



Element Concentrations in Surface Soils of the Coconino Plateau, Grand Canyon Region, Coconino County, Arizona

By Bradley S. Van Gosen

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Contents

Acknowledgments	v
Abstract	1
Introduction	1
Background	2
Sample Collection	5
Sample Preparation	5
Analytical Techniques	5
Summary of Results	5
References Cited	7
Appendix 1. Geochemical Analyses of Soils Collected on the Surface of the Coconino Plateau Grand Canyon Region, Northern Arizona	9

Figures

1. Index map for background soil samples collected from the surface of Coconino Plateau	3
2. Aerial view of the SBF breccia pipe showing the locations of background soil samples collected at this feature in 1985	4

Table

1. Summary statistics of geochemical analyses of soils collected on the surface of the Coconino Plateau	6
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 1927).

Acknowledgments

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Abstract

This report provides the geochemical analyses of a large set of background soils collected from the surface of the Coconino Plateau in northern Arizona. More than 700 soil samples were collected at 46 widespread areas, sampled from sites that appear unaffected by mineralization and (or) anthropogenic contamination. The soils were analyzed for 47 elements, thereby providing data on metal concentrations in soils representative of the plateau. These background concentrations can be used, for instance, for comparison to metal concentrations found in soils potentially affected by natural and anthropogenic influences on the Coconino Plateau in the Grand Canyon region of Arizona.

The soil sampling survey revealed low concentrations for the metals most commonly of environmental concern, such as arsenic, cobalt, chromium, copper, mercury, manganese, molybdenum, lead, uranium, vanadium, and zinc. For example, the median concentrations of the metals in soils of the Coconino Plateau were found to be comparable to the mean values previously reported for soils of the western United States.

Introduction

This report provides geochemical analyses of more than 700 background soil samples collected in 1984, 1985, and 1986 by the U.S. Geological Survey (USGS) at 46 widely separated areas on the surface of the Coconino Plateau, south of the Grand Canyon in northern Arizona. Analytical results for 47 elements in these soils are provided in the accompanying spreadsheet “Geochemical Analyses of Soils Collected on the Surface of the Coconino Plateau, Grand Canyon Region, Northern Arizona” (see appendix 1). A statistical summary of the analytical results is provided to represent the chemistry of soils at the surface of the Coconino Plateau, specifically, a large set of representative soils that appear unaffected by mineralization and (or) anthropogenic contamination.

The accompanying dataset can be used to represent the elemental concentrations typical of soils of the Coconino Plateau (“background values”¹) for comparison to other soils that may have been altered by anthropogenic activities or natural influences. For example, the geochemistry of background soils provided in this report can be compared to the concentrations in soils near uranium mining operations in this region (Alpine, 2010; Bills and others, 2011; Bureau of Land Management, 2011; Naftz and Walton-Day, 2016).

¹In this context, geochemical “background” is used to describe “a relative measure to distinguish between natural element or compound concentrations and anthropogenically-influenced concentrations in real sample collectives,” as discussed by Matschllat and others (2000, p. 991).

Background

In 1984, 1985, and 1986, the USGS conducted a soil sampling survey across numerous solution-collapse features exposed on the surface of the Coconino Plateau, south of the Grand Canyon in northern Arizona (Van Gosen and Wenrich, 1991). These features were selected for the soil survey because they were thought to typify the outcrop manifestation of sedimentary solution-collapse features in the Grand Canyon region, which can include

- deeply rooted, solution-collapse breccia pipes that sometimes contain significant deposits of uranium and base metals (Wenrich, 1985, 1986; Chenoweth, 1986, 1988; Wenrich and others, 1989b; Alpine, 2010; Ross and Moreton, 2012);
- shallow collapse features formed by dissolution of underlying beds of gypsum (“gypsum collapses”); and
- shallow sinkholes.

The soil surveys were conducted across the surface of the following types of features exposed on the surface of the Coconino Plateau (fig. 1): (a) 3 solution-collapse breccia pipes known to contain substantial uranium and base-metal mineralization at depth—the Canyon, “SBF,” and Mohawk Canyon breccia pipes; (b) 1 feature interpreted to overlie a “gypsum collapse”; (c) 1 feature interpreted to be a sinkhole; (d) 37 circular features that may overlie breccia pipes, which were identified and mapped by Wenrich and others (1997) and Billingsley and others (2000) but that remain of unknown origin because they have not been drilled or further explored as of mid-2016; and (e) 4 near-surface, stratabound copper deposits, which are perhaps related to breccia pipes but, as of mid-2016, their origin is undetermined.

The unusual solution-collapse breccia pipes of northern Arizona, some of which host high-grade uranium orebodies, are commonly expressed on plateau surfaces as shallow topographic depressions enclosed by a roughly circular, raised rim of sedimentary rocks (Wenrich and Sutphin, 1988; Wenrich, 1992). The features sampled by the 1984–1986 survey were identified and mapped as collapse features that possibly overlie breccia pipes as part of a study of potential for uranium-bearing breccia pipes within the Hualapai Indian Reservation (Billingsley and others, 2000; Wenrich and others, 1989a, 1992, 1997). The 37 circular features included in this report were selected for the soil survey primarily based on their appearance; that is, they are topographic depressions surrounded by a circular rim of rock exposed on the surface of the Coconino Plateau (fig. 2).

All soil samples were collected on the weathered surface of the Kaibab Formation, which is capped primarily by fossiliferous sandy limestone. The Kaibab Formation forms the cap rock unit for the vast majority of the Coconino Plateau (Billingsley, 2000; Billingsley and Wellmeyer, 2003; Billingsley and others, 2006a, 2006b).

In the soil sampling surveys of 1984, 1985, and 1986, several samples were collected 50–150 meters outside of each collapse feature to provide background samples for comparison to the samples collected inside the collapse features, as shown in figure 2. In general, an equal (or nearly equal) number of soil samples were collected inside and outside (background areas) the collapse feature. The latitude and longitude information listed in the spreadsheet “Geochemical Analyses of Soils Collected on the Surface of the Coconino Plateau, Grand Canyon Region, Northern Arizona” (appendix 1) refers to the location at the center of the collapse feature. Refer to Van Gosen and Wenrich (1991) for detailed maps of sample locations at each feature. ***Only the geochemical analyses of the background soils are the data provided in this report.*** Analytical results of soil samples that were collected inside the collapse features are available in Van Gosen and Wenrich (1991).

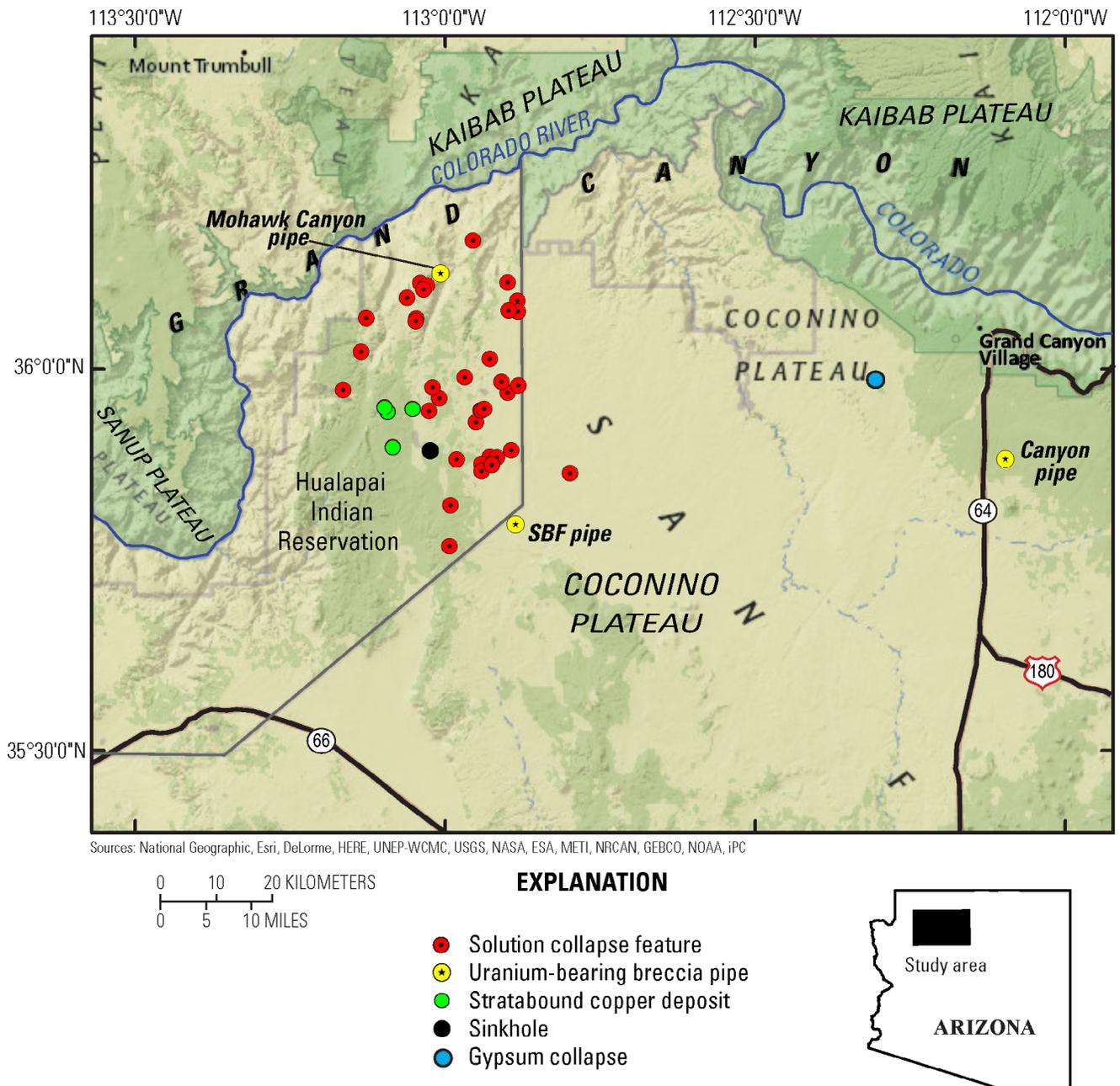


Figure 1. Background soil samples were collected from the surface of Coconino Plateau near the collapse features shown on the map, which are located in the Grand Canyon region of northern Arizona.

The principal goal of the 1984–1986 soil sampling program was to determine if soils could provide a relatively inexpensive method of distinguishing collapse structures that lack mineralization from those that overlie breccia pipes with mineralization at depth (Wenrich and Aumente-Modreski, 1994). However, the geochemical results of the 1984–1986 sampling survey and a recent soil study at the Canyon breccia pipe (Naftz and Walton-Day, 2016) indicate that soils cannot be used to distinguish breccia pipes with mineralization at depth from other collapse features. That is, soils at the surface of the collapse feature do not display a distinct geochemical contrast from nearby background soils. The results of the soil surveys across three uranium-bearing breccia pipes (fig. 1) found no evidence of

mineralization on the surface of the collapse feature, including the soils above the Canyon pipe (Naftz and Walton-Day, 2016), the Mohawk Canyon pipe (Wenrich and others, 1988; Van Gosen and Wenrich, 1991); and the SBF pipe (Van Gosen and Wenrich, 1991). Also, no additional mineralized breccia pipes were discovered by this soil survey.

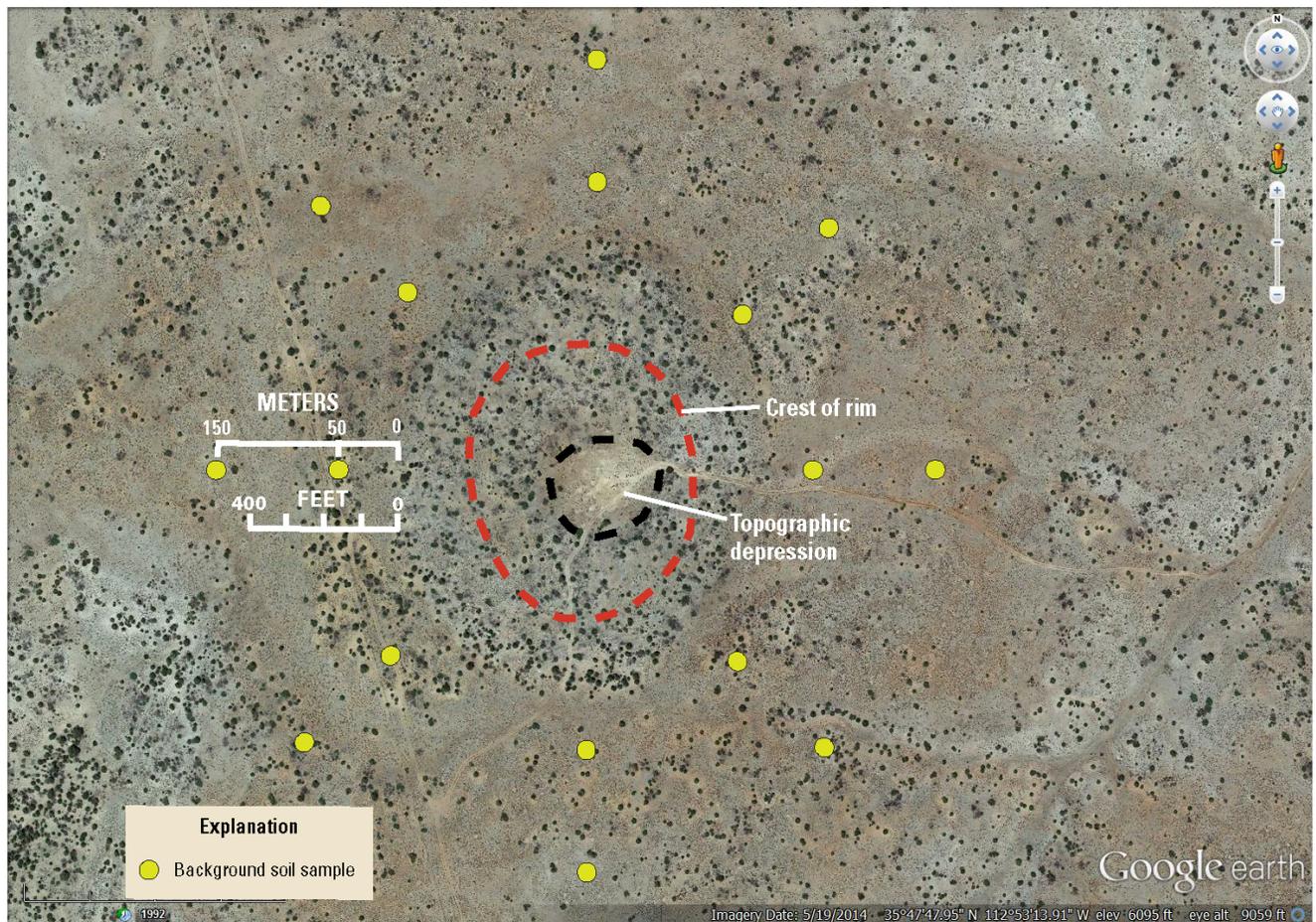


Figure 2. Aerial view of the “SBF” breccia pipe (fig. 1) showing the locations of background soil samples collected at this feature in 1985. This is an example of the radial sampling pattern employed for the background soil sites, with most background samples collected 50 and 150 meters beyond the outer rim of the collapse feature. The background soils at this site are samples 0562-AG-SC5 to 0562-BJ-SC5, rows 183 to 198, in the accompanying spreadsheet “Geochemical Analyses of Soils Collected on the Surface of the Coconino Plateau, Grand Canyon Region, Northern Arizona” (appendix 1). The center of the SBF breccia pipe is located at latitude 35.79659 North and longitude 112.88774 West (datum of WGS84).

Sample Collection

The soil samples of the Van Gosen and Wenrich (1991) study were consistently collected at 3–4 inches (in.) of depth and just below from holes dug by a hand trowel. Sampling was done at these depths rather than at the surface to avoid organic matter and other extraneous surface materials, such as windblown material. An individual sampled weighed about 4 pounds.

A pilot sampling study during 1984 compared the analytical results from 3–4 in. depth samples with 7–8 in. depth samples; the pilot study found no discernible difference in metal concentrations between horizons. Thus, the 3–4 in. depth was used in the subsequent larger soil sampling programs of 1985 and 1986. A statistical summary of the analytical results is shown in table 1.

Sample Preparation

All of the soil samples were sieved through an 80 mesh screen opening (equal to 0.0067 in.). The <80 mesh material was then pulverized to <100 mesh, and this <100 mesh material was submitted for geochemical analyses.

Analytical Techniques

The geochemical analyses of the <80 mesh fraction of the soil samples were performed by the USGS Analytical Laboratory, Denver, Colorado, and Geochemical Services, Inc., Sparks, Nevada. The analytical methods applied to these samples by the USGS laboratory included inductively coupled plasma-atomic emission spectroscopy, atomic absorption, and delayed neutron activation; refer to Taggart (2002) for analytical processing procedures. Geochemical Services, Inc., analyzed the soil samples by digesting 5.0 grams of each sample (procedures are proprietary) and analyzing the dissolved sample by inductively coupled plasma-atomic emission spectroscopy.

Summary of Results

This report summarizes the basic statistical results of the geochemical analyses of the soil samples collected on the surface of the Coconino Plateau. The background soils did not exhibit elevated concentrations for the metals that are most commonly of environmental concern, including arsenic, cobalt, chromium, copper, mercury, manganese, molybdenum, lead, uranium, vanadium, and zinc. For example, the median concentrations of these elements are comparable to the mean values found in soils of the western United States as previously reported in another study.

Soil surveys conducted over the collapse features of the Coconino Plateau have not proven successful in identifying breccia pipes that contain uranium deposits. That is, based on the chemistry of soils collected on the surface of collapse features, breccia pipes with known uranium deposits at depth could not be identified or distinguished from the other types of unmineralized collapse features that are typical of the region.

Table 1. Summary statistics of geochemical analyses of soils collected on the surface of the Coconino Plateau, Grand Canyon region, northern Arizona.

[ppm, parts per million; DN, delayed neutron activation analyses; wt. %, weight percent; ICP, inductively coupled plasma-atomic emission spectroscopy analyses; AA, atomic absorption analyses; nr, not reported. The “Number” column provides the number of samples analyzed for that element. Values in the “West U.S.” column are mean concentrations in samples of soils in the western United States, as reported by Shacklette and Boerngen (1984)]

Element	Symbol	Unit	Method	Median	Maximum	Number	West U.S.
Thorium	Th	ppm	DN	10.1	17.8	366	9.1
Uranium	U	ppm	DN	3.5	8.8	366	2.5
Aluminum	Al	wt. %	ICP	4.9	8.0	366	5.8
Calcium	Ca	wt. %	ICP	2.0	14	366	1.8
Iron	Fe	wt. %	ICP	2.3	4.1	366	2.1
Potassium	K	wt. %	ICP	1.6	2.7	366	1.8
Magnesium	Mg	wt. %	ICP	0.97	4.8	366	0.74
Sodium	Na	wt. %	ICP	0.47	0.91	366	0.97
Phosphorus	P	wt. %	ICP	0.1	0.9	366	0.03
Titanium	Ti	wt. %	ICP	0.26	0.46	366	0.22
Silver	Ag	ppm	AA, ICP	0.08	<2	717	nr
Arsenic	As	ppm	AA, ICP	<10	70	717	5.5
Gold	Au	ppm	ICP	<8	<8	717	nr
Barium	Ba	ppm	ICP	430	700	366	580
Beryllium	Be	ppm	ICP	1	2	366	0.68
Bismuth	Bi	ppm	ICP	<0.5	<10	717	nr
Cadmium	Cd	ppm	ICP	<0.5	18	717	nr
Cerium	Ce	ppm	ICP	57	83	366	65
Cobalt	Co	ppm	ICP	10	20	366	7.1
Chromium	Cr	ppm	ICP	64	220	366	41
Copper	Cu	ppm	ICP	22	390	717	21
Europium	Eu	ppm	ICP	<2	<2	366	nr
Gallium	Ga	ppm	ICP	4.5	20	717	16
Mercury	Hg	ppm	ICP	<0.5	0.83	410	0.05
Holmium	Ho	ppm	ICP	<4	<4	366	nr
Lanthanum	La	ppm	ICP	34	51	366	30
Lithium	Li	ppm	ICP	28	60	366	22
Manganese	Mn	ppm	ICP	510	1100	366	380
Molybdenum	Mo	ppm	ICP	<2	11	717	0.85
Niobium	Nb	ppm	ICP	8	15	31	8.7
Neodymium	Nd	ppm	ICP	30	42	366	36
Nickel	Ni	ppm	ICP	25	62	366	15
Palladium	Pd	ppm	ICP	<0.25	<0.25	410	nr
Lead	Pb	ppm	ICP	13	170	717	17
Platinum	Pt	ppm	ICP	<0.5	<0.5	410	nr
Antimony	Sb	ppm	ICP	<0.25	4.1	410	0.47
Scandium	Sc	ppm	ICP	7	14	366	8.2
Selenium	Se	ppm	ICP	<1	5.8	410	0.23
Tin	Sn	ppm	ICP	<0.5	2.5	717	0.90
Strontium	Sr	ppm	ICP	140	560	366	100
Tantalum	Ta	ppm	ICP	<40	<40	366	nr
Tellurium	Te	ppm	ICP	<0.5	1	410	nr
Thallium	Tl	ppm	ICP	<0.5	1.95	410	nr
Vanadium	V	ppm	ICP	52	100	366	70
Yttrium	Y	ppm	ICP	22	49	366	22
Ytterbium	Yb	ppm	ICP	2	3	366	2.6
Zinc	Zn	ppm	ICP	57	330	717	55

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Appendix 1. Geochemical Analyses of Soils Collected on the Surface of the Coconino Plateau, Grand Canyon Region, Northern Arizona

The Excel spreadsheet [Appendix-1.xls](#) provides geochemical analyses of soils collected on the surface of the Coconino Plateau, Grand Canyon region, northern Arizona.