

Soil chemical signatures of a historic sod house: activity area analysis of an arctic semisubterranean structure on Nelson Island, Alaska

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Received: 23 April 2010 / Accepted: 14 July 2010 / Published online: 29 July 2010
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Abstract On Nelson Island in western Alaska, some Yup'ik inhabitants built and inhabited semisubterranean houses until the early 1960s. This affords a unique opportunity to examine known activity areas of ethnoarchaeological soils using multielement chemical characterization of soils. These data can then be compared to archaeological investigations, allowing a nuanced and sophisticated understanding of the activities performed in the past. Here, we present elemental concentration data from soil extracts, generated with a quadrupole inductively coupled plasma mass spectrometer, of the following elements in the soil extract recorded in parts per billion: sodium (Na), magnesium (Mg), aluminum (Al), phosphorus (P), potassium (K), calcium (Ca), titanium (Ti), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), strontium (Sr), barium (Ba), lead (Pb), and uranium (U). When compared to an offsite area, the sod house samples were enriched in phosphorus and magnesium, and specific areas within the sod house exhibited different signatures related to different activities, including the incorporation of wood ash and waste into the soil.

Keywords Elemental concentration · Q-ICP-MS · Yup'ik · Ethnoarchaeology

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Western Alaska is one of the few places in North America where people lived in semisubterranean houses within living memory. As such, it is an ideal place to examine the chemical signatures of known activity areas through chemical analysis of ethnoarchaeological soils. Activity area analysis of archaeological soils using multielement characterizations can be a very useful tool, yet in many regions it is impossible to perform ethnoarchaeological investigations of known activities using local soils. Here, we present new elemental concentration data from a recently abandoned semisubterranean sod house in the Yup'ik community of Tununak, western Alaska (Fig. 1). First, we briefly introduce activity area analysis through soil chemistry, as well as the environmental and cultural background of the study region. We then discuss our field and laboratory methods, followed by a presentation of our data and interpretations from our multielement chemical characterization of ethnoarchaeological soils. We conclude with a discussion of future directions for research.

Principles and methods of soil chemistry and activity area analysis

Soil chemistry, specifically soil phosphate analysis, was initially useful for the identification of archaeological sites (e.g., Arrhenius 1962; Dauncey 1952; Eidt 1977). More recently, multielement characterization of archaeological soils has increased the resolution with which archaeologists can examine past activities (e.g., Aston et al. 1998; Barba 1986; Bintliff et al. 1992; Entwistle and Abrahams 1997; Fernández et al. 2005; Guttman et al. 2008; Homsey and Capó 2006; Manzanilla and Barba 1990; Middleton 2004;

Sampietro and Vattuone 2005; Wells 2004) and focus on “cultural soilscapes” (Wells 2006). Ethnoarchaeological studies of known activity areas in a number of regions have shown similar patterns (Barba and Ortiz 1978; Fernández et al. 2002; Knudson et al. 2004a; Middleton and Price 1996; Terry et al. 2004; Wilson et al. 2005, 2006b, 2008). For example, anthropogenic soils in human activity areas can be elevated in calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), and phosphorus (P) (Arnold 2006; Carr 1982; Entwistle et al. 2000; Hayden 1997; Konrad et al. 1983; Middleton and Price 1996; Pierce et al. 1998). More specifically, hearths can have elevated potassium (K), magnesium (Mg), lead (Pb), and phosphorus (P) concentrations and can be a significant source of anthropogenic elemental enrichment (Meharg et al. 2006; Middleton 2004; Pierce et al. 1998; Wilson et al. 2006a). In addition, food preparation and/or consumption areas can have elevated calcium (Ca) and strontium (Sr) concentrations (Knudson et al. 2004a; Middleton and Price 1996). Elemental analysis of archaeological soils has been successful in both Old and New World sites from 10,000 to 300 years old, demonstrating the utility of this technique (Entwistle and Abrahams 1997; Entwistle et al. 2000, 2007, 2009; Hutson and Terry 2006; Konrad et al. 1983; Linderholm 2007; Linderholm and Lundberg 1994; Middleton 2004; Middleton and Price 1996; Parnell et al. 2002; Sullivan and Kealhofer 2004; Terry et al. 2004; Wells et al. 2000, 2007).

Environmental and cultural background

The community of Tununak on Nelson Island, Alaska

Nelson Island is located on the coast of western Alaska in the Yukon–Kuskokwim Delta, which is composed of several alluvial fans (Fig. 1; Shaw 1983). The delta is bordered in the northeast by late Cretaceous rocks including shallow marine and nonmarine paralic sandstones, shales, conglomerates, and coals (Ager 1982; Dobey and Hartman 1973; McNab and Avers 1994) and in the south by the Kilbuck Mountains, which are composed of Mesozoic sedimentary rocks such as shale, siltstone, and sandstone (McNab and Avers 1994; Selkregg 1979). Nelson Island itself consists of Quaternary and Tertiary olivine basalt and underlying Cretaceous or Tertiary sedimentary bedrock (Dobey and Hartman 1973; Lyle et al. 1982; Miller and Whitehead 1999).

The delta is very wet and contains thousands of lakes, rivers, and brackish river courses as well as a discontinuous permafrost layer that can be 200 m deep (McNab and Avers 1994; Selkregg 1979). Soils on the delta are generally Histic Pergelic Cryaquepts and Pergelic Cryofibrists

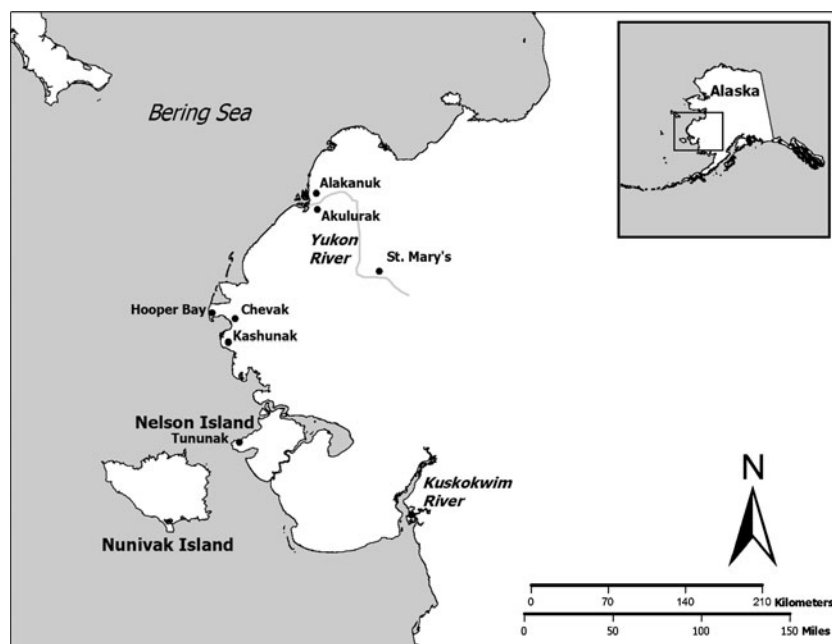
(McNab and Avers 1994) or Histic Cryosols according to the World Reference Base classification scheme (WRB IWG 2006). These soils are poorly drained and slow weathering and contain large amounts of organic matter, all of which should allow the retention of anthropogenic soil signatures (Knudson and Frink 2010; Knudson et al. 2004b; Misarti 2007).

The Yukon–Kuskokwim Delta region experiences extreme temperatures, particularly on the coast. Although the average annual temperature ranges from -4 to -1°C (25°F to 31°F), winter temperatures are often -34°C (-30°F) with wind chills of -73°C (-100°F) (Barker 1993; McNab and Avers 1994). In addition, average annual precipitation is 380 to 560 mm (15 to 22 in.; McNab and Avers 1994). Despite the cold winters, Nelson Island supports a wide variety of animals and edible plants. Muskox (*Ovibos moschatus*), mink (*Mustela vison*), river otter (*Lutra canadensis*), tundra hare (*Lepus othus*), beaver (*Castor canadensis*), and Arctic (*Alopex lagopus*) and red fox (*Vulpes vulpes*) are hunted and trapped. Migratory waterfowl such as Canada geese (*Branta canadensis*), black brandts (*Branta nigricans*), emperor geese (*Phalacrocorax canagica*), sandhill cranes (*Grus canadensis*), and king eiders (*Somateria spectabilis*) are also important seasonal resources. In addition, edible plants on Nelson Island include ferns (*Dryopteris dilatata*), wild potato (*Claytonia tuberosa*), marsh marigold (*Caltha palustris*), sour dock (*Rumex arica*), and several species of berries including blueberries (*Vaccinium uliginosum*) and salmonberries (*Rubus chamaemorus*).

Although terrestrial subsistence resources are important, the Nelson Island Yup'ik rely most heavily on a variety of marine resources. Among the most important marine resources is the Pacific bearded seal (*Erignathus barbatus*), although Northern (*Callorhinus ursinus*), ringed (*Phoca hispida*), harbor (*Phoca vitulina*), spotted (*Phoca largha*), and ribbon (*Phoca fasciata*) seals are also hunted (Ager 1982; Fienup-Riordan 1986; Fitzhugh and Kaplan 1982; Frink 2005). Migrating Pacific walrus (*Odobenus rosmarus*) and the beluga whale (*Delphinapterus leucas*) are also captured along the coast.

Finally, fish are the most important subsistence source on Nelson Island and in the Yukon–Kuskokwim Delta more generally. After the initial run of herring (*Clupea harengus*) in late May through mid-June, salmon began to run in late June or early July and continued to run through September (Levin and Schiewe 2001; Pete et al. 1987). The most important salmon species are chinook or king salmon (*Oncorhynchus tshawytscha*) and the Coho or silver salmon (*Oncorhynchus kisutch*). In addition, Pacific halibut (*Hippoglossus stenolepis*) and Pacific cod (*Gadus macrocephalus*) are procured in the summer while freshwater fish like the blackfish (*Dallia pectoralis*) are important resources

Fig. 1 Location of the study area in western Alaska, including the study site of Tununak on Nelson Island (image from Frink 2009)



throughout the year (Fienup-Riordan 1986; Frink 2002; Pete et al. 1987).

The Yup'ik communities of Nelson Island were one of the last Alaskan areas to experience intensive Anglo-North American economic, political, social, and religious interaction (Pete 1993). Though present in AD 1889, the Catholic church was thwarted in its efforts to build a church until AD 1927 (Fienup-Riordan 1983). Two years later, a Northern Commercial Company trade store was in operation as was a government school with a couple who taught at the school. This does not mean that island residents have been sheltered from historical cultural change (Frink 2010). However, the impact of colonialism and contemporary development came relatively late to Nelson Island, particularly as seen through subsistence practices. For instance, although summer fish and fall berry camps are the vestige of family seasonal mobility, today, only men tend to make harvest forays. However, until fairly recently, Yup'ik communities were seasonally mobile, moving from colonial period aggregate villages to family spring seal camps, summer herring and salmon camps, and fall hunting camps (Fienup-Riordan 1983; Lantis 1946; Oswalt 1990). Current village residents supplement their harvest foods with those purchased from small local stores. Located along the shores of the Bering Sea on the northwestern coast of Nelson Island, Tununak is in an ideal broad-harvest location and most residents continue to depend heavily on resources, particularly herring.

The antiquity of occupation of the northwestern Coast of Nelson Island is testimony to the productive harvest location of Tununak. Adjacent to the village is the ancient site of Old Tununak—an archaeological and historical

phenomenon of cultural and material context found throughout the Arctic (e.g., Oswalt and VanStone 1967). The site of Old Tununak is a large area of approximately 250 features running parallel to the coastline. It has been estimated that occupation spans at least 3,000 years (Okada et al. 1982: 9). These earliest inhabitants were members of the Norton Tradition, whose material remains are found along the coastline from northwestern Alaska to the Alaskan Peninsula (Dumond and Bland 1995; Nowak 1988). The subsequent Thule culture (AD 1000) is considered ancestral to modern Alaskan Eskimo groups. Like their predecessors, the Thule resided in small semi-subterranean houses and over time adopted the larger communal or men's houses, wherein men over approximately 10 years of age would sleep, politic, work, eat, and instruct younger men in the arts and skills of being a Yup'ik man (Crowell 1988; Fienup-Riordan 1983; Griffin 2004; Larson 1991, 1995; Nelson 1983 [1899]; Oswalt 1990; Sheehan 1997). The smaller houses where women and children resided could house several families of grandmothers, mothers, and children (Griffin 2004: 122; Lantis 1946: 157). The houses were built with an interior framing of driftwood and superstructure covered in sod blocks. Snow insulated the home and people moved in and out through tunnel entrances (Barker 1979; Ménager 1962; Nelson 1983 [1899]).

During the colonial period, whose timing varied in different regions, the general architectural trend was for houses to become increasingly shallow over time with an eventual loss of the subterranean tunnel entrance/exit replaced with a porch (see VanStone 1972). Even though families typically have exterior storage facilities, these

porches are commonly used for household items and subsistence gear, as well as some foods, both for current use and storage. It is fairly common to find a range of architectural styles and building materials both in archaeological and current villages (e.g., Fienup-Riordan 1983).

Additionally, the social composition of the Native Alaskan house has changed dramatically over time. Early historic, ethnographic, and oral historic data demonstrate that the composition of the household was quite different compared to today. The architectural manifestation of significant house demographic change is the abandonment of the men's house and the full-time relocation of village men into nuclear and extended-kinship households. While the decline of the men's house and demographic shifts of the smaller dwellings historically vary, in Tununak, the men's house was abandoned in the late 1970s. As photographed by Fienup-Riordan (1983: 23), the structures' wooden interior and superstructure were still intact in AD 1977, but today only the pit and some driftwood flooring and framing planks remain. The abandonment of the men's houses signaled the transformation of the composition of the family houses which now include all men. This would have been one of the several significant changes in house use and construction; however, little research has specifically focused on changes in regional style, house morphology, materiality, or internal organization over time (for some discussions, see Ackerman 1970; Griffin 2004; Lee and Graburn 2003; Oswalt 1963; Oswalt and VanStone 1967; VanStone 1972).

Ethnoarchaeological context of semisubterranean structures at Tununak

Located underneath and among the contemporary village of Tununak is an earlier, historic occupation. Up until the later 1960s, some of the Tununak inhabitants lived in hybrid-style, shallow, semisubterranean sod-covered houses excavated into the earth. Prehistoric sod houses were generally dug some meters deep (Dumond 1977) and through the colonial period houses tended to be more shallowly dug and eventually aboveground; as previously discussed, the timing of this shift varied with the timing and intensity of colonial influence (see Frink 2003; VanStone 1972). Griffin (2004: 121–122) found that the neighboring Nunivak Island men experimented with housing styles and started building ground-dedicated dwellings in the mid-1920s. Fienup-Riordan (1983: 20, 33) reports that, as early as the 1920s, one-room plywood houses were built but that there were “no aboveground cabins” in AD 1936. At Tununak, the remains of five sod house pits amidst the aboveground houses in the older section of town were identified and are largely still intact. Although the currently occupied houses in Tununak no longer have dirt floors that retain anthropo-

genic soil chemical signatures, there are a number of abandoned houses that may have had dirt floors and covered by wooden slats (Frink 2007). Elders spent much of their lives in these houses, and a number of middle-aged adults remember living in hybrid semisubterranean houses as children (Frink 2005).

The sod house studied here is a 7 m×7 m semi-subterranean structure that was reportedly built in the 1930s and was lived in by various members of the same family until AD 1969 (Figs. 2 and 3). The structural and social composition of this house inevitably would have changed over time. There are several significant shifts that occur during the early and mid-1900s that would have influenced both the materials used and the internal workings of the sod-covered house. However, these shifts and implications are beyond the scope of this paper.

The grandparents of the core mother and father (today in their 60s) were the last to live in the house with several of their grandchildren. As told to us by our consultants who lived in the house at the time of abandonment, the living area was in the central part of the building with the kitchen and stove area in the central eastern section. The family had a cut 55 gallon steel container and protruding stovepipe which was popular in the region (as were the cast-iron stoves) and were used at least by AD 1935 if not earlier (see photograph of house with stovepipe in Fienup-Riordan 1983: 23). Given their prominence and how they undoubtedly would have influenced house architecture, we know little of when steel stoves and pipes were adopted—likely, however, they would have entered with traders and missionaries. The north end of the house was the sleeping area. The southern section still has a 3 m×4.5 m area of thin wooden slats (that would have also been on the living



Fig. 2 Abandoned semisubterranean dwelling at Tununak, Nelson Island, Alaska with sample locations identified with flags (photography by Kelly Knudson)

SOD HOUSE 1

317-321	322-326	397-401	402-406	477-481	482-486	557-561	562-566
312-316	327-329	392-394	407-411	472-476	487-491	552-556	567-571
307-311	332-336	387-391	412-416	467-471	492-496	547-551	572-576
302-306	337-341	382-386	417-421	462-466	497-501	542-546	577-581
297-301	342-346	377-381	422-426	457-461	502-506	537-541	582-586
292-296	347-351	372-376	427-431	452-456	507-511	532-536	587-591
287-291	352-356	367-371	432-436	447-451	512-516	527-531	592-596
282-286	357-361	362-366	437-441	442-446	517-521	522-526	597-601



Fig. 3 Abandoned semisubterranean dwelling sampled at Tununak with sample locations identified

floor) out on the house entrance porch which is used for storage of equipment and foodstuffs.

The sod house was lived in until the early 1960s. The resident family built a fully aboveground house adjacent to the former dwelling using some of the building materials and, as is typical, recycling other materials for different uses. Since abandonment and up to today, the former house locale has been used as an open storage area for the family.

Field methods

Ethnoarchaeological soil samples were collected from an abandoned semisubterranean sod house at Tununak. More specifically, we collected soil samples from test excavations and soil cores from known activity areas in the abandoned semisubterranean sod house (Fig. 3). Survey and excavation methodology was based on that applied in other regions of the delta coast (Griffin 2004). In addition, interviews with family members focused on the life history of the sod house, such as the length of occupation, time of abandonment, and identification of activity areas in and around the house. A galvanized steel soil sampler was used to take soil cores from 1-m grids laid over the semi-subterranean structure (Caldwell et al. 2005; Feek et al. 2006). These samples allowed us to examine the trace element concentrations of soils in three dimensions, which will enable comparisons of activities over time in the semisubterranean houses at Tununak. In other words, in each sampling location within and around the sod house, samples were collected from the surface soil, which included roof fall in some areas, from the house floors, and from underneath the house floors. Approximately 10 g of soil (wet weight) were collected every meter in this area; the soil corer was used to collect samples at depths of every 5 cm at each point. Point sampling strategies do not mask variability like larger bulk soil samples (Entwistle et al. 2000; Haslam and Tibbett 2004).

Offsite soil samples were collected to determine the chemical composition of Nelson Island soils that have not been affected by anthropogenic alteration (Fig. 4; Haslam and Tibbett 2004; Saldaña et al. 1998). Given the long occupation history of the narrow stretch of land along the bay, it was not possible to sample multiple sites that were located in the same coastal soils yet were far removed from occupied sites; for example, offsite area 1 was located next to a dirt road used by all-terrain vehicles, as shown in Fig. 4. However, we chose two offsite sampling areas that were located on the coast yet as far as possible from the village of Tununak. Another offsite sampling area was located on a bluff above Tununak.

We used a nested sampling regime at three offsite sampling locations to elucidate the spatial variation of the autochthonous metal concentrations in the soil (Andronikov et al. 2000; Lark 2005; Youden and Mehlich 1937). At each offsite sampling location, four primary sampling stations were established 40 m apart. Two secondary stations, located 20 m apart, were established at each primary station. Two tertiary stations were assigned to each secondary station; each tertiary station was located 10 m apart. Finally, offsite samples were collected from two sampling points associated with each tertiary station and located 5 m apart. We also opportunistically sampled a fourth offsite sampling location to examine the incorporation of bird waste into the soil.

Laboratory methods

In the Archaeological Chemistry Laboratory at the Arizona State University, soil samples were dried at 120°C for 48 h, pulverized with a Coors porcelain mortar and pestle and screened with a 2-mm screen. Two milligrams of each sample was extracted in 20.0 mL of 1 M HCl for 14 days. Five hundred microliters (0.5 mL) of the sample extract was diluted with 14.5 mL of 0.7 M HCl to create a 1:30

Table 1 Mean elemental concentrations (parts per billion or microgram per kilogram) in external standard USGS SDO-1 ($n=15$, 1σ) as well as certified values

Element	Observed concentration			Certified concentration	
	Mean (ppb)	Standard deviation (ppb)	Number	Mean (ppb)	Standard deviation (ppb)
Na	2,858	66	15	2,819	193
Mg	8,407	2,417	15	9,287	229
Al	68,678	18,799	15	64,879	1,216
P	427	102	15	480	31
K	25,998	5,535	15	16,560	302
Ca	6,523	1,882	15	7,504	336
Ti	3,948	172	15	3,948	172
Cr	15	13	15	66	8
Mn	283	82	15	325	39
Fe	67,257	22,295	15	65,327	1,469
Co	22	6	15	47	6
Ni	35	10	15	100	10
Cu	20	6	15	60	10
Zn	52	16	15	64	7
As	38	32	15	69	9
Sr	55	17	15	75	11
Ba	71	35	15	397	38
Pb	32	12	15	28	5
U	6	4	15	49	7

Results of elemental concentration analysis

Elemental concentration data for the samples analyzed in this study are presented in Table 2. Figures 3 and 4 include sampling locations for both the offsite and sod house samples. Because offsite areas 2 and 3 were located near historic and prehistoric occupations and offsite area 4 includes bird waste, we use offsite area 1 as the most accurate representation of offsite soils that have not been affected by anthropogenic activities (Knudson and Frink 2010).

Interpretations of elemental concentration analysis

In order to compare samples collected from the sod house and offsite area 1, we present the mean concentrations for the elements included in this study in Table 3. When single elements are compared, the sod house area (SH01) was enriched in phosphorus and magnesium compared to the offsite area. This likely reflects the incorporation of human waste, bone and other organic materials, and wood ash into the soil (Dauncey 1952; Eidt 1977; Entwistle et al. 2007; Knudson and Frink 2010; Knudson et al. 2004b; Middleton and Price 1996; Misarti 2007; Wells 2004; Wells et al. 2007). High magnesium concentrations in the sod house

soils are particularly interesting because the olivine basalt-derived soils on Nelson Island are expected to be particularly high in magnesium and iron; despite the expected high magnesium and iron concentrations in the offsite soils, the sod house soils are still enriched in magnesium from anthropogenic sources. However, other elements do not clearly distinguish between these two areas, when the means of all samples from each area are compared using a one-way analysis of variance (ANOVA) of elemental means from each area.

In order to explore the patterns *within* the sod house, all samples collected from the sod house were analyzed using a cluster analysis of log-transformed elemental concentrations, with the exception of arsenic, nickel, and zinc concentrations, which were removed due to low data quality, including poor reproducibility, in some batches (Fig. 5). When divided into three clusters, all elements are statistically significant according to a one-way ANOVA of elemental means for each cluster with the exception of barium. Cluster 1, shown in dark gray in Fig. 5, has the lowest overall mean magnesium concentration, yet has the highest mean concentrations of the following elements: iron, aluminum, phosphorus, potassium, manganese, barium, titanium, cobalt, chromium, and uranium. Cluster 1 is constrained spatially in the southwest half of the sod house,

Table 2 Elemental concentrations (parts per billion or microgram per kilogram) in samples from semisubterranean dwelling

Laboratory Number	Specimen Number	Na	Mg	Al	P	K	Ca	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Ba	Pb	U
ACL-1151	TUN-0282	8,547	42,854	138,888	7,550	8,062	34,086	169	88	5,506	382,458	50	86	101	5,563	<116	180	1,362	1,105	1.3
ACL-1152	TUN-0283	9,237	49,507	148,879	10,727	7,963	35,118	334	87	5,148	317,381	53	74	97	3,542	122	189	1,305	1,451	1.7
ACL-1153	TUN-0284	8,433	53,106	203,133	7,166	8,709	38,151	258	109	5,727	370,423	61	68	93	3,315	<116	236	1,362	390	1.6
ACL-1154	TUN-0285	8,819	50,533	202,309	5,523	5,470	27,255	127	103	9,752	403,270	73	76	68	1,772	<113	139	1,493	111	1.5
ACL-1155	TUN-0286	7,548	51,927	185,679	5,517	6,158	28,427	187	90	5,784	351,056	59	69	75	1,791	<113	159	1,568	382	1.5
ACL-1156	TUN-0287	7,811	47,086	148,991	8,410	9,041	35,292	187	102	5,168	345,513	50	154	85	4,593	192	173	1,422	421	1.6
ACL-1157	TUN-0288	8,133	48,801	153,493	8,716	7,473	29,637	373	78	4,023	305,118	46	60	69	2,120	135	183	1,348	443	1.4
ACL-1158	TUN-0289	9,235	59,554	212,407	11,405	7,094	44,152	374	112	6,021	356,192	57	62	63	1,201	<115	304	1,555	107	1.4
ACL-1159	TUN-0290	9,438	57,622	188,464	11,838	8,017	39,983	278	101	6,381	353,370	59	76	83	4,185	<114	216	1,477	357	1.6
ACL-1160	TUN-0291	8,482	51,712	187,133	9,403	7,140	27,900	179	94	5,610	354,494	59	75	83	1,925	<113	169	1,149	102	1.5
ACL-1161	TUN-0292	7,672	45,147	146,773	13,774	6,713	46,682	246	72	4,857	280,533	47	50	68	4,485	<114	205	1,202	646	1.5
ACL-1162	TUN-0293	6,761	58,374	185,037	9,582	7,350	34,071	172	100	5,778	363,503	52	75	77	1,670	<114	183	1,296	141	1.4
ACL-1163	TUN-0294	6,612	50,734	202,324	5,108	9,558	30,452	143	95	5,933	373,001	62	79	97	1,417	<112	174	1,563	87	1.6
ACL-1164	TUN-0295	8,403	46,011	172,698	8,353	9,241	36,491	188	86	5,002	319,810	55	72	84	2,750	<114	194	1,308	258	1.6
ACL-1165	TUN-0296	9,435	51,986	190,337	7,986	7,808	33,697	126	86	7,416	361,020	63	76	84	2,424	<34	159	1,732	154	1.8
ACL-1166	TUN-0297	8,236	49,239	159,286	10,419	10,622	36,413	318	113	5,626	386,556	53	86	80	3,408	276	214	1,278	789	1.5
ACL-1167	TUN-0298	7,298	48,132	182,632	8,807	9,791	30,865	246	107	6,240	390,872	59	69	80	1,230	206	190	1,214	181	1.6
ACL-1168	TUN-0302	8,293	42,860	148,927	9,488	8,382	34,851	161	107	4,885	438,386	47	69	130	15,863	157	205	1,255	1,781	1.4
ACL-1169	TUN-0303	7,912	43,572	149,424	14,558	8,380	40,020	245	86	7,270	318,503	53	69	80	4,345	150	224	1,545	273	1.6
ACL-1170	TUN-0304	7,812	48,002	180,533	17,387	7,297	51,902	162	97	6,195	363,288	59	64	81	1,520	129	239	1,613	97	1.5
ACL-1171	TUN-0305	8,514	56,235	179,551	15,526	6,418	51,153	191	95	6,560	356,679	64	80	78	1,624	168	223	1,342	85	1.6
ACL-1172	TUN-0306	7,786	51,683	181,229	16,519	6,736	47,215	178	110	6,751	369,203	60	70	78	1,972	172	208	1,335	79	1.7
ACL-1173	TUN-0307	7,231	42,796	142,200	9,804	10,521	31,979	297	98	5,210	376,690	49	58	74	2,646	141	189	1,231	390	1.7
ACL-1174	TUN-0308	8,968	58,886	181,046	17,901	8,530	57,296	333	93	6,274	381,878	64	72	69	1,225	151	242	1,340	100	1.4
ACL-1175	TUN-0309	9,927	69,876	195,708	6,196	7,484	33,101	271	110	6,925	380,303	70	108	64	993	149	167	1,033	63	1.3
ACL-1176	TUN-0310	6,749	51,249	188,109	6,167	7,262	35,514	183	84	6,188	352,779	62	73	65	1,121	<114	198	1,540	75	1.5
ACL-1177	TUN-0311	10,442	53,353	206,185	7,381	9,549	39,792	164	100	7,572	376,206	65	74	90	1,168	<115	200	1,571	76	1.8
ACL-1178	TUN-0312	7,586	40,781	146,770	10,341	16,366	33,628	237	74	5,025	299,772	48	48	67	2,450	<115	188	1,155	290	1.4
ACL-1179	TUN-0313	9,089	49,100	164,321	9,544	11,890	33,209	260	81	5,216	344,861	54	64	88	2,121	<115	164	1,089	184	1.4
ACL-1180	TUN-0314	7,965	42,972	138,579	8,831	4,826	25,157	407	75	5,276	274,999	47	52	65	869	135	165	1,202	80	1.4
ACL-1181	TUN-0315	8,038	35,584	124,724	10,032	4,658	34,124	550	59	4,041	232,520	36	31	43	665	<115	258	1,290	49	1.5
ACL-1182	TUN-0317	7,285	38,244	136,663	8,997	9,195	23,186	202	69	4,696	278,794	43	42	70	3,567	<114	126	977	241	1.1
ACL-1183	TUN-0318	8,117	41,565	155,619	6,599	7,170	27,031	399	72	3,697	302,291	41	47	50	1,228	<117	167	964	65	1.9
ACL-1184	TUN-0319	9,260	44,733	151,270	9,442	5,464	29,487	289	75	4,924	314,238	50	49	61	4,915	<115	172	1,162	180	1.4
ACL-1185	TUN-0320	8,733	45,594	160,417	13,200	4,852	28,830	273	77	4,957	306,552	51	59	65	1,517	<115	161	1,208	151	1.5
ACL-1186	TUN-0322	7,040	48,964	158,992	9,409	14,300	34,516	263	106	5,497	343,671	51	59	64	2,300	271	190	1,102	223	1.0
ACL-1187	TUN-0323	7,144	48,165	167,293	14,051	8,762	34,728	276	100	5,608	387,742	55	53	74	1,279	208	184	1,296	331	1.4
ACL-1188	TUN-0324	7,418	47,324	162,116	8,052	5,748	25,145	218	100	5,363	386,533	55	67	77	1,361	156	146	1,051	135	1.3
ACL-1189	TUN-0325	8,348	53,257	177,267	10,364	5,521	32,979	280	108	5,678	371,823	56	64	79	1,335	134	196	1,270	235	1.5
ACL-1190	TUN-0327	10,568	44,819	144,420	12,242	15,185	42,381	254	84	5,927	289,592	50	52	72	3,019	132	226	1,327	257	1.6

ACL-1191	TUN-0328	8,121	51,730	178,393	8,881	8,949	32,494	204	95	6,582	355,425	61	72	73	73	1,062	150	185	1,448	128	1.5
ACL-1192	TUN-0329	10,232	49,828	168,418	9,173	7,564	32,003	247	92	5,958	312,549	56	73	71	71	1,124	<11.5	201	1,655	100	1.5
ACL-1193	TUN-0332	8,637	42,337	149,965	15,319	10,695	39,790	243	71	5,771	264,474	53	51	63	63	1,298	<11.3	205	1,273	184	1.6
ACL-1194	TUN-0333	7,753	51,605	163,574	9,427	8,150	31,513	266	78	5,648	309,448	56	61	63	63	1,196	<11.5	180	1,292	89	1.6
ACL-1195	TUN-0334	7,471	51,798	194,603	5,652	7,976	35,858	160	87	6,167	343,030	57	64	69	69	755	<11.5	215	1,341	53	1.4
ACL-1196	TUN-0335	8,166	59,384	215,923	5,143	7,276	45,170	136	90	6,600	374,659	68	76	77	77	768	<10.7	268	2,035	64	1.6
ACL-1197	TUN-0336	9,571	71,337	215,129	7,295	6,043	35,374	128	149	14,353	454,017	82	118	69	69	928	<11.4	165	1,793	62	1.5
ACL-1198	TUN-0337	8,210	52,348	165,495	9,721	9,044	31,133	260	76	6,121	323,948	54	58	71	71	2,398	<3.4	192	1,340	137	1.4
ACL-1199	TUN-0338	8,076	43,749	150,251	9,330	7,998	29,151	327	70	5,121	288,504	51	47	60	60	1,724	<3.5	183	1,331	125	1.5
ACL-1200	TUN-0339	8,213	51,057	195,644	6,740	8,480	38,418	120	111	8,024	403,719	59	68	117	117	909	243	216	2,052	110	2.0
ACL-1201	TUN-0340	9,716	66,774	170,533	5,854	6,370	33,790	81	14	6,439	320,589	55	85	98	98	850	<3.6	215	2,116	128	1.9
ACL-1202	TUN-0341	6,962	71,853	142,754	5,547	5,222	32,030	97	13	5,695	261,685	55	94	70	70	571	<3.6	186	1,710	64	1.6
ACL-1203	TUN-0342	7,929	54,060	123,604	13,437	8,389	41,131	177	12	4,122	277,454	44	71	78	78	2,697	<3.6	222	1,532	311	1.7
ACL-1204	TUN-0343	7,283	59,112	140,443	6,816	6,869	25,232	169	12	5,390	253,336	52	72	58	58	620	<3.6	177	1,334	158	1.6
ACL-1205	TUN-0344	9,202	65,103	150,712	9,320	6,377	29,997	199	14	5,997	279,733	58	80	190	190	1,332	<3.6	207	1,641	740	1.6
ACL-1206	TUN-0345	8,041	66,190	159,686	8,278	7,162	27,064	88	18	7,705	324,419	55	89	159	159	1,079	<3.6	175	1,917	198	2.0
ACL-1207	TUN-0346	7,783	72,107	164,553	5,316	7,774	32,140	123	14	5,123	288,487	56	85	91	91	755	<3.6	216	2,049	167	1.6
ACL-1208	TUN-0347	6,892	49,708	118,030	8,449	6,984	27,478	147	10	4,146	216,463	42	58	54	54	1,416	<3.6	186	1,329	302	1.7
ACL-1209	TUN-0348	7,065	61,817	131,263	7,252	5,545	26,069	143	12	5,205	249,831	51	80	57	57	683	<3.6	160	1,249	149	1.5
ACL-1210	TUN-0349	7,836	63,709	153,856	5,500	6,257	26,453	114	13	4,718	290,047	52	79	90	90	845	<3.6	170	1,693	376	1.4
ACL-1211	TUN-0350	7,731	62,643	152,859	4,259	6,053	21,967	70	13	4,373	284,927	53	82	78	78	732	<3.6	145	1,834	73	1.8
ACL-1212	TUN-0351	6,553	68,482	148,225	4,418	6,923	26,863	104	12	5,481	270,504	56	85	67	67	553	<3.6	191	1,981	56	1.4
ACL-1213	TUN-0352	7,764	56,333	129,236	8,696	9,619	33,410	147	12	4,291	270,638	47	89	114	114	5,304	<3.6	207	1,546	577	1.4
ACL-1214	TUN-0353	7,677	63,442	135,117	7,371	7,772	33,443	201	11	5,386	235,954	53	74	74	74	1,449	<3.6	224	1,266	2,512	1.3
ACL-1215	TUN-0354	7,168	59,055	135,221	3,880	6,208	18,415	97	12	5,013	258,408	49	76	70	70	888	<3.5	109	1,176	180	1.3
ACL-1216	TUN-0355	7,711	57,920	157,893	4,196	6,709	23,702	74	16	5,723	326,405	55	81	83	83	1,155	<3.6	152	1,779	89	1.4
ACL-1217	TUN-0356	8,744	61,039	151,760	4,656	7,922	29,677	82	15	5,450	294,532	56	87	81	81	1,006	<3.6	197	1,906	131	1.7
ACL-1218	TUN-0358	7,506	63,130	135,715	5,537	8,113	30,629	89	14	5,419	274,843	52	84	71	71	2,493	<3.6	170	1,421	244	1.3
ACL-1219	TUN-0359	8,036	58,347	129,891	8,646	6,299	30,771	201	13	5,181	264,338	47	68	88	88	1,891	<3.6	188	1,395	900	1.4
ACL-1220	TUN-0360	7,860	49,558	157,447	5,830	6,467	25,464	75	14	4,138	296,991	45	69	87	87	1,232	<3.6	147	1,097	585	1.3
ACL-1221	TUN-0361	8,637	53,764	147,992	3,819	5,651	23,591	76	17	7,083	318,279	55	78	79	79	1,021	<3.6	159	1,879	91	1.2
ACL-1222	TUN-0362	9,026	60,047	125,725	10,149	8,884	38,692	203	13	4,157	244,489	47	76	69	69	2,197	<3.8	241	1,411	198	1.7
ACL-1223	TUN-0363	8,954	36,338	94,242	15,579	5,602	28,467	151	10	2,566	196,400	35	54	219	219	2,734	4.2	177	1,276	421	1.1
ACL-1224	TUN-0364	9,244	46,875	141,489	14,865	7,195	26,908	221	13	3,906	252,295	43	61	71	71	1,258	<3.6	171	1,652	94	1.2
ACL-1225	TUN-0365	5,324	33,849	94,150	8,268	4,398	16,981	91	8	2,819	176,716	31	41	56	56	842	2.4	112	902	117	0.8
ACL-1226	TUN-0367	7,159	60,336	116,030	9,935	11,390	37,160	133	13	5,171	416,512	55	89	68	68	3,713	<3.6	202	1,362	194	1.3
ACL-1227	TUN-0368	7,928	46,060	106,831	8,769	7,515	29,002	165	15	4,419	487,734	40	72	85	85	2,286	<3.6	179	1,255	363	1.2
ACL-1228	TUN-0369	6,997	53,064	134,062	5,792	6,022	28,231	150	12	6,260	250,833	55	71	54	54	1,178	<3.6	189	1,210	74	1.0
ACL-1229	TUN-0370	7,186	68,500	165,457	5,231	5,862	29,087	120	14	5,730	305,200	53	81	65	65	778	<3.5	188	1,051	49	1.2
ACL-1230	TUN-0371	7,678	57,032	157,535	5,502	5,576	27,900	86	15	6,334	308,852	58	75	68	68	995	3.6	174	1,349	88	1.3
ACL-1231	TUN-0372	7,678	54,824	122,287	8,820	8,879	31,849	121	13	4,759	243,796	46	71	73	73	3,460	4.3	178	1,331	250	1.2
ACL-1232	TUN-0373	6,898	53,873	117,423	7,054	6,988	23,774	176	12	4,941	240,243	46	70	51	51	1,120	<3.6	148	1,068	88	1.2
ACL-1233	TUN-0374	7,413	50,641	125,431	5,485	6,529	33,651	87	13	5,148	286,527	46	63	119	119	1,922	<3.6	233	1,265	244	1.1
ACL-1234	TUN-0375	7,443	69,471	132,579	5,622	5,405	23,249	123	12	4,531	260,349	52	94	64	64	826	3.7	145	1,046	52	1.2

Table 2 (continued)

Laboratory Number	Specimen Number	Na	Mg	Al	P	K	Ca	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Ba	Pb	U
ACL-1235	TUN-0377	7,668	56,751	125,165	13,439	9,478	42,593	154	12	5,846	233,361	48	63	61	2,869	3.7	274	1,441	276	1.1
ACL-1236	TUN-0378	7,916	48,513	115,406	5,764	6,756	24,419	160	14	5,011	235,633	45	60	53	673	<3.6	163	1,109	76	1.1
ACL-1237	TUN-0379	7,925	51,906	117,290	6,238	5,158	24,635	169	12	4,584	232,119	44	61	241	1,050	<3.6	175	1,108	118	1.0
ACL-1238	TUN-0380	7,679	59,792	147,612	4,464	6,356	31,255	82	14	4,924	279,447	51	69	78	604	<3.6	204	1,728	50	1.7
ACL-1239	TUN-0382	8,442	56,341	116,461	7,970	10,772	36,143	150	11	4,742	225,628	44	61	63	3,476	<3.5	223	1,321	234	1.0
ACL-1240	TUN-0383	7,858	46,240	110,689	8,814	8,556	30,517	157	10	3,672	207,721	43	60	48	690	<3.6	181	1,238	96	1.0
ACL-1241	TUN-0384	7,508	54,246	128,637	5,466	7,155	26,971	123	12	4,970	242,838	48	63	111	829	<3.6	189	1,329	256	1.1
ACL-1242	TUN-0385	6,367	57,831	140,794	5,695	7,156	27,150	66	14	8,810	262,526	48	71	80	920	<3.5	176	1,575	74	1.4
ACL-1243	TUN-0386	7,103	62,593	152,679	4,895	6,482	26,535	60	15	6,334	312,967	54	77	85	611	<3.6	169	1,627	63	1.3
ACL-1244	TUN-0387	7,259	51,685	118,583	10,198	8,686	44,343	131	10	5,171	221,834	42	59	61	1,926	<3.5	245	1,536	184	0.9
ACL-1245	TUN-0388	7,068	50,962	116,468	8,813	7,365	28,590	162	10	4,216	223,689	44	59	51	630	<3.6	186	1,186	117	1.0
ACL-1246	TUN-0389	8,504	59,502	132,100	4,892	4,500	30,588	140	11	5,451	239,562	49	67	59	958	<3.6	223	1,353	58	1.0
ACL-1247	TUN-0390	7,250	52,269	120,013	5,414	4,257	27,290	136	9	4,378	236,413	42	57	50	1,165	<3.6	191	1,212	52	1.0
ACL-1248	TUN-0391	7,274	54,860	122,823	5,125	5,020	27,758	147	10	4,531	229,200	44	58	58	950	<3.6	206	1,374	54	1.3
ACL-1249	TUN-0392	7,004	55,922	110,793	6,370	10,702	27,064	160	11	4,242	223,076	43	69	49	995	<3.5	180	1,021	134	1.0
ACL-1251	TUN-0394	9,708	56,980	152,988	7,618	6,296	29,651	137	15	5,091	278,588	46	65	55	617	3	173	1,259	44	0.9
ACL-1252	TUN-0397	11,587	50,482	115,927	11,862	14,226	53,233	218	13	4,492	233,307	39	72	59	5,087	3	241	1,290	193	1.5
ACL-1253	TUN-0398	10,504	55,189	144,456	10,706	11,921	36,943	197	13	4,741	281,372	48	72	55	1,562	4	196	1,529	195	1.0
ACL-1254	TUN-0399	9,388	53,335	144,388	10,466	8,460	34,295	192	14	5,054	320,428	50	75	66	2,183	3	192	1,317	319	0.9
ACL-1255	TUN-0400	9,579	54,578	142,634	8,611	7,283	31,380	185	12	4,469	258,353	45	69	53	1,293	3	170	961	138	1.0
ACL-1256	TUN-0401	9,101	59,103	160,061	8,852	7,653	36,958	205	13	4,994	328,715	51	67	63	1,398	3	210	1,189	173	1.0
ACL-1257	TUN-0402	8,491	58,823	146,021	8,984	14,803	30,328	192	15	5,041	281,972	48	70	57	1,723	3	169	1,027	223	1.0
ACL-1258	TUN-0403	8,538	60,312	151,426	7,520	9,078	30,712	231	27	5,437	366,257	58	73	62	2,125	3	187	1,132	1,121	1.0
ACL-1259	TUN-0404	8,467	55,769	146,177	7,354	6,048	31,313	176	13	4,929	299,006	48	63	56	2,051	3	194	1,207	455	0.9
ACL-1260	TUN-0405	10,188	66,901	166,083	7,489	6,498	33,871	185	15	5,387	291,478	53	79	60	1,389	3	200	1,265	391	1.2
ACL-1261	TUN-0407	10,256	58,968	143,856	10,386	14,618	41,779	210	11	5,030	247,564	46	61	54	1,450	3	218	1,111	198	1.0
ACL-1262	TUN-0408	9,394	63,359	161,177	8,676	10,878	31,034	204	13	4,888	307,332	52	77	59	1,052	3	174	1,020	122	1.0
ACL-1263	TUN-0409	8,682	60,365	155,607	7,534	8,627	31,315	205	12	4,650	252,933	48	69	54	868	3	192	1,143	92	1.0
ACL-1264	TUN-0410	9,013	66,938	168,930	9,171	7,315	32,573	225	13	5,068	297,129	51	76	60	856	3	199	1,226	166	1.0
ACL-1265	TUN-0412	8,616	69,238	161,566	11,617	11,551	35,727	206	15	5,091	293,873	49	70	55	860	3	189	1,242	104	1.0
ACL-1266	TUN-0413	10,881	67,597	166,801	7,094	8,075	30,504	241	13	5,334	270,358	52	76	55	660	3	181	1,157	83	1.0
ACL-1267	TUN-0414	9,563	56,831	142,209	6,131	5,689	25,827	189	15	4,796	276,835	46	65	50	884	3	165	1,101	81	0.9
ACL-1268	TUN-0415	9,982	61,433	155,685	8,134	5,711	33,212	211	15	5,212	280,911	49	67	61	822	3	190	1,252	99	1.1
ACL-1269	TUN-0417	9,788	59,430	147,459	9,020	12,618	44,874	154	13	5,045	257,518	45	65	60	2,219	4	266	1,275	193	0.9
ACL-1270	TUN-0418	8,487	55,297	146,347	7,696	9,566	30,224	180	14	5,054	256,365	48	70	51	678	4	180	1,210	88	1.0
ACL-1271	TUN-0419	9,019	62,603	158,037	7,220	6,974	34,869	197	14	6,074	281,924	52	70	52	1,006	5	197	1,246	116	1.0
ACL-1272	TUN-0420	9,859	69,073	169,398	5,996	6,385	29,537	109	18	5,858	340,415	61	101	67	1,100	4	153	1,310	62	1.3
ACL-1273	TUN-0422	9,969	68,084	171,623	10,213	15,481	32,568	133	16	5,172	311,850	53	85	71	2,452	5	177	1,757	168	1.2
ACL-1274	TUN-0423	8,828	50,012	129,030	7,297	9,856	25,869	157	11	3,928	226,927	40	60	48	1,701	3	156	1,039	122	0.9
ACL-1275	TUN-0424	9,302	61,595	164,639	7,205	7,393	30,691	211	13	5,145	269,111	51	65	55	1,554	3	201	1,195	161	1.0

ACL-1276	TUN-0425	11,251	64,010	154,906	7,700	5,853	32,334	181	13	5,329	278,556	50	79	83	3,320	4	194	1,276	232	1.0
ACL-1277	TUN-0426	10,597	63,803	167,654	7,867	8,118	33,005	181	16	6,414	303,753	55	75	65	2,609	4	191	1,413	332	1.1
ACL-1278	TUN-0427	9,711	47,499	116,545	8,975	8,721	35,760	164	16	5,166	414,033	49	80	108	15,671	3	192	1,189	527	0.8
ACL-1279	TUN-0428	9,091	52,084	130,225	7,544	8,983	33,103	189	16	5,250	492,053	54	118	197	4,183	2	182	1,071	357	0.9
ACL-1280	TUN-0429	8,962	54,480	136,876	7,972	7,063	25,630	319	12	3,998	274,625	43	59	48	1,066	3	162	1,063	79	1.1
ACL-1281	TUN-0430	9,113	68,168	162,831	8,871	6,113	29,312	154	15	4,536	296,742	49	85	53	930	4	162	1,006	78	1.1
ACL-1282	TUN-0431	9,073	63,402	177,568	7,577	6,932	23,583	119	17	4,907	347,344	51	79	77	1,468	3	128	1,052	82	0.9
ACL-1283	TUN-0432	9,489	54,960	146,893	8,439	10,186	32,053	175	12	4,853	293,968	45	61	65	6,341	3	178	1,048	2,163	1.1
ACL-1284	TUN-0433	9,126	58,766	149,699	7,286	8,441	32,106	198	14	4,883	275,849	48	61	60	1,876	3	189	1,104	667	1.0
ACL-1285	TUN-0434	10,487	68,289	165,635	7,404	7,407	35,981	204	13	5,332	270,659	51	69	54	1,458	3	213	1,055	139	0.9
ACL-1286	TUN-0435	10,598	64,763	159,777	7,266	6,289	32,873	208	12	4,655	256,401	48	68	65	1,448	3	202	1,070	151	0.9
ACL-1287	TUN-0437	8,968	64,372	159,699	13,343	12,072	36,784	211	17	5,313	312,245	52	71	109	2,883	5	202	1,393	439	0.9
ACL-1288	TUN-0438	10,266	64,027	168,988	24,152	8,589	39,276	269	16	3,132	305,087	46	69	194	2,376	7	247	1,632	168	0.8
ACL-1289	TUN-0439	10,120	44,414	125,533	18,651	5,426	28,636	205	13	3,201	250,284	38	55	85	1,699	4	173	1,115	87	1.0
ACL-1290	TUN-0442	10,411	65,572	155,596	8,005	10,835	34,453	156	16	5,136	314,495	50	84	71	3,719	4	176	1,130	249	0.9
ACL-1291	TUN-0443	10,271	51,218	143,262	9,220	6,472	23,401	273	13	3,093	255,596	46	68	56	3,676	3	148	1,409	70	1.2
ACL-1292	TUN-0444	9,796	60,523	181,236	5,691	6,180	22,146	180	17	6,325	346,455	56	73	55	1,563	4	128	1,355	47	1.0
ACL-1293	TUN-0445	9,463	69,980	193,920	5,521	7,299	24,526	99	19	9,047	358,716	65	98	70	890	3	153	1,931	52	1.3
ACL-1294	TUN-0447	8,576	56,300	135,281	6,517	11,873	28,413	170	14	5,053	307,198	45	66	55	6,072	3	166	1,014	372	0.9
ACL-1295	TUN-0448	11,450	55,624	144,398	7,375	7,326	29,485	200	13	4,982	261,029	47	65	54	1,086	3	179	1,066	87	1.1
ACL-1296	TUN-0452	11,232	64,282	167,080	9,047	12,868	43,084	177	17	5,921	404,264	57	78	104	13,003	7	258	1,447	677	0.9
ACL-1297	TUN-0457	9,739	61,947	149,041	7,245	7,493	30,400	134	15	6,346	276,286	47	70	66	47,970	4	184	1,442	162	0.9
ACL-1298	TUN-0458	10,794	66,982	166,576	8,779	9,732	29,981	212	13	5,727	286,859	52	74	58	1,535	3	164	1,108	111	1.1
ACL-1299	TUN-0459	9,718	62,554	160,661	7,498	8,965	32,282	204	12	5,292	261,948	51	67	53	895	3	189	1,118	84	1.0
ACL-1300	TUN-0460	9,374	65,943	152,463	6,745	5,638	27,292	224	12	5,307	260,642	50	73	48	618	3	170	1,149	76	1.0
ACL-1301	TUN-0462	6,444	52,068	125,658	8,554	9,813	31,694	204	19	3,725	251,407	41	91	48	1,226	5	174	861	88	0.7
ACL-1302	TUN-0463	6,119	55,492	141,320	7,016	8,682	29,767	189	23	4,700	281,977	48	98	55	667	5	171	1,060	59	0.7
ACL-1303	TUN-0464	6,576	58,155	136,477	6,897	5,915	30,385	269	20	4,099	258,828	45	93	48	707	5	178	1,037	51	0.7
ACL-1304	TUN-0465	6,861	52,536	132,145	6,533	3,617	32,649	247	17	3,790	231,640	42	80	47	1,102	4	201	1,161	77	0.7
ACL-1305	TUN-0467	7,241	55,317	123,344	8,569	15,957	48,186	147	19	5,412	233,082	44	82	64	3,655	7	261	1,264	144	0.6
ACL-1306	TUN-0468	5,273	62,505	156,172	9,358	12,648	35,614	197	22	5,098	332,978	52	93	63	963	5	199	1,182	94	0.8
ACL-1307	TUN-0469	5,339	60,061	147,062	7,955	7,182	30,112	187	19	4,567	265,397	47	89	60	1,007	4	177	1,203	166	0.9
ACL-1308	TUN-0470	4,757	62,672	148,691	7,681	5,358	30,505	194	21	5,219	284,364	53	105	62	1,160	4	187	1,305	63	0.8
ACL-1309	TUN-0472	4,793	59,334	142,455	9,383	11,660	39,446	176	18	4,841	270,751	45	83	55	1,574	5	220	1,170	115	0.8
ACL-1310	TUN-0473	4,491	59,541	144,753	8,129	9,078	32,314	238	20	5,526	314,759	49	91	73	1,297	4	186	1,350	93	0.8
ACL-1311	TUN-0474	4,222	51,327	127,882	7,493	5,890	27,958	193	28	5,181	478,091	60	107	96	939	<3.6	178	1,209	188	0.8
ACL-1312	TUN-0475	4,140	52,726	133,425	6,480	3,628	27,381	135	18	4,119	261,460	47	81	66	417	<3.6	163	1,391	44	0.9
ACL-1313	TUN-0477	5,315	54,786	129,085	10,667	10,246	33,640	200	18	4,626	289,056	48	83	62	1,827	4	183	1,068	243	0.8
ACL-1314	TUN-0478	4,358	62,207	154,085	10,940	9,394	35,939	183	21	5,713	322,378	54	96	76	1,486	6	186	1,157	112	0.9
ACL-1315	TUN-0479	<3697	63,974	151,723	10,099	7,079	38,087	160	21	5,210	286,693	50	91	63	666	5	184	1,386	72	1.0
ACL-1316	TUN-0480	5,203	68,300	163,107	9,932	6,579	37,195	159	25	6,928	311,647	57	102	67	721	6	189	1,430	68	0.9
ACL-1317	TUN-0482	5,154	54,782	129,683	9,016	9,688	32,143	201	22	4,207	262,035	43	79	53	1,524	4	174	1,079	339	0.7
ACL-1318	TUN-0483	6,032	54,320	139,554	12,116	9,175	38,123	215	21	4,403	275,036	44	78	61	2,114	5	207	1,257	171	0.8
ACL-1319	TUN-0484	5,740	58,275	149,621	8,833	7,389	37,563	164	22	5,116	292,518	47	80	61	1,400	5	193	1,271	54	0.7

Table 2 (continued)

Laboratory Number	Specimen Number	Na	Mg	Al	P	K	Ca	Ti	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Sr	Ba	Pb	U
ACL-1320	TUN-0485	6,531	65,247	162,285	8,459	6,387	36,963	184	23	4,900	291,347	51	94	72	870	5	209	1,424	53	0.9
ACL-1321	TUN-0487	6,791	58,462	139,085	9,116	13,421	43,748	190	22	5,035	273,690	47	92	57	1,540	5	241	1,247	96	0.7
ACL-1322	TUN-0488	6,307	50,723	126,021	15,365	8,749	49,815	224	20	4,733	272,137	48	91	74	2,356	5	211	1,270	262	0.8
ACL-1323	TUN-0489	6,217	54,374	117,720	7,063	4,969	33,138	180	18	4,622	251,691	47	91	54	1,000	3	192	1,116	94	0.8
ACL-1324	TUN-0490	6,427	64,394	149,824	10,062	4,042	31,103	172	21	4,911	281,489	50	95	61	798	4	187	1,203	79	0.9
ACL-1326	TUN-0492	5,439	58,154	139,463	8,199	14,396	30,913	175	19	4,752	267,822	48	81	53	936	4	174	972	53	0.7
ACL-1327	TUN-0493	4,993	63,239	155,844	7,509	10,026	32,844	218	21	5,190	291,002	53	89	60	708	5	192	1,208	75	0.8
ACL-1328	TUN-0494	5,198	62,235	144,618	7,243	5,857	31,982	197	21	5,299	279,878	51	83	57	682	5	176	1,217	71	0.9
ACL-1329	TUN-0495	4,946	62,979	160,940	5,996	4,865	33,954	150	20	5,808	299,144	51	85	55	489	4	204	1,448	43	0.8
ACL-1330	TUN-0497	4,717	57,978	137,341	9,234	11,165	32,046	173	20	4,430	263,778	44	76	51	1,952	5	176	1,059	113	0.7
ACL-1331	TUN-0498	5,170	51,759	133,619	7,714	8,459	29,037	273	20	4,022	251,736	43	73	53	878	5	164	976	101	0.9
ACL-1332	TUN-0499	5,033	56,843	145,621	7,632	8,362	29,664	185	22	4,864	304,571	49	78	62	2,058	5	168	1,067	89	0.8
ACL-1333	TUN-0502	5,499	58,259	132,890	11,861	7,866	38,314	188	20	4,791	265,871	46	81	62	1,894	5	192	1,162	118	0.8
ACL-1334	TUN-0507	6,129	70,070	170,467	9,590	7,188	44,540	109	24	6,017	314,438	57	96	84	1,033	5	206	1,773	81	0.9
ACL-1335	TUN-0512	5,403	49,504	120,489	10,807	8,563	35,613	139	28	5,229	610,846	50	86	150	7,084	24	177	1,196	455	0.7
ACL-1336	TUN-0517	5,135	61,444	147,430	8,511	13,205	35,854	111	22	5,324	294,569	50	86	95	3,850	6	176	1,259	155	0.8
ACL-1337	TUN-0518	5,846	65,640	161,811	9,435	13,035	42,379	130	27	5,686	331,674	55	98	83	3,128	6	190	1,467	147	0.9
ACL-1338	TUN-0519	4,363	39,756	136,181	7,361	4,632	17,445	65	25	20,925	305,281	49	74	56	3,367	5	85	1,087	58	0.8
ACL-1339	TUN-0522	6,246	66,213	176,033	7,643	7,112	43,213	106	25	6,009	340,005	57	93	83	799	6	201	1,647	79	1.1
ACL-1340	TUN-0523	7,281	71,268	169,546	8,712	6,726	44,078	95	25	6,153	332,146	56	101	79	969	6	193	1,698	91	1.0
ACL-1341	TUN-0524	7,054	72,105	174,187	8,349	7,417	49,282	123	24	6,474	314,849	57	100	80	1,651	5	230	1,771	171	1.1
ACL-1342	TUN-0525	6,217	68,343	168,294	7,311	7,407	47,321	115	24	6,149	317,265	55	96	75	2,535	6	220	1,743	85	1.0
ACL-1343	TUN-0527	6,648	70,648	162,568	8,539	10,453	37,511	98	25	5,926	334,962	56	101	86	1,130	6	170	1,458	106	1.0
ACL-1344	TUN-0528	7,104	69,963	182,855	8,487	6,716	42,898	138	26	6,456	338,465	59	94	70	539	6	216	1,748	55	1.0
ACL-1345	TUN-0529	7,027	64,854	152,460	7,198	5,894	40,652	107	22	4,953	294,240	51	94	67	410	5	165	1,670	39	1.0
ACL-1346	TUN-0532	5,570	68,362	161,686	6,961	9,270	38,569	94	22	6,062	308,016	55	95	81	718	6	167	1,537	61	1.0
ACL-1347	TUN-0533	5,518	70,479	170,913	7,137	7,669	46,295	101	23	6,080	317,909	57	98	83	557	6	204	1,746	59	1.0
ACL-1348	TUN-0537	5,415	65,460	159,128	7,164	12,420	37,431	116	24	5,916	304,465	51	89	77	771	5	167	1,651	63	0.9
ACL-1349	TUN-0538	4,862	69,007	173,884	7,020	7,471	45,172	92	23	6,452	323,636	53	84	73	573	7	202	1,515	70	0.9
ACL-1350	TUN-0539	4,311	67,591	158,536	7,604	6,355	45,219	86	23	5,664	311,776	52	85	77	666	7	189	1,566	104	0.8
ACL-1351	TUN-0540	4,128	63,290	147,067	7,454	5,800	47,348	107	24	6,147	291,952	50	93	72	699	7	182	1,454	77	0.9
ACL-1352	TUN-0542	11,951	65,952	150,610	5,485	10,357	36,269	221	17	5,350	248,440	51	72	50	848	<70	209	1,114	70	0.9
ACL-1353	TUN-0543	12,125	64,740	149,645	8,625	11,715	33,417	195	19	4,754	260,637	44	69	53	876	<70	210	1,115	146	1.1
ACL-1354	TUN-0544	10,451	64,115	149,522	5,610	6,372	33,124	192	16	5,063	244,808	48	64	45	643	<70	211	1,023	62	1.0
ACL-1355	TUN-0545	11,789	72,826	153,301	5,520	4,067	30,772	211	17	5,401	254,034	49	76	46	614	<69	206	1,077	64	1.0
ACL-1356	TUN-0547	13,872	63,462	136,080	9,688	16,177	48,708	135	16	5,952	229,081	44	62	64	1,644	<69	249	1,456	128	1.0
ACL-1357	TUN-0548	8,870	67,866	155,302	8,617	14,541	30,519	172	19	5,400	285,589	51	75	65	962	<69	185	1,324	133	1.1
ACL-1359	TUN-0552	10,611	62,296	168,256	9,542	13,341	33,911	217	18	4,910	261,261	46	64	66	1,043	<70	212	1,070	184	1.0
ACL-1360	TUN-0553	10,077	65,808	191,472	7,059	9,404	32,438	234	18	5,444	248,832	53	65	88	834	<70	216	1,203	155	1.1
ACL-1361	TUN-0554	10,066	54,665	152,073	5,644	4,881	24,649	234	16	4,402	232,206	39	57	70	764	<69	154	1,213	108	1.3

ACL-1362	TUN-0555	11,553	35,188	105,060	6,458	4,781	24,824	153	9	1,722	136,374	27	45	44	585	<69	184	1,400	57	1.4
ACL-1363	TUN-0557	9,950	57,381	129,084	12,498	10,297	60,305	125	20	7,149	227,291	43	58	66	1,827	<70	248	1,165	187	0.9
ACL-1364	TUN-0558	10,364	67,635	149,725	7,619	7,946	26,692	217	17	4,534	305,554	50	61	52	714	<70	168	882	102	1.2
ACL-1365	TUN-0559	9,934	59,141	135,163	9,473	5,755	22,283	189	16	3,364	308,576	40	69	61	746	<70	137	994	100	1.2
ACL-1366	TUN-0562	10,723	64,637	147,895	17,475	11,660	44,873	211	15	4,346	228,301	43	61	58	1,431	<70	274	1,293	254	1.1
ACL-1367	TUN-0563	11,447	55,060	126,107	21,126	7,645	54,075	194	20	7,877	236,107	46	63	84	2,601	<69	298	1,507	1,679	1.3
ACL-1368	TUN-0567	10,782	83,418	145,444	9,031	11,809	42,455	172	22	5,451	271,526	50	97	61	1,389	<232	252	1,137	153	0.9
ACL-1369	TUN-0568	10,215	66,888	148,957	9,154	9,232	35,142	223	19	5,567	266,920	48	66	59	1,365	<233	221	1,124	272	1.1
ACL-1370	TUN-0569	11,869	63,074	147,753	22,617	9,930	67,599	235	20	4,887	255,743	43	60	90	1,704	<233	327	1,529	188	1.9
ACL-1371	TUN-0572	11,419	70,475	157,503	8,827	15,895	44,164	156	19	5,975	270,027	50	66	72	1,625	<70	251	1,254	163	1.1
ACL-1372	TUN-0573	10,270	61,286	145,416	9,423	11,972	37,282	185	18	5,012	290,326	46	56	60	1,369	<69	211	1,176	257	1.1
ACL-1373	TUN-0574	12,306	65,270	148,900	6,673	6,578	35,318	184	18	4,867	261,946	47	73	58	1,085	<69	206	1,219	158	1.1
ACL-1374	TUN-0575	10,233	70,668	156,632	7,120	8,131	38,226	138	22	5,540	320,540	53	82	72	1,318	<69	207	1,205	135	1.2
ACL-1375	TUN-0577	10,187	75,520	170,602	6,930	10,821	36,041	116	22	5,791	337,588	51	71	66	736	<69	177	1,436	81	1.2
ACL-1376	TUN-0578	11,312	78,181	174,380	7,196	7,333	41,160	111	20	6,052	306,468	54	74	84	771	<69	190	1,564	101	1.4
ACL-1377	TUN-0579	10,349	65,891	146,316	8,711	6,684	34,387	166	16	4,529	255,125	45	56	59	848	<69	175	1,034	112	1.0
ACL-1378	TUN-0582	10,558	78,565	184,949	6,391	15,072	39,890	116	22	5,952	294,299	53	74	73	748	<69	226	1,556	71	1.2
ACL-1379	TUN-0583	10,302	75,124	171,012	7,153	9,405	38,230	110	21	6,975	290,129	53	72	74	659	<69	184	1,674	102	1.5
ACL-1380	TUN-0584	11,076	69,158	164,136	7,337	6,215	38,509	100	18	8,255	285,523	53	65	70	617	<69	166	1,655	79	1.3
ACL-1381	TUN-0587	10,295	77,570	176,099	6,721	9,506	35,149	93	22	6,000	306,065	55	78	78	642	<69	165	1,553	62	1.4
ACL-1382	TUN-0588	10,138	82,648	189,226	7,144	10,667	41,162	94	23	7,344	328,999	56	81	79	636	<69	191	1,605	61	1.6
ACL-1383	TUN-0589	9,415	72,560	176,154	6,102	7,337	42,274	79	20	6,407	300,765	53	67	76	599	<70	182	1,515	60	1.4
ACL-1384	TUN-0592	9,865	70,826	177,377	5,806	7,094	35,368	89	20	6,046	296,014	54	67	82	553	<69	191	1,886	59	1.5
ACL-1385	TUN-0593	9,889	80,940	189,434	5,857	6,865	38,337	82	21	6,029	306,933	54	69	68	562	<69	224	1,759	57	1.3
ACL-1386	TUN-0594	10,003	73,579	165,047	13,396	6,285	45,110	97	18	6,184	293,721	54	73	71	554	<69	181	1,586	63	1.8
ACL-1387	TUN-0595	10,732	68,330	147,193	5,741	6,646	39,787	129	17	5,388	249,822	50	63	65	501	<69	188	1,533	40	1.6
ACL-1388	TUN-0597	10,305	73,938	175,886	9,454	6,334	36,312	126	25	6,149	333,854	66	73	77	771	<232	179	1,580	135	1.2
ACL-1389	TUN-0598	11,149	81,064	201,335	8,172	6,261	40,160	147	23	8,940	331,638	56	67	69	597	<231	202	1,656	73	1.4
ACL-1390	TUN-0599	11,007	89,037	197,177	10,674	6,218	47,059	91	26	15,244	364,527	60	88	81	577	<69	206	2,354	56	2.1
ACL-1391	TUN-0600	12,120	72,288	180,274	8,476	7,015	48,024	86	19	5,370	298,478	50	63	71	568	<69	247	1,733	70	1.5

Table 3 Comparison of mean elemental concentrations in samples from the semisubterranean dwelling (SH01) and from offsite area 1 (OSA1)

Element	SH01			OSA1		
	Mean (log)	Standard deviation	Number	Mean (log)	Standard deviation	Number
Fe	5.47	0.08	238	5.53	0.32	15
Al	5.18	0.65	238	5.04	0.12	15
Mg	4.76	0.73	238	4.51	0.14	15
Ca	4.53	0.09	238	4.68	0.15	15
K	3.89	0.13	238	4.05	0.10	15
Na	3.91	0.11	238	3.95	0.07	15
P	3.91	0.14	238	3.74	0.12	15
Mn	3.73	0.10	238	4.52	0.35	15
Ba	3.12	0.08	238	3.56	0.19	15
Ti	2.22	0.17	238	1.96	0.09	15
Sr	2.28	0.07	238	2.71	0.14	15
Co	1.70	0.06	238	2.05	0.32	15
Cu	1.84	0.12	238	1.91	0.09	15
Pb	2.14	0.35	238	2.17	0.08	15
Cr	1.37	0.32	238	1.08	0.14	15
U	-0.19	0.31	238	0.67	0.11	15
Ba/Sr	0.84	0.09	238	0.85	0.09	15
Ba/Ca	-1.40	0.10	238	-1.12	0.09	15
Sr/Ca	-2.25	0.06	238	-1.97	0.04	15

and persists from the topsoil to approximately 25 cm below the topsoil (Fig. 5). Samples in this cluster are less similar to samples in both clusters 2 and 3 when examined using a dendrogram. This area was used as a trash dump after the house was abandoned, which likely contributed to the high concentrations of anthropogenic metals and other elements like phosphorus, which is associated with human and animal waste and organic materials.

Cluster 2, shown in light gray, exhibits the lowest overall mean concentrations of aluminum, manganese, cobalt, and chromium and the highest overall mean concentrations of calcium, sodium, potassium, strontium, lead, and copper (Fig. 5). Cluster 2 is prominent in samples from the topsoil and becomes less common in samples collected from lower depths that were located underneath the living surface. In this case, it is likely that the samples in cluster 2 reflect anthropogenic alteration from the activities performed in the sod house. In other studies, calcium and strontium had been associated with house floors (Entwistle et al. 2007; Konrad et al. 1983; Middleton and Price 1996; Pierce et al. 1998; Wells 2004; Wells et al. 2007). In addition, potassium has been associated with wood ash and organic matter (Entwistle et al. 2007; Knudson and Frink 2010; Knudson et al. 2004b; Konrad et al. 1983; Middleton and Price 1996; Misarti 2007; Pierce et al. 1998; Wells 2004; Wells et al. 2007).

Finally, cluster 3, shown in white, exhibits the lowest overall mean concentrations of the following elements: iron, calcium, sodium, phosphorus, potassium, barium, strontium,

titanium, lead, copper, and uranium (Fig. 5). Cluster 3 is more similar to cluster 2. While cluster 3 is present in samples from all soil depths, it is more common on the northeast side of the sod house and in samples taken at lower depths. Given the low elemental concentrations and the location of the samples under much of the furniture, as described by former house inhabitants, it is likely that this cluster exhibits the least amount of anthropogenic alteration.

A cluster analysis was also performed using five clusters and 13 clusters. In these analyses, the samples continue to group in three large clusters, as discussed previously (Fig. 5), yet begin to arrange themselves into subgroups. For example, when divided into five clusters, both clusters 1 and 2 split into two groups. These two subgroups are significantly different in mean elemental concentrations of aluminum, cobalt, potassium, and lead. The first subgroup is distinguished by higher concentrations of potassium and lead and consists of the samples collected from the uppermost 10 cm of soil, while the second subgroup largely contains samples collected approximately 10–15 cm below the topsoil. In both the three- and five-cluster analysis, the samples assigned membership in cluster 2 remain the same. However, the four subgroups in cluster 2 are only apparent when the entire set of samples is split into 13 clusters.

Finally, cluster 3 also split into two subgroups when divided. The first subgroup is distinguished by higher concentrations of magnesium, calcium, and barium and

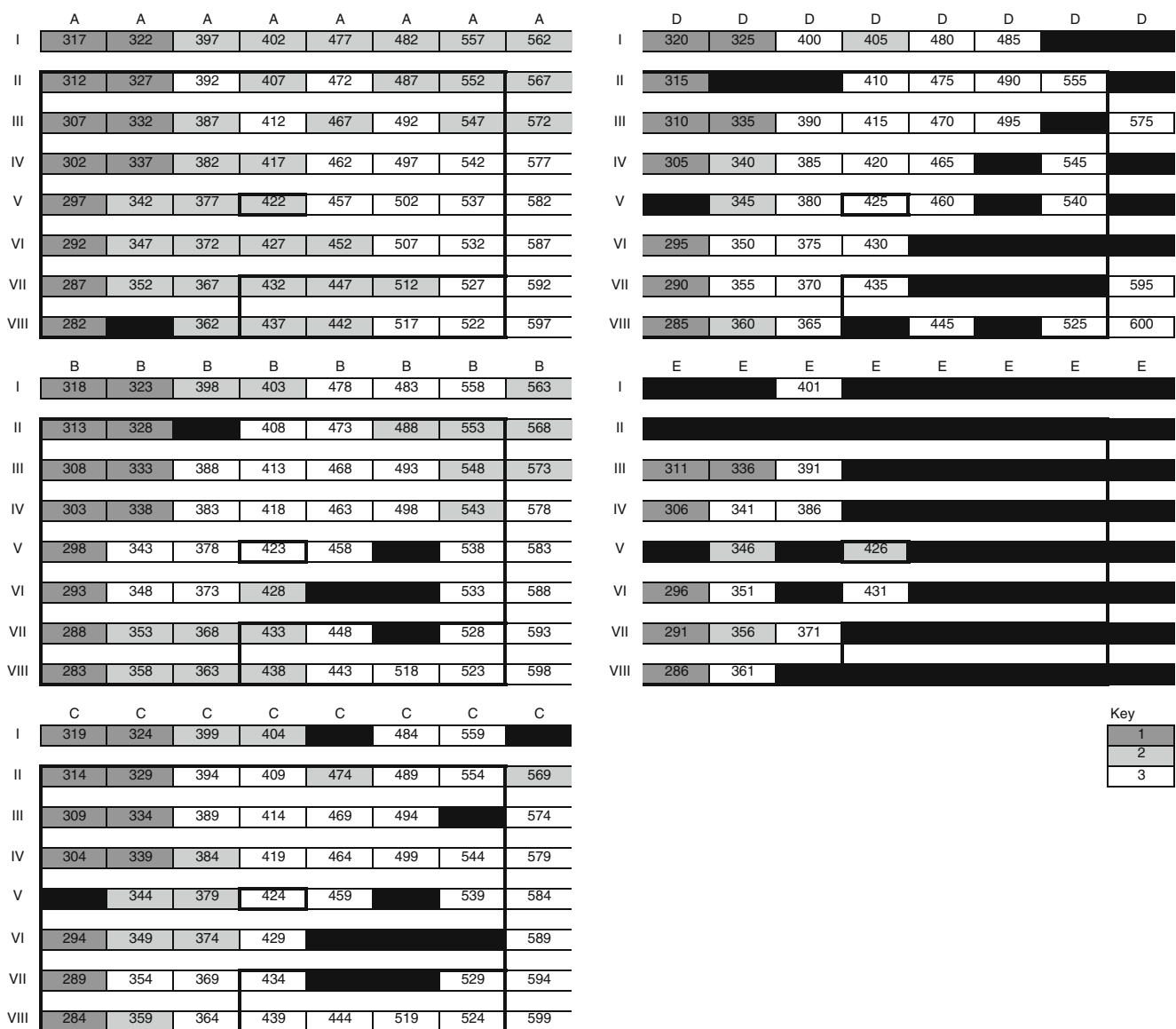


Fig. 5 Abandoned semisubterranean dwelling sampled at Tununak with sample locations and cluster membership identified. Samples collected from the surface are listed as *A* while samples *B* through *E* were sequentially collected at depths of 5 cm. Variable soil depths and

permafrost locations ensured that it was impossible to collect five samples in every sample location; *black boxes* indicate sampling locations where the soil was too shallow for sample collection at each depth or where a sample was not collected

consists of the samples collected from the uppermost 10 cm of soil in the northeast sector of the sod house. The second subgroup of cluster 3 largely contains samples collected approximately 10–25 cm below the topsoil and is depleted in many of the elements included in this study. Both of these subgroups are split into smaller groups when the data set is divided into 13 clusters.

Directions for future research and conclusion

Test excavations and the collection and analysis of soil samples from a recently inhabited semisubterranean sod

house at Tununak, Nelson Island, Alaska were undertaken to elucidate the soil signatures of known activity areas. When compared to an offsite area, the sod house samples were enriched in phosphorus and magnesium. However, when comparing all samples collected from the sod house to samples collected from an offsite area, it is clear that there is a complex pattern that varies spatially. Spatial variation within the house was examined through a cluster analysis that allowed a more detailed identification of specific areas within the sod house. The postabandonment use of the sod house as a midden was particularly apparent in cluster 1 and demonstrates the role of site history and postabandonment uses in anthropogenic soil signatures.

Incorporating known activity areas with different postuse histories and different ages is a particularly important yet little known aspect of soil chemistry studies. While most soil chemistry studies focus on contemporary sites or archaeological sites, there are relatively few studies that focus on abandoned sites with known histories. These data contribute to our understanding of how anthropogenic soil signatures can elucidate past activity areas and help bridge the gap between long-abandoned archaeological sites and contemporary sites in current use. As researchers continue to investigate features with both known activities and known postuse histories, the role of both can be better understood. In Alaska, for example, future research can augment this data set with additional historic sod houses samples as well as samples from archaeological sod houses that can be compared with the known historic sod house data.

More generally, this project demonstrates the potential impact of activity area analysis through elemental analysis of soils in the Arctic context. Many Native Arctic communities continue to be spatially linked to historic and prehistoric archaeological villages—a unique data set that is ideal for soils analysis. We hope that this project stimulates Arctic researchers to include soil chemistry in their projects as well as showcasing the potential contribution of Arctic studies to studies of hunter-gatherers.

Acknowledgements This research was funded by the National Science Foundation (ARC-0710687). The Tununak Traditional Elder Council, the US Fish and Wildlife Service (Anchorage and Bethel offices), the Archaeological Chemistry Laboratory at Arizona State University, and the W. M. Keck Foundation Laboratory for Environmental Biogeochemistry at Arizona State University provided logistical support in the field and laboratory. The fieldwork assistance of Ashley Evans and Glendee Ane Osborne, the laboratory assistance of Ashley Evans and Gwyneth Gordon, the statistical expertise of Destiny Crider, Steve Schmich, and Arelyn Simon, and the permission and assistance of the community of Tununak were all invaluable, and we are very grateful for them. Finally, we are very grateful for the constructive comments from two anonymous reviewers.

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