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Geochemistry of Background Sediment Samples at Technical Area 39

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Summary

This report presents results of chemical analyses of 24 analytes in 16 background sediment samples collected from Ancho Canyon and Indio Canyon at Technical Area (TA) 39. Systematic variations in the background chemistry of sediments at TA-39 occur between different geomorphic settings and different particle sizes. These differences indicate that the best comparison of potentially contaminated sediments to background should utilize the most comparable subset of the background data set. The lowest concentrations of most analytes occur within coarse, well-sorted sands in active stream channels (which are dominated by quartz and sanidine crystals), and the concentrations of most analytes generally increase with decreasing sediment particle size. The concentration of U within a sample of black sand (dominated by high density magnetite grains) was within the range of other background samples. This relationship is important because the presence of higher concentrations of U in black sand deposits would thus indicate anthropogenic U that was concentrated by density as in a placer deposit.

Analyte concentrations in sediments are generally lower than those associated with B horizons in soils, but are comparable to elemental concentrations within the A and C horizons. Concentrations of elements in the sediments are strongly influenced by the total surface area available for adsorption, and concentrations of trace elements are minimal within the medium- and coarse-grained sediments with low surface areas relative to silt and clay. Different minerals concentrated in the sediments, such as magnetite, however, are higher in trace elements resulting

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mainly from ionic substitution within the mineral lattice. For example, magnetite-rich black sands are higher in As, Be, Cr, Mn, Ni, Pb, Th, U, V, and Zn relative to silicate-rich sediments.

Correlations exist between concentrations of different metals in the sediment samples (i.e., Fe and As, Fe and Be) that are similar to those present in soils at the Laboratory, although the concentrations of metals in the sediments are generally less than in the soils. Relationships between Fe and other metals of concern can be used to evaluate whether anomalously high values in a data set are within background ranges or instead reflect contamination.

Concentrations of many analytes from sampled prehistoric channel and floodplain sediments are higher than their concentrations in recent deposits, probably caused by post-depositional additions of solutes associated with shallow groundwater flow within the alluvium. The processes that increased concentrations of some trace elements within the prehistoric deposits may be similar to the processes affecting old sediments beneath the valley floor penetrated in core holes, suggesting that higher concentrations of many trace elements might be encountered in the subsurface than in surface sediment samples.

Principal components analysis (PCA) indicates that 91% of the variability in the background sediment data set can be accounted for by a single component, which is due to the strong correlations that occur between many major and trace elements. The remaining 9% is almost entirely accounted for by a second component that separates the two sample areas in Ancho and Indio Canyons. These results are similar to those obtained by PCA of the background soil data set of Longmire et al. (1995), for which overall variability is dominated by strongly correlated variation of several major and trace elements, and variation between sample sites is the second most important source of variability. Preliminary upper tolerance limits (UTLs) exceed the maximum values by up to 50%, and will require revision as more background sediment data are obtained.

Introduction

Sixteen sediment samples were collected from Ancho and Indio Canyons, TA-39 (Fig. 1), in August 1994 to provide background chemical concentrations from deposits comparable to those

collected as part of Field Unit 2 (OU 1132) site characterization activities in Ancho Canyon. TA-39 has been used as a high-explosives firing site since 1953, and contaminants of potential concern that may have dispersed during experiments include Ba, Be, Cr, Pb, Tl, and U (LANL, 1993).

Two primary sample areas were chosen to increase the chance that the range of variability in natural sediment deposits were included and that any unanticipated contamination would be detected. The main sample areas are Indio Canyon, the largest drainage basin in the Laboratory entirely within Bandelier Tuff that has had no Laboratory facilities, and a small tributary to Ancho Canyon near State Road 4 that also has no upstream Laboratory activities (Fig. 2). An additional sample site is a stream bank along Ancho Canyon that exposes prehistoric (1000-3000 year old) sediments, which was chosen to evaluate whether such old deposits could also be used to provide valid background values. Sampled deposits were chosen to maximize the natural variability that exists within these sediments, and to evaluate systematic variations in chemistry that may exist between different geomorphic settings (i.e., channel vs. floodplain; Fig. 3) and between different size fractions. Descriptions of the samples analyzed in this study are presented in Table 1.

One limitation of this sampling program is the small size of the sample set from any specific geomorphic setting or type of deposit (i.e., coarse sands in active channel), at most two per sample set. These data, therefore, may not encompass the full range of variability that exist in sediments at TA-39. However, there is generally an internal consistency in this data set and systematic variations exist between settings and size fractions, suggesting that this limited data set may be generally representative of similar settings in drainage basins underlain entirely by Bandelier Tuff.

Laboratory Methods

Sediment samples were dried at low temperature in a laboratory oven and sieved to remove gravel (> 2 mm) and roots. Splits of two large floodplain samples were dry sieved to separate the samples into three different size fractions: 0.25-2 mm (coarse and medium sand), 0.25-0.075 mm (fine sand), and < 0.075 mm (very fine sand, silt, and clay). Clumps of sediment were manually crushed, but no chemical dispersants were used and the larger size fractions may therefore contain small portions of finer particle sizes.

Sample splits of all sediment samples were subject to three laboratory pretreatment procedures: partial digestion using nitric acid (HNO_3) at pH 1 (following EPA procedure 3050), which simulates the bioavailability of elements by humans through ingestion; leaching with deionized water, for analysis of easily dissolved Cl and SO_4; and complete digestion using hydrofluoric acid (HF), to provide total elemental concentrations. Analysis of As was by electrothermal vapor atomic absorption (ETVAA); of Cl and SO_4 by ion chromatography (IC); of Ta, Th, Tl, and U by inductively coupled plasma mass spectroscopy (ICPMS); and the remainder by inductively coupled plasma emission spectroscopy (ICPES). Results of the chemical analyses are presented in Tables 2, 3, and 4.

Quality Assurance Checks

Sample splits of two bulk floodplain samples were submitted for analysis to provide an independent quality assurance (QA) check of the reproducibility of the analyses. For the combined 92 duplicate analyses of 24 analytes from the two sets of paired samples and two sample digestion procedures, 87 of the duplicate analyses (95%) were within the reported uncertainty, and three of the remainder (3%) were within twice the reported uncertainty (analyses of Al, Be, and Ni for one of the sample pairs). Only two sets of analyses (2%) were not consistent within twice the reported uncertainty, As and Ta for the paired samples FS2229 and FS2232. Overall, these results therefore indicate that the laboratory analyses can be considered reproducible within normal statistical limits.

Comparison of Channel Samples and Floodplain Samples

Significant differences in analyte concentrations are present between the samples of coarse channel sands and the bulk floodplain samples, as summarized in Tables 5 and 6. For nearly all analytes, concentrations are higher in the floodplain deposits than in the channel deposits, as shown for As, Be, and U in Figure 4. This is consistent with the dominance of quartz and sanidine phenocrysts derived from the Bandelier Tuff within the channel deposits, and with the higher concentrations of fine-grained sediment in the floodplain deposits that could both have

greater mineralogical variability (including higher abundances of clay minerals and ferric oxyhydroxides) and larger amounts of adsorbed trace elements. These differences indicate that the most precise evaluation of the presence or absence of contaminants within sediment samples and their possible concentrations should consider the geomorphic setting of the sediment samples. Specifically, lower natural concentrations of U, Be, and other analytes should be expected in the channel sands than in the floodplain deposits, and concentrations of these elements within potentially contaminated channel sediments should be compared to the coarser-grained background samples and not the full data set.

Analyses of Black (Magnetite-Rich) Sands

One sample of relatively clean black (primarily magnetite, Fe_3O_4) sand from Indio Canyon was analyzed to examine the natural elemental concentrations within these heavy mineral deposits. Field measurements of one black sand deposit near a TA-39 firing site had indicated above background radioactivity, and laboratory X-ray florescence (XRF) analyses of a sample from this site confirmed high concentrations of U (217 ppm; Ed Essington, unpublished data, 1994). It was thus hypothesized that such black sands may concentrate some anthropogenic heavy metals such as U as a "placer" deposit, and that selective sampling of black sands could provide an additional tool to examine the transport of high-density contaminants away from firing sites.

The sampled black sands from Indio Canyon (FS 2225, Tables 2 and 3) have very high concentrations of many elemental species, including the highest concentrations of Fe, Mn, Sb, Th, V, and Zn from the HNO_3 digestion and Cr, Mn, Ni, Sb, Th, V, and Zn from the HF digestion (the low reported value of Fe in the HF digestion is believed to be due to laboratory error). Notably, although the concentration of U in the black sands was higher than in the typical channel sands, it was within the range of analyses from the floodplain samples. This indicates that where concentrations of U in black sands exceed the range of background floodplain samples, anthropogenic U may be present, and supports the hypothesis that depleted uranium particles from firing sites can be concentrated downstream in black sands due to sorting of sediment particles by their respective densities during transport by surface water.

In addition to U, many other analytes are also present in higher concentrations in the black sands than in other sediments in these canyons. As an example, Figure 5 shows the elemental concentrations for the black sands and the bulk sediment samples collected within the active channel deposits in Indio Canyon. These differences in elemental concentrations indicate the importance of mineralogy in influencing trace element distributions in heterogeneous sediments. The ratio of the elemental concentration in the black sands to the concentration in nearby channel deposits varies greatly between elements, and these ratios (HNO_3 digestion) in decreasing order are: V (47) > Zn (33) > Mn (23) > Be (17) > Cr (12) > Th (10) > Ni (9) > U (5) > As (4) > Pb (3) > Sb (1). The higher concentrations in the magnetite-rich sands occur as a result of ionic substitution of the trace elements with one or more major elements within the mineral lattice (Bloss, 1971) and/or adsorption onto alteration products such as ferric oxyhydroxides (Rai and Zachara, 1984).

Comparison of Different Size Fractions Within Floodplain Samples

Two large samples of floodplain deposits, one each from Ancho and Indio Canyons, were separated into three different size fractions to further examine the relation of particle size to elemental variability. A comparison of the elemental concentrations in these separates with the coarse channel sands (Tables 7 and 8), reveal several notable points.

Concentrations of most analytes progressively increase from the coarse channel sands to the fine sand separate, although element concentrations in the fine sands are generally indistinguishable from the very fine sand, silt, and clay fraction. These variations support the general increase in trace element concentration with decreasing grain size as indicated by the comparison of the channel sands with the bulk floodplain deposits. The similarity of the two finer size separates, however, suggests either that they are mineralogically similar or that they have similar adsorptive properties. Specifically, the percentage of clay minerals in these samples is unknown, and it is possible that they have very low clay contents, being dominated by very fine sands and silts that are geochemically similar to the fine sand fractions. For example, grain size analysis of a texturally-similar floodplain deposit overlying the sampled prehistoric channel sands

in Ancho Canyon indicate the presence of only 8-9% clay-sized particles, compared with 26-44% silt and 47-66% sand (Bw1 and Bw2 horizons of Longmire et al., this report, Ancho Canyon site). Alternatively, because chemical dispersants were not used to disaggregate clays, it is possible that the coarse size fractions include aggregates of silt and clay or thin clay coatings on larger sediment particles. The higher analyte concentrations in the coarse and medium sand separates than in the channel sands suggest that the latter are perhaps better sorted, containing a higher percentage of quartz and sanidine crystals from the Bandelier Tuff, and also suggest that the coarse and medium sand separates may provide an analog with relatively "dirty" or less well sorted channel deposits.

Mud Deposit

One sample of a one-day old mud deposit from a flood in Indio Canyon (FS 2226, flood of August 24, 1994) was collected as a possible fine-grained end member of natural sedimentary deposits in this environment. This deposit has the highest concentrations analyzed for several elements, including Al, Ba, Be, Ca, Mg, Na, Pb, and U for the HNO_3 digestion and Ta, Tl, and U for the HF digestion (Tables 2 and 3). Comparisons of concentrations of As, Be, and U in the mud deposits with channel and floodplain deposits are shown in Figure 4. For several analytes, the mud deposit exceeded element concentrations in the fine floodplain fractions taking into account the analytical uncertainties. These analytes are Be, Cu, Pb, and U for both the HNO_3 and HF digestion and also Na for the HNO_3 digestion. The difference between the dominance of certain elements in the partial (HNO_3) and total (HF) digestions of samples from this deposit may be due to the presence of dissolved components that had been deposited at this site by evaporation, followed by precipitation and/or adsorption of solutes onto silt- and clay-sized sediments. Another possible complication with this deposit is that the proximity of State Road 4 may be responsible for the anomalous presence of certain elements derived from automobile exhaust, such as Pb. The high concentrations of other elements, such as U, may be more likely due to their adsorption onto silt- and clay-sized particles, although part of the U and other elements may be anthropogenic, dispersed from the TA-39 firing sites (see discussion in Longmire et al., this report, concerning possible anthropogenic U in surface horizons of some mesa-top soils).

Comparison of Modern Sediment Samples and Prehistoric Samples

Samples of prehistoric sediments exposed in a stream bank along the main fork of Ancho Canyon were analyzed to test the hypothesis that prehistoric sediments could provide a reasonable local background in areas where adequate local background samples could not otherwise be obtained from active channels and floodplains because of the possibility of contamination. Alternatively, these samples may be more comparable to sediments penetrated at depth in a core hole than to surface samples because of post-depositional geochemical changes associated with shallow groundwater flow or vadose zone transport over long periods of time. Erosion of the sampled stream bank along the main drainage of Ancho Canyon exposed a section of coarse channel sands and gravels overlying an older floodplain deposit, shown schematically in Figure 3. Radiocarbon dating of charcoal contained within these sediments provided ages of about 1200 yrs for the channel sands and about 3200 yrs for the underlying floodplain deposit, demonstrating their prehistoric age.

Analyses from the prehistoric sediment deposits (FS2227 and FS2228) were compared to both the bulk channel and floodplain deposits and to appropriate size fractions from the separated floodplain deposits to ensure that possible natural variability within the modern deposits was being considered (Tables 9 and 10). The prehistoric channel sands were thus compared with the medium and coarse sand fractions of the floodplain deposits, and the prehistoric floodplain deposits were compared with the fine sand to clay fractions of the modern floodplain deposits.

This comparison indicated that for most elements the modern and prehistoric samples could not be distinguished, but that for some elements significant differences exist that suggest post-depositional elemental mobility over the last 1000 to 3000 years. The old channel sand deposit in particular differed from both the modern channel deposits and also the medium and coarse sand fraction of the floodplain deposits with higher concentrations of Co, Cr, Fe Mn, V, and Zn in both the HNO_3 and the HF digestions, Ba, Ca, Mg, and Ni in only the HF digestion, and Cl and SO_4 in the deionized water leachate. As compared to the finer fractions of the recent floodplain

deposits, the old floodplain deposits had higher concentrations of Na in the HNO_3 digested fraction and Cl and SO_4 in the deionized water leachate.

The differences seen between the modern and the prehistoric deposits suggest which elements may be naturally higher in subsurface samples penetrated in boreholes due to solute transport, mineral precipitation, and adsorption processes. Notably, some contaminants of concern at TA-39, such as Be and U, are similar between the recent and the old deposits, suggesting that natural concentrations of Be and U in the subsurface may be similar to those in young deposits.

Arsenic and Beryllium in Sediments

Arsenic and Be are of special concern at the Laboratory in evaluations of possible contamination because their concentrations in soils routinely exceed action levels established by the Environmental Protection Agency (EPA) (0.4 ppm for As and 0.16 ppm for Be, using HNO_3 digestion) (Longmire et al., 1995). As a result, the evaluation of As and Be in soils currently is based on a comparison with background values, and not to action levels, and background values thus play a key role in the decision making process. The analytical data obtained in this study similarly show that concentrations of As and Be in the sediment samples exceed the previously established action levels, although their concentrations are generally less than observed in soils.

The concentrations of As and Be are generally strongly correlated with Fe concentration in soils at the Laboratory (Longmire et al., 1995, this report), and these elemental relationships are also present in the sediments collected within Ancho and Indio Canyons. Figures 6 and 7 are bivariate plots of As versus Fe and Be versus Fe for these sediments, showing high regression coefficients (r^2) of 0.84 and 0.95, respectively. These plots are useful in defining the natural distribution field for As and Be as they relate to Fe concentration, and in recognizing which values may indicate contamination as opposed to natural variations in background concentrations of these analytes.

Comparison With Background Soils

The background sediment samples from Ancho and Indio Canyons were compared with background soils data from the Laboratory (Longmire et al., 1995) to evaluate if the sediment chemistry was similar to certain parts of the soil data set. In general, elemental concentrations in the sediments are most similar to soil samples that contained low concentrations of Fe. In the soils, Fe concentration is generally correlated with the percentage of clay-sized particles in each sample (Longmire et al., 1995), and the lower elemental concentrations present in the TA-39 sediments are consistent with their relatively low Fe content. For example, bivariate plots of As versus Fe and Be versus Fe for background soils and sediments collected at the Laboratory are shown in Figures 8 and 9. Arsenic, Be, and Fe concentrations in the sediments are most similar to concentrations within A and C horizons or within weakly developed B horizons in soils. We thus infer that either the dominant source for the sediments is erosion of soils containing low concentrations of Fe, or that much of the fine-grained Fe-rich component of the soils is winnowed out of the sediments during transport in floods, being carried downstream towards the Rio Grande.

Principal Components Analysis

The variability within the background chemical data set was examined statistically using a principal components analysis (PCA). The concentrations of 21 major and trace elements that are generally observed above detection levels in each sample can be represented by a vector in a 21-dimensional space. PCA is a rotation of these natural coordinates that allows us to capture most of the variability among the samples in far fewer than 21 dimensions, however, because concentrations of the various elements are in general highly correlated (Everitt and Dunn, 1991). In brief, PCA describes the dispersion of an array of m observations in n-dimensional space (here, the concentrations of n elements in m samples of soil and/or sediments) in terms of a set of orthogonal coordinates (called the principal components) that are ordered as follows. The first principal component is in the direction of greatest variation. If we consider the observations as a cloud of points in a n-dimensional space, the first principal component is the direction parallel to which this cloud has its greatest length. The second principal component is constrained to be orthogonal to the first and oriented in the direction in which the cloud has the largest width, and so

forth. Typically a cloud of multivariate observations is elongated, with significant variation in far fewer than n dimensions, so that PCA allows for the reduction of the dimensionality of the problem of evaluating multidimensional data. In this section we use PCA to further evaluate, both qualitatively and quantitatively, the differences and similarities between the background soil data of Longmire et al. (1995) and the background sediment samples of this report.

Principal components analysis of the background soil samples of Longmire et al. (1995) (21 analytes in 44 samples assigned to A, B, or C horizons, using a HNO_3 digestion) shows that 68% of the total variance among these samples is accounted for by the first principal component, and 92% by the first three principal components (out of 21).

Large values of the first principal component correspond to high concentrations of many elements and correlations that exist between elements. In particular, the major elements Al, Fe, Mg, and K are highly correlated with this first principal component (and with each other), as are several minor and trace elements: As, Be, Cr, Cu, Ni, Th, and V. Sulfate, Cl, Mn, Na, U, and Zn are poorly correlated with this component and with the elements listed above. Samples above median total enrichment for soils (as measured by the first principal component) are predominantly from B horizons (Fig. 10), suggesting that the most important control on variability in these data is the degree of soil development (most likely due to increases in clay and iron oxyhydroxides), as postulated by Longmire et al. (1995).

Variations in the concentrations of Ca, Zn, Mn, Na, and sulfate dominate the second and third principal components. These components serve primarily to separate the discrete locations sampled by Longmire et al. (1995). For example, soil samples collected in upper Los Alamos Canyon (exceptionally high in organic matter) are strung out at the upper end of the second component (towards the top of Fig. 10). Samples collected in TA-69 from a well-developed, clay-rich soil, cluster at lower end of this component but are high relative to the third component, with a couple of exceptions. The samples collected from a poorly developed soil in lower Los Alamos Canyon near the Tsankawi ruins are grouped at the low end of the third component.

Exploiting the reduction in dimensionality obtained by PCA allows us to visualize the large multivariate data set in two or three dimensions, and further, to see where the sediment samples

that are the subject of this report fall with respect to the soil samples. The floodplain sediment samples from Ancho and Indio Canyons generally occur well within the cloud defined by the background soil samples (Fig. 10). Relative to the soil samples, the floodplain samples have low concentrations of many elements, that is they occur at the low end relative to the first principal component. With respect to the next two principal components they generally occur near the middle of the distributions. The recent mud deposit sample is similar to the finer-grained separates of the floodplain samples (Fig. 10).

The channel sands lie on the edge of the cloud formed by the soil samples (Fig. 10). The modern channel sands are typically lowest in concentrations of most analytes, and they also fall at the low end of the third component. By contrast, the old channel sand sample is higher in many analytes compared to the floodplain samples but has a larger third component than any soil sample.

The power of the PCA method for detecting outliers is best seen in the case of the unique black magnetite-rich sand sample. With respect to the first principal component, it is only slightly above the average for the soil samples. With respect to the next two components, however, it is well outside the range covered not only by the other sediment samples but also by all the samples discussed by Longmire et al. (1995). That is, although not extraordinarily high compared to B-horizon samples in general, the proportions of the elements in this sample are such as to place it far outside the "cloud" of other observations in the 21-dimensional space.

Among the modern floodplain samples, segregation of analyte concentration by grain size is pronounced. The coarse fraction (0.25 to 2 mm) varies from 5223 to 6174 in the first principal component, while the medium and fine fractions vary from 10388 to 11475. The bulk samples are intermediate, at 7148 to 11534.

Similar results are observed when the sediment samples are analyzed by themselves using PCA. Specifically, a first principal component is highly correlated with general enrichment in almost all elements, induced largely by the different grain sizes among the available samples (Fig. 11). This first principal component accounts for 91% of the variability among the modern floodplain and channel samples. The remaining 9% is almost entirely accounted for by a second

component that separates the two sample areas, Ancho and Indio Canyons, indicating minor chemical differences between sediments from these sites.

Summary Statistics For Background Sediment Samples

Summary statistics for the sediment data are presented in Table 11. In view of the fact that for both the soil data and the sediment data, sample location is the second most important explanatory factor for the variation in observed concentrations, as shown by the principal components analysis, the sediment data discussed in this report should be considered strictly preliminary. Two sample areas are almost certainly insufficient to represent the scope of variability that will be encountered when more background sediment locations from other parts of the Pajarito Plateau are added.

This caveat should be borne in mind when using the statistics shown in Table 11, which include medians, means, standard deviations, minima, maxima and (.95,.95) UTLs based on the 16 sediment samples. The statistics were calculated based on values from all samples, excluding outliers in the data set that would inflate the estimate of the mean by more than 10%. These outliers are presented in Table 12, and include values for the black magnetite-rich sands, the recent mud deposit, and the prehistoric channel and floodplain deposits. The UTLs in Table 11 are calculated following procedures discussed in EPA (1989), and indicate values that we are 95% confident exceed the 95th percentiles of the true distributions. These UTLs are up to 50% larger than the maximum values observed, as a result of the small sample size, and will require revision as more background sediment samples are obtained.

Implications for Sampling and Interpretation of Data

The data set discussed in this report is limited by its small sample size, and thus may not be representative of the full range of background sediment chemistry present at TA-39. In addition, this data set is not intended to be representative of all sediments on the Pajarito Plateau as the sampled canyons entirely drain areas underlain by the Bandelier Tuff. For example, additional variation will undoubtedly occur in the canyons that head in the Sierra de los Valles and thus drain

areas underlain by Tschicoma Formation dacite. However, the results of this study suggest several implications for the collection of samples and the interpretation of analytical data that should allow improved evaluations of potential contamination in sediments at the Laboratory.

First, because of the dependence of sediment geochemistry on grain size and mineralogy, field notes on the characteristics of each sample (such as the general grain size or the presence of black sands) can be valuable in understanding variations in the analytical data. Second, the correlations that are present between Fe and other metals can be used as an additional test for possible deviations from background, such as for high values that may lie beyond the background data set but still be consistent with the natural elemental trends. Third, selective sampling of certain types of deposits (such as black magnetite-rich sands where dense particles like depleted U may be concentrated) may be useful in examining the distributions of contaminants. Finally, sediments in the subsurface sampled in core holes may have significantly higher concentrations of certain elements than surface sediment due to post-depositional alteration associated with migrating water, and selection of appropriate background samples for comparison needs to be made accordingly.

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Figure Captions

Figure 1. Location map of TA-39.

Figure 2. Location map of background sediment sample sites in Ancho and Indio Canyons.

Figure 3. Schematic sketch showing geomorphic setting of background sediment samples. Approximate ages of sediments are from radiocarbon analyses of charcoal collected from Ancho Canyon sample site.

Figure 4. Comparison of the concentrations of As, Be, and U between floodplain deposits (sample FS 2220), active channel deposits (sample FS 2224), and mud deposits (sample FS 2226) in Indio Canyon, using HNO_3 digestion.

Figure 5. Comparison of the concentrations of selected elements in black, magnetite-rich sands (sample FS 2225) and active channel sands (sample FS 2224) in Indio Canyon, using HNO_3 digestion.

Figure 6. Plot of As vs. Fe for background sediment samples in Ancho and Indio Canyons (excluding samples FS 2223, 2225, 2228, and 2232), using HNO_3 digestion.

Figure 7. Plot of Be vs. Fe for background sediment samples in Ancho and Indio Canyons (excluding samples FS 2223, 2225, 2228, and 2232), using HNO_3 digestion.

Figure 8. Plot of As vs. Fe for background sediment samples in Ancho and Indio Canyons (excluding samples FS 2223, 2225, 2228, and 2232), and the A, B, and C horizons of background soils at the Laboratory (Longmire et al., 1995), using HNO_3 digestion.

Figure 9. Plot of Be vs. Fe for background sediment samples (from active channels and floodplains) in Ancho and Indio Canyons (excluding samples FS 2223, 2225, 2228, and 2232), and the A, B, and C horizons of background soils at the Laboratory (Longmire et al., 1995), using HNO_3 digestion.

Figure 10. Background soil samples of Longmire et al. (1995) and sediment samples of this report displayed in a coordinate system defined by the first two principal components of the background soil data set. The black sand sample lies outside of this plot. See text for discussion.

Figure 11. Sediment samples from Ancho and Indio Canyons displayed in a coordinate system defined by their first two principal components. The black sand sample and the prehistoric channel sample from Ancho Canyon lie outside of this plot.

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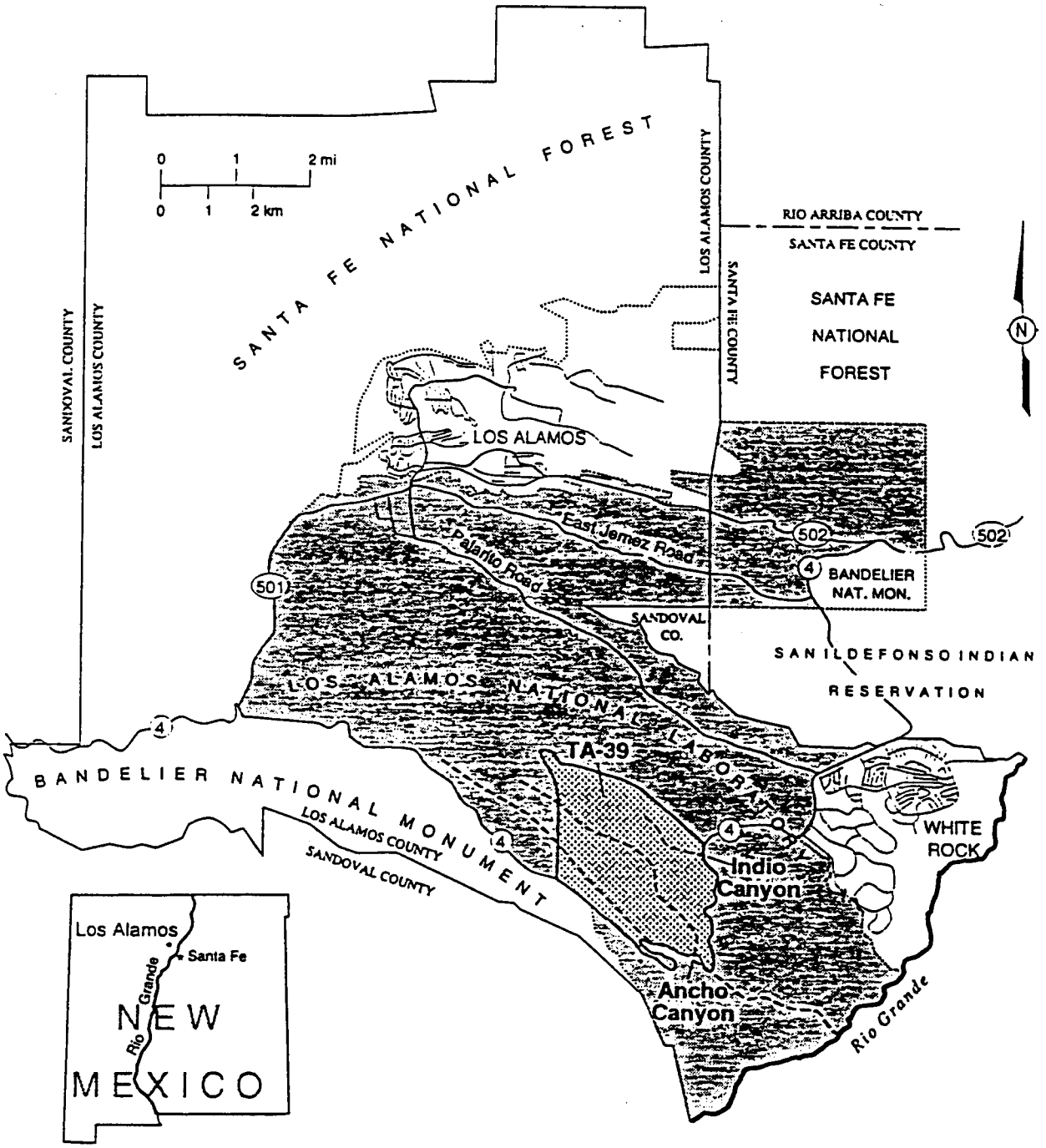
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LOS ALAMOS
East Jemez Road
Pajarito Road
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502
4
BANDELIER
NAT. MON.
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SANDOVAL
CO.
SAN ILDEFONSO INDIAN
RESERVATION
LOS ALAMOS NATIONAL LABORATORY
TA-39
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BANDELIER NATIONAL MONUMENT
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SANDOVAL COUNTY
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Santa Fe
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NEW
MEXICO

Fig. 1

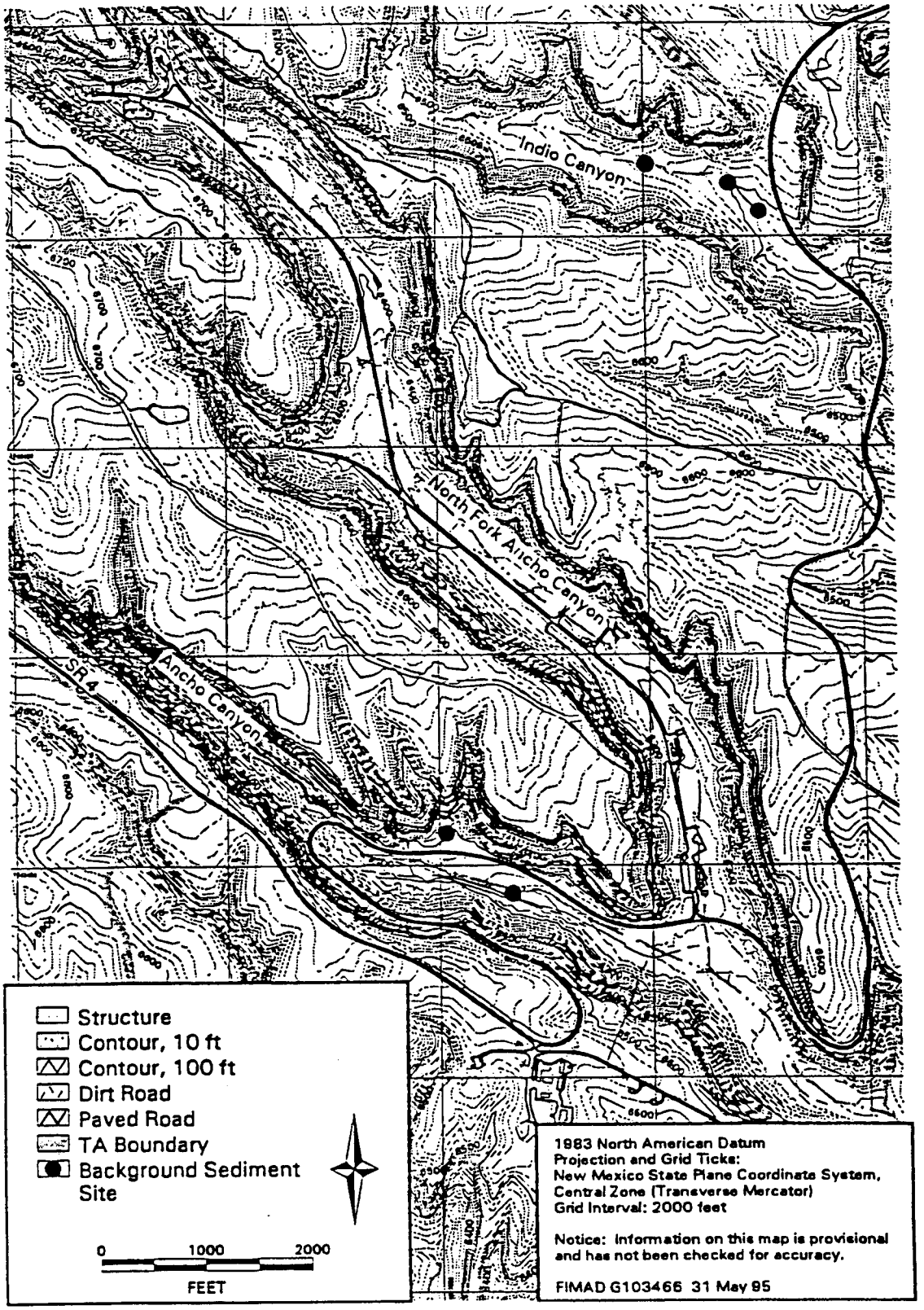
Indio Canyon
North Fork Ancho Canyon
Ancho Canyon
SR 4
Structure
Contour, 10 ft
Contour, 100 ft
Dirt Road
Paved Road
TA Boundary
Background Sediment Site
0
1000
2000
FEET
1983 North American Datum
Projection and Grid Ticks:
New Mexico State Plane Coordinate System,
Central Zone (Transverse Mercator)
Grid Interval: 2000 feet
Notice: Information on this map is provisional and has not been checked for accuracy.
FIMAD G103466 31 May 95

Fig. 2

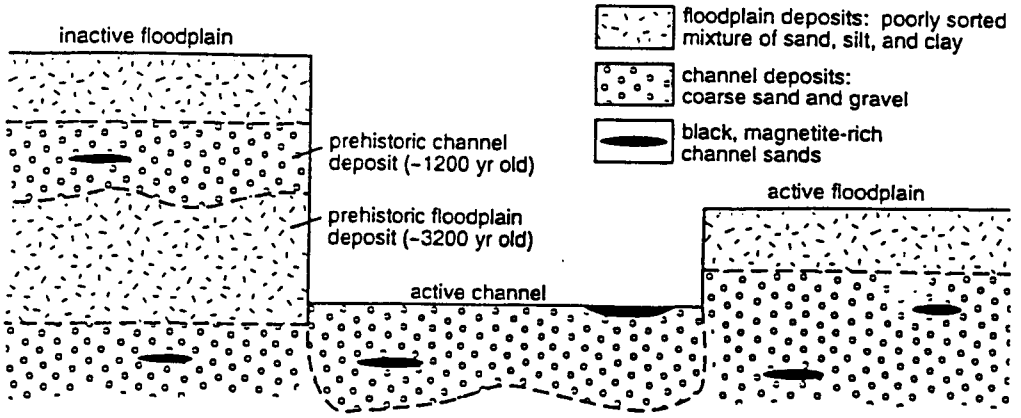
inactive floodplain
prehistoric channel deposit (~1200 yr old)
prehistoric floodplain deposit (~3200 yr old)
active channel
active floodplain
floodplain deposits: poorly sorted mixture of sand, silt, and clay
channel deposits: coarse sand and gravel
black, magnetite-rich channel sands

Fig 3

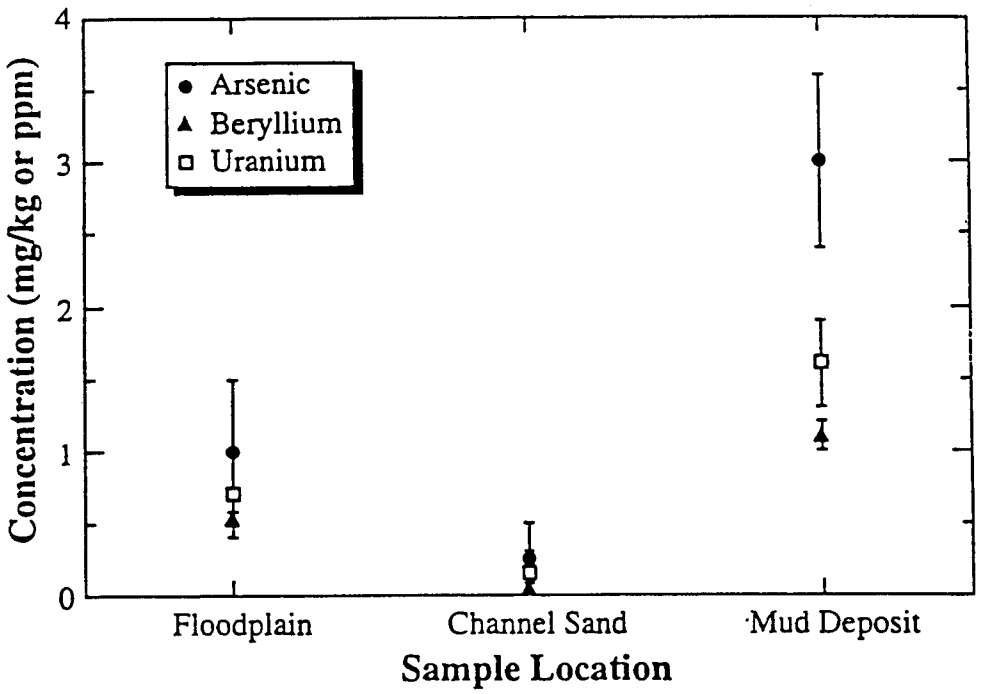
Arsenic
Beryllium
Uranium
Concentration (mg/kg or ppm)
0
1
2
3
4
Floodplain
Channel Sand
Mud Deposit
Sample Location

Fig. 4

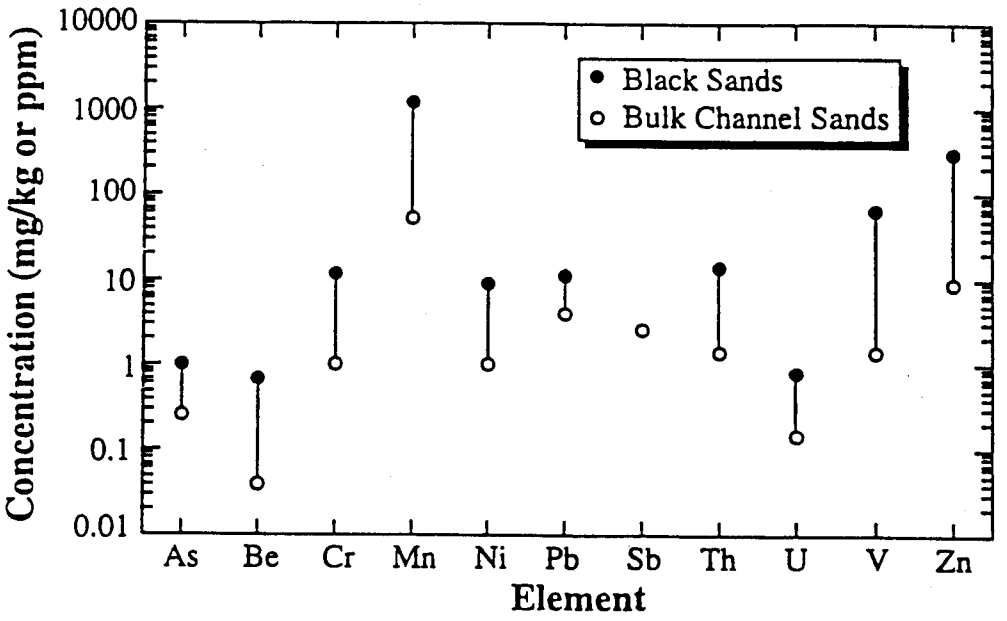
Concentration (mg/kg or ppm)
10000
1000
100
10
1
0.1
0.01
Black Sands
Bulk Channel Sands
As
Be
Cr
Mn
Ni
Pb
Sb
Th
U
V
Zn
Element

Fig. 5

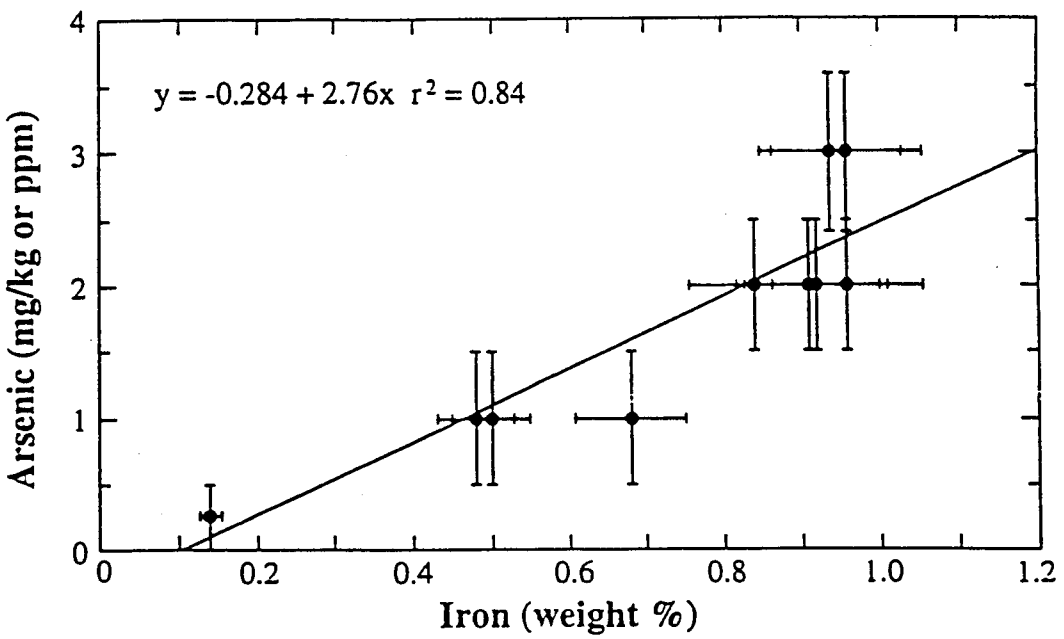
y = -0.284 + 2.76x r² = 0.84
Arsenic (mg/kg or ppm)
Iron (weight %)
0
1
2
3
4
0
0.2
0.4
0.6
0.8
1.0
1.2

Fig. 6

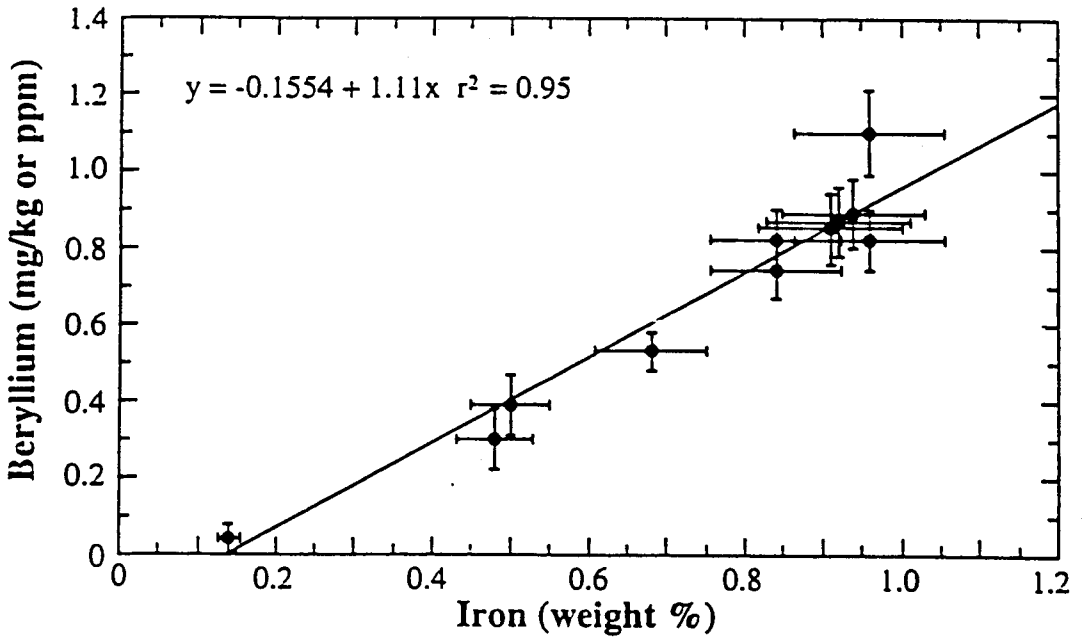
y = -0.1554 + 1.11x r² = 0.95
Beryllium (mg/kg or ppm)
Iron (weight %)
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

Fig. 7

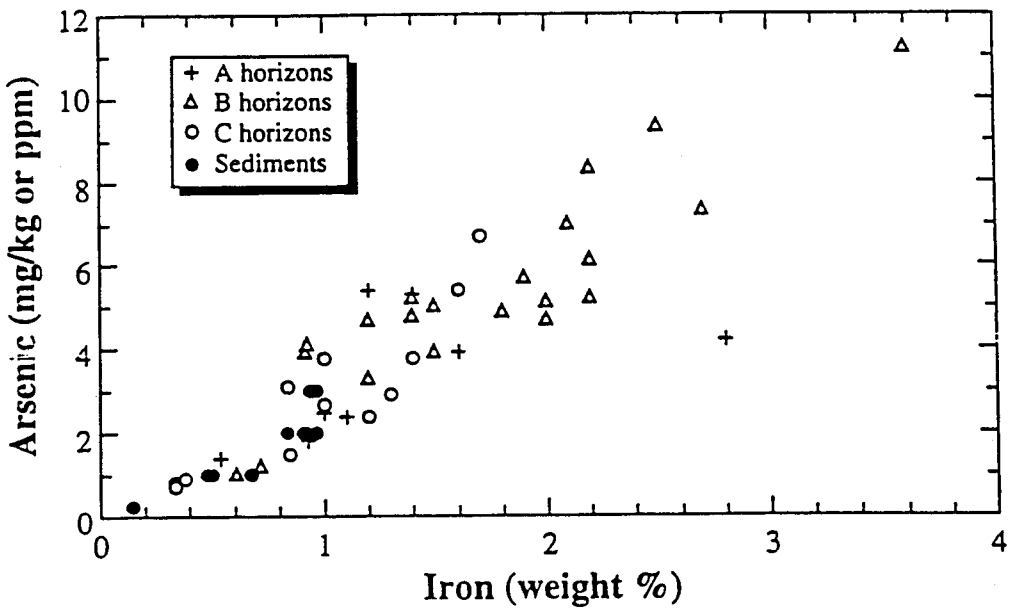
A horizons
B horizons
C horizons
Sediments
Arsenic (mg/kg or ppm)
Iron (weight %)
0
2
4
6
8
10
12
0
1
2
3
4

Fig. 8

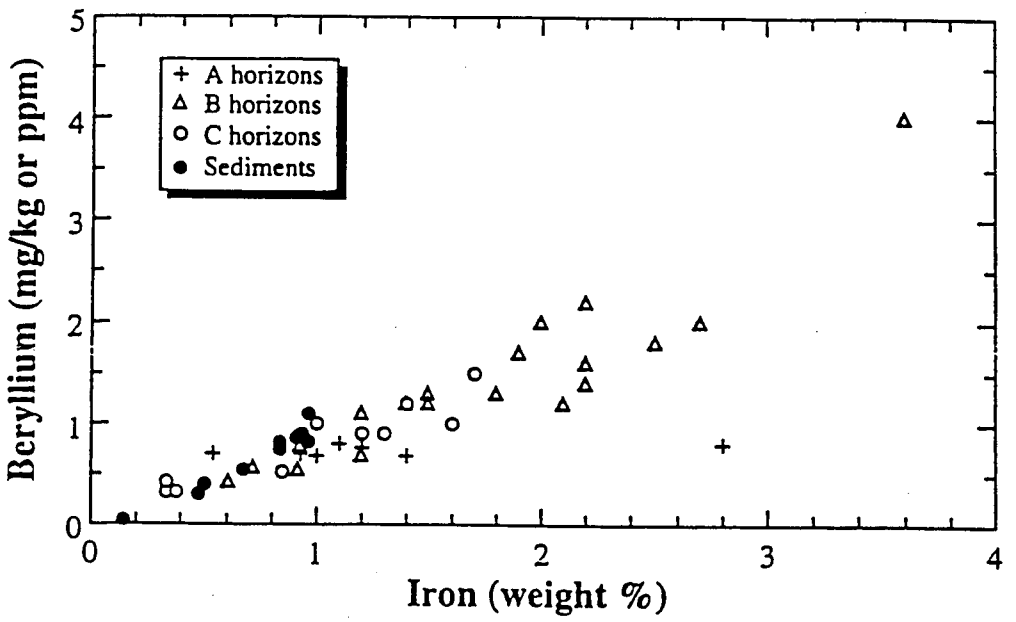
A horizons
B horizons
C horizons
Sediments
Beryllium (mg/kg or ppm)
Iron (weight %)
0
1
2
3
4
5

Fig. 9

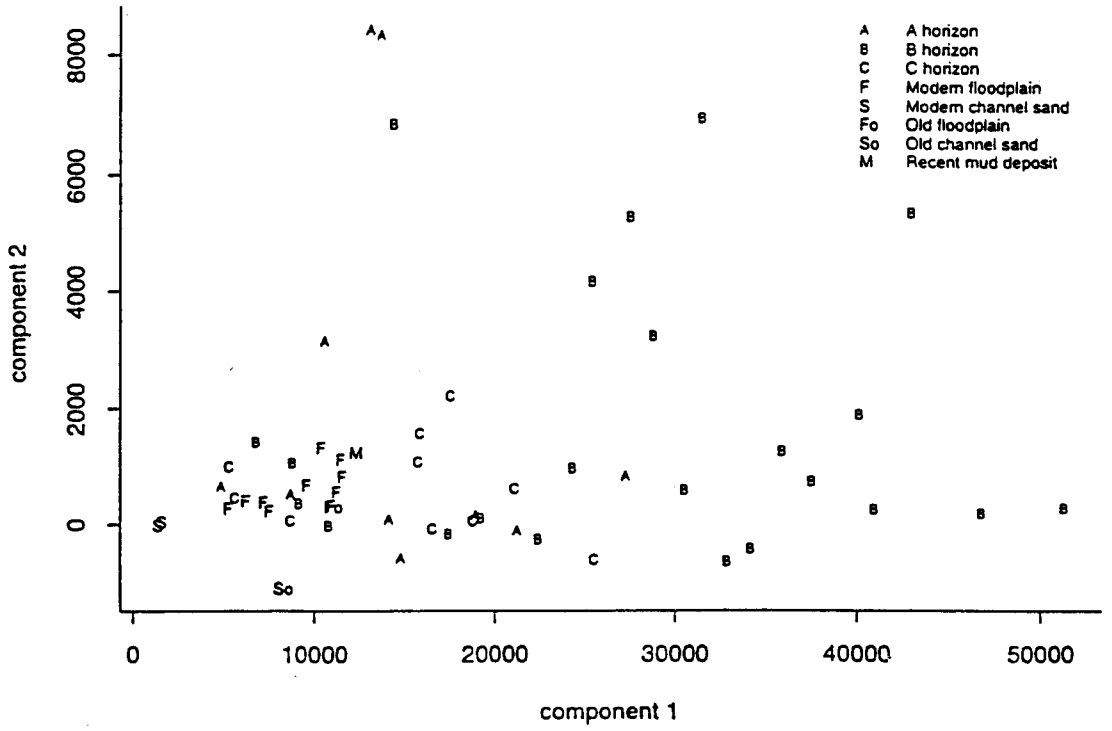
A A horizon
B B horizon
C C horizon
F Modern floodplain
S Modern channel sand
Fo Old floodplain
So Old channel sand
M Recent mud deposit
component 2
component 1
0
2000
4000
6000
8000
10000
20000
30000
40000
50000

Figure 10

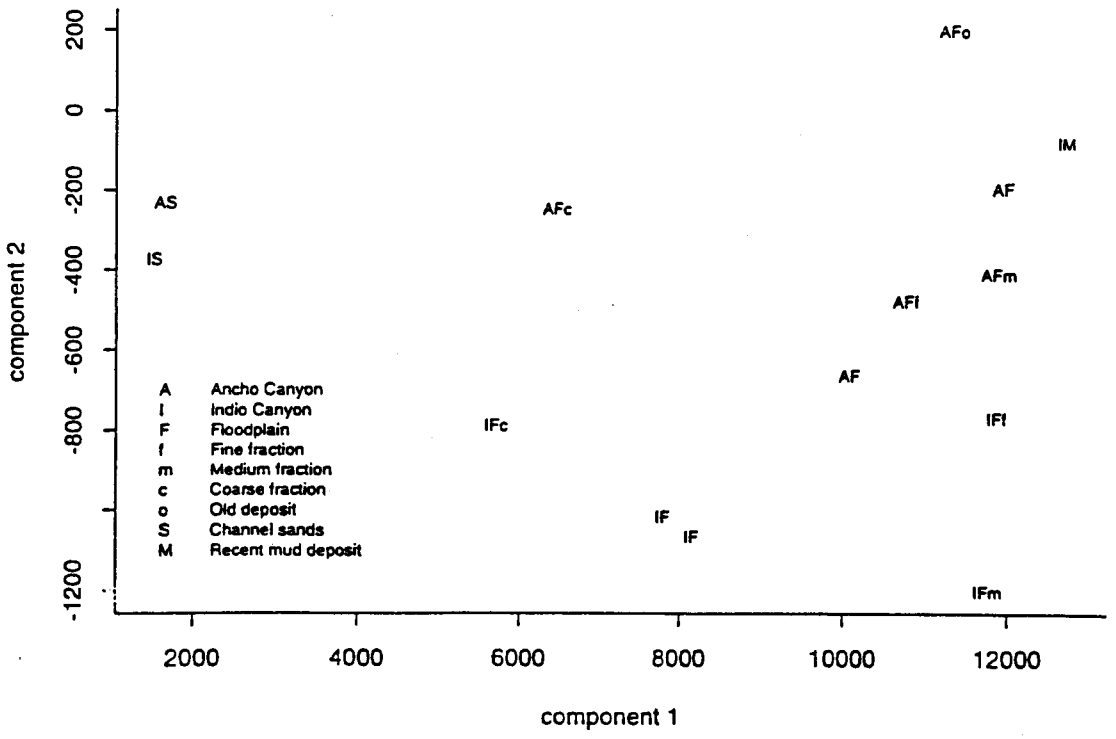
component 2
200
0
-200
-400
-600
-800
-1200
component 1
2000
4000
6000
8000
10000
12000
AFo
IM
AF
AFc
AS
IS
AFm
AFf
AF
IFf
IFc
IF
IF
IFm
A Ancho Canyon
I Indio Canyon
F Floodplain
f Fine fraction
m Medium fraction
c Coarse fraction
o Old deposit
S Channel sands
M Recent mud deposit

Fig. 11

Table 1
Location of Sample Sites and Description of Samples, TA-39

Sample Number	Sample Location	Type of Deposit	Sample Depth	Particle Size	Notes
FS 2220	Indio Cyn, 6425'	floodplain	0-18"	< 2 mm (sand, silt, clay)	bulk sample, gravel removed
FS 2221	Indio Cyn, 6425'	floodplain	0-18"	< 0.075 mm (very fine sand, silt, clay)	sample split, sieved
FS 2222	Indio Cyn, 6425'	floodplain	0-18"	0.25-0.075 mm (fine sand)	sample split, sieved
FS 2223	Indio Cyn, 6425'	floodplain	0-18"	< 2 mm (sand, silt, clay)	duplicate of FS 2220
FS 2224	Indio Cyn, 6425'	channel sands	0-6"	< 2 mm (mainly coarse sand)	bulk sample, gravel removed
FS 2225	Indio Cyn, 6400'	channel sands	0-1"	< 2 mm (mainly fine sand)	black (magnetite) sands
FS 2226	Indio Cyn, 6387'	mud in channel	0-1"	< 2 mm (mainly fine sand, silt, clay)	mud deposits from recent flood
FS 2227	Ancho Cyn, 6228'	old floodplain	4.1-4.6'	< 2 mm (sand, silt, clay)	bulk sample, gravel removed
FS 2228	Ancho Cyn, 6228'	old channel sands	2.6-3.1'	< 2 mm (mainly coarse sand)	bulk sample, gravel removed
FS 2229	Ancho Cyn, 6295'	floodplain	8-16"	< 2 mm (sand, silt, clay)	bulk sample, gravel removed
FS 2230	Ancho Cyn, 6295'	floodplain	8-16"	< 0.075 mm (very fine sand, silt, clay)	sample split, sieved
FS 2231	Ancho Cyn, 6295'	floodplain	8-16"	0.25-0.075 mm (fine sand)	sample split, sieved
FS 2232	Ancho Cyn, 6295'	floodplain	8-16"	< 2 mm (sand, silt, clay)	duplicate of FS 2229
FS 2233	Ancho Cyn, 6295'	channel sands	0-6"	< 2 mm (mainly medium sand)	bulk sample, gravel removed
FS 2234	Indio Cyn, 6425'	floodplain	0-18"	0.25-2 mm (coarse+medium sand)	sample split, sieved
FS 2235	Ancho Cyn, 6295'	floodplain	8-16"	0.25-2 mm (coarse+medium sand)	sample split, sieved

Table 2. TA-39 Background Sediment Chemistry Data, HNO_3 Digestion

Sample	Al (ppm)	Al (+/-)	As (ppm)	As (+/-)	Ba (ppm)	Ba (+/-)	Be (ppm)	Be (+/-)	Ca (ppm)	Ca (+/-)
FS2220	4600	460	1	0.5	53	5.3	0.53	0.05	1200	120
FS2221	7300	730	3	0.60	99	9.90	0.89	0.09	1900	190
FS2222	6900	690	2	0.50	77	7.70	0.82	0.08	1700	170
FS2223	4400	440	2	0.50	54	5.40	0.56	0.06	1300	130
FS2224	740	74	<0.5		8	0.80	<0.08		180	18
FS2225	1400	140	1	0.50	14	1.40	0.70	0.08	990	99
FS2226	8400	840	3	0.60	100	10	1.10	0.11	2600	260
FS2227	7700	770	2	0.50	71	7.10	0.74	0.07	1500	150
FS2228	2300	230	0.90	0.50	32	3	0.17	0.08	770	77
FS2229	7800	780	2	0.50	90	9	0.85	0.09	2100	210
FS2230	6800	680	2	0.50	90	9	0.82	0.08	2500	250
FS2231	7600	760	3	0.60	95	9.50	0.87	0.09	2400	240
FS2232	6200	620	2	0.50	75	7.50	0.67	0.08	1800	180
FS2233	930	93	<0.5		8.30	0.83	<0.08		230	23
FS2234	3200	320	1	0.50	37	3.70	0.30	0.08	960	96
FS2235	4100	410	1	0.50	49	4.90	0.39	0.08	1100	110

Sample	Co (ppm)	Co (+/-)	Cr (ppm)	Cr (+/-)	Cu (ppm)	Cu (+/-)	Fe (ppm)	Fe (+/-)	K (ppm)	K (+/-)	Mg (ppm)	Mg (+/-)
FS2220	2.2	0.5	3.5	0.5	3.5	0.5	6800	680	970	97	920	92
FS2221	3.50	0.50	5.80	0.60	7.30	0.70	9400	940	1500	150	1500	150
FS2222	3	0.50	4.70	0.50	5.60	0.60	9600	960	1400	140	1300	130
FS2223	2.30	0.50	3.30	0.50	3.50	0.50	6500	650	990	99	870	87
FS2224	0.60	0.50	1	0.50	0.80	0.50	1400	140	180	74	170	17
FS2225	6	0.60	12	1.20	4.40	0.50	57000	5700	220	22	530	53
FS2226	3.50	0.50	5.60	0.60	12	1.20	9600	960	1800	180	1700	170
FS2227	2.70	0.50	5.20	0.50	4.30	0.50	8400	840	1600	160	1400	140
FS2228	3.10	0.50	5.40	0.50	1.80	0.50	13000	1300	540	54	570	57
FS2229	3.50	0.50	5.70	0.60	5.70	0.60	9100	910	1900	190	1500	150
FS2230	3	0.50	5.90	0.60	7.50	0.80	8400	840	1900	190	1500	150
FS2231	3.80	0.50	5.90	0.60	7.30	0.70	9200	920	2200	220	1600	160
FS2232	3.20	0.50	4.70	0.50	4.80	0.50	8000	800	1600	160	1300	130
FS2233	0.70	0.50	0.80	0.50	0.90	0.50	1400	140	200	20	200	20
FS2234	1.50	0.50	2.20	0.50	2.70	0.50	4800	480	650	65	590	59
FS2235	2	0.50	2.50	0.50	3	0.50	5000	500	1100	110	820	82

Table 2. TA-39 Background Sediment Chemistry Data, HNO_3 Digestion (continued)

Sample	Mn (ppm)	Mn (+/-)	Na (ppm)	Na (+/-)	Ni (ppm)	Ni (+/-)	Pb (ppm)	Pb (+/-)	Sb (ppm)	Sb (+/-)
FS2220	240	24	120	14	4	2	5	4	<5	
FS2221	330	33	120	14	7	2	10	4	<5	
FS2222	350	35	120	14	5	2	10	4	<5	
FS2223	240	24	95	14	4	2	8	4	<5	
FS2224	53	5.30	46	14	<2		4	4	<5	
FS2225	1200	120	68	14	9	2	11	4	<5	
FS2226	380	38	190	19	6	2	16	4	5	5
FS2227	220	22	150	15	4	2	7	4	<5	
FS2228	240	24	66	14	4	2	5	4	<5	
FS2229	330	33	100	14	6	2	10	4	<5	
FS2230	230	23	76	14	5	2	7	4	<5	
FS2231	300	30	110	14	7	2	9	4	<5	
FS2232	280	28	91	14	6	2	8	4	<5	
FS2233	46	4.60	34	14	<2		<4		<5	
FS2234	180	18	75	14	4	2	5	4	<5	
FS2235	190	19	80	14	4	2	6	4	<5	

Sample	Ta (ppm)	Ta (+/-)	Th (ppm)	Th (+/-)	Tl (ppm)	Tl (+/-)	U (ppm)	U (+/-)	V (ppm)	V (+/-)	Zn (ppm)	Zn (+/-)
FS2220	<0.3		5.2	0.4	0.5	0.3	0.7	0.3	7.2	0.7	31	3.1
FS2221	<0.3		7.70	0.50	<0.3		0.90	0.30	12	1.20	38	3.80
FS2222	<0.3		7.10	0.50	<0.3		1	0.30	10	1	44	4.40
FS2223	<0.3		5.80	0.40	<0.3		0.90	0.30	7	0.70	31	3
FS2224	<0.3		1.40	0.30	<0.3		<0.3		1.40	0.50	9	1
FS2225	<0.3		14	1	<0.3		0.80	0.30	66	6.60	300	30
FS2226	<0.3		6.60	0.50	<0.3		1.60	0.30	11	1.10	48	4.80
FS2227	<0.3		5.80	0.40	<0.3		0.60	0.30	9	0.90	33	3
FS2228	<0.3		2.20	0.30	<0.3		<0.3		20	2	47	5
FS2229	<0.3		8	0.60	<0.3		0.70	0.30	11	1.10	39	4
FS2230	<0.3		6.90	0.80	<0.3		0.60	0.30	13	1.30	32	3
FS2231	<0.3		7.10	0.80	<0.3		0.60	0.30	12	1.20	37	3.70
FS2232	<0.3		6	0.70	<0.3		0.60	0.30	9	0.90	34	3.40
FS2233	<0.3		0.90	0.30	<0.3		<0.3		1	0.50	9	1
FS2234	<0.3		3.60	0.40	<0.3		0.50	0.30	5	0.50	24	2
FS2235	<0.3		4.30	0.50	1.50	0.30	0.40	0.30	5	0.50	24	2

Table 3. TA-39 Background Sediment Chemistry Data, HF Digestion

Sample	Al (ppm)	Al (+/-)	As (ppm)	As (+/-)	Ba (ppm)	Ba (+/-)	Be (ppm)	Be (+/-)	Ca (ppm)	Ca (+/-)	Co (ppm)	Co (+/-)
FS2220	61000	6100	8.20	1.60	222	22	3.20	0.32	3800	380	2.30	0.50
FS2221	57000	5700	5.30	1	370	37	3.80	0.38	4900	490	4	0.50
FS2222	62000	6200	5.30	1	270	27	4.40	0.44	4300	430	3.80	0.50
FS2223	61000	6100	6.30	1.30	240	24	3.50	0.35	4000	400	2.60	0.50
FS2224	51000	5100	6.20	1.20	130	13	1.10	0.11	2000	200	0.70	0.50
FS2225	11000	1100	4.80	1	32	3.20	1.60	0.16	3400	340	< 0.5	
FS2226	63000	6300	8.60	1.70	300	30	5.30	0.50	4900	490	3.40	0.50
FS2227	69000	6900	10.40	2.10	340	34	4	0.40	6100	610	3.90	0.50
FS2228	63000	6300	7.50	1.50	290	29	1.50	0.15	8100	810	7	0.70
FS2229	60000	6000	8	1.60	330	33	3.60	0.36	4900	490	3.50	0.50
FS2230	56000	5600	9.10	1.80	410	41	3.20	0.32	5800	580	3.80	0.50
FS2231	59000	5900	5.90	1.20	380	38	3.60	0.36	5500	550	3.90	0.50
FS2232	61000	6100	3.60	0.70	310	31	3.40	0.34	4700	470	3.30	0.50
FS2233	48000	4800	2.10	0.40	120	12	0.91	0.09	1800	180	1	0.50
FS2234	61000	6100	3	0.60	180	18	2.40	0.24	3400	340	1.50	0.50
FS2235	59000	5900	2.50	0.50	210	21	2.90	0.29	3500	350	2	0.50

Sample	Cr (ppm)	Cr (+/-)	Cu (ppm)	Cu (+/-)	Fe (ppm)	Fe (+/-)	K (ppm)	K (+/-)	Mg (ppm)	Mg (+/-)	Mn (ppm)	Mn (+/-)
FS2220	8.30	0.80	5.10	0.50	13000	1300	27000	2700	1700	170	420	42
FS2221	18	1.80	12	1.20	17000	1700	23000	2300	2700	270	490	49
FS2222	12	1.20	9.60	1	17000	1700	27000	2700	2500	250	580	58
FS2223	9.90	1	6	0.60	14000	1400	29000	2900	1900	190	430	43
FS2224	1.10	0.50	1	0.50	4900	490	26000	2600	470	47	180	18
FS2225	83	8.30	< 0.5		110	11	3600	360	3000	300	13000	1300
FS2226	14	1.40	15	1.50	16000	1600	26000	2600	2600	260	540	54
FS2227	15	1.50	7.60	0.80	17000	1700	27000	2700	3300	330	450	45
FS2228	23	2.30	2.60	0.50	52000	5200	25000	2500	2500	250	1300	130
FS2229	15	1.50	8.70	0.90	16000	1600	26000	2600	2700	270	460	46
FS2230	23	2.30	13	1.30	19000	1900	22000	2200	3100	310	420	42
FS2231	17	1.70	13	1.30	18000	1800	24000	2400	3100	310	480	48
FS2232	14	1.40	8.10	0.80	15000	1500	24000	2400	2500	250	430	43
FS2233	2.50	0.50	1.20	0.50	4100	410	24000	2400	530	53	130	13
FS2234	4.40	0.50	3.40	0.50	8500	850	25000	2500	1000	100	290	29
FS2235	7.50	0.80	4.80	0.50	11000	1100	26000	2600	1600	160	330	33

Table 3. TA-39 Background Sediment Chemistry Data, HF Digestion (continued)

Sample	Na (ppm)	Na (+/-)	Ni (ppm)	Ni (+/-)	Pb (ppm)	Pb (+/-)	Sb (ppm)	Sb (+/-)	Ta (ppm)	Ta (+/-)	Th (ppm)	Th (+/-)
FS2220	19000	1900	5	2	11	4	< 5		6	0.40	13	0.30
FS2221	15000	1500	11	2	20	4	< 5		4.70	0.30	17	0.30
FS2222	18000	1800	6	2	16	4	< 5		5.30	0.30	18	0.40
FS2223	20000	2000	7	2	13	4	< 5		4.20	0.30	13	0.30
FS2224	20000	2000	< 2		< 4		< 5		1.20	0.20	3.90	0.20
FS2225	2700	270	47	5	50	5	14	5	15	0.90	130	4
FS2226	18000	1800	7	2	27	4	< 5		5.70	0.30	18	0.40
FS2227	18000	1800	8	2	14	4	< 5		4.40	0.40	15	0.60
FS2228	20000	2000	14	2	< 4		< 5		2.60	0.30	9.40	0.40
FS2229	16000	1600	8	2	12	4	< 5		4.30	0.40	15	0.60
FS2230	14000	1400	10	2	13	4	< 5		4	0.40	16	0.60
FS2231	14000	1400	8	2	13	4	< 5		4.40	0.40	15	0.60
FS2232	16000	1600	14	2	13	4	< 5		4.60	0.50	15	0.60
FS2233	18000	1800	< 2		4	4	< 5		0.90	0.20	3.30	0.20
FS2234	21000	2100	2	2	8	4	< 5		3	0.30	8.80	0.40
FS2235	19000	1900	5	2	10	4	< 5		3.20	0.30	10	0.40

Sample	Tl (ppm)	Tl (+/-)	U (ppm)	U (+/-)	V (ppm)	V (+/-)	Zn (ppm)	Zn (+/-)
FS2220	0.50	0.20	3.90	0.20	16	1.60	64	6.40
FS2221	0.70	0.20	5.70	0.30	33	3.30	70	7
FS2222	0.70	0.20	5.60	0.30	25	2.50	88	8.80
FS2223	0.50	0.20	4	0.20	19	1.90	66	6.60
FS2224	0.20	0.20	1.10	0.20	2.70	0.50	25	2.50
FS2225	0.30	0.20	4	0.20	450	45	2500	250
FS2226	0.90	0.30	7.20	0.40	25	2.50	89	8.90
FS2227	0.80	0.20	4.70	0.40	27	2.70	72	7.20
FS2228	0.40	0.20	1.50	0.20	84	8.40	210	21
FS2229	0.80	0.20	4.30	0.30	27	2.70	69	7
FS2230	0.80	0.20	4.90	0.40	41	4.10	68	6.80
FS2231	0.80	0.20	4.30	0.30	33	3.30	73	7.30
FS2232	0.80	0.20	4.30	0.30	26	2.60	65	6.50
FS2233	0.30	0.20	0.70	0.20	4	0.50	34	3.40
FS2234	0.50	0.20	2.50	0.20	9	0.90	43	4.30
FS2235	0.60	0.20	3	0.20	14	1.40	52	5.20

Table 4
TA-39 Background Sediment Chemistry Data,
Deionized Water Leachate

Sample	Cl (ppm)	Cl (+/-)	SO4 (ppm)	SO4 (+/-)
FS2220	<2.5		<5	
FS2221	<2.5		10	5
FS2222	<2.5		5.9	5
FS2223	<2.5		<5	
FS2224	<2.5		<5	
FS2225	<2.5		<5	
FS2226	<2.5		<5	
FS2227	8.4	2.5	35	5
FS2228	10.3	2.5	26.5	5
FS2229	<2.5		<5	
FS2230	<2.5		<5	
FS2231	<2.5		<5	
FS2232	<2.5		<5	
FS2233	<2.5		<5	
FS2234	<2.5		<5	
FS2235	<2.5		<5	

Table 5
Summary of Background Sediment Analyses, TA-39, HNO_3 and Deionized Water Digestion

Element	Coarse Channel Sands, Average (ppm) *	Bulk Floodplain Deposit, Average (ppm) **	Minimum Value (ppm) ***	Maximum Value (ppm) ***
Al	835 ± 134	5750 ± 1768	740 ± 74 a	8400 ± 840 c
As	< 0.5	1.8 ± 0.4	< 0.5 a	3 ± 0.6 c, e, f
Ba	8.2 ± 0.2	68 ± 21	8 ± 0.8 a	100 ± 10 c
Be	< 0.08	0.65 ± 0.15	< 0.08 a	1.1 c
Ca	205 ± 35	1600 ± 495	180 ± 18 a	2600 ± 260 c
Cl	< 2.5	< 2.5	< 2.5	10.3 ± 2.5 i
Co	0.65 ± 0.07	2.8 ± 0.8	0.6 ± 0.5 a	3.8 ± 0.5 f
Cr	0.9 ± 0.14	4.3 ± 1.3	0.8 ± 0.5 a	5.9 ± 0.6 e, f
Cu	0.85 ± 0.07	4.4 ± 1.2	0.8 ± 0.5 a	7.3 ± 0.7 e
Fe	1400 ± 140	7650 ± 1273	1400 ± 140 a	57000 ± 5700 d
K	190 ± 14	1365 ± 544	180 ± 74 a	2200 ± 220 f
Mg	185 ± 21	1148 ± 357	170 ± 17 a	1700 ± 170 c
Mn	50 ± 5	272 ± 46	46 ± 4.6 a	1200 ± 120 d
Na	40 ± 8	102 ± 8	34 ± 14 a	190 ± 19 c
Ni	< 2	5 ± 1.4	< 2 a	9 ± 2 d
Pb	< 4	7.8 ± 1.8	< 4 a	16 ± 4 c
Sb	< 5	< 5	< 5	5 ± 5 d
SO4	< 5	< 5	< 5	26.5 ± 5 i
Ta	< 0.3	< 0.3	< 0.3	< 0.3
Th	1.2 ± 0.4	6.3 ± 1.1	0.9 ± 0.3 a	14 ± 1 d
Tl	< 0.3	< 0.3	< 0.3	1.5 ± 0.3 g
U	< 0.3	0.7 ± 0.1	< 0.3 a	1.6 ± 0.3 c
V	1.2 ± 0.3	8.6 ± 2.1	1 ± 0.5 a	66 ± 6.6 d
Zn	9 ± 1	34 ± 4	9 ± 1 a	300 ± 30 d

Notes
* Samples FS2224 and FS2233.
** Samples FS2220, FS2223 (duplicate), FS2229, and FS2232 (duplicate)
*** a = coarse channel sands; b = bulk floodplain deposit; c= mud deposit; d = black sands; e = very fine sand to clay separate of floodplain sample; f = fine sand separate of floodplain deposit; g = coarse to medium sand separate of floodplain deposit; h = 3000 year old floodplain deposit; i = 1200 year old coarse channel sand.

Table 6
Summary of Background Sediment Analyses, TA-39, HF Digestion

Element	Coarse Channel Sands, Average (ppm) *	Bulk Floodplain Deposit, Average (ppm) **	Minimum Value (ppm) ***	Maximum Value (ppm) ***
Al	49500 ± 2121	60750 ± 354	11000 ± 1100 d	69000 ± 6900 h
As	4.2 ± 2.9	6.8 ± 0.6	2.1 ± 0.4 a	10.4 ± 2.1 h
Ba	125 ± 7	276 ± 63	32 ± 3.2 d	410 ± 41 e
Be	1.0 ± 0.1	3.4 ± 0.1	0.91 ± 0.09 a	5.3 ± 0.5 c
Ca	1900 ± 141	4350 ± 636	1800 ± 180 a	8100 ± 810 i
Co	0.9± 0.2	3.0 ± 0.7	< 0.5 d	7 ± 0.7 i
Cr	1.8 ± 1.0	11.8 ± 3.8	1.1 ± 0.5 a	83 ± 8.3 d
Cu	1.1 ± 0.1	7.0 ± 2.0	< 0.5 d	13 ± 1.3 e, f
Fe	4500 ± 566	14500 ± 1414	4100 ± 410 a	? (d?)
K	25000 ± 1414	26550 ± 2121	3600 ± 360 a	29000 ± 2900 b
Mg	500 ± 42	2200 ± 566	470 ± 47 a	3300 ± 330 h
Mn	155 ± 35	435 ± 14	130 ± 13 a	13000 ± 1300 d
Na	19000 ± 1414	17750 ± 2475	2700 ± 270 d	21000 ± 2100 g
Ni	< 2	8.5 ± 3.5	< 2 a	47 ± 5 d
Pb	< 4	12 ± 0.4	< 4 a, i	27 ± 4 c
Sb	< 5	< 5	< 5	14 ± 5 d
Ta	1.1 ± 0.2	4.8 ± 0.5	0.9 ± 0.2 a	6 ± 0.4 b
Th	3.6 ± 0.4	14 ± 1.4	3.3 ± 0.2 a	130 ± 4 d
Tl	0.3 ± 0.1	0.7 ± 0.2	0.2 ± 0.2 a	0.9 ± 0.3 c
U	0.9 ± 0.3	4.1 ± 0.3	0.7 ± 0.2 a	7.2 ± 0.4 c
V	3.4 ± 0.9	22 ± 6	2.7 ± 0.5 a	450 ± 45 d
Zn	30 ± 6	66 ± 1	25 ± 2.5 a	2500 ± 250 d

Notes

* Samples FS2224 and FS2233.

** Samples FS2220, FS2223 (duplicate), FS2229, and FS2232 (duplicate)

*** a = coarse channel sands; b = bulk floodplain deposit; c= mud deposit; d = black sands; e = very fine sand to clay separate of floodplain sample; f = fine sand separate of floodplain deposit; g = coarse to medium sand separate of floodplain deposit; h = 3000 year old floodplain deposit; i = 1200 year old coarse channel sand.

Table 7
Summary of Different Size Fractions, TA-39, HNO_3 and Deionized Water Digestion

Element	Coarse Channel Sands, Average (ppm) *	Coarse and Medium Sand, Average (ppm) **	Fine Sand, Average (ppm) ***	Very Fine Sand, Silt, Clay, Average (ppm) ****
Al	835 ± 134	3650 ± 636	7250 ± 495	7050 ± 354
As	< 0.5	1 ± 0.5	2.5 ± 0.7	2.5 ± 0.7
Ba	8.2 ± 0.2	43 ± 8	86 ± 13	95 ± 6
Be	< 0.08	0.35± 0.06	0.85 ± 0.04	0.86 ± 0.05
Ca	205 ± 35	1030 ± 99	2050 ± 495	2200 ± 424
Cl	< 2.5	< 2.5	< 2.5	< 2.5
Co	0.65 ± 0.07	1.8 ± 0.4	3.4 ± 0.6	3.3 ± 0.4
Cr	0.9 ± 0.14	2.4 ± 0.2	5.3 ± 0.9	5.9 ± 0.1
Cu	0.85 ± 0.07	2.9 ± 0.2	6.5 ± 1.2	7.4 ± 0.1
Fe	1400 ± 140	4900 ± 141	9400 ± 283	8900 ± 707
K	190 ± 14	875 ± 318	1800 ± 566	1700 ± 283
Mg	185 ± 21	705 ± 163	1450 ± 212	1500 ± 150
Mn	50 ± 5	185 ± 7	325 ± 35	280 ± 71
Na	40 ± 8	78 ± 4	115 ± 7	98 ± 31
Ni	< 2	4 ± 2	6.0 ± 1.4	6.0 ± 1.4
Pb	< 4	5.5 ± 0.7	9.5 ± 0.7	8.5 ± 2.1
Sb	< 5	< 5	< 5	< 5
SO4	< 5	< 5	< 5.5	< 7.5
Ta	< 0.3	< 0.3	< 0.3	< 0.3
Th	1.2 ± 0.4	4.0 ± 0.5	7.1 ± 0.5	7.3 ± 0.6
Tl	< 0.3	< 0.9	< 0.3	< 0.3
U	< 0.3	0.45 ± 0.07	0.80 ± 0.28	0.75 ± 0.21
V	1.2 ± 0.3	5 ± 0.5	11 ± 1	13 ± 1
Zn	9 ± 1	24 ± 2	41 ± 5	35 ± 4

Notes
* Samples FS2224 and FS2233.
** Samples FS2234 and FS2235.
*** Samples FS2222 and FS2231.
*** Samples FS2221 and FS2230.

Table 8
Summary of Different Size Fractions, TA-39, HF Digestion

Element	Coarse Channel Sands, Average (ppm) *	Coarse and Medium Sand, Average (ppm) **	Fine Sand, Average (ppm) ***	Very Fine Sand, Silt, Clay, Average (ppm) ****
Al	49500 ± 2121	60000 ± 1414	60500 ± 2121	56500 ± 707
As	4.2 ± 2.9	2.8 ± 0.4	5.6 ± 0.4	7.2 ± 2.7
Ba	125 ± 7	195 ± 21	325 ± 78	390 ± 28
Be	1.0 ± 0.1	2.7 ± 0.4	4.0 ± 0.6	3.5 ± 0.4
Ca	1900 ± 141	3450 ± 71	4900 ± 849	5350 ± 636
Co	0.9± 0.2	1.8 ± 0.4	3.9 ± 0.1	3.9 ± 0.1
Cr	1.8 ± 1.0	6.0 ± 2.2	15 ± 4	21 ± 4
Cu	1.1 ± 0.1	4.1 ± 1.0	11 ± 2	13 ± 1
Fe	4500 ± 566	9750 ± 1768	17500 ± 707	18000 ± 1414
K	25000 ± 1414	25500 ± 707	25500 ± 2121	22500 ± 707
Mg	500 ± 42	1300 ± 424	2800 ± 424	2900 ± 283
Mn	155 ± 35	295 ± 50	530 ± 71	455 ± 50
Na	19000 ± 1414	20000 ± 1414	16000 ± 2828	14500 ± 707
Ni	< 2	3.5 ± 2.1	7.0 ± 1.4	11 ± 1
Pb	< 4	9.0 ± 1.4	15 ± 2	17 ± 5
Sb	< 5	< 5	< 5	< 5
Ta	1.1 ± 0.2	3.1 ± 0.1	4.9 ± 0.6	4.4 ± 0.5
Th	3.6 ± 0.4	9.4 ± 0.9	17 ± 2	17 ± 1
Tl	0.3 ± 0.1	0.6 ± 0.1	0.8 ± 0.1	0.8 ± 0.1
U	0.9 ± 0.3	2.8 ± 0.4	5.0 ± 0.9	5.3 ± 0.6
V	3.4 ± 0.9	12 ± 4	29 ± 6	37 ± 6
Zn	30 ± 6	48 ± 6	81 ± 11	69 ± 1

Notes
* Samples FS2224 and FS2233.
** Samples FS2234 and FS2235.
*** Samples FS2222 and FS2231.
*** Samples FS2221 andFS 2230.

Table 9
Comparison of Modern and Old Deposits, TA-39, HNO_3 and Deionized Water Digestion

Element	Coarse Channel Sands, Average (ppm) *	Old Channel Sands (ppm) **	Bulk Floodplain Deposit, Average (ppm) ***	Old Floodplain Deposits (ppm) ****
Al	835 ± 134	2300 ± 230 a	5750 ± 1768	7700 ± 770
As	< 0.5	0.9 ± 0.5	1.8 ± 0.4	2 ± 0.5
Ba	8.2 ± 0.2	32 ± 3 a	68 ± 21	71 ± 7.1
Be	< 0.08	0.17 ± 0.08 a	0.65 ± 0.15	0.74 ± 0.07
Ca	205 ± 35	770 ± 77 a	1600 ± 495	1500 ± 150
Cl	< 2.5	10.3 ± 2.5 b, c	< 2.5	8.4 ± 2.5 b
Co	0.65 ± 0.07	3.1 ± 0.5 b	2.8 ± 0.8	2.7 ± 0.5
Cr	0.9 ± 0.14	5.4 ± 0.5 b	4.3 ± 1.3	5.2 ± 0.5
Cu	0.85 ± 0.07	1.8 ± 0.5 a	4.4 ± 1.2	4.3 ± 0.5
Fe	1400 ± 140	13000 ± 1300 b	7650 ± 1273	8400 ± 840
K	190 ± 14	540 ± 54 a	1365 ± 544	1600 ± 160
Mg	185 ± 21	570 ± 57 a	1148 ± 357	1400 ± 140
Mn	50 ± 5	240 ± 24 b	273 ± 46	220 ± 22
Na	40 ± 8	66 ± 14	102 ± 8	150 ±15 b
Ni	< 2	4 ± 2	5 ± 1.4	4 ± 2
Pb	< 4	7 ± 4	7.8 ± 1.8	7 ± 4
Sb	< 5	< 5	< 5	< 5
SO4	< 5	26.5 ± 0.5 b	< 5	35 ± 5 b, c
Ta	< 0.3	< 0.3	< 0.3	< 0.3
Th	1.2 ± 0.4	2.2 ± 0.3 a	6.3 ± 1.1	5.8 ± 0.4
Tl	< 0.3	< 0.3	< 0.3	< 0.3
U	< 0.3	< 0.3	0.7 ± 0.1	0.6 ± 0.3
V	1.2 ± 0.3	20 ± 2 b	8.6 ± 2.1	9 ± 0.9
Zn	9 ± 1	47 ± 5 b	34 ± 4	33 ± 3

Notes

* Samples FS2224 and FS2233.

** Sample FS2228; a = beyond range of modern channel sands, but within range of medium to coarse sand separate of banks; b = beyond range of medium to coarse sand separate of floodplain deposits; c = maximum value from this data set.

*** Samples FS2220, FS2223 (duplicate), FS2229, and FS2232 (duplicate)

**** Sample FS2227; a = beyond range of modern bulk floodplain deposits, but within range of fine sand to clay separates of floodplain deposits; b = beyond range of fine sand to clay separates of floodplain deposits; c = maximum value from this data set.

Table 10
Comparison of Modern and Old Deposits, TA-39, HF Digestion

Element	Coarse Channel Sands, Average (ppm) *	Old Channel Sands (ppm) **	Bulk Floodplain Deposit, Average (ppm) ***	Old Floodplain Deposits (ppm) ****
Al	49500 ± 2121	63000 ± 6300 a	60750 ± 354	69000 ± 6900 c
As	4.2 ± 2.9	7.5 ± 1.5	6.8 ± 0.6	10.4 ± 2.1 a
Ba	125 ± 7	290 ± 29 b	276 ± 63	340 ± 34
Be	1.0 ± 0.1	1.5 ± 0.15 a	3.4 ± 0.1	4 ± 0.4
Ca	1900 ± 141	8100 ± 810 b, c	4350 ± 636	6100 ± 610 a
Co	0.9± 0.2	7 ± 0.7 b, c	3.0 ± 0.7	3.9 ± 0.5
Cr	1.8 ± 1.0	23 ± 2.3 b	11.8 ± 3.8	15 ± 1.5
Cu	1.1 ± 0.1	2.6 ± 0.5 a	7.0 ± 2.0	7.6 ± 0.8
Fe	4500 ± 566	52000 ± 5200 b, c?	14500 ± 1414	17000 ± 1700
K	25000 ± 1414	25000 ± 2500	26550 ± 2121	27000 ± 2700
Mg	500 ± 42	2500 ± 250 b	2200 ± 566	3300 ± 330
Mn	155 ± 35	1300 ± 130 b	435 ± 14	450 ± 45
Na	19000 ± 1414	20000 ± 2000	17750 ± 2475	18000 ± 1800
Ni	< 2	14 ± 2 b	8.5 ± 3.5	8 ± 2
Pb	< 4	< 4	12 ± 0.4	14 ± 4
Sb	< 5	< 5	< 5	< 5
Ta	1.1 ± 0.2	2.6 ± 0.3 a	4.8 ± 0.5	4.4 ± 0.4
Th	3.6 ± 0.4	9.4 ± 0.4 a	14 ± 1.4	15 ± 0.6
Tl	0.3 ± 0.1	0.4 ± 0.2	0.7 ± 0.2	0.8 ± 0.2
U	0.9 ± 0.3	1.5 ± 0.2	4.1 ± 0.3	4.7 ± 0.4
V	3.4 ± 0.9	84 ± 8.4 b	22 ± 6	27 ± 2.7
Zn	30 ± 6	210 ± 21 b	66 ± 1	72 ± 7.2

Notes

* Samples FS2224 and FS2233.

** Sample FS2228; a = beyond range of modern channel sands, but within range of medium to coarse sand separate of floodplain deposits; b = beyond range of medium to coarse sand separate of floodplain deposits; c = maximum value from this data set.

*** Samples FS2220, FS2223 (duplicate), FS2229, and FS2232 (duplicate)

**** Sample FS2227; a = beyond range of modern bulk floodplain deposits, but within range of fine sand to clay separates of floodplain deposits; b = beyond range of fine sand to clay separates of floodplain deposits; c = maximum value from this data set.

Table 11
Summary Statistics For Background Sediment Samples *

Analyte	Number of Outliers	Minimum Value (ppm)	Median Value (ppm)	Mean Value (ppm)	Standard Deviation (ppm)	Maximum Value (ppm)	utl95**
Al	0	740	5400	5023.12	2665.26	8400	11747.57
As	0	<0.5	2	1.65	0.91	3.0	3.94
Ba	0	8	62.5	59.52	32.44	100	141.37
Be	0	<0.08	0.68	0.59	0.32	1.1	1.40
Ca	0	180	1400	1451.88	746.67	2600	3335.73
Co	1	0.6	3	2.57	1.01	3.8	5.16
Cr	1	0.8	4.95	4.15	1.80	5.9	8.77
Cu	1	0.8	4.35	4.21	2.20	7.5	9.85
Fe	2	1400	8400	6971.43	2845.90	9600	14410.60
K	0	180	1250	1171.88	664.49	2200	2848.39
Mg	0	170	1110	1029.38	508.90	1700	2313.33
Mn	1	46	240	240.60	97.21	380	490.04
Na	0	34	93	96.31	39.02	190	194.77
Ni	0	<2	4.5	4.81	2.07	9	10.04
Pb	1	<4	7.5	7.13	2.61	11	13.84
Th	1	0.9	5.9	5.24	2.28	8	11.09
U	1	<0.3	0.6	0.58	0.27	1.0	1.29
V	1	1.0	9.5	8.91	4.82	20	21.27
Zn	1	9	33.5	32.00	11.74	48	62.11
SO_4	2	<5	NA	NA	NA	10	NA

Notes:
* Statistics only presented for results of HNO_3 and deionized digestion procedures, and were calculated after outliers were deleted. Outliers presented in Table 12. No values are presented for Cl because only two analyses were above detection limits, and these are excluded as outliers.
** utl95 is a (.95,.95) UTL, computed using estimated mean and standard deviation and normal assumptions (i.e., selecting a "k-factor" appropriate for a sample of size 16 (0 outliers, k=2.523), 15 (1 outlier, k=2.566) or 14 (2 outliers, k=2.614). Then utl95 = mean + k*standard deviation).

Table 12
Outliers in Background Sediment Data Set *

Sample Number	Sample Description	Analyte	Concentration (ppm)
FS 2225	black magnetite-rich sands	Co	6
		Cr	12
		Fe	57000
		Mn	1200
		Th	14
		V	66
		Zn	300
FS 2226	recent mud deposit	Cu	12
		Pb	16
		U	1.6
FS 2227	prehistoric floodplain deposit	Cl	8.5
		SO_4	35
FS 2228	prehistoric channel sands	Cl	10.3
		Fe	13000
		V	20
		SO_4	26.5

Notes:
* Outliers only calculated for HNO_3 and deionized water digestions. Outliers identified as values that would inflate the estimate of the mean by more than 10%.