ml glass bottles.	
5 ml egg yolk per 250 ml agar, added at the time of plate pouring.	

Table 2.--Procedure for the preparation of samples for *B. cereus* culture plate assay

Step 1. Add 1 g of soil to 9 ml sterile DI water blank.
Step 2. Place tubes in a mechanical shaker for 10 minutes.
Step 3. Place tubes in a 90° C water bath for 1 minute.
Step 4. Remove tubes, quickly invert and place in cool water.
Step 5. Centrifuge at 1200 rpm for 3 minutes.
Step 6. Make 10-fold serial dilutions in distilled water, usually 3.
Step 7. Beginning at the lowest dilution, add 1 ml of solution to a petri dish.
Step 8. Add approximately 8 ml of egg yolk agar to the petri dish directly on top of the 1 ml inoculum.
Step 9. Allow agar to solidify, invert, and allow to develop at 22-29° C for about 18 hours.
Step 10. Count colonies: plates with less than 30 CFU or greater than 300 CFU may not accurately reflect the population density of *B. cereus* in the soil sample.
Step 11. Average the number of CFU from the serial dilution plate counts.

egg yolker were autoclaved at 121° C for 15 minutes. The agar was kept in a 45° C water bath and used within a few hours of preparation. The eggs were surface sterilized with 70 percent ethanol, aseptically added to the yolker in a sterile, laminar flow hood. The egg white was removed and 5 ml portions of the yolk were slowly added to 250 ml portions of agar medium.

Culture plates were prepared using 1 ml aliquot of the 10-fold serial dilutions in distilled water. The test solution was added to the center of a petri dish, gently swirled and some 8 ml of agar was poured directly on the solution and again swirled gently. The agar plates were allowed to cool, inverted, and incubated at room temperature for 18 hours. Population counts or colonies are a measure of one spore or one clump of spores that form single colony, termed a colony forming unit. The colonies are easily counted because they form diffuse white zones in the egg yolk agar due to extracellular enzymatic action. The population of B. cereus in the A-Horizon soil samples is given in Appendix 1.

Positive tests have been noted for some strains of B. anthracis and B. thuringiensis (Watterson, 1985). These two bacteria may be variants of B. cereus (Gordon, 1973). B. anthracis and B. thuringiensis are rarely found in nonagricultural soils. In rare instances, B. cereus can cause ocular damage and is a causative agent of gastroenteritis (1). All cultured plates should be considered a potential biohazard and were autoclaved before disposal.

B. Water Extraction of Soils

A water-leach extraction of the soil samples was conducted to examine the ionic concentrations of some metals and anions that could be readily available within the secondary environment. The technique involved placing 1 g of soil in a test tube with 10 ml of deionized water. The soil was thoroughly mixed and the tube was placed on its side. The samples were hand mixed every other day. Time phased dissolution experiments indicated equilibrium was reached in 5 to 7 days (Tucker, 1987). At the end of 7 days, the samples were centrifuged and the supernatant was placed in a clean test tube. The concentration of dissolved ionic constituents was determined by atomic absorption and ion chromatography (table 3). The concentration of Mg, Na, Ca, K, Cl, SO_4, F, Zn, Cu, and Ag was determined in each sample. The analytical results for the A- and B-horizon soil extractions from St. John are given in Appendices 1 and 2, respectively.

Results and Discussion

A. Geomicrobiological Study

Soil is a complex ecosystem dominated by numerous fungi and bacteria (Brock, 1974). Many kinds of fungi and bacteria compete for the same substrates (Brock, 1974; and Subba-rao and Alexander, 1985). Fungal-bacterial competition in a typical organic-rich soil mayi be minimal due to the large variety of substrate choices. However, in a stressed environment, competition for substrates will increase. Highly mineralized areas are examples of a stressed environment where metal concentrations in the soil generally reach or exceed toxic limits for most organisms.

Elevated concentrations of most heavy metals within a soil greatly disrupts the natural ecology (Brooks, 1972; Kovalevskii, 1979; Tuovinen and others, 1971; and Watterson and others, 1986) and may frequently cause environmental stresses (Brock, 1974; Ehrlich, 1978; Gottschalk, 1979; and

Table 3.--Analytical methods used for determining the concentration of water-extractable ions

Constituents	Method	Reference
SO_4, Cl, F	Ion chromatography	Fishman and Pyen (1979)
Ca, Mg, Na, K, Zn	flame atomic-absorption spectrophotometry	Perkin-Elmer Corp. (1976)
Ag, Cu	Flameless atomic-absorption spectrophotometry	Perkin-Elmer Corp. (1977)

Kuznetsov, 1963). Yet, many plants, fungi, and bacteria can, through adaptation, tolerate or even thrive in areas with elevated concentrations of heavy metals (Ballard and Grassle, 1979; Baross and Deming, 1983; Brierley, 1977, 1978; Cannon, 1960; Gottschalk, 1979; Lyalikova and Levedeva, 1984; and Tuttle and others, 1968). In highly stressed environments, such as arctic tundra or deep sea fumaroles, only a few types of organisms tend to make the adaptations necessary for survival, but tend to occur in vast numbers (Ballard and Grassle, 1979; Baross and Deming, 1983; Kushner, 1978; and Nielson and Beck, 1972).

A few species of bacteria have been observed to graze on fungi (Mitchell and Alexander, 1963). The fungi have been able to produce many chemical and physical defensive strategies to ward off bacterial attack (Pollock, 1950, 1967; and Reading and Cole, 1977). The production of antibiotics is one of the most important of these strategies. Penicillin and several other antibiotics contain the β-lactam bond. Many fungal genera produce β-lactam compounds with various side chains and functional groups (table 4 and fig. 5). The various functional groups modify the chemical and physiological activity of the compounds.

Table 4.--Microfungal genera forming penicillins and (or) cephalosporins (Ogawara, 1981).

	Aspergillus (7 species)
	Cephalosporium
D	Emericellopsis
D	Epidermophyton
	Malbranchea
	Paecilomyces
	Penicillium (23 species)
	Streptomyces
D	Trichophyton

D = dermatophytes

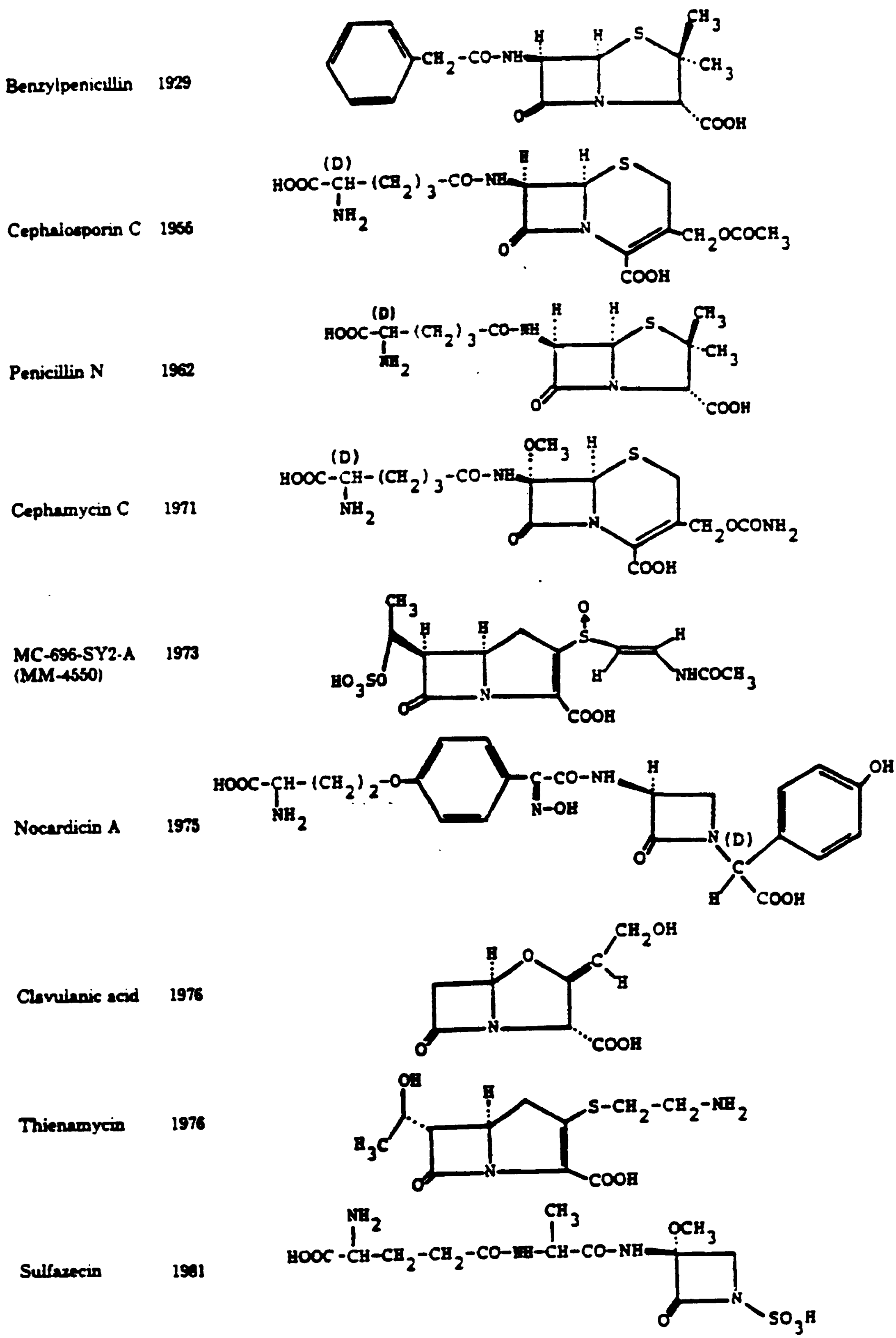


Figure 5. Structures of naturally occurring β-lactam antibiotics (Ogawara, 1981).

The production of β-lactam compounds seems to give the producing organism a slight edge in the competition for organic substrates in its environment by decreasing the numbers of susceptible and often competing bacteria. The β-lactam compounds may have several physiological reactions in the susceptible bacteria but one end result is the inability of the affected bacteria to divide and lysis often occurs (Ogawara, 1981).

Some species of bacteria produce β-lactamases, enzymes which break the β-lactam bond, which greatly reduces the effectiveness of the antibiotic (Pollock, 1950, 1967; Ogawara, 1981; and Watterson and others, 1986). Research has shown that β-lactamase varies in physical and chemical characteristics between the various producing organisms. The β-lactamase molecule may be an example of co-evolution from a variety of initial starting points to a single end activity, inactivation of the β-lactam bond. B. cereus produces at least two varieties of β-lactamase which is undoubtedly related to the wide variety of fungal species upon which they graze (table 5).

It was noted in early research that if certain metal cations were added to a solution containing penicillin, the antibacterial properties were lost (Abraham and Chain, 1942). The metals Cu, Pb, Zn, and Cd had the greatest inactivating effect, but Ni, Hg, and U also caused inactivation. The active complexing form of penicillin is the degradation product penicillamine (Watterson and others, 1986). The penicillamine-metal complex may eliminate potentially toxic concentrations of heavy metals from the immediate environment.

Table 5. Microorganisms digested by a lytic strain of Bacillus cereus (Mitchell and Alexander, 1963)

Organism	lysis
Fusarium oxysporum f. cubense	+
Fusarium oxysporum f. conglutinans	+
Fusarium solani f. phaseoli	+
Penicillium spp	+
Aspergillus spp	+
Rhizoctonia spp	+
Thielaviopsis spp	+
Pythium debaryanum	-
Stemphylium spp	+
Alternaria spp	+
Mucor spp	+
Rhizopus nigricans	+
Neurospora crassa	+
Zygorhynchus spp	+
Saccharomyces cerevisiae	-
Streptomyces spp	-
Agrobacterium spp	-
Pseudomonas spp	-

Several species of bacteria that are tolerant to high concentrations of heavy metals are also resistant to the effects of many antibiotics (Marques and others, 1979; Timoney and others, 1978; and Watterson and others, 1986). Studies conducted over two mineralized areas showed an increase of Bacillus species and particularly B. cereus in soils from over the intensely mineralized zone as compared to nonmineralized areas (Watterson and others, 1986). The B. cereus populations inhabiting the most mineralized soils were also resistant to concentrations of up to 5 μg/ml penicillin in the culture medium. A study of minus-80-mesh stream sediments collected from basins near a buried molybdenum porphyry in Utah found increased numbers of B. cereus spores in drainages near the mineralized zone (Watterson and others, 1983). Genetic coding for heavy-metal tolerance and antibiotic resistance are often found on a single plasmid. The occurrence of these two genetic coding factors on a single plasmid may reflect ecological adaptations (Watterson and others, 1986).

The results of the culture tests from soils on St. John show a wide range in B. cereus population densities. Sample 722 from the White Cliffs, has less than ten colony-forming units per gram (CFU/g) of soil. Sample 664 from the western site of Coral Bay, has over 10 million CFU/g, which is higher than any other reported soil population of B. cereus (Watterson and others, 1986; Parduhn and Watterson, 1984; Barkey and others, 1985; and Tucker unpubl. data).

Population densities of B. cereus greater than 1 million CFU/g of soil are rarely encountered in natural soils. However, in the study area, 17 samples have B. cereus populations greater than 1 million CFU/g. The very high populations of B. cereus reflect optimal growth conditions, such as high soil moisture, temperature, and abundant nutrients.

On St. John, soil samples with B. cereus population densities greater than 700,000 occur along Bordeaux Mountain, in the Ajax Peak and Fredriksdal vicinity, and several sites between Gift Hill and Camelberg Peak (fig. 6). Soils with very low B. cereus population densities occur at several sites on Bordeaux Mountain, Fredriksdal vicinity, Gift Hill, the White Cliffs, and from areas of intense alteration along the west coast of Coral Bay. There is no observed correlation of B. cereus populations with rock type, elevation, or vegetation zone.

The B. cereus populations could be affected by very localized metal-rich veins or altered zones (Parduhn, 1987; Parduhn and Watterson, 1984) or larger scale mineralization (Watterson and others, 1986). The distribution of bacterial populations has been shown to be affected by changing ecosystems. Several order of magnitude changes in B. cereus populations have been observed between pine forests (with 10 CFU or less) and meadows (with over 50,000 CFU) within a small area underlain by a uniform rock type (Tucker, unpubl. data). The natural variability of B. cereus may also be a factor for determining sample spacing.

Replicate samples were obtained by preparing two pour plates from a sample. Replicate culture assays are within the 50 percent precision of the assay technique for all samples except sample 651. The replicate assays for sample 651 gave population densities of 4 and 12 ($X10^4$) CFU/g. The large population variances may be related to factors such as extremely bacterial rich microenvironments within small clumps of soil, or counting errors due to clumping of colony-forming units. With the exception of sample 651, the minus-80-mesh fraction appears to be an adequate size fraction for B. cereus studies.

The between sample variations of B. cereus populations are much greater. Four of the eight duplicate samples have population differences greater than four fold, which is greater than the highest variation observed within a sample. The largest between sample variation occurs in samples 642 and 643

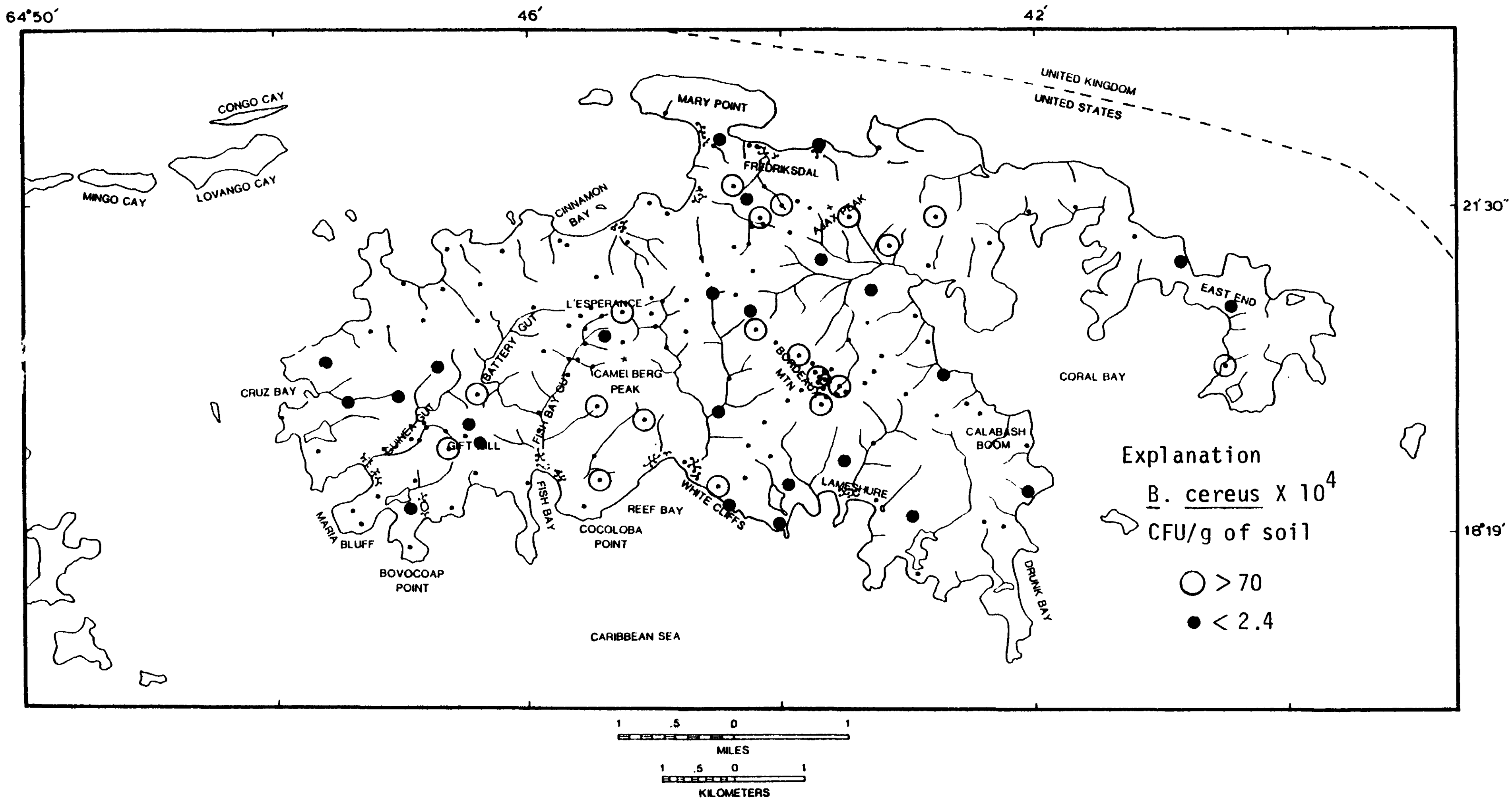


Figure 6. Distribution of B. cereus in A horizon soils, St. John, U.S. Virgin Islands.

with populations of 550 and 12 ($X10^4$) CFU/g, respectively. These samples were collected near Cocoloba Point in an area that is mineralized. The geochemical data for these two samples (Hopkins and others, 1986) and the water-extraction data (discussed later) show only minimal variations. It should also be noted that sample 739 shows a marked increase in Ca, Sr, Pb, Zn, and Sn soil concentrations compared to sample 740 (Hopkins and others, 1986). However, the B. cereus populations are virtually identical, 2.8 and 4.0 ($X10^4$ CFU/g).

To further examine the natural variability of B. cereus, a detailed sampling of the mineralized crest of Bordeaux Mountain was conducted (fig. 7). The area is covered predominantly with Bay Rum trees, which are found sparingly throughout the rest of the study areas. Over most of Bordeaux Mountain, the leaf litter exceeded 7 inches. The leaf litter found throughout the rest of the island rarely exceeded 2 inches. B. cereus populations range from 2 to 150 ($X10^4$) CFU/g. Samples 13 and 14 were collected within 15 feet of each other, but have population densities of 8.3 and 150 ($X10^4$) CFU/g, respectively. The metal concentrations (Hopkins and others, 1986) and the water extractable ions (Appendix 1) from the soils show no significant concentration differences.

There is a two order of magnitude natural variability of B. cereus in this series of samples. This large variability virtually precludes the utilization of B. cereus as an indicator of mineralization within this region, without first understanding more of the ecological and physiological responses to a greater number of geochemical and biological factors.

B. Water Extraction of Soils Study

To further examine the effect of soil-metal concentrations on B. cereus populations, a water-leach extraction was performed on the soil samples. A water-leach extraction was used because water-soluble metals would be readily available in the moist soil environment found over most of the study area. The soils on the East End of the island were much drier than the soils in the heavily vegetated areas but receive considerable rain during the wet season.

The basic statistical data for the A- and B-horizon water-extractable ions are given in tables 6 and 7, respectively. The data were logarithmically transformed. Cohens technique for mean calculation within a truncated data set was used (U.S. Geological Survey Statpac Files).

The results show that a wide range of ionic constituents occur within the data set. The concentrations of Na and Cl show the widest variation in the A-horizon site duplicate soils (Appendix 1). The water-extractable concentrations of Ca and K show the widest variation in the B-horizon site duplicates (Appendix 2).

The concentrations of K, Mg, Ca, and Ag are higher in the A-horizon soils than in B-horizon soils. Sodium, Cl, and Cu have higher mean concentrations in the B-horizon soils. Zinc shows no distinct preference in soil-horizon concentration. The small number of detectable concentrations for F and SO_4 precludes adequate comparison.

The highest concentrations of K, Mg, and Ca in the A-horizon soils may reflect a release from decaying vegetation or upwards transport due to transportation and capillary action.

The A-horizon soils have higher soluble Ag concentrations than the B-horizon soils. The high Cl and Fe concentrations of the B-horizon soils would be expected to entrap mobilized Ag ions. The enigmatic characteristics of Ag mobility suggests a strong organic complexing agent is affecting the mobility of Ag in the entire soil column.

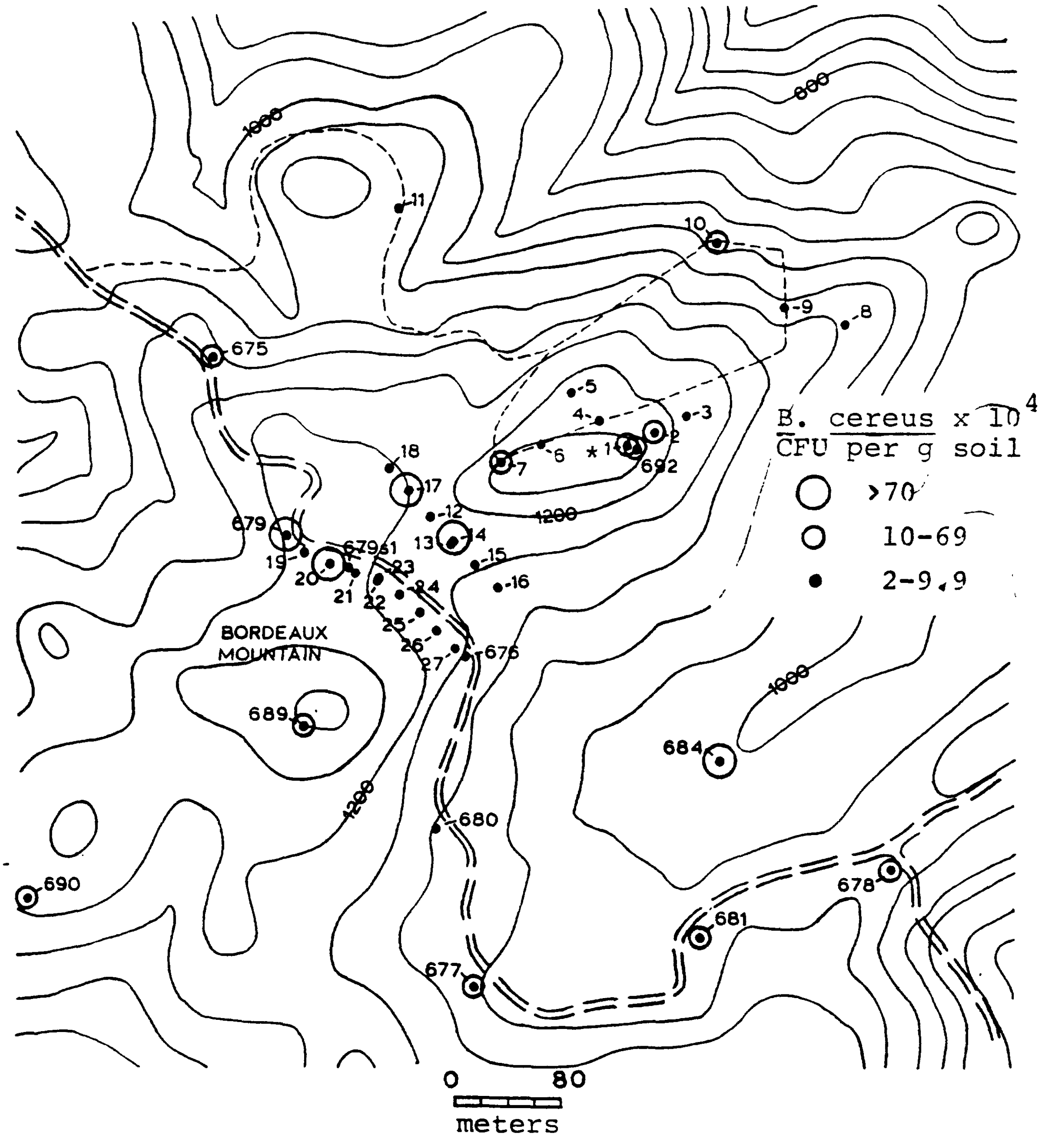


Figure 7 Distribution of B. cereus in A horizon soils from detailed sampling on Bordeaux Mountain, St. John, U.S. Virgin Islands. sites 1-27 are prefixed as SJ767 in Appendix 1.

Table 6.--Basic statistics for water-extractable ions from A-horizon soils, St. John, U.S. Virgin Islands.

Ionic species	Concentration range	Mean	Geometric mean	Standard deviation	Geometric deviation	Valid
Na mg/L	35 - 1500	180	130	210	2.0	215
Cl mg/L	21 - 2100	160	78	330	2.6	213
K mg/L	25 - 620	170	140	100	2.0	215
Mg mg/L	8.0 - 440	140	120	75	1.8	215
Ca mg/L	2.0 - 780	160	120	130	2.4	215
Zn mg/L	0.1 - 9.5	0.62	0.27	0.99	5.5	181
Ag µg/L	1.0 - 100	2.9	1.6	7.6	2.3	159
Cu mg/L*	1.0 - 8.0	2.2	1.8	1.8	1.9	56
F mg/L*	5.0 - 57	15	11	13	2.2	35
SO_4mg/L*	40 - 150	81	75	33	1.5	15

* statistical calculation on valid values only

Table 7.--Basic statistics for water-extractable ions from B-horizon soils, St. John, U.S. Virgin Islands

Ionic species	Concentration range	Mean	Geometric mean	Deviation	Geometric deviation	Valid
Na mg/L	29 - 1550	330	260	220	2.1	185
Cl mg/L	12 - 1600	450	230	410	3.8	185
K mg/L	4.0 - 270	71	52	58	2.2	185
Mg mg/L	3.0 - 260	80	56	56	2.8	184
CA mg/L	1.0 - 330	48	22	51	4.6	172
Zn mg/L	0.2 - 31	0.83	0.43	2.7	2.5	146
Ag µg/L*	1 - 97	3.7	0.95	11.	2.4	90
SO_4 mg/L*	40 - 450	84	76	51	1.5	83
Cu mg/L*	1 - 54	4.3	2.1	10	2.6	27
F mg/L*	5 - 18	7.3	6.5	4.6	1.6	9

* Statistical calculations are for valid values only

The correlation matrix for A-horizon soil data is given in table 8. In the A-horizon soils, Na has statistically significant correlation with Cl, K, Mg, and F. The highest correlation is with Cl, suggesting NaCl is a dominant species in the soil. Magnesium has statistically significant correlation with Na, K, Ca, and F. The highest correlation is with Ca, suggesting a carbonate or possibly a silicate mineral.

Silver, Cu, and Zn have statistically significant correlations with each other but show negative correlation with SO_4, approximately 0 correlation with Cl and slightly positive correlation with F (table 8). The absence of a highly correlatable anion suggests that organic complexing anions may be affecting the solubility of these metals.

B. cereus has statistically significant correlation with K, Mg, and Ca, but no correlation with Cl, Ag, Cu, Zn, and SO_4. These correlations are the reverse of what would be expected if heavy metals are contributing to the selectivity of *B. cereus* over a mineralized zone. The data suggest that other factors than just metal concentrations are affecting the populations of *B. cereus*. High concentrations of a suite of ions may have a synergistic effect on the survival of *B. cereus*. The presence or absence of an ion for which there are no data may have a greater impact on *B. cereus* populations than those ions examined in this study.

The correlation matrix for B-horizon water-extractable ions is given in table 9. In the B-horizon soils, Na has statistically significant correlation with Cl, K, Mg, Ca, and SO_4. The very high correlation coefficient with Cl suggests a NaCl association. The high correlation of Mg and Ca suggests a mineralogical association. Silver and Cu do not show a statistically significant correlation. Copper and Zn do have statistically significant correlation.

There is a change in anionic correlations with Ag, Cu, and Zn from the A-horizon to the B-horizon soils. In the A-horizon soils, SO_4 shows strong negative correlation with Ag, Cu, and Zn, but positive correlation in the B-horizon soils. Chloride shows no correlation with the three metals in the A-horizon soils but has a statistically significant correlation with Cu in the B horizon. These relationships indicate changing chemical parameters and complexing agents within the soil column.

The presence of SO_4 is a reliable geochemical indicator of the weathering of metal sulfides. The distribution of elevated SO_4 concentrations coincides very well with areas of postulated sulfide mineralization and intense alteration of Bordeaux Mountain, White Cliffs, and Maria Bluff (fig. 8). Elevated SO_4 concentrations also occur in the Gift Hill to Fredriksdal altered zone. The SO_4 concentrations may be a reflection of localized sulfides at depth and (or) the overprinting of soluble sulfate minerals, such as K_2SO_4, that were present in the hydrothermal solutions. The SO_4 distribution is not restricted to a particular rock type or rainfall patterns, but follows the mineralization and alteration trends previously delineated (fig. 4; Tucker and others, 1985; and Tucker, 1987).

The distribution of Ca concentrations in the A-horizon soils is given on figure 9. The elevated Ca concentrations occur in the highlands from Gift Hill to Ajax Peak and on Bordeaux Mountain. The elevated Ca concentrations on Bordeaux Mountain seem to reflect secondary calcite veining. The Ca distributions do not suggest that the presence of caliche is a dominant factor, except for a few sites on the East End and perhaps along the northern coast. There is a possibility that biogenic carbonate could be formed via oxidative reactions or the dissolving of land-snail-shell fragments. However, the high Ca concentrations coincide with the zones of alteration, indicating a greater contribution from the altered source material than biogenic sources.

Table 8. Correlation matrix for water extractable ions and *B. cereus* populations from A-horizon soils, logarithmically transformed, St. John, U.S. Virgin Islands

	Na	Cl	K	Mg	Ca	Ag	Cu	Zn	F	SO_4	*B. cereus*
Na	**	.82	.24	.27	-.04	.10	.01	.10	.37	-.31	.07
Cl	213*	**	.18	.13	.00	.05	.11	-.02	.02	-.24	-.01
K	215	213	**	.56	.31	-.08	-.03	.26	.53	-.11	.35
Mg	215	213	215	**	.70	-.10	-.38	-.15	.57	-.41	.46
Ca	215	213	215	215	**	-.20	-.52	-.30	.39	-.29	.32
Ag	159	157	159	159	159	**	.51	.37	.16	-.19	-.05
Cu	56	55	56	56	56	49	**	.50	.11	.31	-.20
Zn	181	179	181	181	181	155	55	**	.30	-.29	-.05
F	35	35	35	35	35	26	14	28	**	1.00	.31
SO_4	15	15	15	15	15	11	3	14	2	**	-.14
B cereus	214	212	214	214	214	158	55	180	35	14	**

*Number of pairs used for calculating the correlation coefficients.
Underlined correlation coefficients are significant at the 95 percent confidence level.

Table 9. Correlation matrix for water extractable ions from B-horizon soils, logarithmically transformed, St. John, U.S. Virgin Islands

	Na	Cl	K	Mg	Ca	Ag	Cu	Zn	F	SO_4
Na	**	.88	.43	.39	.22	.04	.28	-.12	.04	.39
Cl	185*	**	.48	.48	.27	.00	.39	-.16	.30	.45
K	185	185	**	.43	.40	.11	.08	.02	-.30	.06
Mg	184	184	184	**	.74	-.03	-.05	-.44	-.23	-.05
Ca	172	172	172	172	**	-.14	-.21	-.46	-.58	-.14
Ag	90	90	90	89	78	**	.29	.48	.00	.29
Cu	27	27	27	27	22	23	**	.46	.00	.66
Zn	146	146	146	145	133	77	26	**	-.11	.33
F	9	9	9	9	8	4	2	7	**	.38
SO_4	88	88	88	88	86	35	17	71	4	**

*Number of pairs used for calculating the correlation coefficients.
Underlined correlation coefficients are significant at the 95 percent confidence level.

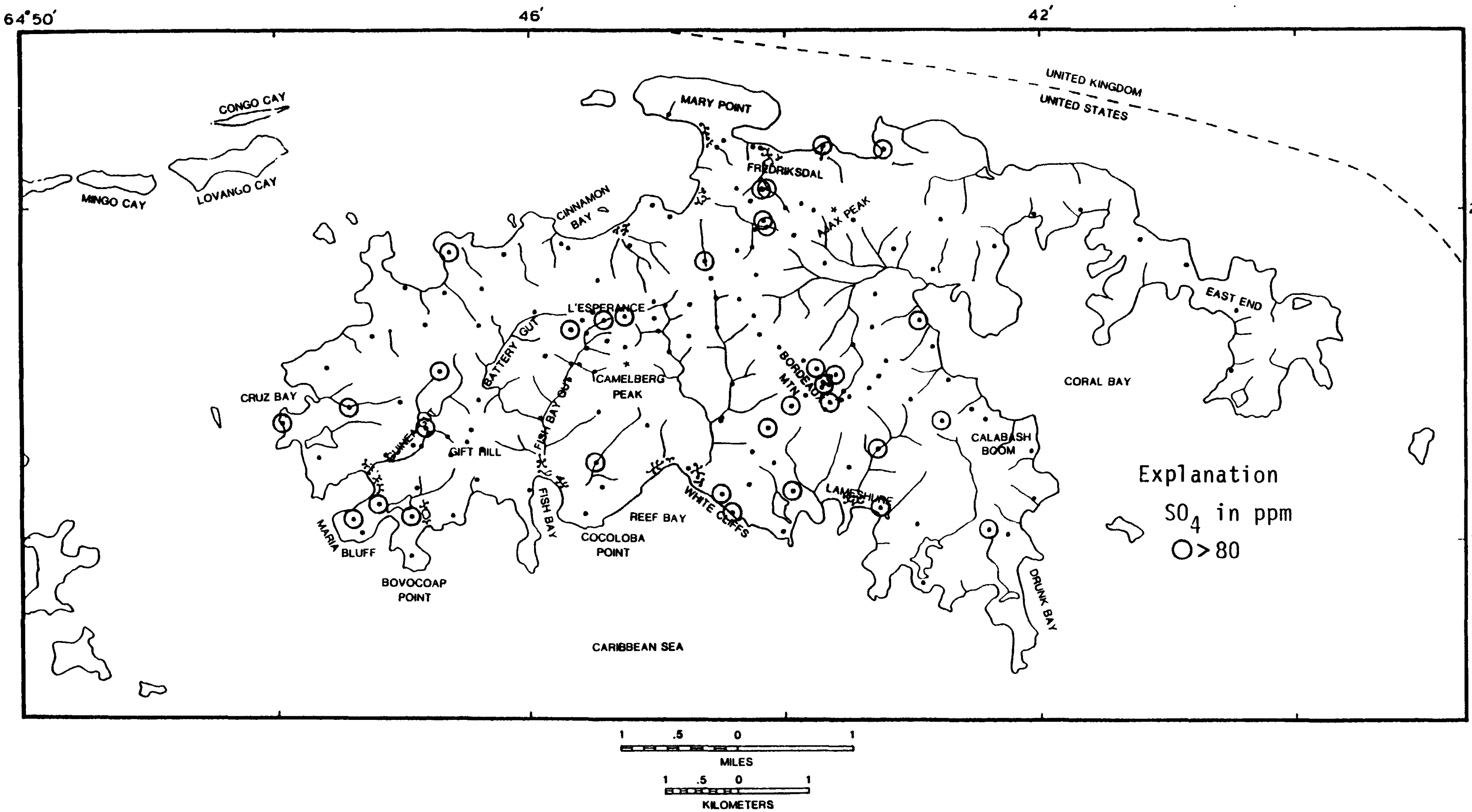


Figure 8 Distribution of elevated water soluble sulfate concentrations in B horizon soils, St. John, U.S. Virgin Islands.

The distribution of very low Ca concentrations cluster in areas of postulated sulfide mineralization or acidic alteration, such as Bordeaux Mountain, White Cliffs, and Maria Bluff. The Ca depletions can be attributed to acid leaching (pyrite weathering). The areas of high SO_4 concentrations generally coincide with the areas of Ca depletion. There is no distinct correlation of Ca concentrations with rock type, although the rocks of the Louisenhoj Formation contain a much higher Ca content than the rocks of the Water Island Formation (Tucker, 1987).

The distribution of Ca concentrations within the B-horizon soils is given on figure 10. The elevated Ca concentrations cluster in the L'Esperance and Fredriksdal areas. These areas also show a significant hydrothermal imprint in soils and rock samples (Tucker, 1987). The distribution of elevated Ca concentrations is more extensive in the B-horizon soils than in the A-horizon soils. The high Ca concentrations in these areas may represent a movement of Ca ions upwards from a deeper source region.

The distribution of Cl concentrations in the A-horizon soils is given on figure 11. The elevated Cl concentrations cluster in the altered zone between L'Esperance to Fredriksdal and near Lameshure. The sites with elevated Cl concentrations transect the Louisenhoj-Water Island formational boundary in the central highlands. The distribution of low Cl concentrations cluster in the Bordeaux Mountain vicinity, near the west side of Coral Bay and near some zones of intense hydrothermal alteration. The low Cl concentrations may reflect a more sulfide-rich parent source or hydrothermal alteration with minor Cl content.

The distribution of Cl concentrations in the B-horizon soils is given on figure 12. In the Bordeaux Mountain area and the L'Esperance to Fredriksdal zone, both high and low Cl concentrations occur in close proximity. These relationships are difficult to interpret geochemically.

Elevated Ag and Cu concentrations in A-horizon soils occur on Bordeaux Mountain, Maria Bluff, and in the Cocoloba Point vicinity (fig. 13). Silver occurs sparingly in the Gift Hill to Fredriksdal altered zone. The highest Ag value in the study area is 100 ppb from site 619, located northwest of Battery Gut. This site is in the Louisenhoj Formation.

Elevated Ag and Cu concentrations in B-horizon soils occur on Bordeaux Mountain, Maria Bluff, and the White Cliffs (fig. 14). Soils with elevated Cu concentrations seem to be restricted to areas of intense mineralization and hydrothermal alteration. The distribution of elevated Ag concentrations are more widespread, suggesting extensive overprinting by circulating hydrothermal waters.

Conclusions

The biogeochemical results show a very large range in B. cereus population densities throughout the study area. A natural variability of two orders of magnitude occurs in the B. cereus populations from soils in an apparently uniform ecosystem. The concentration of water-extractable Ag, Cu, and Zn show no correlation with B. cereus populations. The concentrations of other soil metals and water-extractable ions cannot account for the population differences observed in closely spaced samples. This study indicates that complex geochemical and physiological factors other than those examined have a pronounced affect on B. cereus populations. Until these factors are more closely examined, the distributions of B. cereus cannot be successfully utilized to define mineralized zones in this region.

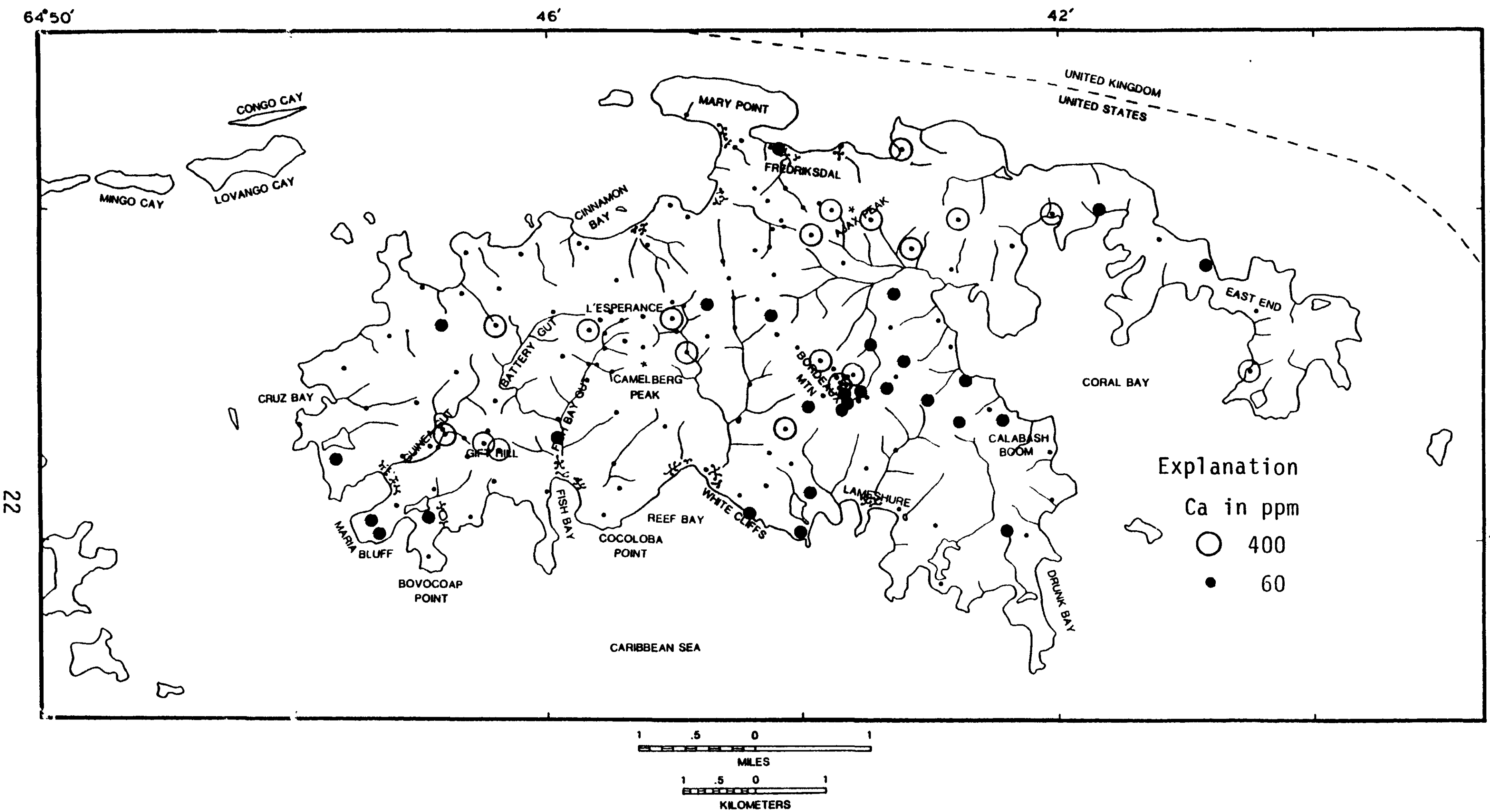


Figure 9 Distribution of water soluble calcium concentrations in A horizon soils, St. John, U.S. Virgin Islands.

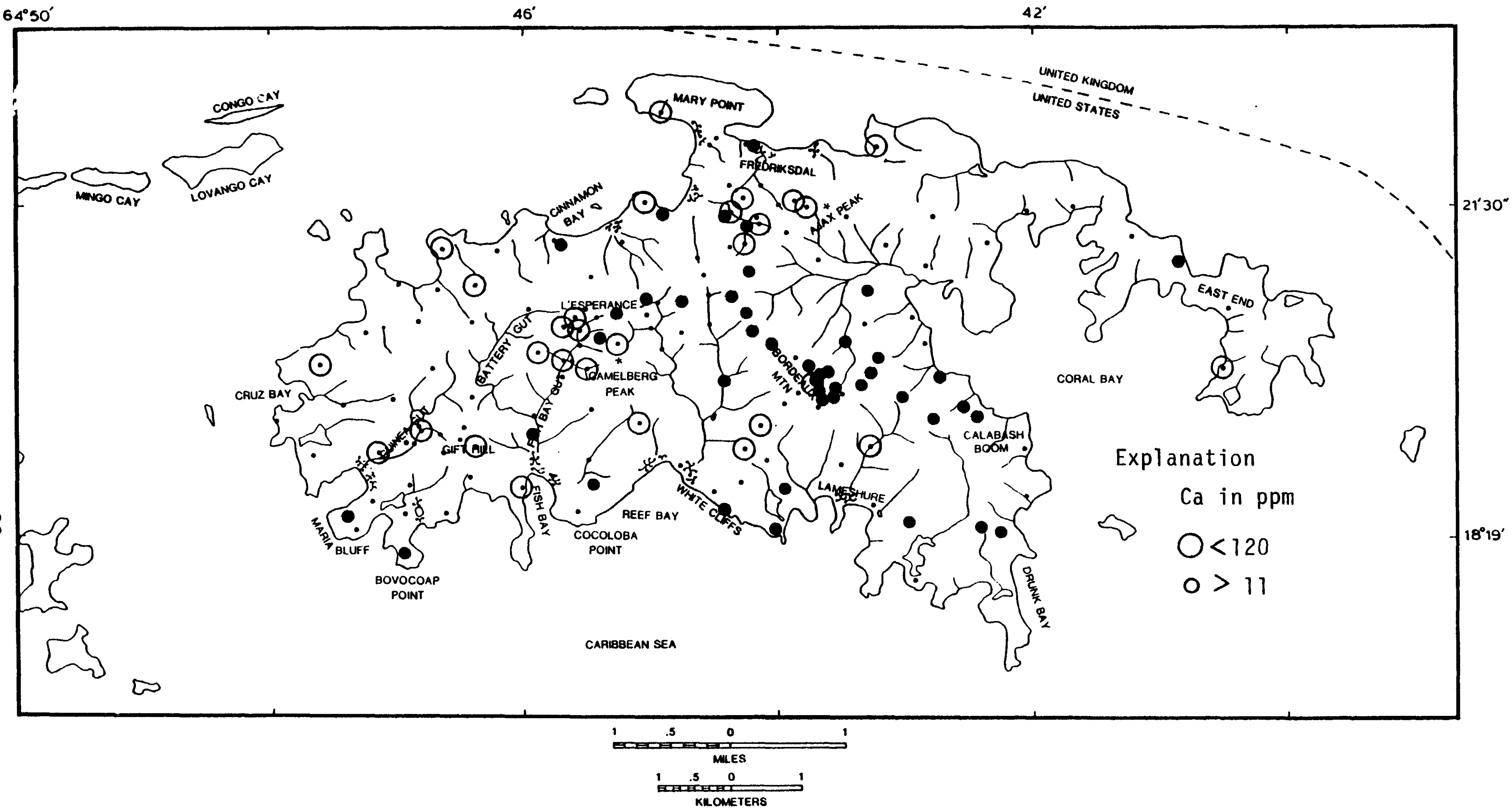


Figure 10 Distribution of water soluble calcium concentrations in B horizon soils, St. John, U.S. Virgin Islands.

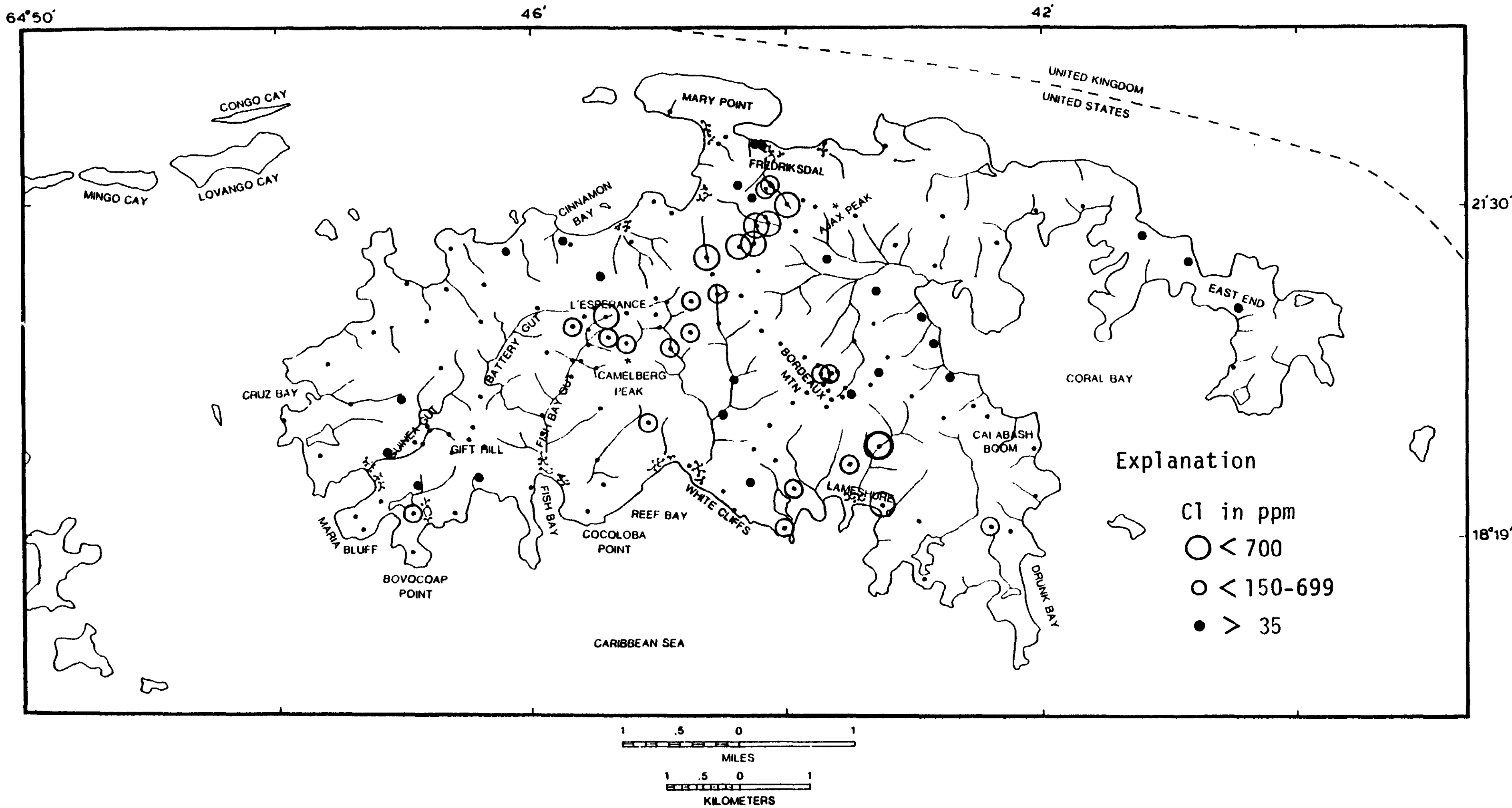


Figure 11 Distribution of water soluble chloride concentrations in A horizon soils, St. John, U.S. Virgin Islands.

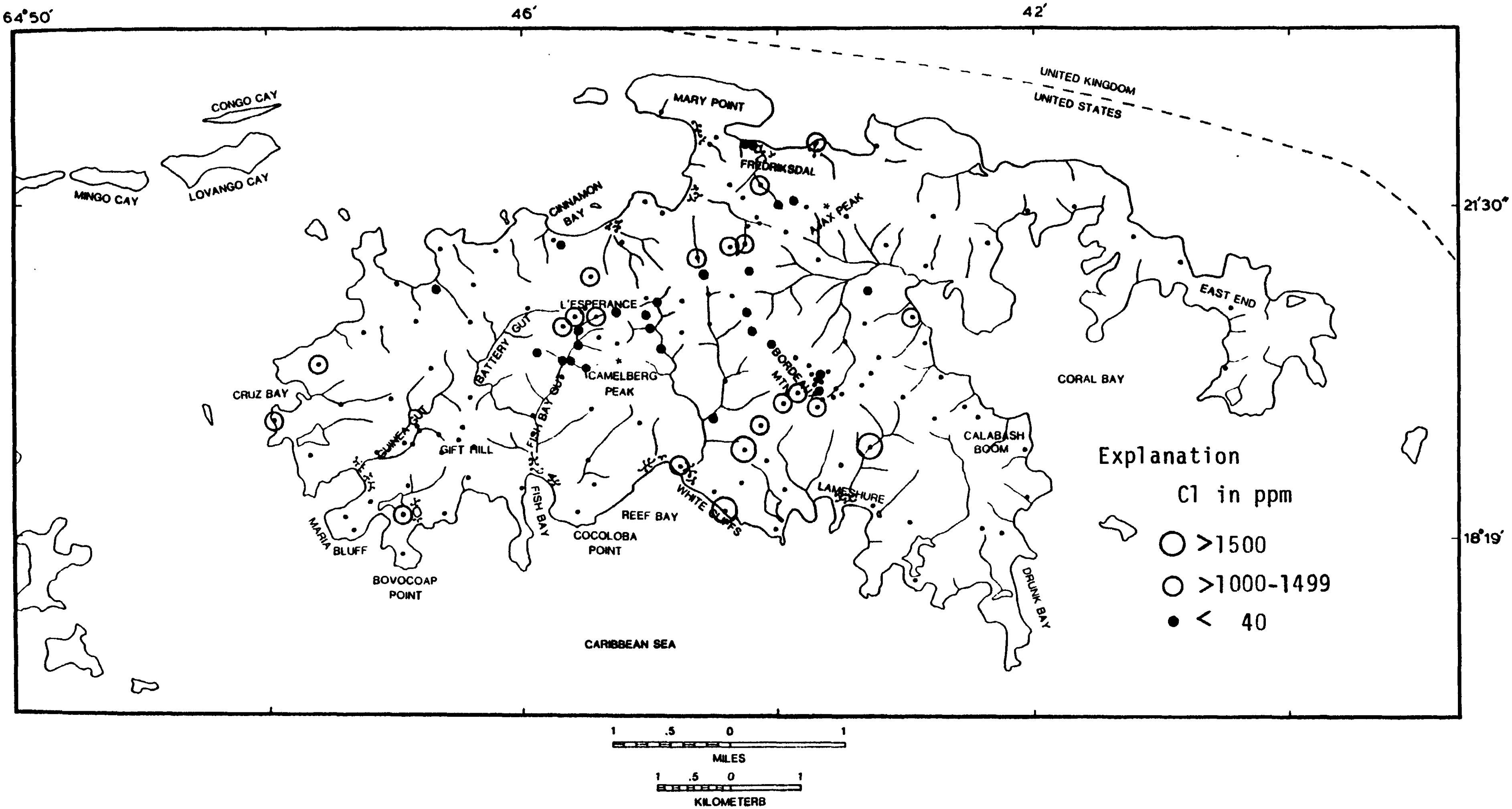


Figure 12 Distribution of water soluble chloride concentrations in B horizon soils, St. John, U.S. Virgin Islands.

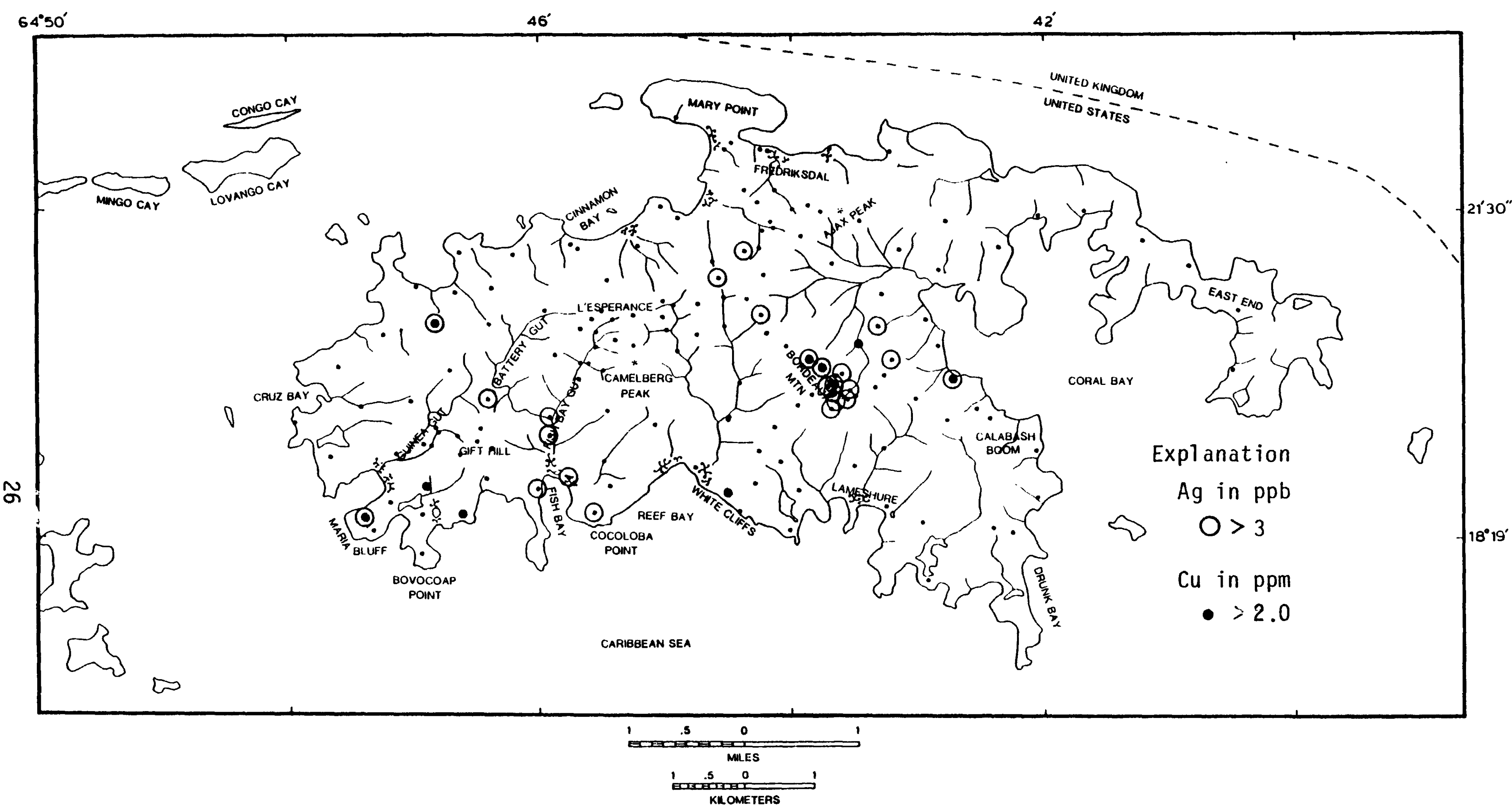


Figure 13 Distribution of elevated water soluble silver and copper concentrations in A horizon soils, St. John, U.S. Virgin Islands.

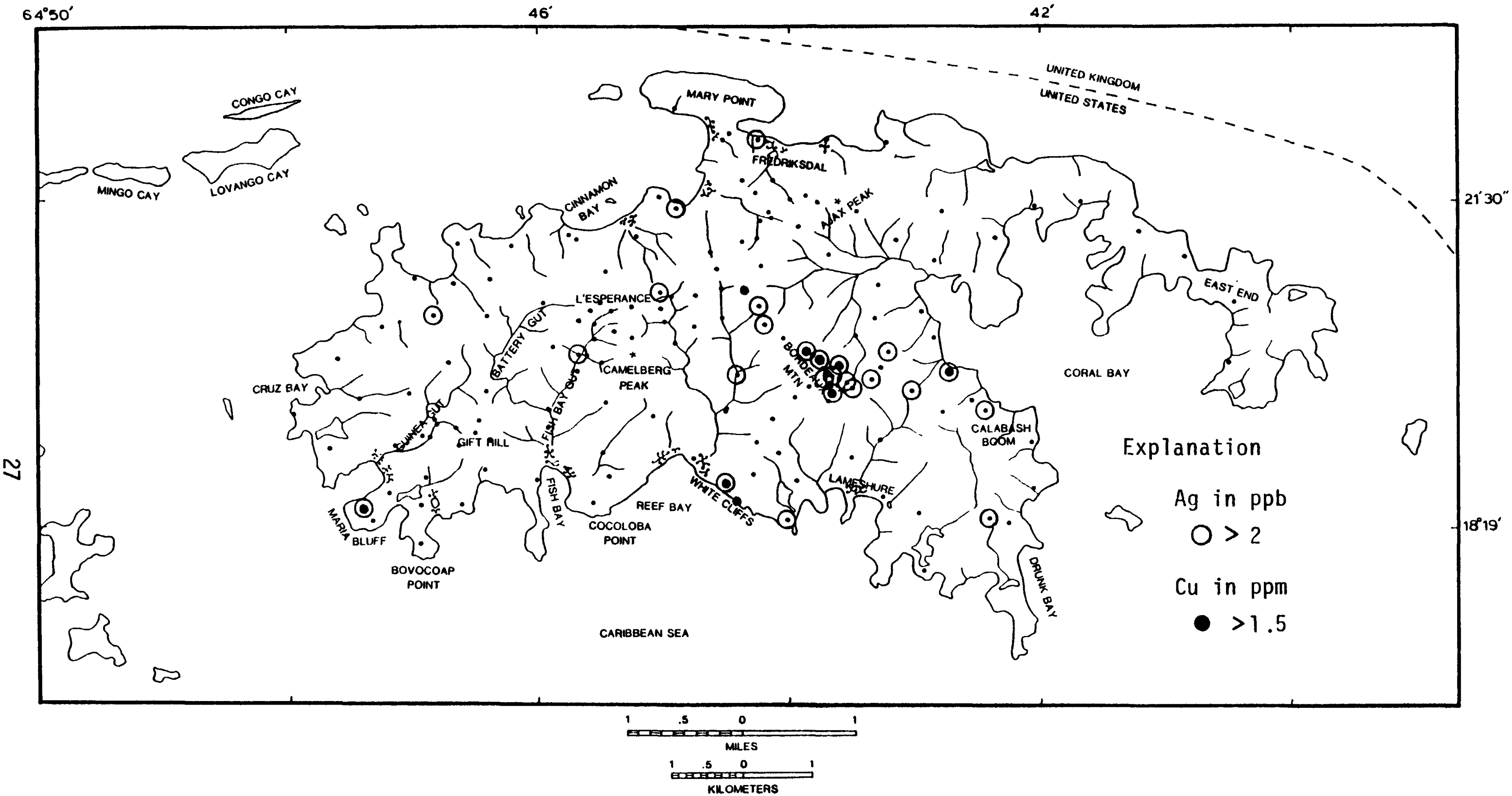


Figure 14 Distribution of elevated water soluble silver and copper concentrations in B horizon soils, St. John, U.S. Virgin Islands.

The distribution of water-extractable ions in soils coincides nicely with other analytical data from rock and soil samples (Tucker and others, 1985; Alminas and Tucker, 1987; and Tucker, 1987). The distribution of SO_4, Ag, and Cu coincides with areas of sulfide mineralization. Silver forms an extended enrichment zone around the sulfide mineralization zone. Silver also occurs in some hydrothermally altered zones, suggesting a pulsing of metal-rich solutions into the hydrothermal cells.

Calcium has been leached from within and near zones of sulfide-rich rocks and from most zones showing hydrothermal alteration. Calcium enrichment, as veins, has also occurred in some zones of hydrothermal alteration, suggesting pulsing or changing compositions of the hydrothermal solutions.

Extensive Cl enrichment occurs within the altered zone extending from Gift Hill to Fredriksdal. The Cl distribution cannot be readily correlated with rainfall patterns. The Cl concentrations are undoubtedly related to movement of soluble salts into the A-horizon soils from an enriched source at depth, such as, fluid inclusions or alteration phases. The elevated Cl concentrations associated with many hydrothermally altered areas or hydrothermal cells suggests a possible significant seawater component in the hydrothermal solutions. The Cl distribution transects all rock types indicating that at least one phase of mineralization occurred after the postulated accretion of material onto the original platform.

The upward migration of ionic constituents within the soil column appears to reflect the mineralization characteristics of the underlying rocks. The examination of water-extractable constituents may be a valuable tool for geochemical exploration in areas of extensive soil or alluvium cover.

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APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND *B. CEREUS* POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS

[N, not detected; <, detected but below the limit of determination shown; >, determined to be greater than the value shown.]

Sample	LAT	LONG	NA(PPM)	CL(PPM)	K(PPM)	MG(PPM)	CA(PPM)
84SJ601A	18 19 43	64 46 23	170	55	250	190	460
SJ602A	18 20 5	64 46 24	200	54	110	200	68
SJ603A	18 19 29	64 46 26	100	34	160	90	86
SJ604A	18 19 24	64 46 0	170	72	260	200	240
SJ605A	18 19 47	64 45 55	150	45	120	98	38
SJ606A	18 21 14	64 45 13	92	42	170	140	150
SJ607A	18 21 33	64 45 2	92	37	190	180	260
SJ608A	18 21 27	64 44 54	89	47	180	200	240
SJ609A	18 21 41	64 44 23	75	21	250	90	100
SJ610A	18 21 58	64 44 11	55	26	84	64	54
SJ611A	18 22 2	64 44 29	58	<10	120	90	120
SJ612A	18 21 59	64 43 41	--	--	--	--	--
SJ613A	18 21 57	64 43 12	68	37	200	130	440
SJ614A	18 21 35	64 44 16	75	31	170	114	320
SJ615A	18 21 14	64 45 45	140	34	250	98	78
SJ616A	18 21 11	64 46 6	60	25	110	94	86
SJ617A	18 21 10	64 46 38	48	49	300	110	300
SJ618A	18 20 55	64 46 59	99	61	190	200	184
SJ619A	18 20 39	64 46 50	110	45	75	76	60
SJ620A	18 20 34	64 47 14	72	42	230	160	160
SJ621A	18 20 34	64 47 14	71	38	172	130	160
SJ621AD	18 20 34	64 47 14	58	38	160	140	170
SJ622A	18 20 19	64 47 36	86	42	98	160	130
SJ623A	18 19 54	64 47 56	110	42	210	78	78
SJ624A	18 20 1	64 47 15	64	37	69	160	130
SJ625A	18 20 3	64 47 1	82	35	86	140	76
SJ626A	18 20 17	64 46 42	100	69	130	150	84
SJ627A	18 20 55	64 46 23	92	53	99	100	110
SJ628A	18 21 25	64 44 10	100	39	250	160	240
SJ629A	18 19 38	64 47 39	210	85	130	110	42
SJ630A	18 19 40	64 47 8	78	34	140	120	320
SJ631A	18 19 10	64 47 23	150	74	300	140	92
SJ632A	18 19 4	64 47 19	82	60	140	24	16
SJ633A	18 19 17	64 47 11	120	75	240	190	130
SJ634A	18 19 24	64 46 53	130	27	110	94	64
SJ635A	18 19 12	64 46 56	130	171	140	46	38
SJ636A	18 18 53	64 46 56	190	64	170	150	110
SJ637A	18 19 12	64 46 36	190	40	200	140	64
SJ638A	18 20 38	64 46 24	60	43	180	120	500
SJ639A	18 20 44	64 45 57	60	33	110	120	150
SJ640A	18 20 44	64 45 30	98	51	150	150	120
SJ641A	18 19 12	64 45 33	130	70	200	300	200
SJ642A	18 19 12	64 45 25	110	60	260	190	280
SJ643A	18 19 12	64 45 25	101	81	184	192	240
SJ643AD	18 19 12	64 45 25	90	37	186	180	190

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND *B. CEREUS* POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	AG(PPB)	CU(PPM)	ZN(PPM)	F(PPM)	SO4(PPM)	B.CEREUS CFμ/gX10
84SJ601A	<1.0	<1.0	.9	<5	<40	2.000
SJ602A	3.1	<1.0	.3	<5	<40	75.000
SJ603A	<1.0	1.5	.9	<5	<40	6.500
SJ604A	2.8	<1.0	.5	7	<40	16.000
SJ605A	2.6	<1.0	.4	<5	<40	4.400
SJ606A	1.0	<1.0	.4	<5	<40	5.700
SJ607A	1.2	<1.0	.5	<5	<40	7.600
SJ608A	<1.0	<1.0	.3	24	<40	8.000
SJ609A	1.6	1.0	1.0	<5	<40	171.000
SJ610A	2.0	1.5	.7	<5	<40	3.400
SJ611A	1.0	<1.0	.2	<5	<40	1.900
SJ612A	--	--	--	--	--	.870
SJ613A	1.2	<1.0	.5	<5	<40	7.400
SJ614A	<1.0	<1.0	.3	<5	<40	1.700
SJ615A	1.0	1.5	.6	<5	<40	35.000
SJ616A	<1.0	1.0	.6	<5	<40	7.300
SJ617A	<1.0	<1.0	.4	<5	<40	58.000
SJ618A	<1.0	<1.0	.3	<5	<40	6.500
SJ619A	100.0	3.7	.8	<5	<40	2.900
SJ620A	1.0	1.2	.9	<5	<40	20.000
SJ621A	1.2	2.0	1.0	<5	<40	3.100
SJ621AD	1.2	<1.0	.5	<5	<40	7.100
SJ622A	1.4	1.1	.6	<5	<40	1.700
SJ623A	1.0	1.2	.8	<5	<40	31.000
SJ624A	1.6	N	.2	<5	<40	1.700
SJ625A	2.2	<1.0	.2	<5	<40	2.400
SJ626A	2.0	<1.0	.6	<5	<40	1.700
SJ627A	<1.0	<1.0	.6	<5	<40	10.000
SJ628A	1.0	1.1	.4	<5	<40	187.000
SJ629A	1.4	1.9	1.0	<5	<40	8.500
SJ630A	<1.0	<1.0	.4	<5	<40	3.200
SJ631A	15.0	3.0	2.1	<5	<40	4.400
SJ632A	1.4	<1.0	2.4	<5	<40	4.000
SJ633A	1.8	1.0	.7	<5	<40	16.000
SJ634A	1.8	2.2	.8	<5	<40	15.000
SJ635A	1.6	<1.0	1.1	<5	56	1.100
SJ636A	1.2	<1.0	.8	<5	<40	13.000
SJ637A	2.2	2.2	1.5	<5	<40	9.100
SJ638A	1.2	<1.0	.2	<5	<40	16.000
SJ639A	1.2	<1.0	.4	<5	<40	13.000
SJ640A	1.6	1.1	.7	<5	<40	14.000
SJ641A	3.0	<1.0	.8	<5	<40	15.000
SJ642A	1.2	<1.0	1.2	15	<40	550.000
SJ643A	<1.0	<1.0	.4	27	<40	12.000
SJ643AD	1.2	<1.0	.7	17	<40	20.000

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	LAT	LONG	NA(PPM)	CL(PPM)	K(PPM)	MG(PPM)	CA(PPM)
SJ644A	18 19 22	64 45 45	140	52	150	150	82
SJ645A	18 19 56	64 45 55	190	82	210	170	150
SJ646A	18 20 18	64 40 29	69	43	130	78	480
SJ647A	18 20 44	64 40 27	52	22	180	60	86
SJ648A	18 21 4	64 40 51	73	<10	33	16	14
SJ649A	18 21 17	64 41 13	110	34	450	170	98
SJ650A	18 21 30	64 41 40	73	48	250	58	56
SJ651A	18 21 30	64 41 40	54	38	290	100	84
SJ651AD	18 21 30	64 41 40	69	26	300	80	50
SJ652A	18 21 28	64 42 2	100	53	120	130	360
SJ653A	18 21 14	64 42 22	120	41	230	150	150
SJ654A	18 21 4	64 42 50	100	41	190	150	96
SJ655A	18 19 44	64 46 55	120	56	130	100	180
SJ656A	18 19 52	64 46 48	120	51	110	120	200
SJ657A	18 19 50	64 47 47	72	63	300	220	540
SJ658A	18 19 44	64 46 51	86	36	150	100	94
SJ659A	18 19 40	64 46 37	160	65	210	220	140
SJ660A	18 19 47	64 46 37	87	50	170	170	320
SJ661A	18 19 51	64 46 28	110	43	140	180	120
SJ662A	18 19 36	64 46 30	83	40	89	190	360
SJ663A	18 21 25	64 42 46	91	53	460	300	460
SJ664A	18 21 13	64 43 8	150	74	360	300	380
SJ665A	18 21 25	64 43 27	170	76	300	400	540
SJ666A	18 21 19	64 43 55	120	48	200	130	440
SJ667A	18 21 0	64 44 13	140	76	290	150	92
SJ668A	18 20 59	64 44 35	120	130	620	260	300
SJ669A	18 20 48	64 45 1	170	130	250	130	70
SJ670A	18 20 49	64 44 21	230	91	190	340	150
SJ671A	18 20 42	64 44 15	100	73	350	80	42
SJ672A	18 20 34	64 44 11	170	86	190	220	110
SJ673A	18 20 29	64 44 2	110	39	68	130	62
SJ674A	18 20 20	64 43 51	110	54	140	100	360
SJ675A	18 20 19	64 43 45	190	92	390	300	220
SJ676A	18 20 11	64 43 39	340	190	310	46	16
SJ677A	18 20 4	64 43 38	120	44	97	120	30
SJ678A	18 20 6	64 43 29	84	32	240	110	130
SJ679A	18 20 14	64 43 44	340	240	380	440	460
SJ680A	18 20 7	64 43 40	88	43	88	40	20
SJ681A	18 20 5	64 43 33	120	41	100	150	62
SJ682A	18 20 10	64 43 20	160	85	180	120	54
SJ683A	18 20 15	64 43 16	86	21	260	110	60
SJ684A	18 20 8	64 43 33	130	60	150	170	54
SJ685A	18 20 30	64 43 27	160	37	100	160	54
SJ686A	18 20 52	64 43 17	100	32	92	120	42
SJ687A	18 20 37	64 43 19	130	60	220	120	150

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	AG(PPB)	CU(PPM)	ZN(PPM)	F(PPM)	SO4(PPM)	B.CEREUS
SJ644A	2.8	<1.0	.7	<5	<40	7.000
SJ645A	2.8	<1.0	.3	<5	<40	11.000
SJ646A	1.6	<1.0	.6	<5	<40	130.000
SJ647A	2.2	1.2	.7	<5	<40	.940
SJ648A	1.4	1.2	.5	<5	<40	.380
SJ649A	1.2	<1.0	.5	<5	<40	13.000
SJ650A	1.4	<1.0	.8	<5	<40	11.000
SJ651A	1.0	<1.0	.4	<5	117	4.400
SJ651AD	1.6	<1.0	.6	<5	<40	12.000
SJ652A	1.4	<1.0	.4	<5	<40	2.900
SJ653A	1.2	<1.0	.6	<5	<40	8.500
SJ654A	1.8	<1.0	.4	<5	<40	8.200
SJ655A	1.8	<1.0	.4	<5	<40	7.400
SJ656A	<1.0	<1.0	.3	25	<40	8.400
SJ657A	1.2	<1.0	.2	<5	<40	20.000
SJ658A	<1.0	1.0	.9	<5	<40	19.000
SJ659A	<1.0	1.2	.4	<5	<40	179.000
SJ660A	<1.0	<1.0	.3	17	<40	8.600
SJ661A	1.8	<1.0	.4	<5	<40	1.700
SJ662A	<1.0	<1.0	.2	<5	<40	16.000
SJ663A	<1.0	<1.0	.3	<5	<40	194.000
SJ664A	<1.0	<1.0	.6	37	<40	1,130.000
SJ665A	1.6	<1.0	.3	<5	<40	140.000
SJ666A	1.0	<1.0	.4	<5	<40	16.000
SJ667A	1.4	<1.0	1.0	<5	<40	28.000
SJ668A	2.6	<1.0	1.3	<5	<40	23.000
SJ669A	2.2	<1.0	1.3	<5	<40	15.000
SJ670A	1.4	<1.0	.6	<5	<40	12.000
SJ671A	3.6	<1.0	1.0	<5	<40	1.800
SJ672A	2.0	<1.0	.7	<5	<40	191.000
SJ673A	1.2	<1.0	.2	<5	<40	41.000
SJ674A	22.0	2.0	9.0	<5	<40	167.000
SJ675A	28.0	3.8	1.4	57	<40	26.000
SJ676A	20.0	7.6	3.8	<5	<40	2.300
SJ677A	2.8	<1.0	.8	<5	<40	32.000
SJ678A	1.6	1.1	1.6	<5	<40	14.000
SJ679A	5.2	1.2	.9	<5	<40	174.000
SJ680A	10.0	3.0	3.2	<5	<40	7.800
SJ681A	2.6	<1.0	.7	<5	<40	27.000
SJ682A	2.4	<1.0	.6	<5	<40	14.000
SJ683A	1.8	<1.0	1.1	<5	<40	17.000
SJ684A	4.8	<1.0	.9	<5	<40	100.000
SJ685A	1.8	2.2	.7	<5	<40	8.200
SJ686A	1.4	<1.0	.5	<5	<40	2.100
SJ687A	2.6	<1.0	.6	<5	<40	16.000

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	LAT	LONG	NA(PPM)	CL(PPM)	K(PPM)	MG(PPM)	CA(PPM)
SJ688A	18 20 23	64 43 12	210	54	230	200	52
SJ689A	18 20 10	64 43 42	140	69	300	280	140
SJ690A	18 20 7	64 43 50	170	82	170	190	160
SJ691A	18 20 0	64 43 40	200	120	320	170	60
SJ692A	18 20 16	64 43 41	180	100	210	260	380
SJ693A	18 21 6	64 43 40	48	24	160	130	84
SJ694A	18 20 40	64 42 56	86	31	170	150	120
SJ695A	18 20 29	64 42 50	110	32	150	180	120
SJ969A	18 20 14	64 42 43	78	32	180	30	18
SJ697A	18 19 56	64 42 26	140	55	380	220	22
SJ698A	18 19 42	64 42 3	210	130	190	340	140
SJ699A	18 19 20	64 42 3	84	78	340	150	120
SJ700A	18 19 6	64 42 23	300	200	210	76	40
SJ701A	18 19 8	64 42 57	190	86	230	90	68
SJ702A	18 20 2	64 43 57	92	62	200	140	60
SJ703A	18 19 51	64 44 8	120	49	340	260	420
SJ704A	18 19 41	64 44 15	150	140	440	280	340
SJ705A	18 19 25	64 44 17	95	33	180	220	130
SJ706A	18 19 21	64 44 30	140	95	290	220	100
SJ707A	18 19 33	64 44 45	200	100	150	180	72
SJ708A	18 20 5	64 43 1	110	70	130	58	30
SJ709A	18 19 55	64 42 46	130	130	180	88	52
SJ709A	18 19 25	64 42 29	130	130	180	88	52
SJ710A	18 19 36	64 44 5	100	62	150	200	140
SJ711A	18 19 23	64 43 52	440	520	69	46	14
SJ712A	18 19 34	64 43 29	480	460	160	120	64
SJ713A	18 19 34	64 43 29	660	820	150	130	58
SJ713AD	18 19 34	64 53 29	640	990	140	120	44
SJ714A	18 19 43	64 43 15	800	1,500	230	260	280
SJ715A	18 19 15	64 43 14	900	1,400	300	300	320
SJ716A	18 20 33	64 44 45	370	400	250	200	180
SJ717A	18 20 47	64 44 45	480	630	100	54	32
SJ718A	18 20 47	64 44 45	130	58	140	78	26
SJ718AD	18 20 47	64 44 45	110	58	145	74	30
SJ719A	18 20 37	64 44 32	75	51	240	140	96
SJ720A	18 20 12	64 44 24	120	32	190	200	120
SJ721A	18 19 56	64 44 30	77	29	120	140	100
SJ722A	18 19 13	64 44 25	150	140	44	8	2
SJ723A	18 20 42	64 45 15	110	58	130	220	180
SJ724A	18 20 42	64 45 15	110	76	110	160	158
SJ724AD	18 20 42	64 45 15	125	68	110	168	150
SJ725A	18 20 40	64 45 35	100	70	120	150	76
SJ726A	18 19 52	64 45 5	280	180	180	220	280
SJ727A	18 19 59	64 45 35	150	140	180	170	170
SJ728A	18 20 13	64 45 41	120	91	160	160	80

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	AG(PPB)	CU(PPM)	ZN(PPM)	F(PPM)	SO4(PPM)	B.CEREUS
SJ688A	9.0	1.0	1.3	<5	<40	2.900
SJ689A	8.0	3.0	.4	15	<40	14.000
SJ690A	2.2	<1.0	.5	<5	<40	22.000
SJ691A	4.2	<1.0	.3	<5	<40	287.000
SJ692A	12.0	1.2	1.1	34	<40	10.000
SJ693A	<1.0	1.1	.3	<5	<40	2.300
SJ694A	1.0	<1.0	.6	<5	<40	16.000
SJ695A	1.8	<1.0	.3	<5	<40	18.000
SJ969A	13.0	8.0	9.5	<5	<40	1.400
SJ697A	3.0	1.4	.9	10	<40	11.000
SJ698A	1.0	1.0	.7	<5	<40	23.000
SJ699A	1.8	<1.0	.5	<5	<40	.860
SJ700A	2.2	<1.0	.8	<5	<40	3.300
SJ701A	2.4	<1.0	.9	<5	<40	1.800
SJ702A	2.0	<1.0	.6	<5	<40	12.000
SJ703A	1.0	<1.0	.2	<5	<40	9.500
SJ704A	1.6	<1.0	.9	<5	<40	23.000
SJ705A	2.2	<1.0	.8	<5	<40	20.000
SJ706A	2.4	7.7	1.5	<5	<40	75.000
SJ707A	2.2	<1.0	.7	<5	<40	9.800
SJ708A	<1.0	<1.0	.3	<5	<40	31.000
SJ709A	1.6	<1.0	1.5	<5	<40	14.000
SJ709A	1.6	<1.0	1.5	<5	<40	14.000
SJ710A	1.6	<1.0	.5	<5	<40	3.900
SJ711A	1.2	<1.0	.5	<5	41	1.400
SJ712A	1.8	<1.0	1.6	<5	<40	6.200
SJ713A	1.2	<1.0	.8	14	<40	2.100
SJ713AD	1.2	<1.0	.7	<5	44	1.700
SJ714A	<1.0	<1.0	.3	<5	<40	7.600
SJ715A	<1.0	<1.0	.6	18	<40	17.000
SJ716A	1.6	<1.0	.6	<5	<40	19.000
SJ717A	<1.0	<1.0	.7	<5	<40	3.200
SJ718A	1.8	<1.0	.4	<5	<40	12.000
SJ718AD	2.4	<1.0	.5	<5	<40	14.000
SJ719A	1.4	<1.0	.4	<5	<40	8.600
SJ720A	1.2	<1.0	.9	<5	<40	9.100
SJ721A	2.2	<1.0	.7	32	<40	2.100
SJ722A	1.2	4.4	.4	<5	154	<.001
SJ723A	1.0	<1.0	.5	<5	<40	140.000
SJ724A	<1.0	1.0	.6	<5	<40	20.000
SJ724AD	<1.0	<1.0	.3	<5	<40	17.000
SJ725A	1.6	<1.0	.5	10	<40	19.000
SJ726A	1.0	<1.0	.4	8	<40	110.000
SJ727A	<1.0	<1.0	<.2	<5	<40	51.000
SJ728A	<1.0	<1.0	.4	<5	<40	20.000

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	LAT	LONG	NA(PPM)	CL(PPM)	K(PPM)	MG(PPM)	CA(PPM)
SJ729A	18 20 34	64 45 33	88	80	250	140	190
SJ730A	18 20 36	64 45 40	160	180	300	280	440
SJ731A	18 20 28	64 45 15	130	150	170	140	340
SJ732A	18 20 31	64 45 24	440	590	57	90	86
SJ733A	18 20 40	64 45 25	900	1,600	110	220	180
SJ734A	18 20 58	64 45 27	1,100	26	120	280	300
SJ735A	18 22 14	64 44 55	720	88	86	130	130
SJ736A	18 20 50	64 44 35	450	620	120	120	120
SJ737A	18 19 5	64 44 0	400	460	94	16	14
SJ738A	18 21 31	64 44 0	850	1,400	270	180	200
SJ739A	18 21 38	64 44 7	290	310	250	120	320
SJ739AA	18 21 38	64 44 9	290	310	250	120	320
SJ740A	18 21 38	64 44 7	160	190	260	110	340
SJ740AD	18 21 38	64 44 7	145	176	156	116	340
SJ741A	18 21 13	64 44 15	900	1,500	290	190	170
SJ742A	18 21 21	64 44 15	630	910	120	140	80
SJ743A	18 21 22	64 44 8	1,500	2,100	140	240	120
SJ744A	18 21 12	64 44 22	670	1,000	290	280	180
SJ745A	18 21 12	64 44 22	840	1,300	410	220	84
SJ745AD	18 21 12	64 44 22	840	1,480	420	220	200
SJ746A	18 21 7	64 44 38	1,000	1,700	150	200	190
86SJ747A	18 20 52	64 46 40	49	52	40	37	65
SJ748A	18 21 30	64 43 47	60	74	155	140	490
SJ749A	18 21 33	64 43 52	80	56	83	88	205
SJ750A	18 21 32	64 43 59	116	68	66	260	345
SJ751A	18 20 24	64 44 54	130	46	52	87	85
SJ751A1	18 20 24	64 44 54	41	82	178	160	245
SJ751A2	18 20 24	64 44 54	124	76	86	118	100
SJ751A3	18 20 24	64 44 54	96	81	225	310	455
SJ751A4	18 20 24	64 44 54	112	155	330	360	780
SJ751A5	18 20 24	64 44 54	65	62	200	200	220
SJ751A6	18 20 24	64 44 54	116	67	126	125	120
SJ751A7	18 20 24	64 44 54	104	77	115	135	160
SJ751A8	18 20 24	64 44 54	108	65	157	120	140
SJ751A9	18 20 24	64 44 54	180	74	108	135	125
SJ751A10	18 20 24	64 44 54	84	71	117	185	235
SJ751A11	18 20 24	64 44 54	54	87	165	250	335
SJ752A	18 20 36	64 44 58	45	74	53	58	68
SJ753A	18 20 46	64 44 57	84	48	30	75	100
SJ754A	18 20 41	64 45 2	49	75	120	67	450
SJ755A	18 20 23	64 45 53	56	47	59	96	330
SJ756A	18 20 20	64 45 42	100	52	42	125	205
SJ757A	18 20 19	64 45 36	57	50	28	120	250
SJ758A	18 20 27	64 45 32	77	48	42	58	120
SJ759A	18 20 16	64 45 30	76	41	25	76	105

Sample	AG(PPB)	CU(PPM)	ZN(PPM)	F(PPM)	SO4(PPM)	B.CEREUS
SJ729A	1.0	1.2	.6	<5	<40	19.000
SJ730A	1.4	<1.0	.2	<5	<40	25.000
SJ731A	2.0	<1.0	.3	<5	<40	16.000
SJ732A	<1.0	1.3	.6	<5	<40	2.200
SJ733A	<1.0	<1.0	.4	<5	59	14.000
SJ734A	<1.0	<1.0	.4	<5	68	7.900
SJ735A	2.2	1.0	.6	32	71	14.000
SJ736A	<1.0	<1.0	1.4	<5	<40	1.200
SJ737A	1.2	<1.0	.3	<5	120	.059
SJ738A	<1.0	<1.0	.5	<5	<40	83.000
SJ739A	1.0	1.0	.2	<5	<40	2.800
SJ739AA	1.0	1.0	.2	<5	<40	2.800
SJ740A	<1.0	<1.0	.5	<5	<40	4.000
SJ740AD	<1.0	<1.0	.4	<5	<40	6.100
SJ741A	<1.0	<1.0	.5	<5	110	6.400
SJ742A	<1.0	<1.0	.6	<5	<40	4.200
SJ743A	<1.0	<1.0	.5	<5	100	14.000
SJ744A	5.6	<1.0	.6	<5	<40	22.000
SJ745A	3.4	<1.0	.7	<5	<40	23.000
SJ745AD	4.0	<1.0	.4	<5	48	21.000
SJ746A	1.0	<1.0	.3	<5	68	5.400
86SJ747A	<1.0	<1.0	<.2	<5	<40	1.100
SJ748A	<1.0	<1.0	<.2	<5	<40	1.800
SJ749A	<1.0	<1.0	<.2	<5	<40	1.000
SJ750A	<1.0	<1.0	<.2	<5	<40	2.600
SJ751A	<1.0	<1.0	<.2	<5	<40	3.700
SJ751A1	1.0	<1.0	<.2	5	<40	5.500
SJ751A2	1.2	<1.0	.2	<5	<40	8.900
SJ751A3	1.0	<1.0	.2	<5	<40	9.600
SJ751A4	<1.0	<1.0	.2	<5	<40	75.000
SJ751A5	<1.0	<1.0	<.2	<5	<40	5.400
SJ751A6	1.0	<1.0	<.2	<5	<40	4.700
SJ751A7	1.0	<1.0	<.2	5	<40	2.700
SJ751A8	1.6	<1.0	<.2	<5	<40	2.900
SJ751A9	1.8	<1.0	.2	<5	<40	6.500
SJ751A10	<1.0	<1.0	<.2	<5	<40	9.600
SJ751A11	1.0	<1.0	<.2	5	<40	15.000
SJ752A	1.1	<1.0	.2	<5	<40	23.000
SJ753A	1.0	<1.0	<.2	<5	<40	5.700
SJ754A	<1.0	<1.0	<.2	6	<40	13.000
SJ755A	<1.0	<1.0	<.2	<5	<40	2.600
SJ756A	<1.0	<1.0	<.2	<5	<40	8.500
SJ757A	<1.0	<1.0	<.2	5	<40	4.500
SJ758A	<1.0	<1.0	<.2	<5	<40	6.100
SJ759A	<1.0	<1.0	<.2	<5	<40	4.000

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	LAT	LONG	NA(PPM)	CL(PPM)	K(PPM)	MG(PPM)	CA(PPM)
SJ760A	18 20 35	64 45 35	68	45	60	92	240
SJ761A	18 18 41	64 42 55	109	114	51	54	79
SJ762A	18 19 3	64 42 14	190	94	54	68	90
SJ763A	18 19 9	64 47 25	160	97	86	72	30
SJ764A	18 19 36	64 45 28	200	41	32	97	100
SJ765A	18 19 55	64 44 30	59	36	42	108	245
SJ766A	18 19 59	64 42 31	130	111	130	49	68
SJ767A1	18 20 16	64 44 34	128	92	370	195	325
SJ767A2	18 20 16	64 44 34	116	60	200	225	260
SJ767A3	18 20 16	64 44 34	165	150	48	130	160
SJ767A4	18 20 16	64 44 34	75	55	39	70	96
SJ767A5	18 20 16	64 44 34	110	59	28	64	125
SJ767A6	18 20 16	64 44 34	91	49	26	48	84
SJ767A7	18 20 16	64 44 34	86	89	155	130	225
SJ767A8	18 20 15	64 43 37	73	55	50	63	105
SJ767A9	18 20 15	64 43 37	113	116	156	57	86
SJ767A10	18 20 15	64 43 37	72	99	52	32	36
SJ767A11	18 20 21	64 43 38	80	52	45	64	57
SJ767A12	18 20 15	64 43 39	35	39	26	48	32
SJ767A13	18 20 15	64 43 39	63	47	98	160	155
SJ767A14	18 20 15	64 43 39	80	66	145	180	140
SJ767A15	18 20 15	64 43 39	128	73	220	155	180
SJ767A16	18 20 15	64 43 39	76	88	98	70	40
SJ767A17	18 20 15	64 43 39	85	71	43	53	55
SJ767A18	18 20 15	64 43 39	85	75	42	18	8
SJ767A19	18 20 13	64 43 42	59	50	48	49	42
SJ767A20	18 20 13	64 43 42	185	140	78	160	125
SJ767A21	18 20 13	64 43 42	94	78	64	66	70
SJ767A22	18 20 13	64 43 42	84	49	43	115	170
SJ767A23	18 20 11	64 43 39	160	93	58	120	130
SJ767A24	18 20 11	64 43 39	100	40	55	125	82
SJ767A25	18 20 11	64 43 39	132	50	32	135	125
SJ767A26	18 20 11	64 43 39	128	64	38	113	70
SJ767A27	18 20 11	64 43 39	135	112	62	62	60
SJ768A	18 20 49	64 40 47	92	46	40	62	96
SJ769A	18 21 14	64 45 43	73	57	112	130	275
SJ770A	18 21 59	64 44 17	50	33	52	93	180

APPENDIX 1. DATA RESULTS FOR WATER-EXTRACTABLE IONS AND B. CEREUS POPULATIONS FROM A-HORIZON SOILS, ST.JOHN, U.S. VIRGIN ISLANDS--Continued

Sample	AG(PPB)	CU(PPM)	ZN(PPM)	F(PPM)	SO4(PPM)	B.CEREUS
SJ760A	<1.0	<1.0	<.2	<5	<40	14.000
SJ761A	<1.0	<1.0	<.2	5	<40	9.800
SJ762A	<1.0	<1.0	<.2	<5	<40	6.600
SJ763A	24.0	5.8	2.5	5	67	1.400
SJ764A	1.0	<1.0	<.2	<5	<40	12.000
SJ765A	<1.0	<1.0	<.2	<5	<40	2.800
SJ766A	2.3	<1.0	<.2	<5	94	5.300
SJ767A1	2.2	<1.0	<.2	<5	<40	20.000
SJ767A2	3.4	<1.0	<.2	25	<40	15.000
SJ767A3	6.5	<1.0	.2	<5	<40	8.700
SJ767A4	3.8	<1.0	<.2	<5	<40	5.500
SJ767A5	3.2	<1.0	.2	<5	<40	6.700
SJ767A6	3.9	<1.0	.2	<5	<40	5.900
SJ767A7	2.1	<1.0	.2	<5	<40	12.000
SJ767A8	5.2	<1.0	.3	<5	<40	3.000
SJ767A9	3.7	<1.0	<.2	<5	<40	4.100
SJ767A10	2.2	<1.0	.2	<5	<40	32.000
SJ767A11	4.2	3.6	.4	<5	<40	2.500
SJ767A12	6.2	2.7	.3	<5	<40	3.400
SJ767A13	2.1	<1.0	.2	<5	<40	8.300
SJ767A14	1.7	<1.0	.2	<5	<40	150.000
SJ767A15	2.3	<1.0	<.2	<5	<40	7.500
SJ767A16	5.4	3.8	.3	5	<40	5.800
SJ767A17	2.6	1.5	.5	<5	<40	96.000
SJ767A18	3.5	6.9	2.0	<5	<40	5.800
SJ767A19	8.0	1.0	.3	5	<40	3.900
SJ767A20	3.6	1.2	.2	6	<40	75.000
SJ767A21	3.6	<1.0	.2	5	<40	9.300
SJ767A22	2.6	1.4	<.2	<5	<40	8.700
SJ767A23	2.2	2.0	.3	40	<40	9.400
SJ767A24	6.6	2.1	.7	5	<40	4.700
SJ767A25	2.5	1.0	.3	5	<40	5.400
SJ767A26	2.5	1.0	.3	6	<40	4.600
SJ767A27	4.0	1.0	.2	5	<40	5.500
SJ768A	1.2	<1.0	<.2	<5	<40	2.300
SJ769A	<1.0	<1.0	<.2	<5	<40	8.000
SJ770A	<1.0	<1.0	<.2	<5	<40	2.000

APPENDIX 2. DATA RESULTS FOR WATER-EXTRACTABLE IONS FROM B-HORIZON SOILS, ST. JOHN, U.S. VIRGIN ISLANDS

[N, not detected; <, detected but below the limit of determination shown; >, determined to be greater than the value shown.]

Sample	LAT	LONG	NA-PPM	CL-PPM	K-PPM	MG-PPM	CA-PPM	AG-PPB	CU-PPM	ZN-PPM	F-PPM	SO4-PPM
84SJ601B	18 19 43	64 46 23	450	454	160	120	140	<1.0	<1.0	.2	<5	50
SJ602B	18 20 5	64 46 24	550	776	80	190	38	1.1	<1.0	<.2	<5	<40
SJ603B	18 19 29	64 46 26	340	436	90	100	63	<1.0	<1.0	<.2	<5	<40
SJ604B	18 19 24	64 46 0	390	532	150	200	110	<1.0	<1.0	.2	<5	<40
SJ605B	18 19 47	64 45 55	330	402	43	23	4	1.0	<1.0	.6	<5	54
SJ606B	18 21 14	64 45 13	290	462	40	48	30	1.1	<1.0	.3	<5	62
SJ607B	18 21 33	64 45 2	100	48	88	140	110	1.0	<1.0	.2	<5	<40
SJ608B	18 21 27	64 44 54	210	92	23	15	5	4.0	<1.0	.4	<5	<40
SJ609B	18 21 41	64 44 23	84	39	150	71	39	1.5	<1.0	.7	<5	<40
SJ610B	18 21 58	64 44 11	100	19	20	4	<2	1.2	<1.0	.7	<5	<40
SJ611B	18 22 2	64 44 29	71	44	50	37	18	1.0	<1.0	.5	<5	<40
SJ612B	18 21 59	64 43 41	77	1,004	19	48	81	2.4	<1.0	<.2	<5	108
SJ613B	18 21 57	64 43 12	510	872	130	65	110	<1.0	<1.0	.2	<5	112
SJ614B	18 21 35	64 44 16	77	46	130	110	110	<1.0	<1.0	.8	<5	<40
SJ615B	18 21 14	64 45 45	390	394	48	32	14	<1.0	<1.0	.5	<5	44
SJ616B	18 21 11	64 46 6	160	102	60	100	28	<1.0	<1.0	.3	<5	<40
SJ617B	18 21 10	64 46 38	440	776	54	55	130	2.9	<1.0	<.2	<5	96
SJ618B	18 20 55	64 46 59	230	304	93	170	89	<1.0	<1.0	.2	<5	<40
SJ619B	18 20 39	64 46 50	450	888	34	120	79	7.5	<1.0	.3	<5	68
SJ620B	18 20 34	64 47 14	380	658	50	76	42	<1.0	<1.0	.4	<5	64
SJ621B	18 20 34	64 47 14	270	424	68	76	38	<1.0	<1.0	.3	<5	<40
SJ621BD	18 20 34	64 47 14	270	462	66	72	34	<1.0	<1.0	.4	<5	52
SJ622B	18 20 19	64 47 36	600	1,210	44	190	120	<1.0	<1.0	<.2	<5	<40
SJ623B	18 19 54	64 47 56	500	1,022	79	110	78	<1.0	<1.0	.3	<5	102
SJ624B	18 20 1	64 47 15	450	776	52	130	40	<1.0	<1.0	.3	5	86
SJ625B	18 20 3	64 47 1	88	46	26	79	20	<1.0	<1.0	.2	<5	<40
SJ626B	18 20 17	64 46 42	460	648	56	74	12	<1.0	<1.0	.4	<5	88
SJ627B	18 20 55	64 46 23	480	706	55	160	120	1.0	<1.0	.6	<5	48
SJ628B	18 21 25	64 44 10	380	556	120	100	82	<1.0	<1.0	.3	<5	108
SJ629B	18 19 38	64 47 39	370	262	31	100	30	<1.0	<1.0	.6	12	<40
SJ630B	18 19 40	64 47 8	130	150	56	86	110	<1.0	<1.0	<.2	<5	<40
SJ631B	18 19 10	64 47 23	350	482	120	65	32	10.0	1.7	2.0	<5	86
SJ632B	18 19 4	64 47 19	350	742	50	53	14	1.4	<1.0	1.0	<5	82
SJ633B	18 19 17	64 47 11	310	482	110	87	46	1.1	<1.0	.2	<5	<40
SJ634B	18 19 24	64 46 53	360	614	27	71	30	<1.0	<1.0	.8	<5	62
SJ635B	18 19 12	64 46 56	710	1,360	55	98	55	1.4	<1.0	.6	<5	148
SJ636B	18 18 53	64 46 56	500	484	57	74	9	<1.0	<1.0	.2	<5	64
SJ637B	18 19 12	64 46 36	460	482	58	57	13	1.9	1.0	.7	<5	68
SJ638B	18 20 38	64 46 24	200	204	34	44	75	<1.0	<1.0	.2	<5	<40
SJ639B	18 20 44	64 45 57	160	126	40	91	85	<1.0	<1.0	<.2	6	<40
SJ640B	18 20 44	64 45 30	270	394	37	50	20	1.3	<1.0	.4	<5	60
SJ641B	18 19 12	64 45 33	330	514	110	110	31	1.1	<1.0	.6	<5	76
SJ642B	18 19 12	64 45 25	160	88	39	36	8	1.1	<1.0	.4	<5	<40
SJ643B	18 19 12	64 45 25	200	136	75	50	20	<1.0	<1.0	.4	<5	<40
SJ643BD	18 19 12	64 45 25	200	146	71	43	20	<1.0	<1.0	.6	<5	<40

Sample	LAT	LONG	NA-PPM	CL-PPM	K-PPM	MG-PPM	CA-PPM	AG-PPB	CU-PPM	ZN-PPM	F-PPM	SO4-PPM
SJ644B	18 19 22	64 45 45	320	348	55	120	23	1.2	<1.0	.7	<5	<40
SJ645B	18 19 56	64 45 55	180	156	110	180	78	<1.0	<1.0	<.2	<5	<40
SJ646B	18 20 18	64 40 29	320	598	77	49	160	1.0	<1.0	<.2	<5	66
SJ647B	18 20 44	64 40 27	160	206	77	57	49	1.1	<1.0	.3	<5	<40
SJ648B	18 21 4	64 40 51	320	416	18	23	6	<1.0	<1.0	.3	<5	<40
SJ649B	18 21 17	64 41 13	390	556	170	120	57	<1.0	<1.0	<.2	<5	50
SJ650B	18 21 30	64 41 40	430	568	250	61	21	<1.0	<1.0	<.2	<5	62
SJ651B	18 21 30	64 41 40	330	566	160	46	24	1.0	<1.0	.6	<5	58
SJ651BD	18 21 30	64 41 40	350	532	180	50	27	1.2	<1.0	.5	<5	70
SJ652B	18 21 28	64 42 2	370	592	44	120	56	<1.0	<1.0	<.2	<5	66
SJ653B	18 21 14	64 42 22	430	562	55	59	30	<1.0	<1.0	.4	<5	54
SJ654B	18 21 4	64 42 50	320	424	30	67	22	<1.0	<1.0	.6	<5	48
SJ655B	18 19 44	64 46 55	511	794	35	62	92	<1.0	<1.0	.2	<5	72
SJ656B	18 19 52	64 46 48	460	752	30	68	75	<1.0	<1.0	.6	<5	88
SJ657B	18 19 50	64 47 47	340	588	190	180	170	<1.0	<1.0	<.2	<5	<40
SJ658B	18 19 44	64 46 51	520	870	79	130	68	<1.0	<1.0	.3	<5	<40
SJ659B	18 19 40	64 46 37	290	106	30	81	22	<1.0	<1.0	.2	<5	<40
SJ660B	18 19 47	64 46 37	280	330	34	58	82	<1.0	<1.0	<.2	<5	66
SJ661B	18 19 51	64 46 28	280	308	41	110	38	1.4	<1.0	.5	<5	<40
SJ662B	18 19 36	64 46 30	130	80	27	81	71	<1.0	<1.0	.2	<5	<40
SJ663B	18 21 25	64 42 46	280	284	260	66	64	<1.0	<1.0	.3	<5	66
SJ664B	18 21 13	64 43 8	380	588	140	220	100	<1.0	<1.0	.3	<5	<40
SJ665B	18 21 25	64 43 27	170	44	100	110	44	<1.0	<1.0	.6	<5	<40
SJ666B	18 21 19	64 43 55	260	70	90	61	67	<1.0	<1.0	.2	<5	<40
SJ667B	18 21 0	64 44 13	130	34	17	3	<2	<1.0	<1.0	.3	<5	<40
SJ668B	18 20 59	64 44 35	84	30	250	110	40	<1.0	<1.0	.5	<5	<40
SJ669B	18 20 48	64 45 1	180	54	30	20	3	2.0	1.1	.8	<5	<40
SJ670B	18 20 49	64 44 21	340	106	60	4	<2	1.8	1.7	4.4	5	<40
SJ671B	18 20 42	64 44 15	340	28	44	14	2	2.7	<1.0	.8	<5	<40
SJ672B	18 20 34	64 44 11	130	20	32	7	<2	2.0	<1.0	1.2	<5	<40
SJ673B	18 20 29	64 44 2	210	28	12	3	<2	1.6	<1.0	1.6	<5	<40
SJ674B	18 20 20	64 43 51	110	58	43	140	28	10.0	1.2	5.8	<5	<40
SJ675B	18 20 19	64 43 45	160	122	28	8	2	2.8	6.0	5.3	<5	126
SJ676B	18 20 11	64 43 39	170	94	74	110	15	5.2	<1.0	1.7	<5	<40
SJ677B	18 20 4	64 43 38	230	208	190	4	<2	3.5	6.1	31.0	<5	108
SJ678B	18 20 6	64 43 29	120	60	60	25	14	2.4	<1.0	1.1	<5	<40
SJ679B	18 20 14	64 43 44	170	172	140	140	58	1.9	1.0	.4	<5	<40
SJ679S1B	18 20 13	64 43 41	380	622	15	28	3	<1.0	<1.0	1.5	<5	62
SJ680B	18 20 7	64 43 40	68	40	32	6	<2	1.5	3.1	4.0	<5	<40
SJ681B	18 20 5	64 43 33	210	166	32	18	3	1.0	<1.0	1.1	<5	<40
SJ682B	18 20 10	64 43 20	180	58	34	25	5	3.0	<1.0	1.2	<5	<40
SJ683B	18 20 15	64 43 16	170	154	41	10	4	<1.0	<1.0	1.4	<5	<40
SJ684B	18 20 8	64 43 33	240	122	22	60	5	6.0	<1.0	1.3	<5	44
SJ685B	18 20 30	64 43 27	86	44	82	20	4	1.9	1.1	1.2	<5	<40
SJ686B	18 20 52	64 43 17	140	36	17	3	<2	1.4	<1.0	1.1	<5	<40

Sample	LAT	LONG	NA-PPM	CL-PPM	K-PPM	MG-PPM	CA-PPM	AG-PPB	CU-PPM	ZN-PPM	F-PPM	SO4-PPM
SJ687B	18 20 37	64 43 19	280	346	40	58	21	1.1	<1.0	.5	<5	<40
SJ688B	18 20 23	64 43 12	220	122	88	140	15	3.5	<1.0	.6	<5	<40
SJ689B	18 20 10	64 43 42	500	810	100	260	110	2.8	<1.0	.6	<5	<40
SJ690B	18 20 7	64 43 50	660	1,190	40	160	77	<1.0	<1.0	.2	<5	54
SJ691B	18 20 0	64 43 40	620	1,142	49	130	37	1.5	<1.0	.2	<5	<40
SJ692B	18 20 16	64 43 41	280	426	140	13	3	3.2	6.5	1.5	<5	94
SJ693B	18 21 6	64 43 40	220	342	42	130	39	<1.0	<1.0	<.2	<5	<40
SJ694B	18 20 40	64 42 56	610	1,146	30	74	14	<1.0	<1.0	.5	<5	126
SJ695B	18 20 29	64 42 50	350	504	50	97	36	1.0	<1.0	<.2	<5	60
SJ696B	18 20 14	64 42 43	210	188	58	28	7	97.0	1.8	3.5	<5	<40
SJ697B	18 19 56	64 42 26	350	352	26	9	<2	1.3	<1.0	.6	<5	<40
SJ698B	18 19 42	64 42 3	250	126	73	200	14	<1.0	<1.0	<.2	<5	<40
SJ699B	18 19 20	64 42 3	370	572	90	100	51	<1.0	<1.0	.3	<5	74
SJ700B	18 19 6	64 42 23	840	838	180	7	<2	2.2	1.1	2.9	<5	114
SJ701B	18 19 8	64 42 57	510	782	50	45	11	<1.0	<1.0	.8	<5	54
SJ702B	18 20 2	64 43 57	560	1,042	42	87	18	<1.0	<1.0	.5	<5	88
SJ703B	18 19 51	64 44 8	680	1,128	200	160	150	1.2	<1.0	<.2	5	148
SJ704B	18 19 41	64 44 15	790	1,546	200	230	120	<1.0	<1.0	<.2	<5	<40
SJ705B	18 19 25	64 44 17	560	844	47	130	64	1.0	<1.0	.4	<5	52
SJ706B	18 19 21	64 44 30	570	916	100	93	24	15.0	6.5	1.4	<5	106
SJ707B	18 19 33	64 44 45	660	1,266	37	200	64	<1.0	<1.0	<.2	<5	72
SJ708B	18 20 5	64 43 1	330	390	130	5	<2	2.2	1.1	1.2	<5	<40
SJ709B	18 19 55	64 42 46	470	788	28	38	8	<1.0	<1.0	1.2	<5	94
SJ709S1B	18 19 25	64 42 29	320	370	160	84	78	10.0	1.0	1.1	<5	<40
SJ710B	18 19 36	64 44 5	120	124	38	83	42	1.7	<1.0	<.2	<5	<40
SJ711B	18 19 23	64 43 52	410	652	38	54	8	<1.0	<1.0	.4	<5	92
SJ712B	18 19 34	64 43 29	660	776	77	120	24	<1.0	<1.0	.9	<5	<40
SJ713B	18 19 34	64 43 29	460	520	77	130	28	1.5	<1.0	.4	<5	<40
SJ713BD	18 19 34	64 53 29	470	522	80	130	31	1.0	<1.0	.3	<5	<40
SJ714B	18 19 43	64 43 15	810	1,622	100	190	110	<1.0	<1.0	<.2	<5	96
SJ715B	18 19 15	64 43 14	770	952	94	120	33	<1.0	<1.0	.4	<5	94
SJ716B	18 20 33	64 44 45	130	136	88	130	66	1.3	<1.0	.3	<5	<40
SJ717B	18 20 47	64 44 45	100	64	33	34	6	1.0	<1.0	1.6	<5	<40
SJ718B	18 20 47	64 44 45	83	66	71	53	16	1.2	<1.0	.6	<5	<40
SJ718BD	18 20 47	64 44 45	92	88	70	56	16	1.2	<1.0	.5	<5	<40
SJ719B	18 20 37	64 44 32	340	568	63	92	48	<1.0	<1.0	.7	<5	46
SJ720B	18 20 12	64 44 24	130	42	130	7	<2	3.0	<1.0	3.3	<5	<40
SJ721B	18 19 56	64 44 30	150	144	27	50	19	1.0	<1.0	1.0	<5	<40
SJ722B	18 19 13	64 44 25	950	1,578	30	64	6	<1.0	54.0	3.2	<5	454
SJ723B	18 20 42	64 45 15	140	36	14	8	2	1.0	<1.0	.5	<5	<40
SJ724B	18 20 42	64 45 15	450	782	36	50	15	<1.0	<1.0	.7	<5	100
SJ724BD	18 20 42	64 45 15	440	836	37	47	14	<1.0	<1.0	.4	<5	90
SJ725B	18 20 40	64 45 35	530	1,034	53	170	110	<1.0	<1.0	<.2	<5	<40
SJ726B	18 19 52	64 45 5	620	858	61	220	150	<1.0	<1.0	.3	5	<40
SJ727B	18 19 59	64 45 35	260	320	53	83	50	<1.0	<1.0	.7	<5	<40

Sample	LAT	LONG	NA-PPM	CL-PPM	K-PPM	MG-PPM	CA-PPM	AG-PPB	CU-PPM	ZN-PPM	F-PPM	SO4-PPM
SJ728B	18 20 13	64 45 41	500	758	97	140	27	1.0	<1.0	.7	<5	<40
SJ729B	18 20 34	64 45 33	380	586	83	98	77	<1.0	<1.0	.2	<5	56
SJ730B	18 20 36	64 45 40	720	1,206	94	130	110	<1.0	<1.0	<.2	<5	96
SJ731B	18 20 28	64 45 15	480	722	52	110	140	<1.0	<1.0	<.2	<5	48
SJ732B	18 20 31	64 45 24	390	536	26	29	7	<1.0	<1.0	.2	<5	46
SJ733B	18 20 40	64 45 25	600	1,138	62	110	48	<1.0	<1.0	.3	<5	126
SJ734B	18 20 58	64 45 27	570	1,070	55	94	40	<1.0	<1.0	.2	<5	76
SJ735B	18 22 14	64 44 55	210	158	85	120	110	<1.0	<1.0	.2	<5	<40
SJ736B	18 20 50	64 44 35	180	202	53	61	24	1.0	<1.0	.2	<5	<40
SJ737B	18 19 5	64 44 0	270	418	41	32	9	2.6	<1.0	.9	<5	64
SJ738B	18 21 31	64 44 0	340	296	92	33	12	1.2	<1.0	.8	<5	<40
SJ739B	18 21 38	64 44 7	520	1,050	270	140	130	<1.0	<1.0	.3	<5	94
SJ739S1B	18 21 38	64 44 9	1,550	1,020	35	13	4	<1.0	<1.0	.4	18	124
SJ740B	18 21 38	64 44 7	690	1,284	180	120	84	<1.0	<1.0	.4	<5	86
SJ740BD	18 21 38	64 44 7	780	1,354	190	120	80	<1.0	<1.0	.5	<5	<40
SJ741B	18 21 13	64 44 15	760	1,330	200	180	110	<1.0	<1.0	.3	<5	52
SJ742B	18 21 21	64 44 15	260	188	26	<2	<2	1.2	<1.0	1.0	<5	<40
SJ743B	18 21 22	64 44 8	570	894	37	100	28	<1.0	<1.0	.9	<5	96
SJ744B	18 21 12	64 44 22	350	576	67	140	82	1.2	1.0	<.2	<5	<40
SJ745B	18 21 12	64 44 22	790	1,386	270	170	100	1.1	<1.0	.6	<5	<40
SJ745BD	18 21 12	64 44 22	770	1,456	270	180	110	1.1	<1.0	<.2	<5	46
SJ746B	18 21 7	64 44 38	550	1,022	67	94	50	<1.0	<1.0	.3	<5	106
86SJ747B	18 20 52	64 46 40	102	32	12	35	40	<1.0	<1.0	<.2	<5	40
SJ748B	18 21 30	64 43 47	55	41	68	49	145	<1.0	<1.0	<.2	<5	<40
SJ749B	18 21 33	64 43 52	70	19	58	61	115	1.8	<1.0	<.2	<5	<40
SJ750B	18 21 32	64 43 59	315	31	22	125	170	<1.0	<1.0	<.2	<5	<40
SJ751B	18 20 24	64 44 54	136	40	74	80	22	1.8	<1.0	.8	<5	<40
SJ752B	18 20 36	64 44 58	41	40	31	42	42	<1.0	<1.0	.2	<5	<40
SJ753B	18 20 46	64 44 57	75	29	14	44	50	<1.0	<1.0	<.2	<5	<40
SJ754B	18 20 41	64 45 2	55	24	15	32	330	<1.0	<1.0	<.2	<5	<40
SJ755B	18 20 23	64 45 53	75	20	20	75	250	1.5	<1.0	<.2	<5	<40
SJ756B	18 20 20	64 45 42	245	24	12	38	28	4.1	1.0	.2	<5	<40
SJ757B	18 20 19	64 45 36	135	27	10	47	44	1.2	<1.0	.2	5	<40
SJ758B	18 20 27	64 45 32	60	17	8	24	19	1.0	<1.0	<.2	<5	<40
SJ759B	18 20 16	64 45 30	80	23	11	115	180	<1.0	<1.0	<.2	<5	<40
SJ760B	18 20 35	64 45 35	69	30	22	58	150	<1.0	<1.0	<.2	<5	<40
SJ761B	18 18 41	64 42 55	102	78	30	46	52	<1.0	<1.0	<.2	<5	<40
SJ762B	18 19 3	64 42 14	195	65	48	58	8	<1.0	1.0	.8	<5	<40
SJ763B	18 19 9	64 47 25	205	129	60	65	10	40.0	4.0	3.8	<5	177
SJ764B	18 19 36	64 45 28	330	280	60	210	13	1.0	1.2	1.5	<5	109
SJ765B	18 19 55	64 44 30	130	30	25	46	15	1.0	<1.0	.8	<5	<40
SJ766B	18 19 59	64 42 31	112	67	16	30	10	1.1	<1.0	.3	<5	55
SJ767B6	18 20 16	64 44 34	147	137	200	88	6	5.2	6.0	.9	5	44
SJ767B23	18 20 11	64 43 39	29	27	14	10	2	<1.0	1.2	.4	<5	49
SJ767B24	18 20 11	64 43 39	72	30	15	10	1	<1.0	1.4	.5	<5	146
SJ767B25	18 20 11	64 43 39	87	50	4	20	1	<1.0	<1.0	.7	<5	145
SJ767B26	18 20 11	64 43 39	60	40	15	17	1	2.4	2.1	.7	<5	70
SJ767B27	18 20 11	64 43 39	45	31	14	13	1	1.0	1.3	.5	<5	43
SJ769B	18 21 14	64 45 43	100	16	14	31	9	1.2	<1.0	.2	<5	<40
SJ770B	18 21 59	64 44 14	112	12	11	29	42	2.0	<1.0	<.2	<5	<40