Sample Collection of Ash and Burned Soils from the October 2007 Southern California Wildfires

Todd M. Hoefen, Raymond F. Kokaly, Deborah A. Martin, Carlton Rochester, Geoffrey S. Plumlee, Greg Mendez, Eric G. Reichard, and Robert N. Fisher

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Introduction

Between November 2 through 9, 2007 scientists from the U.S. Geological Survey (USGS) collected samples of ash and burned soils from 28 sites in six areas burned as a result of the Southern California wildfires of October 2007, including the Harris, Witch, Santiago, Ammo, Canyon, and Grass Valley Fires (fig. 1). The primary goal of this sampling and analysis effort was to understand how differences in ash and burned soil composition relate to vegetation type, underlying bedrock geology, burn intensity, and residential versus wildland fire (Plumlee and others, 2007). Sampling sites were chosen with the input of local experts from the USGS Water Resources and Biological Resources Disciplines to help understand possible effects of the fires on water supplies, ecosystems, and endangered species. The sampling was also carried out in conjunction with detailed field analysis of the spectral reflectance characteristics of the ash, so that chemical and mineralogical characteristics of the field samples could be used to help interpret data collected as part of an airborne, hyperspectral remote-sensing survey of several of the burned areas in mid-late November, 2007.

This report presents an overview of the field sampling methodologies used to collect the samples, includes representative photos of the sites sampled, and summarizes important characteristics of each of the collection sites. In this report we use the term "ash" to refer collectively to white mineral ash, which results from full combustion of vegetation and black charred organic matter from partial combustion of vegetation or other materials. These materials were found to be intermingled as a deposited residue on the soil surface following the Southern California fires of 2007.

Sampling Strategies

Several sampling strategies were implemented during ash and soil collection. We used spoke, transect, random, and grab sampling techniques for this effort as different topographic, residential and environmental conditions required different sampling techniques. Of the 28 samples collected, 12 were collected using the transect sampling method, ten using the spoke sampling method, four using grab sampling and two using random sampling (table 1). Most of the samples were collected from wildland areas.

The spoke sampling method is a method modified from a sampling technique developed by Smith and others (2000) to collect and composite multiple subsamples over spatially variable mine-waste piles. Our sampling plan involved collecting an ash and soil subsample every four meters along each of four 16-m spokes radiating from a centroid. At each subsample location we pressed a 15.24 x 15.24 cm (6 x 6 in.) Tupperware ® container composed of HDPE (high density polyethylene) into the ash to delineate our collection area. We used this consistent standard sample area in order to collect enough material for multiple chemical analyses and to allow rough estimates to be made of ash mass at each of the different sampling locations. Using a stainless steel spade, we scraped off all of the ash from within the delineated area, noting the approximate ash depth (using one cm increments) on the data sheet, and placed the ash sample into a one gallon plastic freezer bag. The underlying soil to a depth of three cm within the collection area was collected with a stainless steel spade and placed into a separate plastic bag. This process was repeated for all 17 subsample locations. All subsamples were composited into the appropriate ash or soil plastic bag. The plastic bag was then labeled, double bagged, and placed in a plastic cooler for shipping. Specifics for each sample location including site information, apparent fire severity, and sample information were recorded on a data sheet (Appendix 1).

In the spoke sampling, we collected two additional subsamples for ash and two for the underlying soil; these were collected for organics and microbial analysis. The sampling locations were

directly adjacent to each of the 17 delineated subsample locations in the spokes. The organics subsamples, one for the ash sample and another for the underlying soil sample, were collected using a stainless steel spoon and placed into pre-cleaned 60-mL amber glass jars with Teflon-lined lids. The subsamples for microbial analysis were composited into sterile, 50 mL, polypropylene centrifuge tubes using a sterile, V-shaped, polystyrene spatula.

The composite soil and ash samples, organics sample, and microbial sample were collected at each location regardless of the sampling type. The samples were labeled "*fire_name*##A" for the ash sample and "*fire_name*##S" for the soil sample (i.e. Harris01A and Harris01S). Additionally, W is used to designate a white ash sample collected at the Harris02 site, and A, B, and C designate different types of mine tailings collected at the Harris03 site.

At some locations, the topography or some other type of obstacle prevented us from implementing the spoke sampling strategy. In these instances, we sampled along a transect, collecting subsamples in a similar fashion as the spoke sampling but in only one direction. The number of subsample locations within the transect varied according to the site and was dependent on the amount of ash deposition on the surface. Along each transect subsamples were collected and composited until enough ash had been collected for the expected chemical analysis. Ideally, at least 159 grams of the <2mm fraction of material are required to run the full suite of chemical analysis. For example at the Harris06 sample site, the slope was very steep and most of the hill did not have vegetation on it prior to the fire. Accordingly, there were only small areas of ash along the transect, which we sampled as we walked along the hillside.

At the two residential sites, we collected samples using a random sampling technique. At both the Harris07 and GrassValley01 sites, there was too much debris to layout spoke or transect type sampling. At the Harris07 site we collected 1–3 random samples per structure from approximately 10 structures. At the GrassValley01 site we collected approximately five random samples per structure for approximately five structures. A soil sample was collected if we could dig down below the ash to the soil layer. Again, the samples were collected in the same manner as those collected above. Soil and ash were collected separately from each site and composited into the plastic bags, brown glass jars, and polypropylene centrifuge tubes.

All samples were carefully packed in coolers and shipped overnight to USGS labs in Boulder, Colo., where they were unpacked, logged in, and weighed. A subset of these samples was photographed, sieved, and split using cone and quarter methods for various types of analyses. The sample processing methodologies are to be presented in a subsequent report. Initial results of the analyses are presented in Plumlee and others (2007). Results from the leach study of these samples are presented in Hageman and others (2008) and hexavalent chromium results are presented in Wolf and others (2008). Step-by-step instructions for sample collections can be found in Appendix 2.

Collected Samples

Harris Fire

The Harris Fire was the southern most fire in California and burned 366 km^2 (90,440 acres) (CAL FIRE, 2008). The fire started on October 21, 2007. Sample collection took place on November 3 and November 5, 2007. In total, seven samples were collected from within the Harris burn perimeter (fig. 2). Geologic units in this areas include; Mesozoic granitic rocks in the eastern portion of the Harris fire, Mesozoic volcanics/metavolcanics in the western portion, Miocene nonmarine sedimentary rocks along the western edge, and Mesozoic gabbroic rocks in small patches throughout (fig. 3).

Harris01

Collection Date: November 3, 2007
Latitude: 32º 37' 53.90"
Longitude: 116º 52' 04.8"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Disturbed coastal sage scrub
Apparent Fire Severity: Lightly burned
Depth of Ash: <2 cm
Other Information: This area had previously burned in the 2003 Otay Fire. Burn perimeter lines placed over aerial photos show that there is a clear border to the burned area from the 2003 fire. This border can be seen in the field as there is a much lower fuel load in the previously burned area compared to the unburned areas to the south and west. The burned grass from the 2007 fire was still in place and some of it appeared only charred (fig. 4). The soil was light brown in color.

Harris02

Collection Date: November 3, 2007
Latitude: 32º 35' 46.3"
Longitude: 116º 46' 05.7"
Datum: NAD83
Sampling Type: Grab
Slope: Moderate
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Coastal live oak
Apparent Fire Severity: Moderate
Depth of Ash: 2 cm
Other Information: This location was near a dry creek bed with some vegetation. The ash primarily occurred in patches where the larger trees stood prior to the fire (fig. 5), which resulted in our decision to collect only grab samples at this location. White ash was present in areas where the larger trees had grown. A separate sample of white ash (Harris02W) was collected in addition to a representative sample of the total ash (Harris02A) and burned soil (Harris02S). It was also interesting to note that the holes in the ground where the trees once stood were still quite warm 11 days after the fire had passed through the area.

Harris03

Collection Date: November 3, 2007
Latitude: 32º 35' 46.3"
Longitude: 116º 46' 05.7"
Datum: NAD83
Sampling Type: Grab
Slope: Moderate
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Coastal live oak
Apparent Fire Severity: Moderate
Depth of Ash: There was no ash present.

Other Information: These samples were collected adjacent to Harris02. Three samples were collected from a charred tailings pile directly below a small mine opening and above a nearby dry stream bed. Harris03A is the red tailings from the pile (fig. 6). Harris03B is the yellow tailings from the pile. Harris03C is the uppermost charred tailings.

Harris04

Collection Date: November 5, 2007
Latitude: 32º 42' 07.0"
Longitude: 116º 57' 36.9"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Disturbed coastal sage scrub
Apparent Fire Severity: Lightly burned
Depth of Ash: <2cm
Other Information: This sample was collected on a hillside just east of the Sweetwater Reservoir. The area was covered with thick grasses including San Diego Golden Star (*Muilla clevelandii*), Spiny Red-Berry (*Rhamnus crocea*), *Bromus* and *Avena*, but also included shrubs like Laurel Sumac (*Malosma laurina*). The ash was predominantly derived from these scorched and burned grasses (fig. 7). Most of the area consisted of black ash with patches of white ash. This sample location was in the Sweetwater Reservoir watershed, just uphill from the stream that feeds into the reservoir from the east.

Harris05

Collection Date: November 5, 2007
Latitude: 32º 42' 11.0"
Longitude: 116º 57' 39.8"
Datum: NAD83
Sampling Type: Spoke
Slope: Mostly Flat
Geology: Mesozoic volcanics/metavolcanics—this location is near a dry streambed so most surface material was alluvial sediments
Apparent Pre-fire Vegetation: Riparian vegetation with abundant Arundo Giant Reed (*Arundo donax*) in the area
Apparent Fire Severity: Heavily burned
Depth of Ash: <5cm
Other Information: This area is in the flood basin and near the dry creek that feeds into the east side of the Sweetwater Reservoir, a local drinking water supply. The pre-fire vegetation appeared to have been quite dense, and the burn intensity appeared high. All ground litter and fallen trees had been consumed by the fire. The tops of standing trees were scorched and burned as well, a rare occurrence in the sampled areas. Arundo Giant Reed is abundant throughout the area; when burned it produced light, black, and white ash accumulations in excess of one foot. Several fallen trees that had been completely combusted by fire produced abundant white ash. In addition to the ash and soil composite samples, we collected a white ash (Harris05W) and Arundo Giant Reed ash sample at this location (fig. 8).

Harris06

Collection Date: November 5, 2007
Latitude: 32º 39' 47.3"

Longitude: 116º 40' 51.2"
Datum: NAD83
Sampling Type: Transect
Slope: Steep
Geology: Mesozoic granitic rocks
Apparent Pre-fire Vegetation: Coastal sage scrub with some sumac and buckwheat
Apparent Fire Severity: Lightly burned
Depth of Ash: <1cm
Other Information: Harris06 is located on a very steep slope above Cottonwood Creek. Very little duff, litter, and other vegetation appeared to have been present pre-fire. Most of the area consisted of scorched and charred soil with patches of light to moderately burned vegetation (fig. 9). Due to the steepness of the area and patchiness of the ash, random sampling was carried out on a transect following a contour of the hill

Harris07

Collection Date: November 5, 2007
Latitude: 32º 37' 22.2"
Longitude: 116º 41' 26.6"
Datum: NAD83
Sampling Type: Residential random sampling
Slope: Flat
Geology: Not applicable, Mesozoic granitic rocks on the surrounding hills
Apparent Pre-fire Vegetation: Not applicable
Apparent Fire Severity: Heavily Burned
Depth of Ash: 1cm to meters depending on the structure.
Other Information: These samples were collected with permission from the owners of a trailer park alongside Cottonwood Creek. Random samples of ash and, where possible, underlying soil, were collected and composited from approximately ten burned structures. All of the trailers had burned completely, as had almost all other combustible materials. Melted aluminum cans and car wheels provide further indications of high burn intensity (fig. 10).

Witch Fire

The Witch fire was located just north of the Harris fire near San Diego (fig. 11). The fire started on October 21, 2007, burned 801.2 km^2 (197,990 acres), and destroyed 1,125 residential structures and 509 outbuildings (CAL FIRE, 2008). Five samples were collected within the burn perimeter on November 6, 2007. The geologic units in this area include; Mesozoic granitic rocks, Mesozoic gabbroic rocks, Mesozoic volcanics/metavolcanics, Eocene marine sedimentary rocks, Jurassic marine sedimentary and metasedimentary rocks, recent alluvium, Quaternary nonmarine terrace deposits, and pre-Cenozoic granite and metamorphic rocks (fig. 12).

Witch01

Collection Date: November 6, 2007
Latitude: 33º 09' 09.13"
Longitude: 116º 47' 00.91"
Datum: NAD83
Sampling Type: Transect
Slope: Moderately steep
Geology: Mesozoic gabbroic rocks

Apparent Pre-fire Vegetation: Coastal sage scrub with occasional trees
Apparent Fire Severity: Moderately burned
Depth of Ash: 3–4 cm in spots
Other Information: The area generally contains significant charred red, black, and brown soil, many large black boulders, and patches of black ash. White ash is only locally present (fig. 13). There were many indications that windblown sediments had been deposited on top of the ash.

Witch02

Collection Date: November 6, 2007
Latitude: 33º 07' 11.74"
Longitude: 116º 47' 27.11"
Datum: NAD83
Sampling Type: Transect
Slope: Moderately steep
Geology: Metamorphic rocks/Metasedimentary rocks
Apparent Pre-fire Vegetation: Dense shrubland or even woodland with 2–3 meter shrubs.
Apparent Fire Severity: Moderately to severely burned
Depth of Ash: 0–1cm
Other Information: At this location, a single mixed ash/soil sample was collected because the entire hillside and valley showed evidence that soil fines and sands had been redistributed and deposited on top of the ash and charred layers. At the interface with the underlying soil we found a sequence that started with red sands and soil that were covered by a layer of black ash and charred soil, covered by a layer of white ash followed by a 0–1 cm layer of red sands and soil (fig. 14). It appears that the final 0–1 cm layer was blown in by the strong winds and deposited on top of the ash material. There was complete combustion of the canopy including larger twigs. If any understory vegetation existed before the fire, it was completely combusted (fig. 15). No ash sample was collected at this site.

Witch03

Collection Date: November 6, 2007
Latitude: 33º 06' 49.4"
Longitude: 116º 49' 01.4"
Datum: NAD83
Sampling Type: Grab
Slope: Steep
Geology: Mesozoic granitic rocks
Apparent Pre-fire Vegetation: Coastal sage scrub
Apparent Fire Severity: Moderately burned
Depth of Ash: 4cm
Other Information: Sample was taken near a road cut, and included a mixed soil/ash layer that had been deposited on top of the actual soil surface in similar fashion to Witch02 (fig. 16). One integrated soil and ash sample was collected.

Witch04

Collection Date: November 6, 2007
Latitude: 33º 06' 25.3"
Longitude: 116º 49' 37.3"
Datum: NAD83
Sampling Type: Transect

Slope: Shallow
Geology: Mesozoic granitic rocks
Apparent Pre-fire Vegetation: Coastal sage scrub
Apparent Fire Severity: Moderately to heavily burned
Depth of Ash: <1cm
Other Information: This site, along with many of the other sites in the Witch fire, had lots of charred and burned soil and rocks but not much ash (fig. 17). Unlike the Witch03 site, the ash was not buried here, but instead appeared to have been blown away. Evidence of wind erosion and scouring was pervasive throughout the area. Significant trash and glass were also present at the site, so the sample may not be totally representative of natural materials. Ash that was present was mostly black.

Witch05

Collection Date: November 6, 2007
Latitude: 33º 05' 2.5"
Longitude: 116º 59' 18.9"
Datum: NAD83
Sampling Type: Transect
Slope: Flat
Geology: Alluvium
Apparent Pre-fire Vegetation: Willow stands with some evidence of Arundo Giant Reed
Apparent Fire Severity: Moderately burned
Depth of Ash: <4cm
Other Information: This sample was collected in the valley bottom in a dried streambed. The soil here was a sandy, light tan color. Ash deposits, which tended to be fairly thick, were found in small patches. The surface of this area appeared to be windblown. Plants in the area had already started to re-grow (fig. 18). This area is a known habitat of the endangered Arroyo Toad (*Bufo californicus*).

Ammo Fire

The Ammo Fire started on October 23, 2007 on the Camp Pendleton U.S. Marine Corp base (fig. 19). In total the fire burned 85 km^2 (21,004 acres) (CAL FIRE, 2008). The site itself is located just inland from the Pacific Coast. The geologic units in this area include: Eocene marine rocks, Miocene marine rocks, and alluvium (fig. 20).

Ammo01

Collection Date: November 7, 2007
Latitude: 33º 22' 52.3"
Longitude: 117º 32' 55.4"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Miocene marine rocks
Apparent Pre-fire Vegetation: Chaparral, sumac, prickly pear cactus and tall grasses
Apparent Fire Severity: Heavily burned
Depth of Ash: 3cm
Other Information: This site was in the rolling hills of the Marine base just east of the ocean. The site showed indications of the highest burn severity of all sites sampled (fig. 21). Abundant white ash and black char accumulations up to 2 cm were present on brown soil at this location.

Santiago Fire

The Santiago Fire was located in Orange County, California in the Santiago and Silverado Canyons (fig. 22). The fire started on October 21, 2007, burned 114.9 km^2 (28,400 acres), and destroyed 15 residential structures and nine outbuildings (CAL FIRE, 2008). The geologic units in this area include: Jurassic marine, Mesozoic volcanics/metavolcanics, Cretaceous marine undivided, Upper Cretaceous marine, Paleocene marine, Oligocene marine, Oligocene nonmarine, Miocene marine, and Pliocene marine rocks (fig. 23). The area is known to host five sensitive aquatic wildlife species, including resident southern steelhead (*Oncorhynchus mykiss*), speckled dace (*Rhinichthys osculus*), California newt (*Taricha torosa*), two–striped garter snake (*Thamnophis hammandii*), and western pond turtle (*Emys marmorata*).

Santiago01

Collection Date: November 4, 2007
Latitude: 33º 43' 12.0"
Longitude: 117º 35' 54.6"
Datum: NAD83
Sampling Type: Transect
Slope: Shallow
Geology: Jurassic marine
Apparent Pre-fire Vegetation: Sycamore woodland
Apparent Fire Severity: Lightly to moderately burned in patches
Depth of Ash: <3cm
Other Information: Ash and soil subsamples were each collected and composited at regular intervals along a 137-m transect following the course of an intermittent stream. This area is a known southern steelhead habitat. Several pools were present along the creek bed course, and many were severely affected by soil and ash produced by the fire (fig. 24).

Santiago02

Collection Date: November 4, 2007
Latitude: 33º 43' 12.0"
Longitude: 117º 35' 54.6"
Datum: NAD83
Sampling Type: Transect
Slope: Shallow
Geology: Jurassic marine
Apparent Pre-fire Vegetation: Sycamore woodland
Apparent Fire Severity: Lightly to moderately burned in patches
Depth of Ash: <3cm
Other Information: Sampling at this site started at the given location and then ash and soil subsamples were collected at given intervals along the dried streambed heading downstream to the west for approximately 128 m (fig. 25a). This area is also a known southern steelhead habitat and several pools were seen in the area. Many were severely affected by soil and ash.

Santiago03

Collection Date: November 4, 2007
Latitude: 33º 43' 12.0"
Longitude: 117º 35' 54.6"
Datum: NAD83

Sampling Type: Transect
Slope: Shallow
Geology: Jurassic marine
Apparent Pre-fire Vegetation: Sycamore woodland
Apparent Fire Severity: Lightly to moderately burned in patches
Depth of Ash: <3cm
Other Information: Sampling at this site originated at the given location and then ash and soil samples were collected from the hillside at given intervals along the dry streambed (fig. 25), heading downstream to the west for approximately 128 m. This area is also a known southern steelhead habitat and several pools were seen in the area. Many of the pools were severely affected by soil and ash.

Santiago04

Collection Date: November 4, 2007
Latitude: 33º 43' 11.4"
Longitude: 117º 35' 59.6"
Datum: NAD83
Sampling Type: Spoke
Slope: Shallow
Geology: Jurassic marine
Apparent Pre-fire Vegetation: Sycamore/Elderberry woodland
Apparent Fire Severity: Moderately burned
Depth of Ash: <5cm
Other Information: This area had a fairly thick layer of ash covering the surface. There was abundant black and white ash present. The site was located adjacent to the dry stream channel, just downstream from steelhead habitat (fig. 26).

Santiago05

Collection Date: November 4, 2007
Latitude: 33º 43' 03.01"
Longitude: 117º 36' 37.8"
Datum: NAD83
Sampling Type: Spoke
Slope: Shallow
Geology: Jurassic marine
Apparent Pre-fire Vegetation: Sycamore woodland with oak trees
Apparent Fire Severity: Moderately burned
Depth of Ash: 2 to 3 cm
Other Information: The site is on a flat flood plain off the adjacent stream ≈50 m wide and bordered by steep-sided hills. The tops of the sycamores were not scorched but the bases of the trees were charred. Some of the trees were charred deeply enough that they eventually collapsed. Some of the vegetation litter was not consumed during the fire and the soil did not look visibly altered. Some of the logs were completely combusted but many were not. Burned-out stump holes were present in the area. White ash was common on the surface here, with some black charred areas throughout (fig. 27).

Santiago06

Collection Date: November 4, 2007
Latitude: 33º 42' 59.1"
Longitude: 117º 37' 13.2"

Datum: NAD83
Sampling Type: Spoke
Slope: Shallow
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Coastal sage scrub
Apparent Fire Severity: Moderately burned
Depth of Ash: 0–2cm
Other Information: This site was located in a broad valley bottom. The soil was dark to light-brown, coarse–grained, and deep in places. Cobble-size rocks were strewn across the surface. The ash was made up of a mixture of white ash and black charred material (fig. 28).

Santiago07

Collection Date: November 4, 2007
Latitude: 33º 43' 04.2"
Longitude: 117º 37' 15.0"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Mesozoic volcanics/metavolcanics
Apparent Pre-fire Vegetation: Sycamore woodlands
Apparent Fire Severity: Lightly to moderately burned
Depth of Ash: <2cm
Other Information: This site was located in the drainage that stretches toward Santiago06 from the north. Although there were a few trees in the area, vegetation otherwise seemed sparse. Most of the area consisted of black charred soil but white ash was common in the areas where ash was present (fig. 29).

Santiago08

Collection Date: November 4, 2007
Latitude: 33º 43' 02.0"
Longitude: 117º 39' 34.6"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Oligocene nonmarine
Apparent Pre-fire Vegetation: Coastal sage scrub (Lord's Candle (*Yucca whipplei*) present)
Apparent Fire Severity: Moderately burned
Depth of Ash: 1–2cm
Other Information: This site was located mid–slope on a northeast-facing hill. The rocks appeared to be red sandstones and the reddish soil was silty to sandy (fig. 30). The apparent burn severity varied throughout the site. The site appeared moderately to heavily burned at the base of shrubs, with 3–4 cm of thick ash, and lightly burned in the intershrub spaces, with only 1 cm of ash. The ash was mostly black although some white ash was locally present (fig. 31). At times the soil appeared crusted and hard, possibly indicating it had been fused or was hydrophobic.

Santiago09

Collection Date: November 4, 2007
Latitude: 33º 43' 02.0"

Longitude: 117º 39' 34.6"
Datum: NAD83
Sampling Type: grab
Slope: Moderate
Geology: Oligocene nonmarine
Apparent Pre-fire Vegetation: Coastal sage scrub (Lord's Candle present)
Apparent Fire Severity: Moderately burned
Depth of Ash: NA
Other Information: Santiago09 is a sample of the black–crusted soil taken from the same area as Santiago08. The black crust came up as thin pieces with red soil clinging to the bottom. When water was poured on the surface of the black soil, it stayed on the surface and pooled for a few minutes leading us to believe that it might be hydrophobic.

Canyon Fire

The Canyon Fire started on October 21, 2007 and burned 18.3 km^2 (4,521 acres) (CAL FIRE, 2008). The Canyon Fire is located north of Los Angeles near Malibu (fig. 32). Geologic units in this area include: Miocene marine, Oligocene nonmarine, Paleocene marine, and Tertiary volcanic flow rocks (fig. 33).

Canyon01

Collection Date: November 7, 2007
Latitude: 34º 02' 44.0"
Longitude: 118º 42' 16.8"
Datum: NAD83
Sampling Type: Transect
Slope: Steep
Geology: Miocene marine
Apparent Pre-fire Vegetation: Chaparral, chamise, and sumac
Apparent Fire Severity: Moderately burned
Depth of Ash: trace
Other Information: This site was located just east of Pepperdine University campus. The slope here was extremely steep. The rocks appeared to be poorly cemented sandstones. Most of the ash appeared to have already blown away, making it difficult to ascertain the burn severity. Since most of the ash had blown away we took only two samples. Canyon01A was a composite sample of the top mixed layer of ash and soil. The Canyon01S sample was the soil just below the mixed ash/soil layer. We noted that grasses were already coming back in this area (fig. 34).

Canyon02

Collection Date: November 7, 2007
Latitude: 34º 3' 53.0"
Longitude: 118º 41' 50.0"
Datum: NAD83
Sampling Type: Transect
Slope: Steep
Geology: Miocene marine
Apparent Pre-fire Vegetation: Coastal sage scrub and Laurel sumac
Apparent Fire Severity: Moderately burned
Depth of Ash: 0–2cm

Other Information: This site was located on an extremely steep canyon wall, which made sampling difficult. The scrub brush here was charred and burned with little or no leaves remaining (fig. 35). The ash had already been covered by a layer of windblown soil. The ash was mostly black with some white mixed in. The soil was light- to dark-brown and sandy. Local U.S. Forest Service personnel reported that the winds that were blowing during this fire reached ≈26.8 m/sec (≈60 mph). The sample location was downhill from a road and as a result there was a lot of road debris (trash, pavement, glass and so forth) littering the area.

Canyon03

Collection Date: November 7, 2007
Latitude: 34º 3' 45.5"
Longitude: 118º 41' 50.1"
Datum: NAD83
Sampling Type: Transect
Slope: Shallow
Geology: Miocene marine
Apparent Pre-fire Vegetation: Sumac
Apparent Fire Severity: Moderately burned
Depth of Ash: 2 cm
Other Information: This site was just uphill from Canyon02, above the road. Sampling took place in a large, dense sumac stand (fig. 36). The sumac were burnt and charred, and had few to no leaves. The dense sumac appeared to have sheltered the ground from the winds as ash remained fairly thick in this area. The ash was mixture of both black and white.

Canyon04

Collection Date: November 7, 2007
Latitude: 34º 01' 57.7"
Longitude: 118º 42' 04.1"
Datum: NAD83
Sampling Type: Transect
Slope: Moderate
Geology: Miocene marine
Apparent Pre-fire Vegetation: Coastal sage scrub
Apparent Fire Severity: Moderately burned
Depth of Ash: 0–2cm
Other Information: This site was located in a small drainage near the beach. The ash consisted of black and white ash (fig. 37). Only ash and soil plastic bag samples were collected at this site.

Grass Valley Fire

The Grass Valley Fire was located in the San Bernardino National Forest just northwest of Lake Arrowhead (fig. 38). The fire burned 5.05 km^2 (1,247 acres) and destroyed 174 residential structures and 2 outbuildings (CAL FIRE, 2008). The vegetation here was very different than the other areas we sampled. At the Grass Valley Fire most of the trees were conifers. The geologic unit in this area is Mesozoic granitic rocks (fig. 39).

GrassValley01

Collection Date: November 8, 2007
Latitude: 34º 16' 02.6"

Longitude: 117º 13' 06.0"
Datum: NAD83
Sampling Type: Random
Slope: Steep
Geology: Mesozoic granitic rocks
Apparent Pre-fire Vegetation: Conifer and oak trees
Apparent Fire Severity: Moderately burned
Depth of Ash: Varied greatly
Other Information: GrassValley01 is a random residential composite consisting of five random samples taken from each of five different burned structures (fig. 40). The five locations were selected randomly within each structure, and then an ash and (when possible) a soil sample were taken. These structures were located on a very steep slope that drains into the Mojave River.

GrassValley02

Collection Date: November 8, 2007
Latitude: 34º 16' 06.3"
Longitude: 117º 13' 06.6"
Datum: NAD83
Sampling Type: Spoke
Slope: Moderate
Geology: Mesozoic granitic rocks
Apparent Pre-fire Vegetation: Conifer and oak trees
Apparent Fire Severity: Moderately burned
Depth of Ash: 0–3cm
Other Information: This sample was collected in the burned forest near the homes in GrassValley01. In the immediate area around the sample location, the treetops were burned. There were stump holes in areas. The ash was black and white, and the amount of white ash increased in proximity to any stump hole (fig. 41). The soil was light-brown to brown.

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Hageman, Philip L., Plumlee, Geoffrey S., Martin, Deborah A., Hoefen, Todd M., Meeker, Gregory P., Adams, Monique, Lamothe, Paul J., and Anthony, Michael W., 2008, Leachate Geochemical Results for Ash and Burned Soil Samples from the October 2007 Southern California Wildfires: U.S. Geological Survey Open-File Report 2008–1139, 14 p. Available online at *http://pubs.usgs.gov/of/2008/1139/.*

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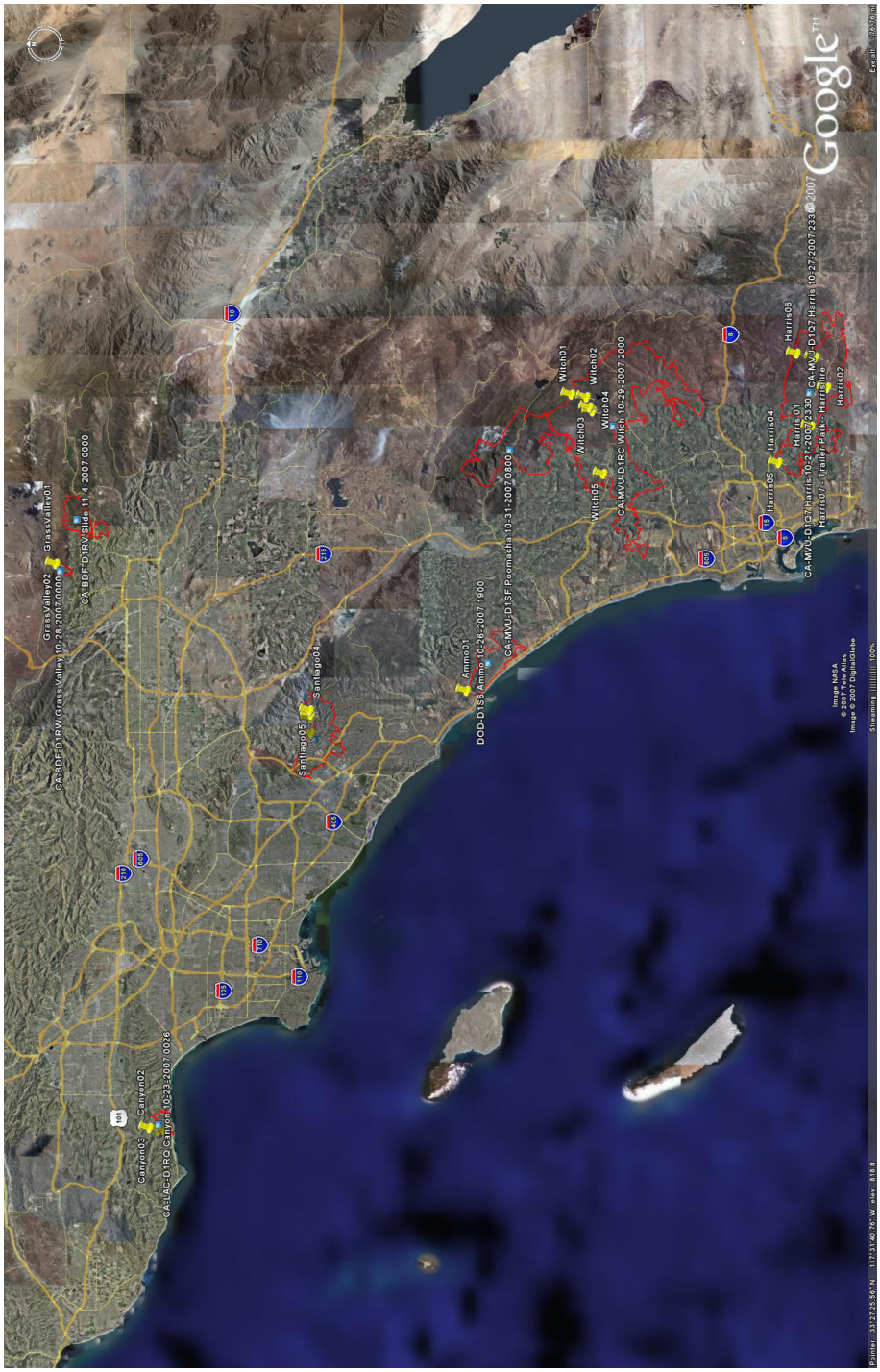

Figure 1. Google Earth satellite image showing southern California fire burn perimeters (Google Earth, 2008; GeoMAC, 2008) and locations of sites where ash and soils were sampled for this study.

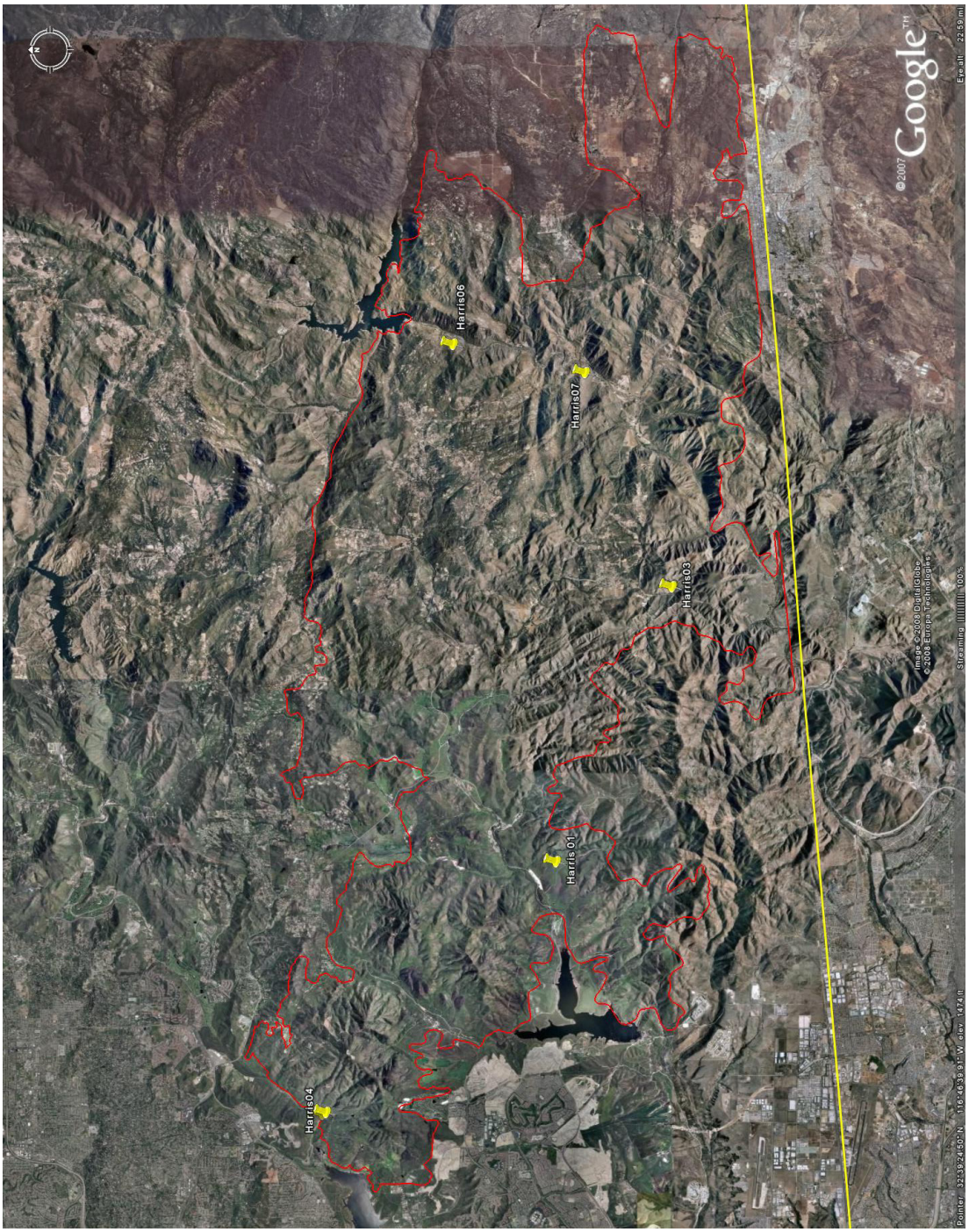

Figure 2. Google Earth map showing the Harris Fire burn perimeter and sample locations (Google Earth, 2008; GeoMAC, 2008). Some of the sample locations were too close together to all be visible on this map.

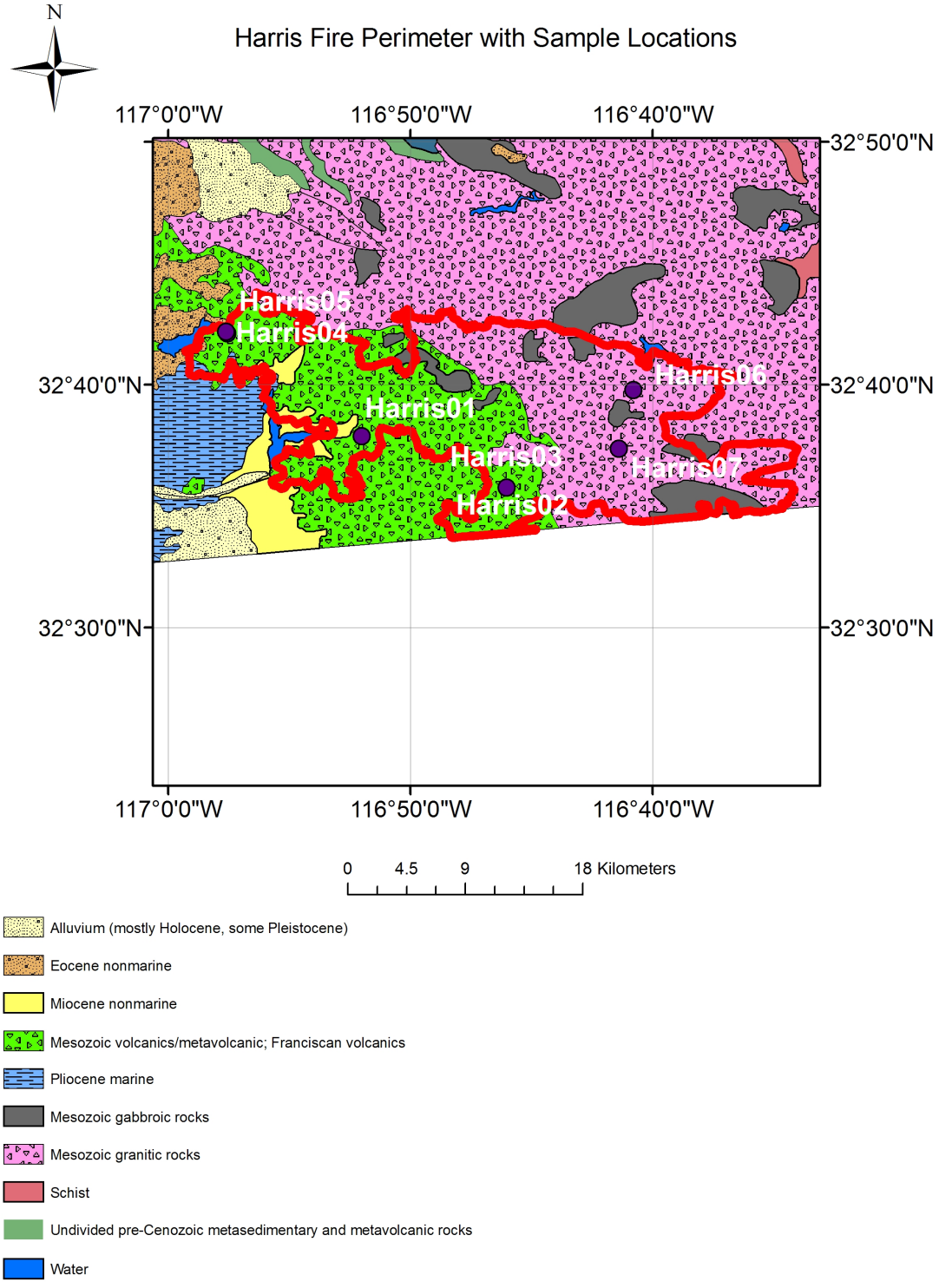

Figure 3. Harris Fire burn perimeter with sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 4. Photos of the Harris 01 sampling site. a. A view looking toward the west shows the typical burn severity of the area. b. View of charred grass that is indicative of a relatively low fuel load.

Figure 5. Photographs of the Harris02 sampling site. a. View of the remains of a fairly large tree with abundant white ash. b. Photo showing the general landscape and lack of ash at the site. The black areas are mostly charred soil and rock.

Figure 6. Photograph of the Harris03 site showing the red, yellow, and charred tailings that were sampled.

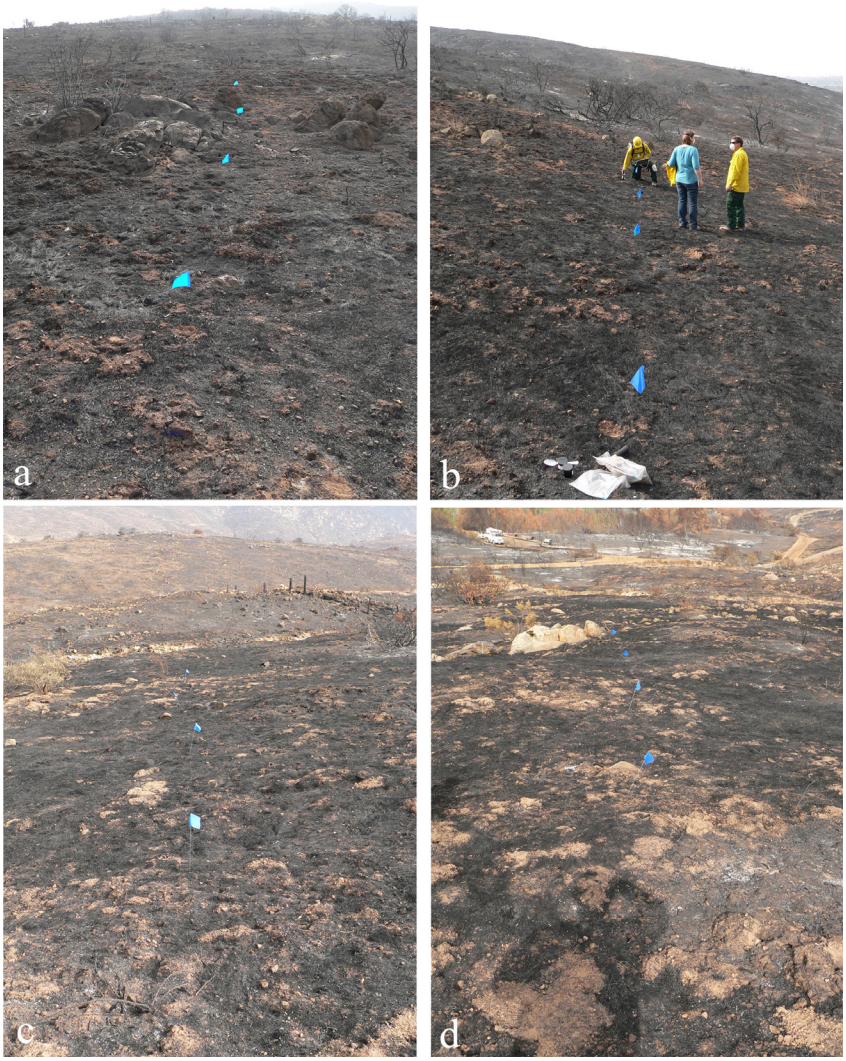

Figure 7. Photographs of the Harris04 sampling area. The photographs were taken from the centroid looking outward along each of the spokes. a. View looking uphill to the south. b. View looking west in the direction of Sweetwater Reservoir. USGS scientist Ray Kokaly (kneeling) can be seen making field measurements with a portable field spectrometer. c. Shows spoke pattern toward the east. d. View looking to the north. Trees near the dry stream bed can be seen at the top of the image.

Figure 8. Photographs looking outward along the sampling spokes for sample Harris05. This area was heavily burned, indicated by the presence of abundant white ash throughout. a. View looking in a northerly direction. The thick accumulation of ash resulted from burning of Arundo Giant Reed. b. View looking east. c. View looking west. A tree that had fallen here was completely combusted, leaving behind the white ash visible in the photograph. d. View looking south. Stump holes and the white ash remains of another fallen tree are visible in the center foreground.

Figure 9. Photograph of the Harris06 site, showing the generally small amounts of ash present. Greater amounts of pre-burn vegetation and post-burn ash were present in the small drainage gullies.

Figure 10. Photographs of the Harris07 burned residential sample site inside a trailer park.

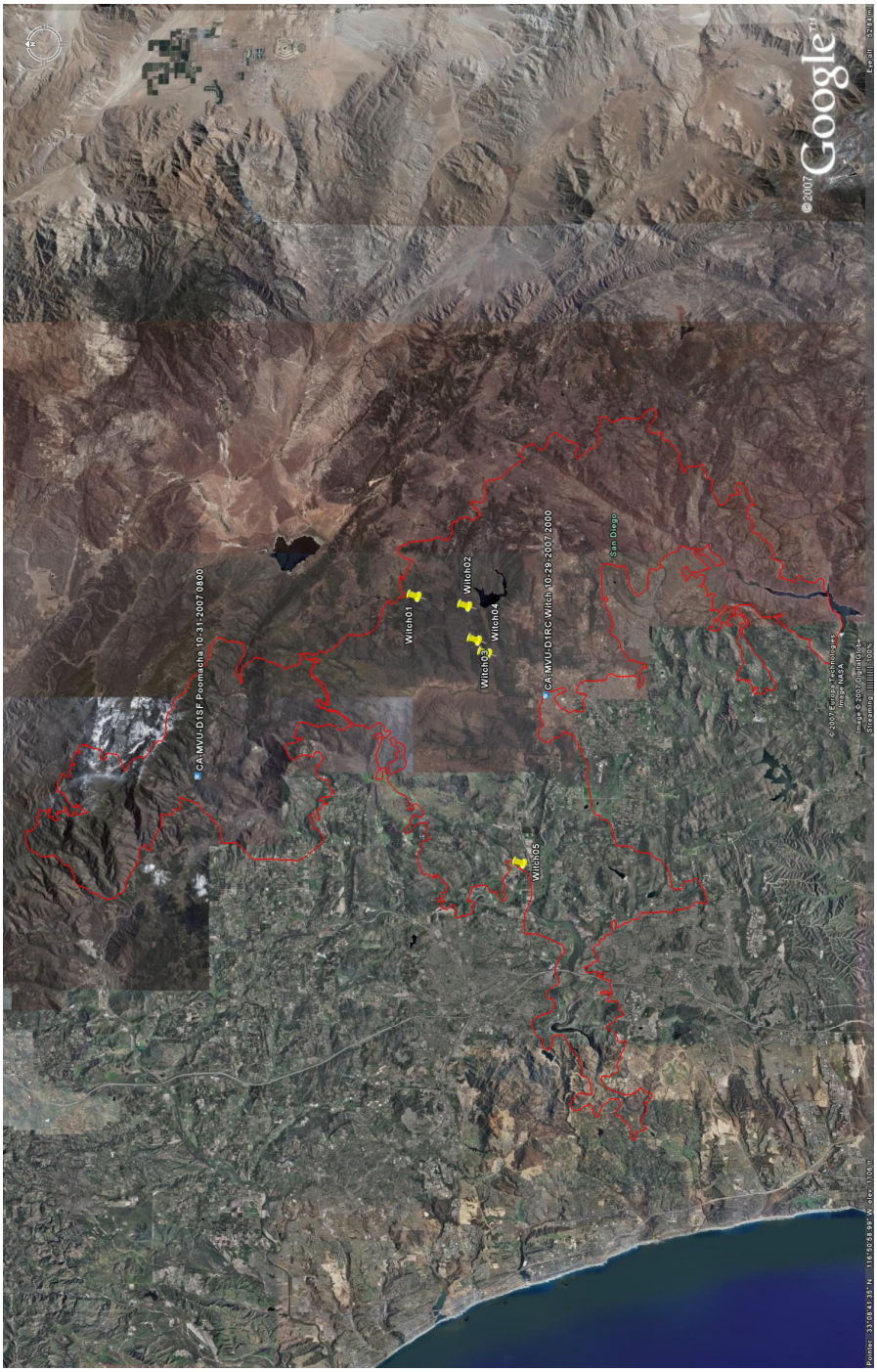

Figure 11. A Google Earth image including the sample locations and burn perimeters for the Witch and Poomacha Fires (Google Earth, 2008; GeoMAC, 2008). No samples were collected in the Poomacha Fire.

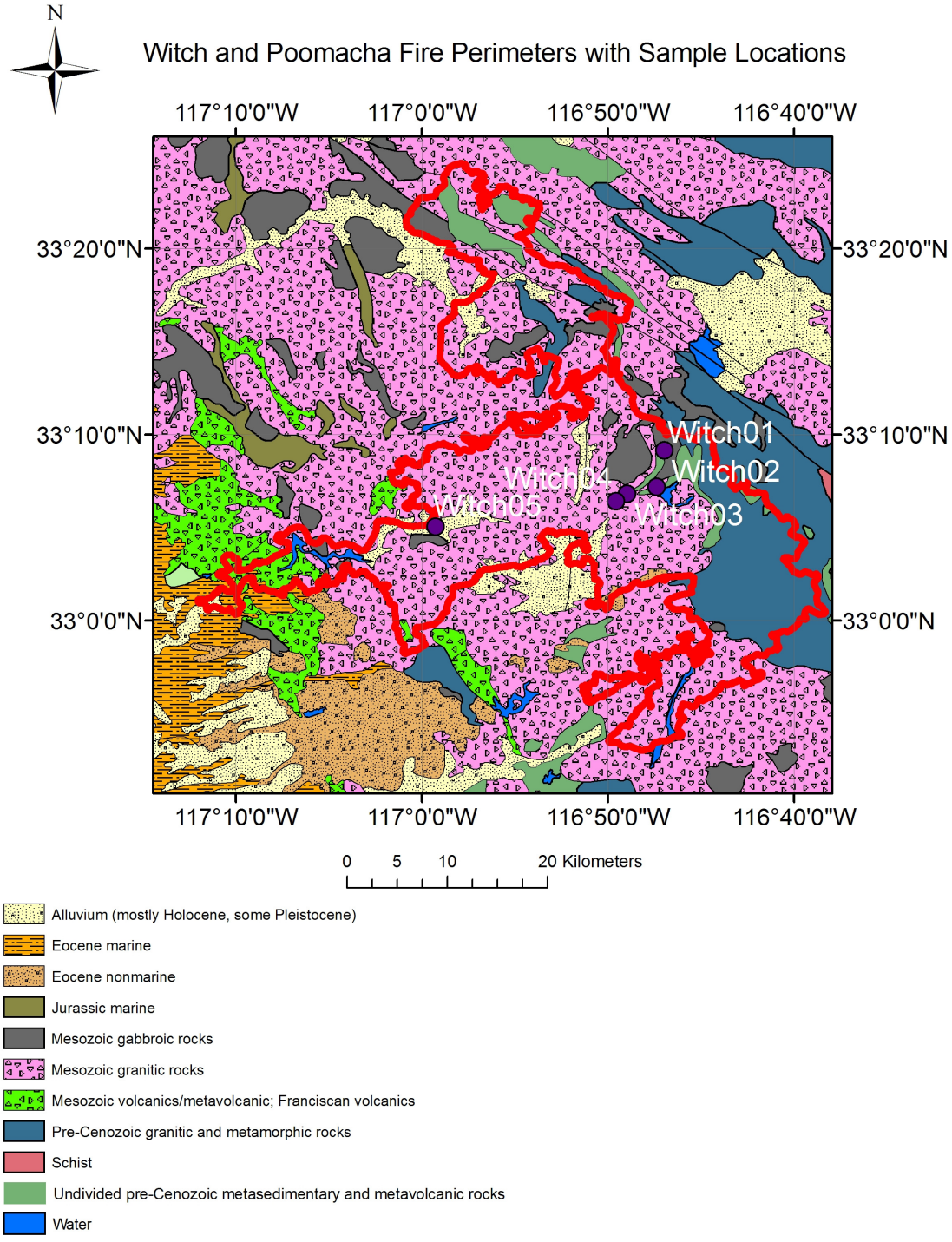

Figure 12. Witch and Poomacha Fires burn perimeters with sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 13. Photograph of the Witch01 sampling site. Very little vegetation was present before the wildfire.

Figure 14. Photograph shows an ash layer coated by wind-blown sediments. This was typical for the Witch02 site and other sites in the area.

Figure 15. Photograph showing the general landscape at the Witch02 site. Readily visible are windblown soils deposited on top of the ash.

Figure 16. Intercalated deposits of ash and sediment at the Witch03 site.

Figure 17. Photograph showing charred soil and rocks at the Witch04 site. Little ash was present here, most likely because it had been blown away.

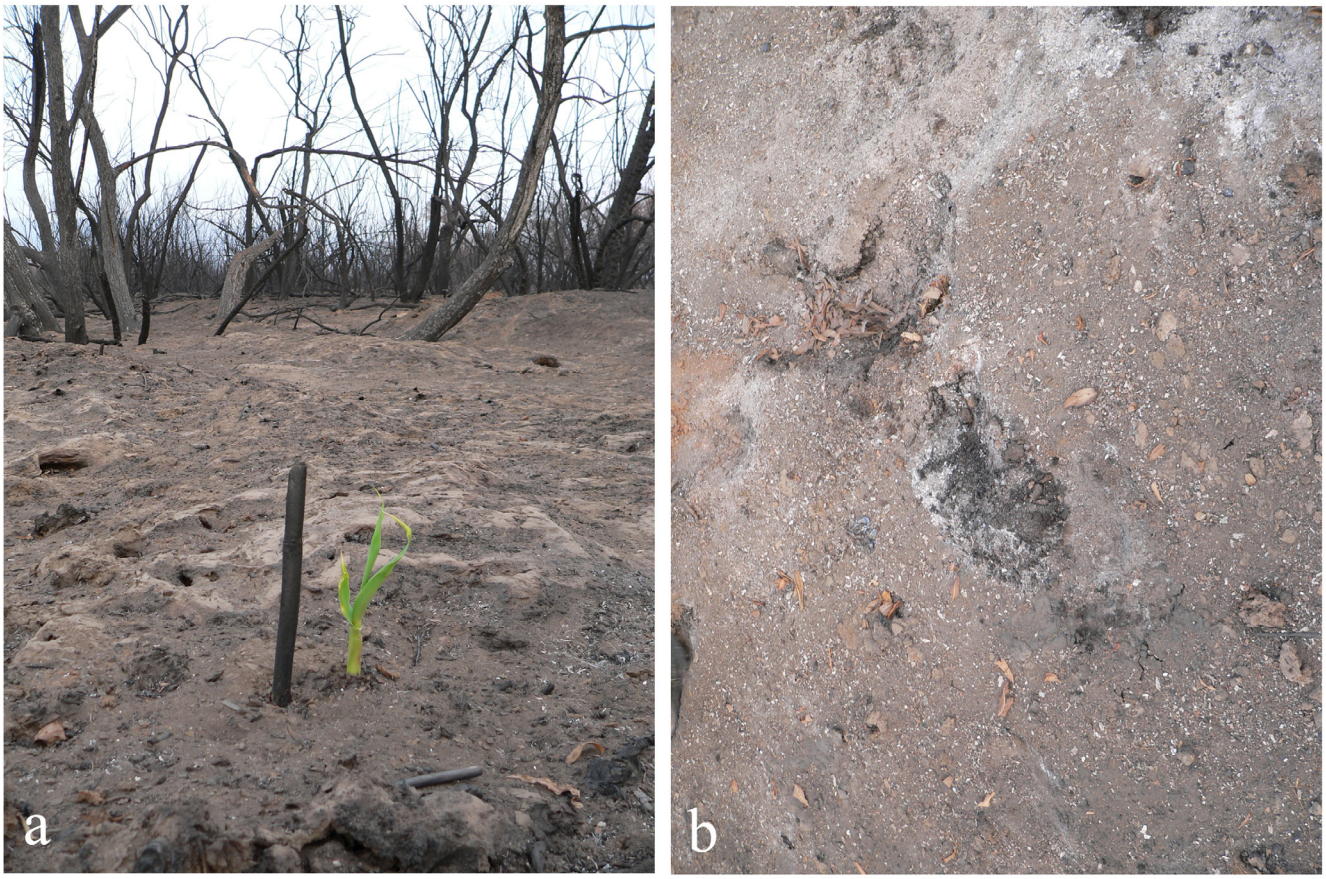

Figure 18. Photographs of the Witch05 site. a. Some vegetation regrowth was occurring just 16 days after the fire. b. The ash layer was covered by a thin layer of reddish sediments. We sampled the dark ash layer in the middle.

Figure 19. Google Earth image showing sample locations and burn perimeter for the Ammo Fire (Google Earth, 2008; GeoMAC, 2008).

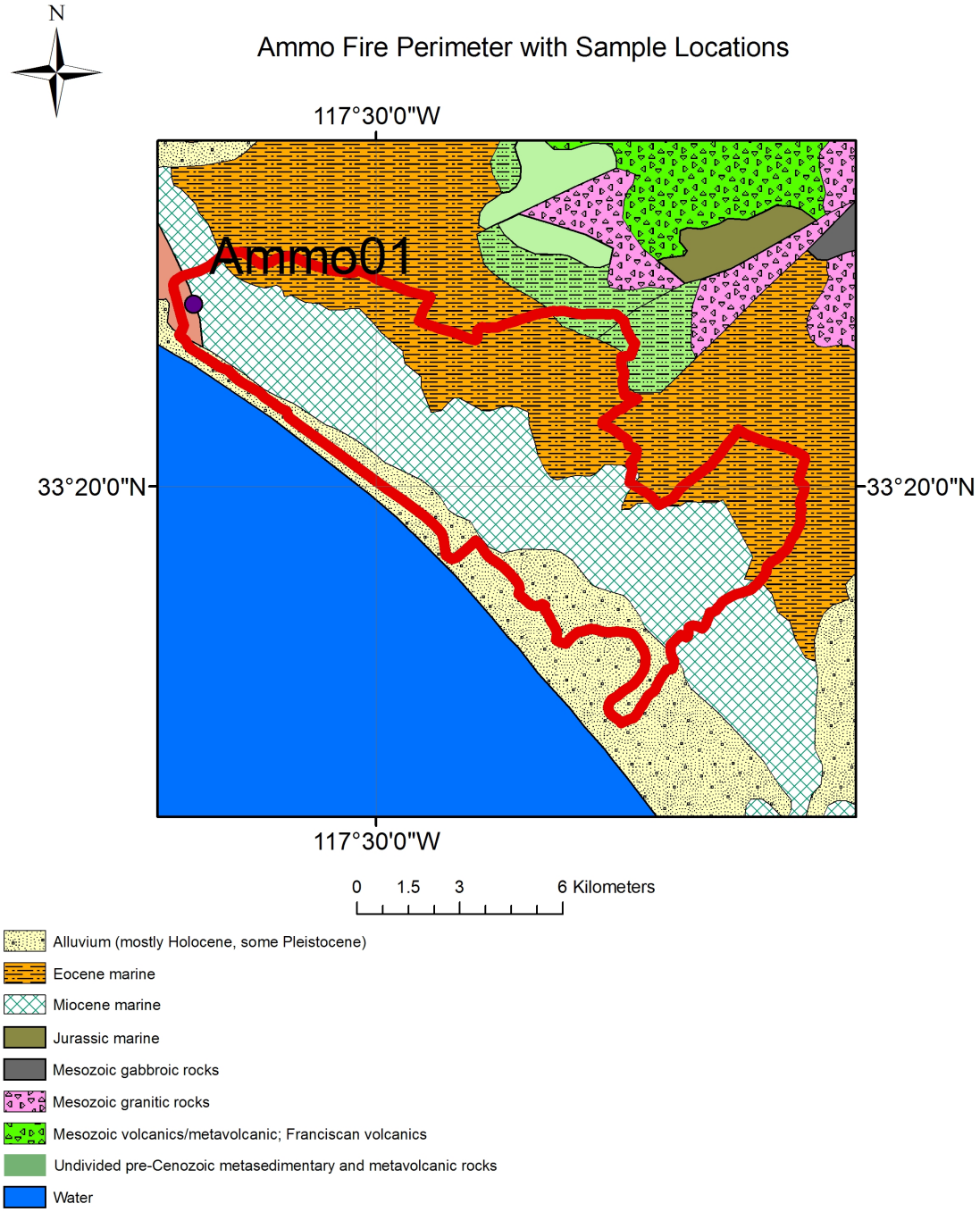

Figure 20. Ammo Fire burn perimeter and sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 21. Photograph of the Ammo01 sample site. The flags show the subsample locations within the sample spoke.

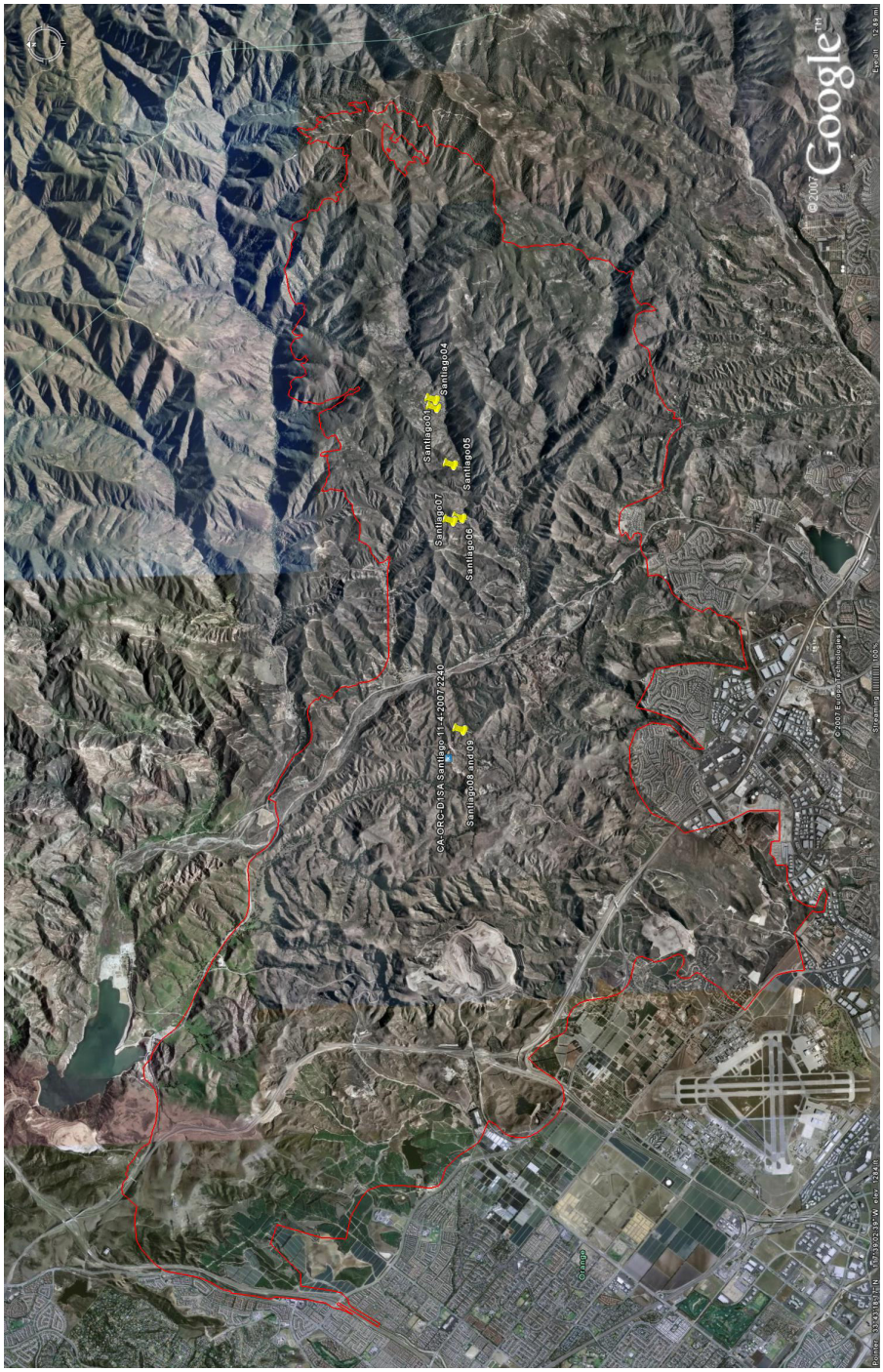

Figure 22. Google Earth image showing the Santiago Fire burn perimeter and sample locations (Google Earth, 2008; GeoMAC, 2008). Some of the sample locations were too close together to be distinctly resolved at the scale of the image.

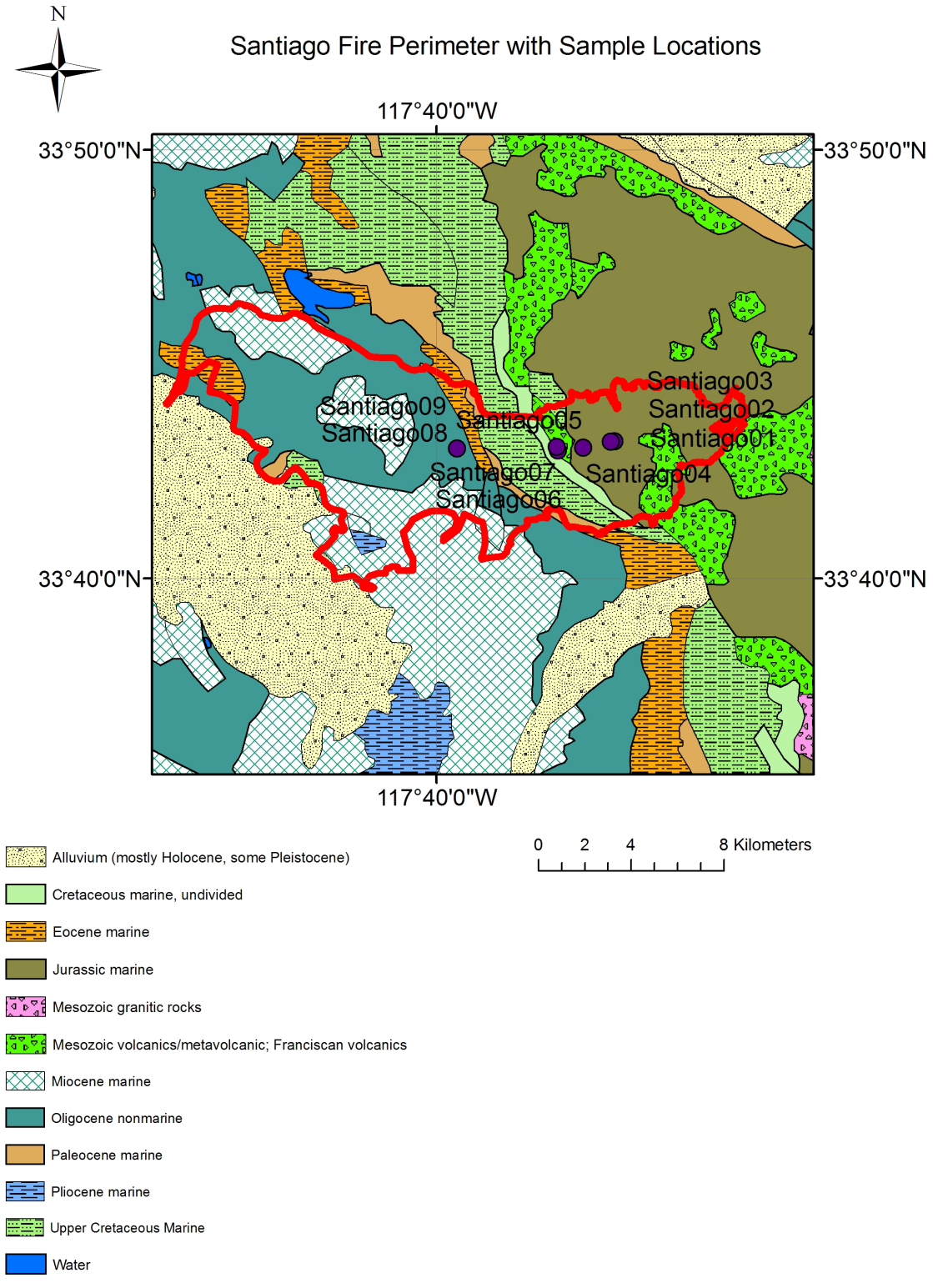

Figure 23. Santiago Fire burn perimeter and sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 24. Photograph of a small pool affected by ash and eroded soil from the Santiago fire. This pool was located near the Santiago01 sampling transect.

Figure 25. Photographs of the Santiago02 and Santiago03 sampling sites. a. Ash deposition typical of the streambed bottom. b. Ash deposition typical of the hillside next to the dry streambed.

Figure 26. Photographs of the Santiago04 sample location looking outward along the sampling spokes. a. View looking generally toward the west. b. View toward the north. c. View toward the east. d. View toward the south.

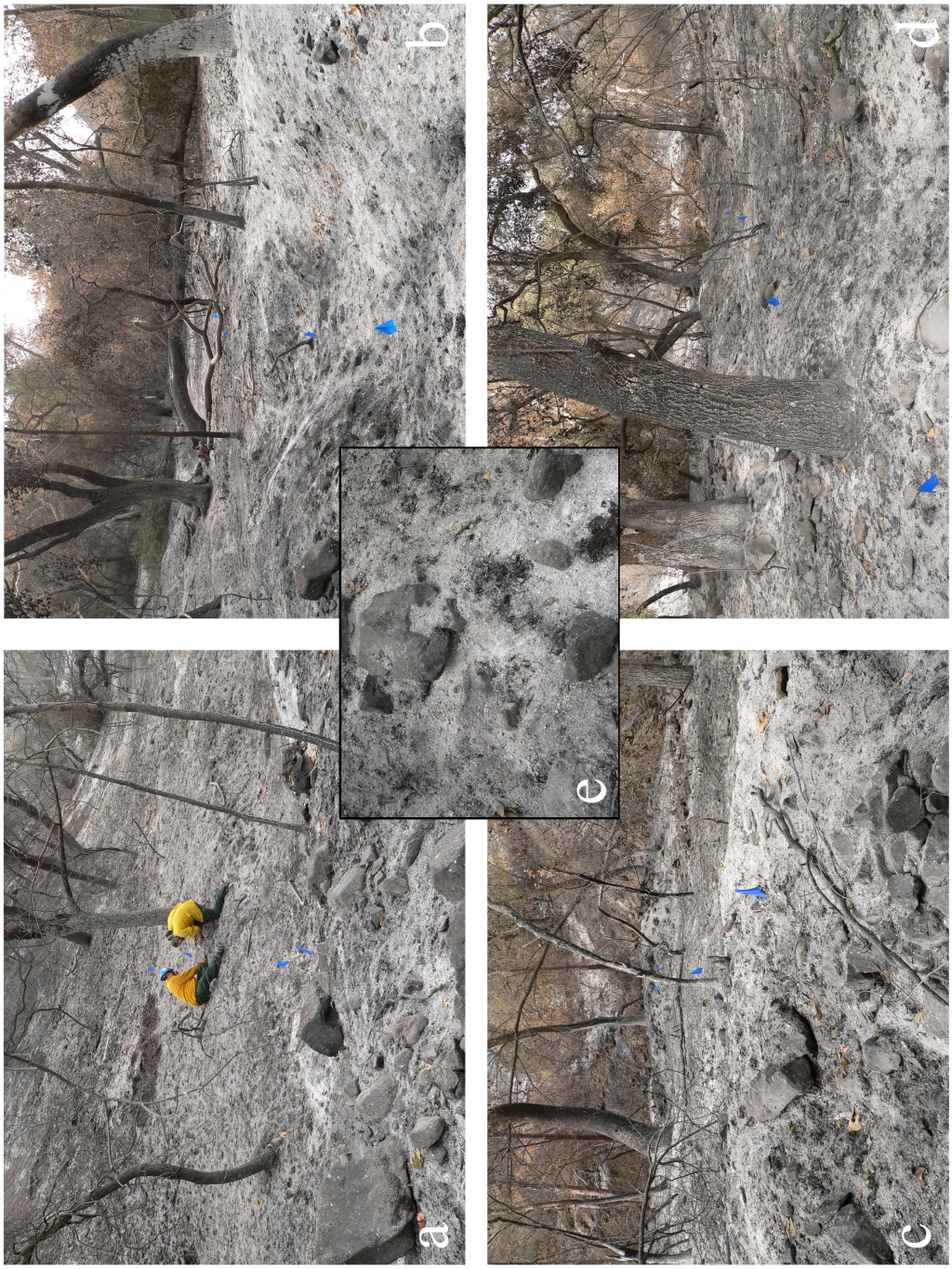

Figure 27. Photographs of the Santiago05 sampling site. a. View looking south. b. View looking west. c. View looking north. d. View looking east. e. View looking straight down at the centroid.

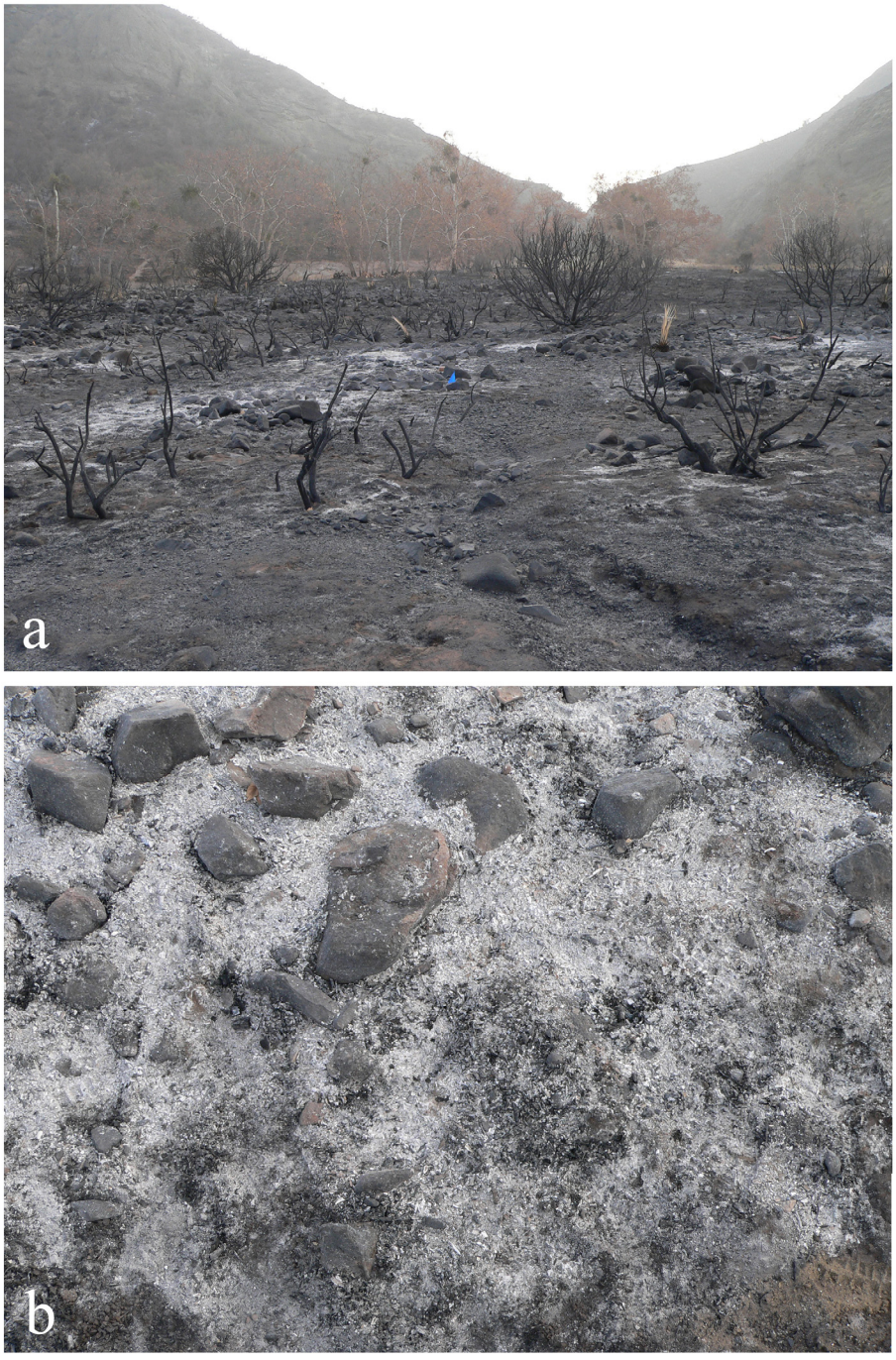

Figure 28. Photographs of the Santiago06 site. a. View of the sampling site before we laid out our sampling spoke. b. Close-up view of the ash and charred material at this site.

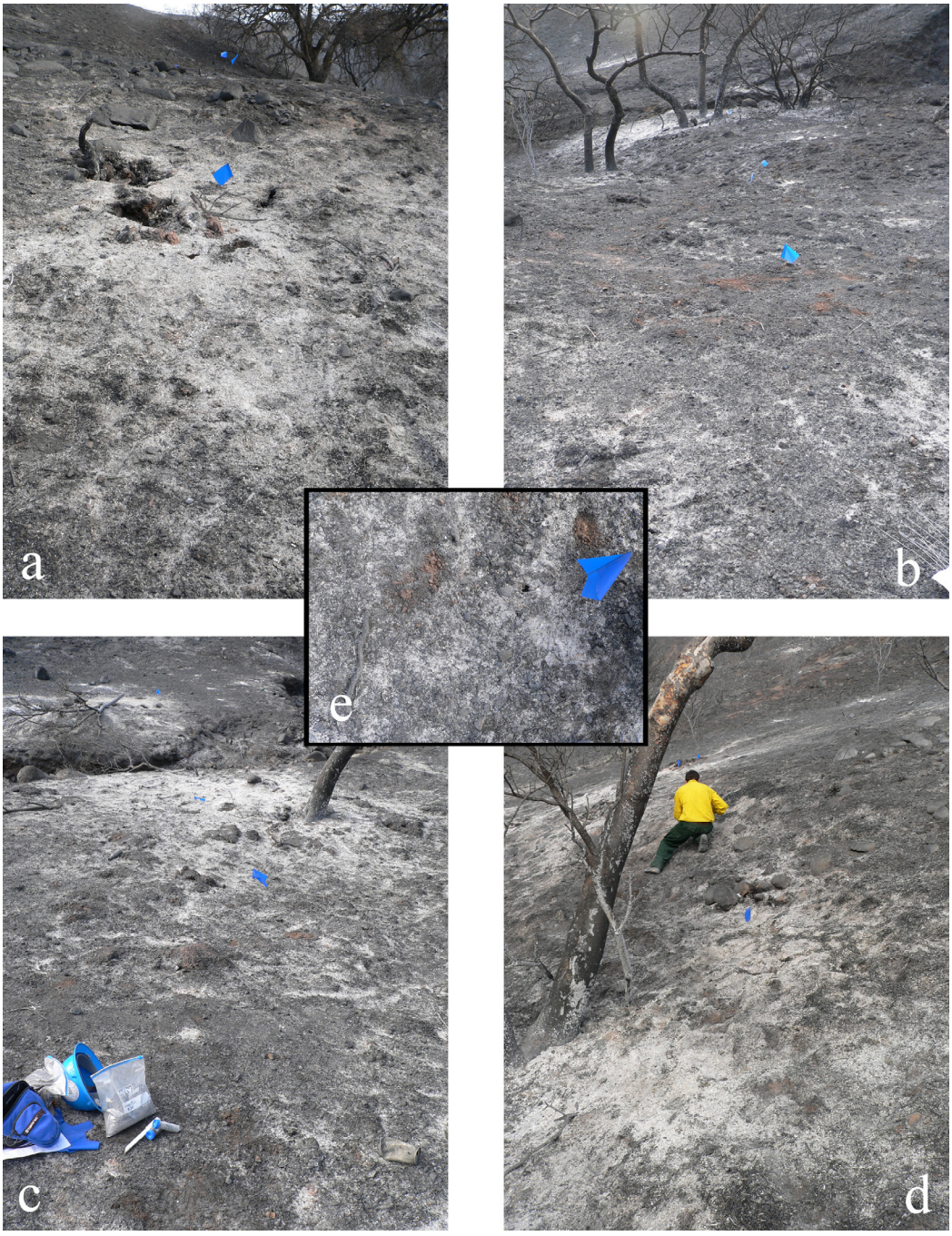

Figure 29. Photographs of sample site Santiago07. a. View of the spoke pointing generally toward the southeast. b. View looking southwest. c. View looking northwest. d. View looking northeast. e. View looking straight down on the centroid.

Figure 30. Photograph of red sandstone outcrops near the Santiago08 site.

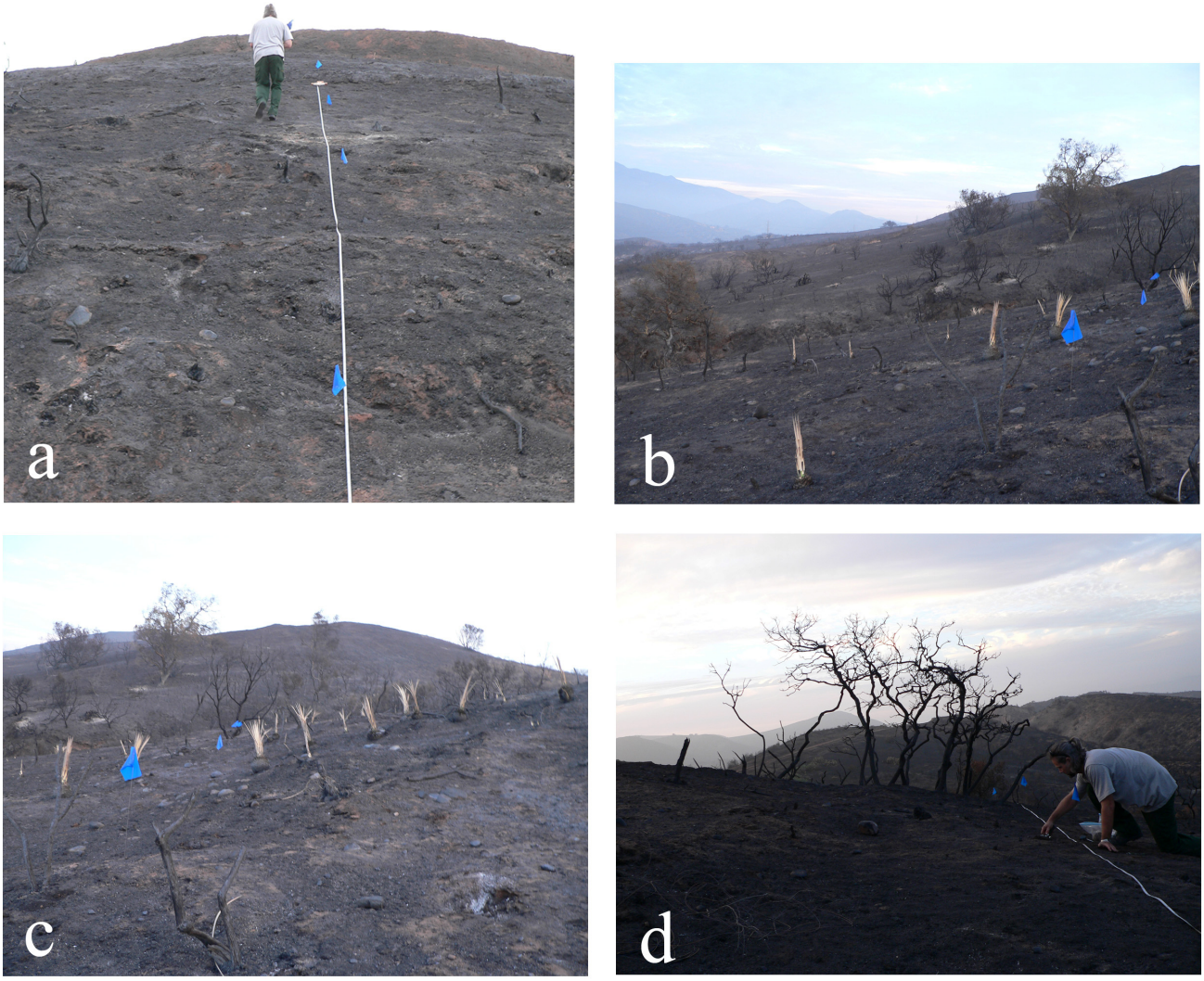

Figure 31. Photographs of the Santiago08 site. a. View of a USGS scientist measuring out the sampling spoke. b., c. Two views of spokes. d. View of a USGS scientist measuring out the last sample for the night.

Figure 32. Google Earth image showing the perimeter and sample locations of the Canyon Fire (Google Earth, 2008; GeoMAC, 2008). Some of the sample locations were too close together to all be visible on this map.

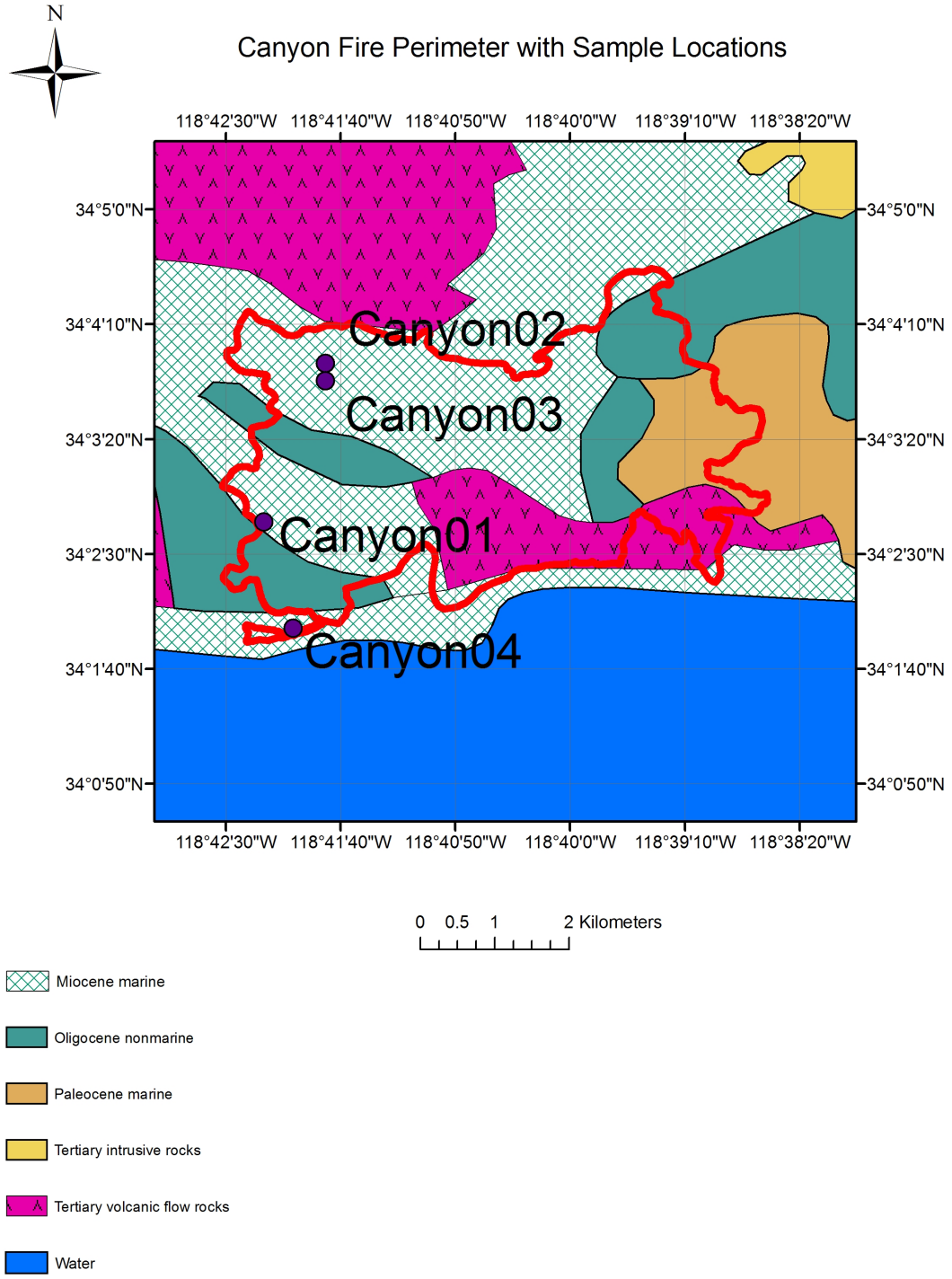

Figure 33. Canyon Fire burn perimeter with sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 34. Photographs showing various aspects of the Canyon01 site. a. View of the rugged terrain and steep slopes in the area. b. View showing that some grasses were already starting to re-grow within a week after the fire. c. Another view of the steep slopes in the area. Malibu and the beach are at the top of the photo. d. View of rocks still coated by orange-red fire retardant.

Figure 35. Photograph showing the charred and burnt scrub brush at the Canyon02 site. The extreme slopes typical of the sample site are seen on the opposite wall of the canyon.

Figure 36. Photographs of the Canyon03 sample site. a. View of the dense sumac population. The sumac bushes were charred and devoid of leaves. b. A close-up view of the ash and soil layer.

Figure 37. Photograph showing the general characteristics of the Canyon04 sampling site. Both uncombusted vegetation and areas with abundant white and black ash were present within the drainage.

Figure 38. Google Earth image of the Grass Valley fire area showing the sample locations and burn perimeter (Google Earth, 2008; GeoMAC, 2008).

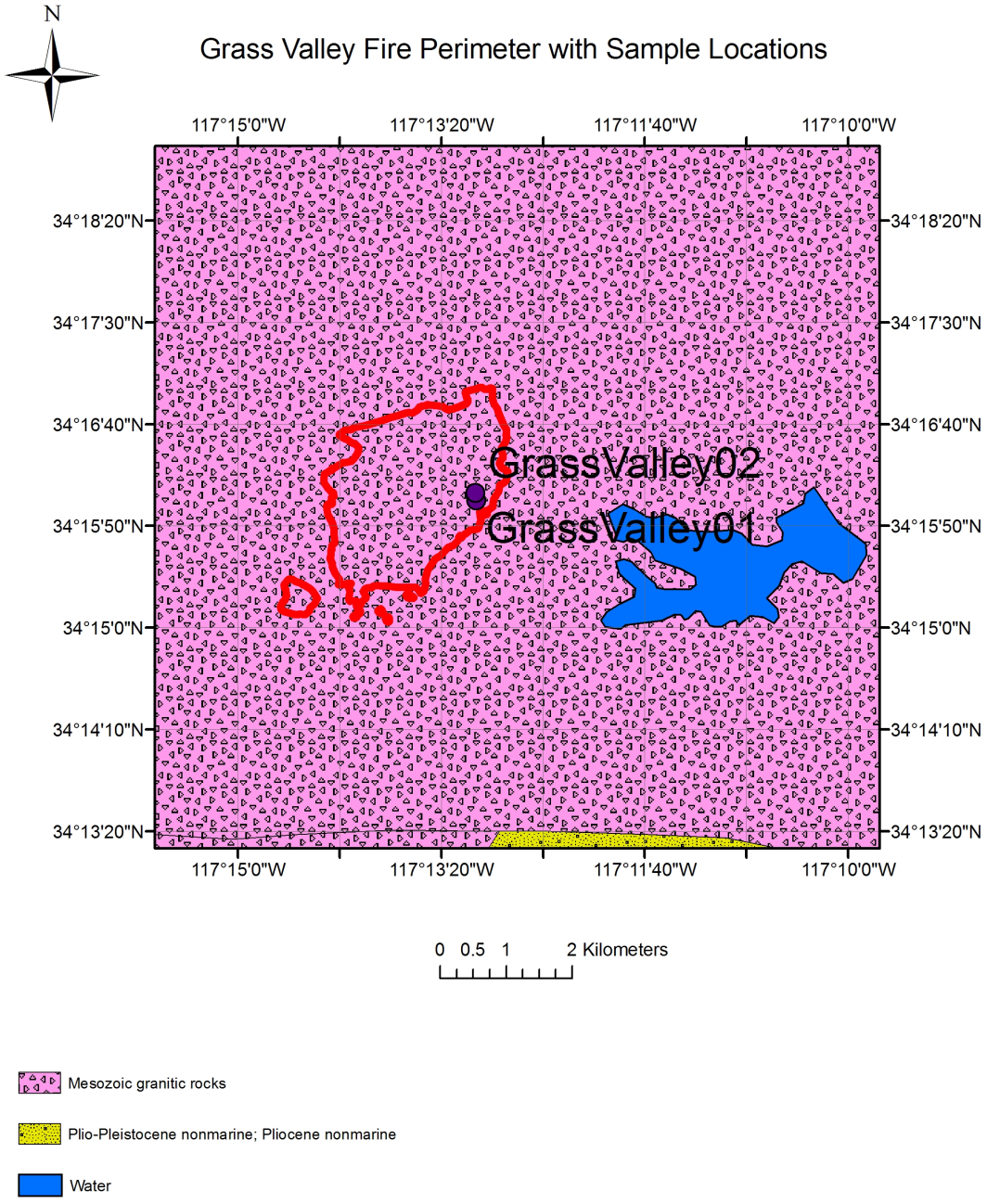

Figure 39. Grass Valley Fire burn perimeter with sample locations overlain on geologic map from Saucedo (2000) and Jennings (1977).

Figure 40. Photographs of some of the burned structures sampled at the GrassValley01 location. a. View illustrating the steepness of the valley. b. View looking across several structures that shows how much of each of the structures was consumed by the fire. c. Close-up view of one of the collection sites. d. General overview of the sampling area.

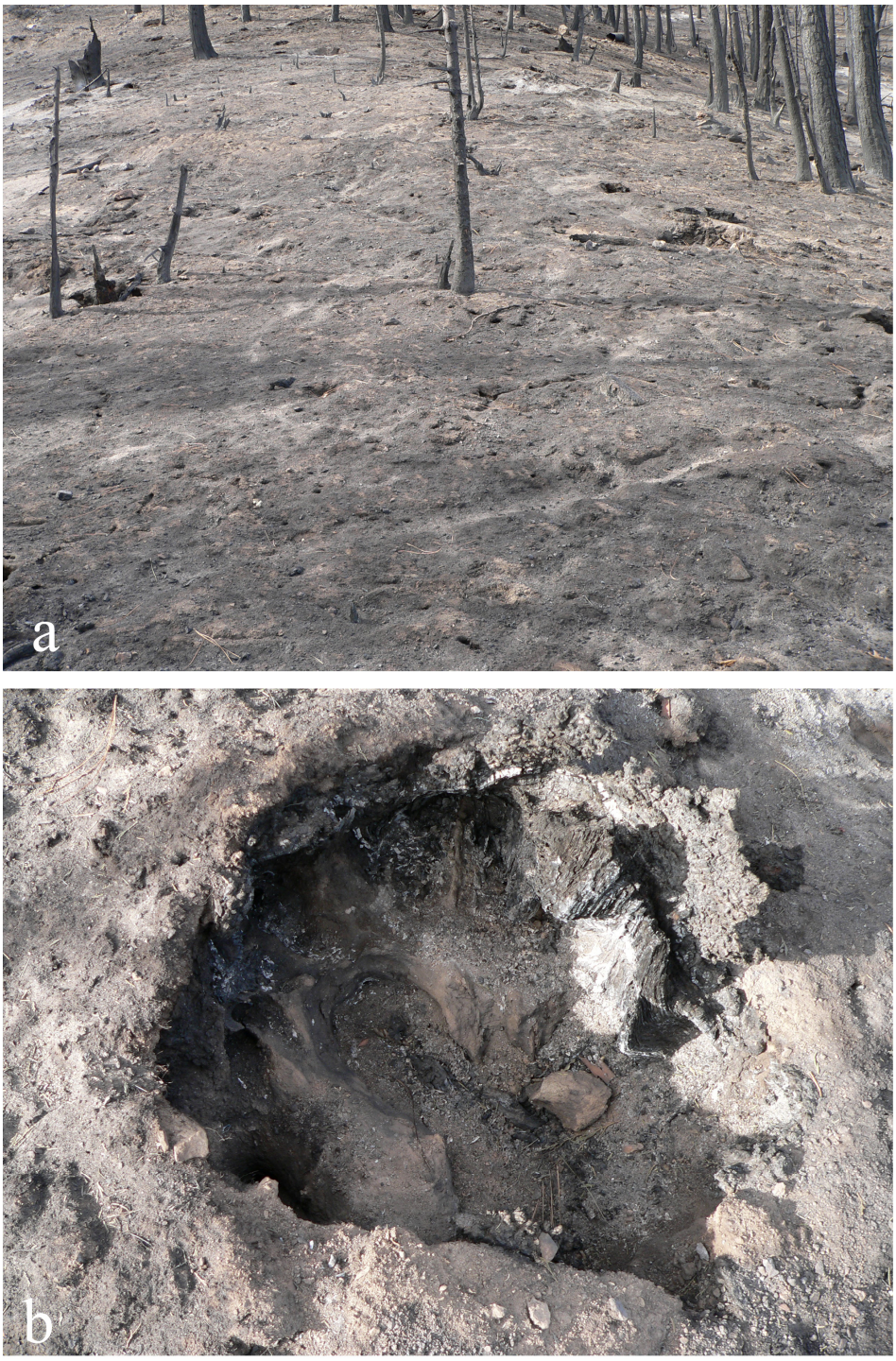

Figure 41. Photographs of the GrassValley02 sampling location. a. View showing the general nature and amounts of ash loading for the sample location. b. View of a burned-out stump in the area.

Table 1. Sample ID, latitude and longitude (datum–NAD 83), sampling type, and location type for the 28 samples collected in this study.

SAMPLE ID	Latitude	Longitude	Sampling Type	Location Type
Harris01	32º 37' 53.90"	116º 52' 04.8"	Spoke	Hilltop
Harris02W,S,A	32º 35' 46.3"	116º 46' 05.7"	Grab	Hillside
Harris03A,B,C	32º 35' 46.3"	116º 46' 05.7"	Grab	Tailings pile
Harris04	32º 42' 07.0"	116º 57' 36.9"	Spoke	Hillside near Sweetwater
Harris05	32º 42' 11.0"	116º 57' 39.8"	Spoke	Drainage basin near Sweetwater
Harris06	32º 39' 47.3"	116º 40' 51.2"	Transect	Steep hillside
Harris 07	32º 37' 22.2"	116º 41' 26.6"	Residential Random	Trailer park
Witch01	33º 09' 09.13"	116º 47' 00.91"	Transect	Steep hillside
Witch02	33º 07' 11.74"	116º 47' 27.11"	Transect	Hillside
Witch03	33º 06' 49.4"	116º 49' 01.4"	Grab	Roadcut
Witch04	33º 06' 25.3"	116º 49' 37.3"	Transect	Hilltop
Witch05	33º 05' 2.50"	116º 59' 18.9"	Transect	Dry streambed
Santiago01	33º 43' 12.0"	117º 35' 54.6"	Transect	Sampled streambed from this point then east 150 yards
Santiago02	33º 43' 12.0"	117º 35' 54.6"	Transect	Sampling started and went west 140 yards in streambed
Santiago03	33º 43' 12.0"	117º 35' 54.6"	Transect	Sampling started and went west 140 yards on hillside
Santiago04	33º 43' 11.4"	117º 35' 59.6"	Spoke	Next to dry streambed
Santiago05	33º 43' 03.01"	117º 36' 37.8"	Spoke	Next to dry streambed
Santiago06	33º 42' 59.1"	117º 37' 13.2"	Spoke	Broad valley bottom
Santiago07	33º 43' 04.2"	117º 37' 15.0"	Spoke	Drainage draining into Santiago06 from the north
Santiago08	33º 43' 02.0"	117º 39' 34.6"	Spoke	Hillside
Santiago09	33º 43' 02.0"	117º 39' 34.6"	Grab	Potential hydrophobic soil
Ammo1	33º 22' 52.3"	117º 32' 55.4"	Spoke	Marine base hillside
Canyon01	34º 02' 44.0"	118º 42' 16.8"	Transect	Very steep hillside near Pepperdine
Canyon02	34º 03' 53.0"	118º 41' 50.0"	Transect	Steep hillside
Canyon03	34º 03' 45.5"	118º 41' 50.1”	Transect	Steep hillside
Canyon04	34º 01' 57.7"	118º 42' 04.1"	Transect	Hillside near beach
GrassValley01	34º 16' 02.6"	117º 13' 06.0"	Residential Random	Modern homes
GrassValley02	34º 16' 06.3"	117º 13' 06.6"	Spoke	Hillside

Appendix 1

FIELD DATA SHEET FOR ASH SAMPLING

Fill in as much information as possible. Leave fields blank if information not known.

Collected by_____ Affiliation_____ Date_____ Time_____

IDENTIFICATION **Sample ID_____e.g. YYYY-MM-DD-FIRENAME-SAMPLE#**
Name of fire_____ Fire number_____
Site name_____ Site number_____
State_____ County_____ Nearest town_____
Road and trail used to access site_____
Latitude_____ Longitude_____ Lat/long datum_____
Elevation_____ ☐ meters ☐ feet Elevation datum_____
Site description/nearby features: Map of site (use other side if necessary):

SITE INFORMATION
Slope (%, or in general- e.g. shallow, steep, etc.)_____ Aspect (degrees, or in general- e.g. N, S, E, W)_____
Topography description_____
Geology_____
Predominant surrounding land use_____
Apparent pre-fire vegetation_____
Weather since fire (Rainfall, temperature, wind speed and direction, etc._____
_____
Other information:

APPARENT FIRE SEVERITY (check one)
____ **Scorched (4)**: Litter partially blackened; duff nearly unchanged; foliage scorched & attached to supporting twigs
____ **Lightly burned (3)**: Litter charred to partially consumed; upper duff layer may be charred but duff not altered over entire depth; surface is black; woody debris partially burned; logs scorched or blackened but not charred
____ **Moderately burned (2)**: Litter mostly to entirely consumed, leaving coarse, light-colored ash; duff deeply charred, but mineral soil not visibly altered; woody debris mostly consumed; logs deeply charred, burned-out stump holes common
____ **Heavily burned (1)**: Litter & duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs deeply charred, rotten logs completely consumed (*From National Park Service's Fire Monitoring Handbook)*
Other information:

SAMPLE INFORMATION
Depth of ash_____ ☐ centimeters ☐ inches Color of ash_____
Other ash information_____
Length and width of plot (30 cm recommended) _____L x _____W ☐ centimeters ☐ inches
Depth of mineral soil collected (5 cm recommended)_____ ☐ centimeters ☐ inches
Length and width of mineral soil sample collected (30 cm recommended) _____L x _____W ☐ centimeters ☐ inches
Description of mineral soil (color, texture, etc.)_____
Method used to collect sample (trowel, plastic spoon, etc.)_____
Photograph ID_____
Microbiology sample collected?_____Centrifuge tube volume?_____
Composite sample collected in separate bag?_____Approximate volume sample e.g. fits in 1 gallon bag?_____
Other information:

Data sheet prepared by Sheila Murphy and Deborah Martin, U.S. Geological Survey. Please send suggestions to damartin@usgs.gov.

Appendix 2

Spoke Sampling Plan

1) Select a centroid spot within the burn area and mark it with a flag.
2) Measure out 16 meters using an open reel tape measure in any direction.
3) Every 4 meters from the centroid insert a marking flag until you reach 16 meters.
4) Standing on the centroid, rotate 90 degrees from the first line and repeat steps 2 and 3.
5) Repeat step 4, 2 more times so you form an X or spoke pattern.
6) At each of the 17 locations use a 15.24 x 15.24 cm Tupperware ® container and "stamp" out an area in the ash.
7) Using a stainless steel spade, scrape off all of the ash within the 15.24 x 15.24 cm stamp and place it into a one gallon plastic freezer bag labeled "FireName#–ASH" where FireName is the name of the fire you are sampling in, # is the sample number and ASH is for the ash portion of the sample. Note the ash depth on the field data sheet. Repeat this process for all 17 locations compositing the ash into one bag as you go along.
8) Using a stainless steel spade, dig down and collect ≈3 cm of soil that resides below the ash layer for the same 15.24 x 15.24 cm area you collected the ash from in step 7. Place the soil into a one gallon plastic freezer bag labeled "FireName#–SOIL" where FireName is the name of the fire you are sampling in, # is the sample number and SOIL is for the soil portion of the sample. Note the soil color and apparent grain size in the field data sheet. Repeat this process for all 17 locations compositing the soil into one bag.
9) Using a stainless steel spoon, start at the centroid and collect a spoonful of ash directly adjacent to the 15.24 x 15.24 cm stamp. Make sure to collect the full profile of ash. Place the spoonful of ash into a 60 mL amber glass jar (with Teflon lined lid) and label it with the same name as in step 7. Repeat this process for all 17 locations compositing the ash into one jar. Make sure to keep the lid on the jar between sampling locations.
10) Using a stainless steel spoon–start at the centroid and collect a spoonful of soil directly adjacent to the 15.24 x 15.24 cm stamp just below the area you collected the ash from in step 9 down to a depth of 3 cm. Place the spoonful of soil into a 60 mL amber glass jar (with Teflon lined lid) and label it with the same name as in step 8. Repeat this process for all 17 locations compositing the soil into one jar. Make sure to keep the lid on the jar between sampling locations.
11) Using a sterile, V–shaped, polystyrene spatula–start at the centroid and collect a scoop of ash directly adjacent to the 15.24 x 15.24 cm stamp. Make sure to collect the full thickness of ash from a fairly small area. Place the ash into a sterile, 50 mL, polypropylene conical tube and label it with the same name as in step 7. Repeat this process for all 17 locations compositing the ash into one tube. Make sure to keep the lid on the tube between sampling locations.
12) Using a sterile, V–shaped, polystyrene spatula–start at the centroid and collect a scoop of soil directly adjacent to the 15.24 x 15.24 cm stamp and under the soil collected in step 11. Make sure to collect down to 3 cm below the ash level. Place the soil into a sterile, 50 mL, polypropylene centrifuge tube and label it with the same name as in step 8. Repeat this process for all 17 locations compositing the soil into one tube. Make sure to keep the lid on the tube between sampling locations.
13) Photograph the location.
14) Complete the field data sheet as much as possible.
15) Take GPS coordinates.

16) Using the one gallon plastic freezer bags–double bag the bag of soil and in a separate bag, double bag the ash. Double bag the brown glass jars and the tubes.
17) Place all of the filled sample bags into a cooler to be shipped overnight. Inorganic samples should be shipped via Fedex in coolers with blue-ice packets. Frozen organic samples in brown glass jars and frozen microbial samples in centrifuge tubes should be shipped by FedEx in coolers with dry ice.