ORIGINAL COPY
RETURN TO LASSEN VOLCANIC NI

Advanced Geologic Exploration, Inc.
Scientists of the Earth™

P.O. Box 2464 • Lake Almanor • California • 96137-2464 • Tel: (530) 596-3221 • Fax: (530) 596-3221
e-mail: info@advancedgeologic.com • Web Site: http://www.advancedgeologic.com

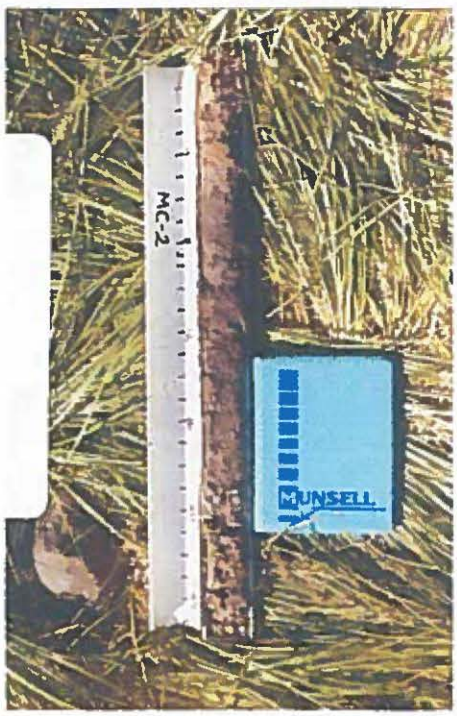
Phase II - Soils and Tephra Sampling Geologic Research Project, Drakesbad Meadow, Lassen Volcanic National Park, California

Prepared for the
National Park Service
Lassen Volcanic National Park
Mineral, California

Contracted by
Lassen Park Foundation
Chico, California

and

GeoScientists-in-the-Parks
National Park Service
Denver, Colorado



Display Copy

II

March 30, 2004

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

March 30, 2004

Louise Johnson
Sara Koenig
Natural Resource Department,
Lassen Volcanic National Park
P.O. Box 100
Mineral, CA 96063

RE: Phase II - a Soil and Tephra Sampling

Dear Colleagues:

As per your request, please find the attached Phase II - a Soil and Tephra Sampling Report. This report serves to inform you as to the preliminary findings of the soils investigation.

Highlights of the investigation include completed soil logs, laboratory results from clay and tephra samples, as well as total organic carbon, and the construction of maps and profiles showing various relationships of soils of the Drakesbad Meadow.

As described in previous progress reports, Drakesbad Meadow is a complex and dynamic environment that has required significant time to gather meaningful evidence to support scientific conclusions. The delays in completing this report reflect the professional diligence committed to giving the National Park Service the best possible information so that they may make meaningful, long-term management decisions.

Therefore, since this report out lines only preliminary findings, recommendations for continued studies and additional investigations are provided.

Thank you for the opportunity to be a part of this project. If you have any questions or if you need further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson
Chief Geologist

Geologic Research Project in the Warner Valley, Phase II - Soils and Tephra Sampling

Prepared for the
National Park Service
Lassen Volcanic National Park
Mineral, California

Contract by

Lassen Park Foundation
Chico, California

and

GeoScientists-in-the-Parks
National Park Service
Denver, Colorado

March 30, 2004

Executive Summary

Preliminary findings shows the Middle Drakesbad Meadow is a product of a complex interplay between the development of organic-rich soils on a prograding alluvial fan and the formation of mineral soils on an active floodplain where flood scour and fill processes dominate. Figure 7 shows a schematic of this relationship.

Soils with organic-rich profiles greater than 10 inches thick are located across the northern half of the Middle Meadow, and the maximum organic-rich profile was 29 inches thick. The soils were predominately peat loams to mucky loams, both of which indicate total organic carbon contents shy of the organic soil or Histosol classification. Although only one horizon from one soil profile met the criteria for Histosols, it is likely many of these organic-rich soils could classify as hydric soils. No soil met the classification of fen.

The organic-rich soils are stratified, forming paleosols related to changes in soil forming processes and aggradational conditions. Longitudinal profiles suggest an a thickening southward over time and along with the angular-shaped grains, confirms a alluvial fan geomorphic province.

The mineral soils are relatively thin packages of soils, usually containing an upper peat-rich horizon that is underlain by a thin mineral soil with less organic matter. These are typical floodplain soils whereby over bank flood waters scour the surface soil, then bury it with thin deposits of fine-grained sediment. The mineral soils are located along the southern half of the meadow closest to Hot Springs Creek.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Buried soils are common in both the mineral and organic-rich soils and have been subdivided into four paleosol intervals. Although similar characteristics exist between the mineral and organic-rich paleosols, their relationship is unclear at this time. All the soils show immature soil development and were likely formed since the mid to late Holocene. Charcoal fragments are found in many paleosols and may provide a means of dating the soils and provide insights to their formation.

Analysis of the Bathhouse Ash revealed it was not a tephra, but a kaolin clay layer associated with Boiling Springs Lake out flows, and thus, is not directly useful for dating purposes. Other white layers discovered in meadow cores are probably not tephras either, and analysis is likely to show they are from either Devils Kitchen or Boiling Springs Lake. Differential settlement between soil cores and a sand-filled fissure found in one soil core appear the result of tectonic processes from large nearby earthquakes.

Introduction

In 2000, researchers proposed a discovery of a rare and possibly endangered fen (peat-rich) deposit in the Drakesbad Meadow of upper Hot Springs Valley in Lassen Volcanic National Park (Cooper, 2000). While ongoing research verify this discovery and establish the spatial distribution and degree of preservation and/or restoration to be applied to the peat-rich soils, little was known about the geology that allowed them to develop.

Understanding the geologic framework of the Drakesbad Meadow is paramount to any meaningful, long-term management conclusions about the preservation and/or restoration of the fen deposit (Watson, 2001). Therefore, in 2002, the National Park Service facilitated a contract for the Geologic Research in Warner Valley Project (GRWVP): Phase 1 - Geologic Mapping, and Phase 2 - Soil and Tephra Sampling.

The primary goal of this project was to provide the researchers of the Drakesbad Meadow Restoration Project with a valuable piece of the complex geologic story from which appropriate management decisions could be made.

This report discusses the preliminary findings of the Phase II - a Soil and Tephra Sampling research project. It supersedes all other information provided to the park.

Soils Investigation Background

Previous geologic reconnaissance of the Hot Springs Valley had discovered a number of flat benches and wide fluvial plains that were believed to be remnant stream terraces post the Late Quaternary glacial period at Lassen Peak. The Drakesbad Meadow and its proposed fen soil occupy one of these surfaces.

The terraces occur at varying elevations and are not necessarily paired on either side of the valley. Along with previously identified nearby faults, this suggests a tectonic element may have influenced the formation of the terraces and thus, the formation of the fen.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

One method for correlating sets of valley terraces is by the use of the relative development of the soil profile. It is a simple concept that says that given fixed or sets of common variables, such as climate, parent material, topography, and organisms, the degree of soil development is a function of time, in other words, older soils will have more developed profiles than younger soils (Birkland, 1999). A number of soil-forming indicators of the soil profile are measured and grouped together by similar characteristics to reveal correlations that occur both spatial and temporal.

Detailed soils analysis can also reveal other valuable information about the terrace-forming environment, such as whether they were formed on, for example, a floodplain, an alluvial fan, or an outwash surface. Multiple processes on a single surface are referred to as complex environments and are challenging to correlate.

One of the advantages of working in a volcanic terrain is that there is a high likelihood of finding tephra layers in still water sedimentary environments. One suspected tephra layer was discovered in the sediments exposed on south embankment to Hot Springs Creek near the Drakesbad Bathhouse (Watson, 1994). Referred to as the "Bathhouse Ash", it is a thin grayish-white layer located in fine-grained sediments a few inches below a rich organic soil horizon, which is thought to be correlative to the fen deposit.

If confirmed to be a tephra and correlated with a specific volcanic eruption with a known date, the discovery represented an important "time-stratigraphic" marker within the terrace-forming period of Hot Springs Valley. It would give a relative age for formation of the sediments that underlie the fen and thus, a maximum age of the fen. In addition, tracing of this and other possible tephra layers across the valley would assist in understanding the tectonic and depositional processes.

Scope of Work and Limitations

The scope of work for the Phase II - Soil and Tephra Sampling Research Project was to

- obtain sediment/soil and tephra from about 40-60 borings at various locations in Hot Springs Valley,
- submit at least 10 samples for laboratory analysis,
- prepare logs and profiles of the borings,
- prepare a sample location map,
- submit a final report of the preliminary findings.
  (see Appendix 4)

The primary sampling period was scheduled for the 2002 field season, which runs from about May to November, with a report of the results due thereafter. The area of coverage was the Hot Springs Creek drainage from the eastern entrance to Lassen Volcanic National Park on Warner Valley Road to the upper drainage near US Route 1 (Highway 89). Soils cores were planned for various stream terraces and still water environments, such as Drake and Bench Lakes.

The work contract outlined the project would be covered under National Park Service Research and Collection Permit, however, delays in application approvals limited the scope of work to just the Drakesbad Meadow. This also adversely affected attempts to correlate various terrace surfaces throughout the valley and the recovery of an appropriate suite of soil and tephra

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

samples. Hence, the project scope was changed several times to focus on the depositional and soil forming processes associated with the Drakesbad Meadow, and in particular the Middle Drakesbad Meadow.

Methods

While the Phase I - Geologic Mapping project located favorable areas for soil borings, the Phase II - Soil and Tephra Sampling projected targeted areas within the Drakesbad Meadow for analysis. The "Bathhouse Ash" soils location was sampled first and other areas of the Drakesbad Meadow were then identified as sampling proceeded. Field work was performed in the late summer to avoid high groundwater conditions from snow melt.

Subsurface soil sampling was done by a hand-operated AMS, 2-inch inside diameter, 16-inch long, split core sampler. Soil and sediment cores were obtained by pounding the sampler barrel into the soil with a slide-hammer. Repeated attempts retrieved a continuous sample of the subsurface soil. Deeper samples required the holes to be enlarged with a 3-1/4" sand or mud hand auger; else, the core sampler was difficult to retrieve from the hole. One augur barrel was broken down-hole and had to be abandoned.

Butyrate plastic barrel liners were split on one side as to allow for easy removal of the soil cores. Barbs were also cut in the liners to act as "catchers" and prevent the core from slipping out the bottom of the tub. Prefabricated metal and plastic "egg-shell" catchers were not durable and failed often.

Soil cores were removed from the liners and placed in 2-inch PVC pipes that had been cut in half. The cores were photographed and general soil descriptions were recorded. The cores were covered with folded paper towels to aid in preservation and the PVC pipe was sealed with duct tape. The cores have been kept horizontal in transport and storage.

Logging of the core was first performed in the field, however, due to the complex nature of the soil stratigraphy, that method was abandoned, and cores were later logged in the laboratory. Cores were photographed and once logging was complete, were sealed with duct tape and archived in a cool, dry location at the Advanced Geologic Exploration Field Office in Lake Almanor, California, until delivery of this report to the park.

The first five soil cores (MC-1-5) were initially logged according to the American Standard of Testing of Materials (ASTM), a rapid soils engineering classification system. However, due to the complexity of the soils, the ASTM classification system was abandoned. Instead, a modified soil description system using applicable taxonomy from US Department of Agriculture (USDA), Soil Conservation Service and the National Technical Committee for Hydric Soils (NTCHS) was selected (see Appendix 1). This is a long and involved process that documents many more properties of the soil profile.

Soil description logs for 17 cores are presented in Appendix 3. Common soil profile properties were group into horizons, which were then compared with other profiles in the valley. Soil taxonomy correlations outside the valley were beyond the scope of this project.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Selected soils were sampled for outside laboratory analyses, including Bulk X-ray Florescence, Scanning Electron Microprobe, and Total Organic Carbon content. Table 1 summarizes the soil core logging. Appendix 2 shows Letters of Requests and Laboratory Results, and Appendix 3 shows the individual logs with the sampled intervals highlighted in red.

It should be noted that some of the cores shrank as they dried out. It was more common in organic-rich soils than mineral soils, however, any future review of these cores should note that intervals might have changed due to shrinkage.

Soil Core Log Data

Twenty-three soil cores were obtained from Hot Springs Creek Valley, two from the Bathhouse Ash location, and 21 from the Drakesbad Meadow (Figure 1). Following the nomenclature from Watson (2001), the distributions of cores in the meadow are as follows:

Upper Meadow:	5
Middle Meadow:	12
Lower Meadow:	2
Bathhouse Ash:	2

Soil description logs for 17 cores are presented in Appendix 3. These logs consist of all the cores from the Middle and Lower Meadow and one from the Bathhouse Ash location. Due to the increased time incurred by using the USDA/NTCHS description procedures, five cores from the Upper Meadow and the second Bathhouse Ash core were not logged (MC-14, MC-15, MC-16, MC-20, MC-21 and BHA-2). They have been archived for future analysis. Table 1 summarizes the results. Two cores from the Lower Meadow, MC-10 and MC-11, were logged, but interpretations are not presented.

Soil cores for the Middle Meadow ranged from 12.5 to 52 inches long. Limitations in core sampling depths included penetration refusal and samples slipping out the bottom of the augur barrel. These latter conditions occurred in cores MC-6, 8, 12, 13, and 18. Soils of MC-6, 8 and 12 also have the greatest thickness to C horizons (see below). The depth of soil cores suggests a relative thickness accumulation of fine-grained sediments; perhaps identifying buried channels or other depressions in the pre-soil subsurface.

Preliminary Findings and Discussions of Soils in the Middle Meadow

This investigation shows the Middle Drakesbad Meadow is a product of a complex interplay between the development of organic-rich soils on a prograding alluvial fan and the formation of soils on an active floodplain where scour and fill processes dominate.

Soils with organic-rich profiles greater than 10 inches thick are located across the northern half of the Middle Meadow and the maximum organic-rich profile was 29 inches thick. The soils were predominately peat loams to mucky loams, both of which indicate total organic carbon contents shy of the organic soil or Histosol classification. Although only one horizon from one soil profile met the criteria for Histosols, it is likely many of these organic-rich soils could classify as hydric soils. No soil met the classification of fen.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

The organic-rich soils are stratified, forming paleosols related to changes in soil forming processes and aggradational conditions. Longitudinal profiles suggest an a thickening southward over time and along with the angular-shaped grains, confirms a alluvial fan geomorphic province.

The following discussions relate to the completed logs for the Middle Meadow (see Table 1; Appendix 3). Large gaps exist between some soil cores, especially on the north side of the meadow, and interpretations between these points are liberally conceived. Identifying specific spatial boundaries was not in the scope of the project.

Organic-rich soils are described first followed by descriptions of the mineral soils. Relationships between charcoal and tephra/kaolin follow these discussions.

Background to Organic Soils

By definition, "organic soils are those formed under conditions of saturation, flooding, or ponding of water long enough during the growing season to develop anaerobic conditions in the upper part of the soil" (Hurt, et. al, 2002; Richardson and Vepraskas, 2001).

"Saturation or inundation when combined with microbial activity in the soil causes a depletion of oxygen. This anaerobiosis promotes a biochemical processes, such as the accumulation of organic matter and the reduction, translocation, and/or accumulation of iron and other reducible elements. These processes result in characteristic morphologies that persist in the soil during both wet and dry periods, making them particularly useful as indicators".

Key organic soil indicators are total organic carbon (TOC), morphology (color, texture, etc.), mineralogy, chemistry, redomorphic features, and thickness (Hurt, et. al, 2002). The principal indicator is total organic carbon (TOC). It has a specific relationship with the clay content that qualifies the soil as organic. It specifies that organic soils have a TOC content (by dry weight) of 12-18% or greater, depending on the percent clay content of the soil (Figure 3). Soil material meeting this qualification is designated fibric (peat), hemic (mucky peat) and sapric (muck).

Organic soils not meeting these indicators are either mucky mineral (organic-rich mineral soils) or mineral soils. Some mucky mineral soils are not Histosols, but may be classified as Histic or hydric soils (see below).

Similar and persistent indicators form horizons that comprise the soil profile, which can be compared to local, regional and national soil taxonomy.

Histosol is type of Soil Order (the highest level of soil taxonomy) that meets specific indicator criteria for organic soils. The basic indicators for a Histosol are:

- have a total organic carbon content (by dry weight) of 12-18% or greater, depending on the percent clay content of the soil (for example, see Figure 3),
- are composed of at least 40 cm (16 inches) of organic soil material,
- have a dominant chroma of 2 or less.
  (Hurt, et. al, 2002.)

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Fens are peat-accumulating Histosols (Richardson and Vepraskas, 2001).

Numerous Suborders of Histosols have been classified, but most pertinent to this investigation are those related to histic epipedon. These are defined as a layer that has saturation and reduction for some time during the growing season that promotes the accumulation of between 12-18% TOC, depending on clay content, but has a reduced thickness between 20 to 40 cm (8-16 inches). By definition, histic soils cannot be Histosols (e.g. thickness indicator), but may qualify as hydric soils (Richardson and Vepraskas, 2001).

Hydric Soils Background

A hydric soil is a specific soil classification used for the identification of wetlands and its hydrophytic vegetation. The definition is broader than Histosols and include all soils saturated or inundated during the growing season, and the soils must be anaerobic (related to or caused by a complete lack of oxygen). Hydric soil classifications are meant to encompass the entire wetlands ecosystem, including the organic soils as well as those in close transition from mineral soils. The identification of hydric soils was beyond the scope of this project; however, the following descriptions will aid further research.

Initially established to better manage wetlands in the United States, the National Technical Committee for Hydric Soils (Hurt, et. al., 2002) has composed of the following criteria or hydric soil:

- All Histosols except Folists, or
- Soils in Aquic Suborders, Great Groups, or Subgroups, Albolls Suborder, Aquisalilds, Pachic Subgroups, or Cumulic Subgroups at are:
  a. somewhat poorly drained with a water table equal to 0.0 foot from the surface during the growing season, or
  b. poorly drained or very poorly drained and have either:
     (1) water table equal to 0.0 feet during the growing season if textures are coarse sand, sand, or fine sand in all layers within 20 inches, or for other soils
     (2) water table at less than or equal to 0.5 feet from the surface during the growing season if permeability is equal to or greater than 6.0 inches/hour in all layers within 20 inches, or
     (3) watertable at less than or equal to 1.0 feet from the surface during the growing season, if permeability is less than 6 inches/hour in any layer within 20 inches, or
- Soils that are frequently ponded for long or very long duration during the growing season, or
- Soils that are frequently flooded for long or very long duration during the growing season.

(Federal Register. February 24, 1995.)

The "growing season" is considered to be that part of the year during which the soil temperature and moisture conditions permit microbial activities.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Hurt, et. al. (2002) describe the specific hydric soil indicators, and their tests are summarized in Richardson and Vepraskas (2001).

Organic-Rich Soil Descriptions

Soils from six cores were identified to have field indicators supporting preliminary Histosol or organic-rich soil classifications (MC-8, 12, 13, 17, 18, and 19; see Table 1). Principal indicators included redox depletions descriptions, chroma of 2 or less, and a potentially acceptably TOC contents over continuous intervals ranging from 13-29 inches thick. Selected horizons within these soils were sampled and submitted for laboratory analysis of total organic carbon (TOC).

The organic-rich soil material tended to be saturated, loose, and have apedal to weakly developed structure. They are non-sticky to slightly sticky, non-plastic to plastic, and contain many fine and large roots, often reaching fibric classifications or modifiers. The surface horizons range from peat, peat loam, to peat silt loam. Illuvial organic matter is moderate to abundant, and decomposition of organic content is slight in upper horizons to progressively abundant with depth. Although the surface horizon are predominately fibric, not one of the profiles produced 40 cm (16 inches) of continuous peat to qualify the soil as a fen.

Redomorphic textures become common to abundant with depth, however, are absent in upper horizons where iron oxide stains and root casts were common. Porosity is moderate to high.

The organic-rich soils are stratified, forming clear packages that have irregular boundaries and appear to be related to changes in soil forming processes and aggradational conditions. Buried peat loam soil horizons have decomposed to mucky loam, and the subsequent illuvial organic matter collects in lower horizons. The organic-rich soils do not show scour and fill processes that are common with mineral soils closer to Hot Springs Creek.

The soil packages have been subdivided into respective paleosols, referred to herein as P-1, P-2, P-3 and P-4, respectively. Although similar characteristics exist between the mineral and organic-rich paleosols, their relationship is unclear at this time.

The organic-rich soils have trace to abundant populations of sub-rounded to angular coarse sand and gravel that, along with the aggradational process, suggest a short transport environment associated with an alluvial fan deposit.

With the exception of MC-7, all the other soils cores in the Middle Meadow had thin organic horizons of three inches or less, higher clay contents, and less decomposed organic material and, therefore, are not classified as Histosols. MC-7 showed an organic-rich section extending 3.5-16.5 inches (or a span of 13 inches); however, the soil is not quite thick enough to qualify as a Histosol and has a chroma of greater than 2. In addition, the organic-rich soil interval is buried under a younger deposit. Although these indicators are insufficient for Histosols, they are likely to be hydric soils.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Total Organic Carbon (TOC) Analyses

Eleven samples were obtained from five cores and analyzed by an outside laboratory for total organic carbon content (TOC; see Appendix 2). The results are shown below with the estimated clay content as determined by field methods in accordance with the National Soil Survey Handbook (Soil Survey Staff. 2001; USDA):

Percent Total Organic Carbon vs. Estimated Percent Clay

Soil Core	% Carbon	Est. % Clay
MC-8 3-6"	17.34	15
MC-8, 8.5-13.5"	12.07	15
MC-8, 22-25"	4.92	30
MC-12, 11-16"	8.49	15
MC-12, 19-25"	5.40	15
MC-13, 4.5-11"	9.85	15
MC-13, 11-18"	4.42	15
MC-18, 4.0-7.5"	8.07	20
MC-19, 5-9"	10.79	5
MC-19, 9-14"	8.13	20
MC-19, 14-21"	5.69	15

The two highest percentages of TOC occurred in MC-8 where it reached more than 17% in the interval from 3-6", and 12% from 8.5-13.5". Although illuvial organic material was abundant in MC-8, analysis from a little deeper in the soil profile at interval 22-25" showed a significant reduction in TOC to only ~5%. Only one other sample showed TOC values in double-digit figures, MC-19, 5-9" – TOC = ~11%. A common result was that a greater percentage of TOC occurred in the upper horizons than the lower horizons.

Figure 3 plots TOC versus the estimated clay content to ascertain the Histosol organic soil classification. The results show that only soil profile MC-8 at 3-6" with 17.34% TOC and 15% clay met this indicator for a Histosol. This is surprising considering the strong organic appearance of the soils.

Six samples returned values between 8-12% with 5-20% clay, classifying them as mucky mineral (or organic-rich mineral) horizons. Although these soils are not Histosols, they are likely to be hydric soils because of the prominent redomorphic features.

Four samples returned results with less than 6% TOC and between 15-30% clay, thus were classified as mineral horizons. These samples are MC-8, 22-25"; MC-12, 11-18" and 19-25"; MC-19, 14-21". It would appear that the dark colors were related to illuvial organic matter than from in situ decomposition.

With these results, classifications in other soil profiles were modified in accordance with similar indicators.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Spatial and Temporal Relationships of Organic-rich Soils

The distribution and thickness of the organic-rich soils from cores MC-8, 12, 13, 17, 18, and 19 are contoured on a map of the Middle Drakesbad Meadow (Figure 4). The outline forms a broad surface on the northern side of the valley and includes a small area on the southwest side, just east of Spring Creek.

Soil Profiles 1, 3 and 4 show the temporal relations associated with specific organic-rich soils. Most notable is the thickening of the soils in P-2 to P-1 time. This is indicative of a prograding alluvial fan. The fan deposits are thickest in the northwest and thinnest in the northeast, which is reflective of the North-Central Spring Complex as a source area, which is described below.

Organic-rich soils in cores MC-12, 13, and 18 appear to have been disrupted in P-3 time by a kaolin clay layer-forming event. This event also appears to have caused the thickening of P-3 mineral soils. The rounding of the coarse-grained fraction of the Paleosol 3 organic-rich soil indicates more active conditions that are associated with active stream processes (see MC-13) and suggests a fluvial rather than an alluvial origin. This finding gives a relative timing that the alluvial fan had not yet prograded this far.

While MC-7 shows a prominent 13 inches-thick section of organic-rich material, the surface of the Paleosol P-3 soil has been scoured and buried by subsequent floods. Although this soil is not Histosols, it is likely to be a hydric soil.

Discussion of Histosol and Hydric Soils

This investigation shows that while the soils of Middle Drakesbad Meadow are organic-rich, the total organic carbon content for nearly all of the soils is not high enough in specific horizons or persistent enough in the soil profile to establish an organic classification of Histosol. The only exception to this is profile MC-8, which easily meets these indicators.

Because large gaps exist between these organic-rich soil profiles, the isolated occurrence of MC-8 organic soils may suggest that pockets or microenvironments conducive to organic soil formation may exist elsewhere in the meadow, however, widespread areas are not likely.

Although the surface horizons are predominately fibric, not one of the profiles produced 40 cm (16 inches) of continuous peat to qualify the soil as a fen.

The identification of hydric soils was beyond the scope of this project; however, descriptions herein will further research towards their understanding. In particular, hydric soil indicators A1, A5, A7, S2, S3, S7, F3, and F7 are likely candidates for various soils of Middle Drakesbad Meadow.

Key to future hydric soils research will be demonstrating that the soils are saturated during the growing season long enough to develop permanent indicators of anaerobic conditions. This can only be attained by a complete analysis of water and soil chemistry, physical properties (including temperature, conductivity, etc.), and biology of several locations by a professional wetlands research expert (Richardson and Vepraskas, 2001).

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Water Source for the Organic-rich Soils

The water source for the alluvial fan and the organic-rich soils is the North-Central Spring Complex. It has a number of slightly active to very active springs that provide significant volumes of fluid to the meadow year round. Water tends to flow on to the meadow as either seeps or rushes, the later of which form natural channels that accumulate the water quickly and move it to other parts of the meadow, and ultimately to Hot Springs Creek.

Figure 5 is a low-altitude, aerial photograph taken of the Drakesbad Meadow during the winter months. Geologic studies show the temperature of the water from North-Central Spring Complex is a consistent 10.4°C (50.7°F) throughout the year. This relatively warmer water melts the snow and helps identify sources of thermal fluids. Notice the barren spots of snow throughout the Drakesbad Meadow clearly outlining the pattern of spring runoff from the North-Central Spring Complex. The photo also shows other geothermal sites near the Drakesbad Meadow, including the Drakesbad Pool Hot Spring and a thermal spring just east of Dream Lake.

In the late 1960s, the National Park Service constructed a water tank within the spring complex to service the Drakesbad Guest Ranch. The access road cut through the eastern part of the spring complex, disrupting the natural flow of water to the meadow. Figure 6 is a map showing the various springs that were disrupted by the construction of the water tank road. The aerial photograph shows North-Central Spring Complex thermal spring waters were diverted and ran down the ruts in the road, exiting at various locations on to the meadow.

As a result, North-Central Spring Complex spring water was diverted and concentrated at various locations, causing the deposition of sediment and the burial of the natural soils, including organic-rich and possibly hydric soils; the erosion of surface soils on the meadow and the development of new non-natural channels; both causing the over-saturation and dehydration of broad areas of the meadow.

For example, the log of MC-13 shows the oxidation of surface organic-rich soils due to the dehydration of the soil. This appears to have been caused by the diversion of spring water from the water tank road up slope from MC-13. Sample MC-13, 4.5-11" returned a TOC of nearly 10%, nearly qualifying as a Histosol. However, the top nine inches were dry to only slightly moist and the anaerobic conditions necessary for anaerobic activity had been disrupted in favor of an oxidizing environment (note the oxide stains and oxidizing roots casts in MC-13, P-1).

Field evidence shows that while the oversaturated areas are flourishing with organic material (for example, MC-8), dehydration and destruction of the organic-rich soils is prevalent within other parts of the meadow. They are in great need of immediate professional restoration to stop further damage. These affected areas are predominately down slope from the water tank road.

Descriptions of Mineral Soils

Soils from ten cores were identified to be mineral soils with insufficient indicators to be classified as organic-rich soils. (MC-1, 2, 3, 4, 5, 6, 7, 9, 10, and 11; see Table 1). Although many of the mineral soils had individual horizons that contained moderate to abundant organic matter,

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Histosol indicators were not met (see Descriptions of Organic Soils above and Figure 3). Specifically, indicators for maximum organic intervals, total organic content and chroma fell substantially short of the classifications.

The mineral soils are relatively thin packages of soils, usually containing an upper peat-rich soil that is underlain by a thin silt loam and/or peaty silt loam. These are typical of floodplain soils whereby over bank flood waters scour the surface soil, then bury it with thin deposits of sand, silt and clay (Richardson and Lietzke, 1983). Sand and silt are the dominant particle size for the surface soils, but as to be expected, clay becomes more prevalent in the lower soils.

Thickness of individual mineral soil horizons range from 2-14 inches and scoured boundaries are common between paleosols. The porosity of the mineral soils was commonly high to medium, but was low with increasing clay content.

The mineral soils contain high populations of rounded to sub-angular coarse sand and gravel. Pebbles are common in these soils and show similar roundness. This shows a degree of transport has occurred to round the grains and suggests Hot Springs Creek as a likely source and not the proximal alluvial fan.

The colors of mineral paleosols are relatively uniform with chroma ranging from 2-4 and values starting at 2 and becoming as light as 5. Most of the hues were 7.5 YR and 10 YR, but occasionally, were slightly redder (5YR) or yellow (2.5Y). Although these are clearly indicative of oxidizing soil processes, the limited chroma range implies either a passive oxidizing environment, an immature soil development, or both. Soils containing kaolin clay tended to be either more red or yellow. This condition is probably a result of acidic conditions associated the geothermally derived clays.

Gley redox depletions or mottling, an indication of a transitory reducing iron environment, occurred in four soil cores, MC-1, 2, 5 and MC-6. These soils occur on the south side of the meadow. Observation taken in May and early June show these soils are saturated from snow melt, and since the southern side of the meadow is the last area to be occupied by snow because of the shade provided by the tall nearby trees, adjacent soils receive prolonged saturation. With the warm days of June and July, the snow rapidly melts and the water table drops quickly, returning the soils to oxidizing environments.

Spatial and Temporal of Mineral Paleosols

Four paleosols have been identified in the mineral-rich soils of the Middle Meadow. They represent specific soil forming environments that persisted for some time and were later acted upon to become either buried or eroded. Specific paleosol intervals are summarized in Table 1 and are referred to herein as P-1, P-2, P-3 and P-4, respectively. The association between the organic-rich and mineral paleosols is not clear, but their similarities are striking.

P-1 and P-2 show the least amount of soil development, and P-3 and P-4 show progressively more. Soil Profiles 1, 2, 3 and 4 show the general relationships between the paleosols and in summary, are suggestive of an active environment where floods, earthquakes, and natural slope processes have played major roles in their development.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Paleosol 1

The weak soil development in Paleosol 1 suggests it is related to historic flooding. Since the 1900s, at least nine major floods have occurred in the upper Feather River drainage, and probably including Hot Springs Valley, (1907, 1919-1920, 1924, 1937, 1940, 1955, 1986, 1997, and 1998; Paulson, et al. 2002). Historic records prior to this suggest major floods were also common, with notable major events in 1867, 1884 and 1895. Anecdotal evidence accounts of the effects following the 1986, 1997, and 1998 floods indicated scouring of the surface soils and widespread deposition of fine-grained sediments along the southern half of the meadow (personal communications with several Drakesbad guests).

The course of Hot Springs Creek takes it around a small topographic rise just up stream from the Spring Creek confluence at the western portion of the Middle Meadow. A gooseneck bend occurs around the topographic rise and the stream quickly bends south, then east. This bend forms a prime opportunity for over-bank conditions. Although the active channel is on the order of 5-6 feet deep east of Spring Creek, flood conditions likely force water to top its banks and flow across the meadow surface. The greater the flood, the deeper the water on the meadow, and the higher potential for scour and fill processes.

The thickness of Paleosol P-1 for both the mineral and organic-rich soils is contoured at intervals of <3 and ≥6 inches to show the relative distributions (Figure 7). All Paleosol P-1 soils with ≥6 inch thickness occur on the northern half of the meadow and within the organic-rich soils. The boundary between the <3 and ≥6 inch contour is strikingly similar to that of the organic-rich soil boundary.

No charcoal was found within this paleosol.

Paleosol 2

The relationship between Paleosol P-2 and historic flooding is not clear. Some P-2 soils show weak soil-forming indicators that are similar to P-1 (for example, MC-1), but others show more soil development, like MC-7. This suggests that since major flooding is common in the valley, identifying which depositional event occurred to which flood may be challenging without better age controls and more soil cores.

In combination, Paleosols P-1 and P-2 are 14 inches thick or less. Minor variations shown in Profiles 1 and 2 are probably the result of flood scour and fill processes. If Paleosol P-2 is related to historic floods, it is not likely the thickness variations are tectonic related as there have not been any large earthquakes in the region during this time (Friends of the Pleistocene, 1995). However, a kaolin clay layer in Paleosol 2 at MC-18 may suggest tectonic influences and its implications are discussed later.

Some charcoal fragments were discovered in this paleosol and suggest a major fire occurred at this time. Carbon-14 dating of this charcoal may provide insights to the development of this paleosol.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Paleosol 3

The Paleosol 3 is a widespread soil that ranges from 7-20 inches thick and is found between 14-27 inches below the surface. Descriptions of the organic-rich Paleosol P-3 soil are similar to the mineral soil descriptions and, therefore, are likely to be correlative.

Paleosol P-3 was found closest to the surface in MC-3 and deepest on the north side of the meadow MC-8 and MC-13, and also within MC-6, which is located in the eastern part of the meadow, just south of the Drakesbad Lodge. Roundness of the coarse-grained mineral fraction is supportive of a parent material with a fluvial origin. It also supports the correlation between mineral and the organic-rich Paleosol P-3 time.

Most of the surface organic horizons of Paleosol P-3 have been eroded, but glimpses of it were discovered in MC-5, 6 and 7, as evident with increased decomposed organic matter and clay content.

The topographic changes in the depth from surface of Paleosol P-3, like in MC-17 and MC-18, and between MC-2 and MC-18, are suggestive of significant scouring and/or tectonic influences and are discussed later in the text. In general, they show an increasing of paleosol thickness to the north, west and east.

Charcoal fragments were common in Paleosol P-3 time and suggest a major fire occurred at this time. Carbon-14 dating of this charcoal may provide insights to the development of this paleosol.

Paleosol 4

The Paleosol 4 is characterized by its increased soil development, including increased clay content, more developed structure, and its relative soil position. Soil cores MC-6 and MC-7 show the thickest P-4 horizons and these characteristics formulated the basis of its identification in other cores.

Paleosol P-4 was not discovered in MC-4, 12, 13, 17 and 19, suggesting either a completely eroded horizon, or it occurred deeper than the cores penetrated.

Charcoal fragments were common in some Paleosol P-4 cores and suggest a major fire occurred at this time. Carbon-14 dating of this charcoal may provide insights to the development of this paleosol.

Alluvial Fan and Floodplain Relationship

In summary, the Middle Drakesbad Meadow is a product of a complex interplay between the development of organic-rich soils on a prograding alluvial fan and the formation of mineral soils on an active floodplain where flood scour and fill processes dominate. Figure 8 is a schematic of this relationship.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Age of Paleosols

All the paleosols show relative poor soil development. This was indicated by

- tightly clustered soil hues and low chroma colors
- low clay content and poor clay illuviation
- weak ped structure and shape
- low stickiness and low plasticity

It suggests that these soils were formed a relatively short time ago geologically, probably in the mid to late Holocene.

The Phase 1–Geologic Mapping portion of the project identified lateral glacial moraines near Devils Kitchen that post-date the late Quaternary glacial epoch. They extend about a mile down-valley from Devils Kitchen along the course of Hot Springs Creek. A prominent outwash apron spreads laterally away from the moraines and extends down-valley through Drakesbad Meadow to the Hot Springs Creek campgrounds. It is presumed that this is the surface on which the soil-forming processes began in the Drakesbad Meadow and correlate to Paleosol P-4 time.

Climate researchers have subdivided the Holocene period into four intervals:

- 13,000 - 10,000 ka — The Younger Dryas (a.k.a. Early Holocene)
- 10,000 - 8,000 ka — Early Hypsithermal (a.k.a. Anithermal)
- 8,000 - 4,000 ka — Hypsithermal Interval (a.k.a. Altithermal)
- 4,000 ka to present — Post-Hypsithermal (a.k.a. Medithermal)

Flint, 1971, documents a glacial maxima shortly after 5,000 ka and again soon after 3,000 ka. He defines these as neoglacial intervals. They partly overlap the Hypsithermal and Post-Hypsithermal intervals. A third interval between 150-300 years ago also produced glacial advances, but these were minor and produced few effects. Albers, 2002, also finds support for these neoglacial advances in the Colorado Rocky Mountains. Importantly, Gerstel, 1989 and Gerstel and Clynne, 1995, reported late Holocene glacial deposits in the vicinity of Lassen Peak, but unfortunately, relationships were not described – yet they are suggestive of a regional correlation that includes Hot Springs Valley.

Although it is not certain at this time which neoglaciation would correlate to the Devils Kitchen moraines, both Post-Hypsithermal dates suggest origins with less than 5,000 ka and supports the data from these studies soil descriptions for young, late Holocene soils.

Dating of the soils can be achieved easily by the abundant charcoal fragments found in both the mineral and organic-rich soils.

Charcoal-rich Soils

Charcoal was found in all paleosols throughout the Middle Meadow, except Paleosol P-1. Table 1 summarizes its occurrence and a map of its distribution is shown in Figure 9. The header on the soil core logs denotes the intervals charcoal was found (Appendix 3).

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Charcoal fragments ranged in size from >0.1-1.0 inches and most were in good to excellent condition. Although no attempt was made here, mapping of the charcoal-rich sediments may discover insights to the soil-forming processes at Drakesbad Meadow.

With the absence of tephrachronology applications, charcoal may provide one of the best means to date the development of the soils.

Depth to the C horizon

Depth to the C horizon or the original mineral horizon varies from 16-31 inches across the Middle Meadow (Table 1; Figure 10). Field observations show the C horizon becomes shallower at various locations near Hot Springs Creek. C horizon depths are shown with generalized 20 inches and 30 inches contours.

The depth to the C horizon is less than 20 inches in cores MC-2, 4 and 17. These are clustered along the southern part of the meadow, between the Dream Lake trail junction and Spring Creek, and form a shallow C horizon peninsula protruding northward into the meadow.

Three soil cores show depths greater than 30 inches (MC-6, 8, 12). MC-12 is located on the western side of the Middle Meadow and west of the shallow C horizon peninsula. MC-8 in along the northern side of the meadow near the Drakesbad horse corral and MC-6 is located in a surface depression south of the Drakesbad Lodge.

It is interesting to note that the C horizon was not encountered MC-18 because the sample slipped out the end of the augur barrel and was unrecoverable. It probably suggests a northern continuation of the 30 inch contour west of the shallow peninsula.

Bathhouse Ash: A Tephra or Kaolin-rich clay?

Part of the soils research was concerned with the thin white clay layers seen in a stream bank exposure near the Drakesbad bathhouse. Known as the Bathhouse Ash, the layers were originally believed to represent air-fall ash or tephra deposits from some Holocene volcanic eruption. However, on July 14, 2002, an event in Hot Springs Valley changed that perspective and eventually led to a remarkable discovery.

Devils Kitchen Outburst of July 14, 2002

On July 14, 2002, a surge in geothermal activity occurred in upper Hot Springs Valley. White hydrothermally-altered clay or kaolin was discharged into the stream at a phenomenal rate, altering the color of the water to a milky white, as though a milk truck had spilled up valley. The discoloration was traced back up stream to the Devils Kitchen geothermal area and was later monitored during the geologic mapping phase of the project. During the peak of the incident, the temperature of Hot Springs Creek was raised 10-15 degrees F over background levels (maximum temperature: 73 degrees F) and stream discharge was increased by about 20-40%. Over time the event relaxed, producing progressively less kaolin and fluid, and the stream returned to its natural clear appearance, but the elevated temperatures persisted through the

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

end of the field season. A full report of the incident will be chronicled in the Phase 1–Geological Mapping report.

In the wake of the Devils Kitchen "blow-out", a thin, white clay layer of kaolin was deposited on the stream channel bottom. The appearance of the clay was similar to that of the Bathhouse Ash layer and other suspected tephra seen in the valley. It immediately raise suspicions that the white layers at the bathhouse exposure were not tephras at all, but kaolin clay deposits from similar, but more robust out-bursts from a geothermal area.

Analyses of the Bathhouse Ash

There are two geothermal areas capable of such activity in Hot Springs Valley, Devils Kitchen and Boiling Springs Lake. Geologic mapping of both areas had shown that the surface rocks in the two areas are dissimilar, Devils Kitchen is surrounded by high silica, calc-alkaline rocks, and Boiling Springs is located entirely within basalt or silica poor, iron and magnesium-rich rocks. Basalts also contain a higher population of trace elements than calc-alkaline rocks.

It was suspected that if the white clays deposits at the Bathhouse Ash exposure were derived from hydrothermally altered clays associated with either geothermal area, that they may have an identifiable chemical fingerprint.

Two clay samples from the Bathhouse Ash soil core (BHA-1 and BHA-2) and a representative sample of hydrothermally altered clay from both the Devils Kitchen (DK-1) and Boiling Springs Lake (BSL-1) geothermal areas were submitted for Bulk X-ray Florescence (XRF) analysis (see Appendix 2). This was an ideal method of analysis because it provided a molecular as well as trace element results, which would be well suited to distinguish a potential source area.

The laboratory results showed both of the Bathhouse Ash samples had nearly identical molecular and trace element analyses as the sample from Boiling Springs Lake.

This remarkable discovery was strong evidence that the thin white clay layers at the Bathhouse Ash stream exposure were not tephra from air-fall volcanic eruptions, but actually hydrothermally-altered kaolin clay from Boiling Springs Lake.

Further evidence came from geologic mapping that revealed that Boiling Springs Creek empties into Hot Springs Creek short distance up stream from the Bathhouse Ash stream exposure. Thick while kaolin deposits coat the Boiling Springs Creek channel as seasonal outflow from the lake carries suspended clays down stream.

It is not conclusive at this time if the Bathhouse clay layers were formed from "out-bursts" at Boiling Springs Lake, like the one seen at Devils Kitchen on July 14, 2002, or from the meandering patterns of Boiling Springs Creek during seasonal out flows.

Drakesbad Meadow Tephra and/or Kaolin Deposits

Nine of 17 soil cores of the Middle Meadow encountered white clay layers and particles within the soil that were believed to be either tephra from a volcanic eruption, reworked tephra from a

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

stream deposit, and/or kaolin clays from a geothermal area. Field and laboratory observations using a 30x optical glass revealed several grains within the sediments that appeared to be tephra glass shards, but the evidence was not conclusive.

A sample of a white clay layer from soil core MC-13 was submitted to Dr. Nick Foit of Western Washington University, an expert in tephrachronology. His preliminary observation indicated that although the sample was largely composed of clay and other detritus, and there was a sufficient number of glass shards in the sample to suggest it might be a reworked tephra deposit.

Sixteen glass shards were then analyzed using a scanning electron microprobe for major molecular compositions. The results were averaged and compared other with tephras of similar chemical compositions for possible correlation.

The analysis suggested that the glass shards had a 97% similarity coefficient to the Rockland Ash or Brokeoff volcano eruptive series dated at 600-622 ka. This is obviously an impossible solution for the clay layers because the sediments from which they were found are unequivocally of late Holocene age (<5 ka). Most of the bedrock in the area to the west of the meadow is from Lassen/Brokeoff volcano so there is a good chance Rockland ash is somewhere in the drainage. Hence, it is possible the tephra glass shards identified by Dr. Foit were weathered out of bedrock elsewhere in the valley and were subsequently washed into the stream to be deposited down valley.

Andrei Sara-Wojcicki, a tephra expert for the US Geological Survey, reported that subsequent volcanic eruptions at the Lassen Volcanic Center had similar geochemistry as the Rockland Ash (personal communication, June 2003). Careful comparative analysis is needed from representative samples in order to tell them apart, however. He has this information in his database and has offered to review the Drakesbad Meadow samples later.

Therefore, because tephra glass shards were discovered in the sample, it cannot be ruled out that some of the white layers found in the soils of Drakesbad Meadow are from volcanic eruptions, but it is not clear which ones and if they occurred during the soil-forming periods.

For the most part, it is now suspected the white clay layers are mostly kaolin deposits from a local geothermal area. This would be in line with similar findings for the "Bathhouse Ash layers", as described above.

Spatial and Temporal Relationships of the Tephra and/or Kaolin Deposits

The spatial distribution of the tephra/kaolin-rich soils is shown in Figure 11 and vertical or temporal relationships are shown in Profiles 1, 2, and 3. Although some soils contained tephra/kaolin-rich particles they appeared to be reworked deposits (for example; MC-19, 21-28") and did not qualify for this correlation.

The distribution is very specific and forms two regions spanning the southwest and northwest portions of the middle meadow. Cores MC-3 and MC-4 occur between the two areas and suggest the two areas may not be contiguous. More importantly, however, is that much of the meadow does not contain these deposits, specifically the five eastern cores (MC-5, 6, 7, 8 and

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

9; for example, Profile 4). It suggests the process was that formed these deposits was specific to certain areas.

The temporal relations indicate all the tephra/kaolin-rich layers occurred during or before Paleosol P-2 time. Profile 2 shows a deposit forming prior to Paleosol P-4 in MC 1 and MC-2. Further west, Paleosol P-4 becomes eroded, and the kaolin layer underlies Paleosol P-3. MC-18 shows two distinct kaolin layers separated by an organic soil-forming period. It indicates the events that created the kaolin-rich layers have occurred multiple times in the past. It also implies that the areas affected seem to be the same.

One of the most noteworthy observations about the tephra/kaolin-rich layers is the change in elevation that occurs from MC-17 to MC-12 (Profile 1) and from MC-18 to MC-13 (Profile 3). These deposits probably formed on a relatively flat, horizontal surface and changes in elevation of 1-2 feet implies the soils have been deformed at some time. Given the tectonic nature of the region, it would seem that these deformations could be related to earthquakes (Friends of the Pleistocene, 1995). The Phase 1–Geologic Mapping Report will explore this reasoning in greater detail; however, in summary, strong shaking from large, nearby earthquakes could have caused liquefaction, soft-sediment deformation (tilting, warping, etc.), differential settling, and lateral spreading. It does not necessarily mean surface fault ruptures occurred across the meadow, but that these secondary effects could have easily caused the changes in elevations observed in the paleosol morphology.

Possible evidence of strong shaking of the soils was discovered in MC-12. An interval within Paleosol P-3 from 16.5-19.5 inches displayed a well sorted coarse-grained sand with considerably less organic matter than its surrounding organic-rich horizons. It was bounded by a similar well sorted sand, but contained slightly more oxidation of minerals and increased illuvial organic matter. These sand layers were obviously not part of the original mineral horizon. The sand intervals look very similar to lateral sand-filled fissures documented from the powerful 1811-1812 New Madrid, Missouri, and 1886 Charleston, South Carolina, earthquakes (McCalpin, 1996). Intense shaking of the ground causes some soils to break or dislocate, creating open fissures whereby liquefied sands can be injected. When they are parallel to sediments or soil horizons, like those in MC-12, they are referred to as sills.

It is interesting that the core MC-12 is located close to one of the deformed kaolin layers. This may imply that strong shaking from an earthquake in Paleosol P-3 time caused differential settling of the ground and subsequent sand-filled fissures, resulting in the subsidence of soils near MC-12 and/or relative uplift of soils in MC-17. The second well-sorted sand lens suggests that a second earthquake occurred, fracturing the same fissure and causing another sand-injection event. It is not known if multiple sand-injection events have ever been seen in the same fissure before.

Considering that the differential settling may have occurred to the soils of Drakesbad Meadow, other areas that showed elevation changes were identified from logs and profiles and plotted on Figure 12. Areas of that settled are labeled "Basins" and areas that were raised are labeled "Uplifted". It is interesting to note that the area denoted as basin closely approximates the organic rich soils. This may be the result of perched groundwater tables, pooling in these basins. Conversely, the uplifted areas tend to be exposed to erosion.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Summary

Preliminary findings shows the Middle Drakesbad Meadow is a product of a complex interplay between the development of organic-rich soils on a prograding alluvial fan and the formation of mineral soils on an active floodplain where flood scour and fill processes dominate. Figure 7 shows a schematic of this relationship.

Soils with organic-rich profiles greater than 10 inches thick are located across the northern half of the Middle Meadow and the maximum organic-rich profile was 29 inches thick. The soils were predominately peat loams to mucky loams, both of which indicate total organic carbon contents shy of the organic soil or Histosol classification. Although only one horizon from one soil profile met the criteria for Histosols, it is likely many of these organic-rich soils could classify as hydric soils. No soil met the classification of fen.

The organic-rich soils are stratified, forming paleosols related to changes in soil forming processes and aggradational conditions. Longitudinal profiles suggest an a thickening southward over time and along with the angular-shaped grains, confirms a alluvial fan geomorphic province.

The mineral soils are relatively thin packages of soils, usually containing an upper peat-rich horizon that is underlain by a thin mineral soil with less organic matter. These are typical floodplain soils whereby over bank flood waters scour the surface soil, then buries it with thin deposits of fine-grained sediment. The mineral soils are located along the southern half of the meadow closest to Hot Springs Creek.

Buried soils are common in both the mineral and organic-rich soils, and have been subdivided into four paleosol intervals. Although similar characteristics exist between the mineral and organic-rich paleosols, their relationship is unclear at this time. All the soils show immature soil development and were likely formed since the mid to late Holocene. Charcoal fragments are found in many paleosols and may provide a means of dating the soils and provide insights to their formation.

Analysis of the Bathhouse Ash revealed it was not a tephra, but a kaolin clay layer associated with Boiling Springs Lake out flows, and thus, is not directly useful for dating purposes. Other white layers discovered in meadow cores are probably not tephras either, and analysis is likely to show they are from either Devils Kitchen or Boiling Springs Lake. Differential settlement between soil cores and a sand-filled fissure found in one soil core appear the result of tectonic processes from large nearby earthquakes.

Recommendations

- Perform a complete and thorough hydric soil investigation of the Drakesbad Meadow soils, including a complete analysis of water and soil chemistry, physical properties (including temperature, conductivity, etc.) and biology of several locations. Preferably, this should be conducted by an expert recognized by National Technical Committee on Hydric Soils.
- Complete soil description logs of the soil cores in the Upper Meadow and incorporate established soil descriptions from the Lower Meadow.

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

- Add additional soil cores in strategic areas to improve classification and correlation of the soil profiles.
- Conduct geophysical investigations across parts of Drakesbad Meadow to better understand its subsurface relationships, including paleo-channels, depressions, depth to bedrock, and tectonic features.
- Perform Carbon-14 dating on selected charcoal samples to better define the age controls of the soils and its parent material.
- Submit samples with suspected tephra to the US Geological Survey for analysis and regional correlations and incorporate the results into an addendum to this report.
- Set up a continuous monitoring network of the geothermal areas and Hot Springs Creek to provide better understanding to their fluctuating behaviors and their potential impact to public safety and the resources of the park.
- Obtain soil cores from other areas of Hot Springs Creek Valley, including Drake and Bench Lakes, the Devils Kitchen outwash surface, and fluvial terrace deposits down valley from Drakesbad Meadow.

Limitations

Results and conclusions contained in this report are based upon field observations, standardized soil testing procedures, and our understanding of the project. The locations selected for testing and/or sampling are, in our opinion, representative of the typical soil conditions on the site. It is possible that variations in soil conditions could exist between the points explored and, therefore, differing results could be achieved. If any soil conditions are encountered at the project site that are different from those used in preparation of this report, our firm should be contacted immediately so we may review the situation and make supplementary recommendations as needed. No other warranties, guarantees, recommendations or conclusions are expressed or implied except for those directly stated in this report.

Selected References

Albers, J. S., 2002, **Regional Glaciation of the Southern Rocky Mountains.** Earth Science Department, Emporia State University, Kansas, U.S.A.

Birkland, Peter, 1999, **Soils and Geomorphology**: New York, Oxford University Press, 470 p.

Cooper, 2000, **Restoration of Drakesbad Meadow, Lassen Volcanic National Park, California.** Dept. of Earth Sciences, Colorado State University, CO 80523

Flint, R. F., 1971, **Glacial and Quaternary Geology**, John Wiley and Sons, Inc., New York, New York. 892 p.

Federal Register. February 24, 1995. Hydric Soils of the United States. Washington, DC.
Friends of the Pleistocene, 1995, **Quaternary geology along the boundary between Modoc Plateau, Southern Cascade Mountains, and Northern Sierra**, Pacific Cell Field Trip Guide, 1995

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Gerstel, 1989, **Glacial Chronology and the Relationship to Volcanic Stratigraphy in the Hat and Lost Creek Drainages, Lassen Volcanic National Park, California**, MSc Thesis, Humboldt State University, 332 p.

Gerstel and Clynne, 1995, **Volcanic and Glacial Stratigraphy in the Hat and Lost Creek Drainages and the Age of Lassen Peak;** in Friends of the Pleistocene Pacific Cell Field Trip Guide, 1995

Hurt, Whited, and Pringle, editors, 2002, **Field indicators of Hydric Soils in the United States**, Version 5.0. USDA, NRCS in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, TX

McCalpin, editor, 1996, **Paleoseismology.** Academic Press, 24-28 Oval Road, London NW1 7DX, UK, 588 p.

Paulson, Chase, Roberts, and Moody, Compilers, 2002(?), **National Water Summary 1988-89- - Hydrologic Events and Floods and Droughts:** *U.S. Geological Survey Water-Supply Paper 2375, 591 p*

Richardson, J. L. and D. A. Lietzke. 1983. **Weathering profiles in fluvial sediments of the Middle Coastal Plain of Virginia**. Soil Sci. Soc. Am. J. 47:301-304.

Schoeneberger, Wysocki., Benham, and Broderson (editors), 2002, **Field Book for Describing and Sampling Soils**. Version 2.0. National Soil Survey Center, USDA, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE

Soil Survey Staff, 1951, **Soil Survey Manual**. USDA, Soil Conservation Service, Agriculture Handbook No. 18, U.S. Government Printing Office, Washington, D.C., 437 p.

Soil Survey Staff, 1998, **Keys to Soil Taxonomy**, 8th ed. USDA, Soil Conservation Service, Agriculture Handbook No. 18, U.S. Government Printing Office, Washington, D.C., 437 p.

Soil Survey Staff, 2001, **National Soil Survey Handbook** (electronic file). USDA, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE (http://soils.usda.gov/procedures/handbook/main.html)

Watson, 2001, **Drakesbad Meadow Meeting Summary, Drakesbad, California, October 29, 2001.** Advanced Geologic Exploration, Inc., PO Box 18012, Reno, Nevada 89511

Watson, 1994, **First notation of a tephra layer, the Bathhouse Ash,** - personal communication; Advanced Geologic Exploration, Inc., PO Box 18012, Reno, Nevada 89511

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

List of Tables, Maps and Profiles

Table 1	Soil Core Log Summary
Table 2	Physical Soil Boring Locations

Figure 1	Soil Core Location Map
Figure 2	Soil Profile Location Map
Figure 3	Percent Organic Carbon Verse Percent Clay
Figure 4	General Location and Thickness of Hydric and Organic-rich soils
Figure 5	Aerial Photo Drakesbad Meadow, March 27, 2003
Figure 6	Drakesbad Water Tank Access Road Spring Complex, August 5, 2002
Figure 7	General Location and Thickness of Paleosol P1 (Relic) Soils
Figure 8	Schematic: Fan/Floodplain Deposits and Generalized Surface Flow
Figure 9	Charcoal-rich Soils Map
Figure 10	Depth to C Horizon Map
Figure 11	Tephra and/or Kaolin-rich Horizon Map
Figure 12	Hypothetical Fracture and Paleo-Basin Map

Profile 1	Center East-West Soil Profile
Profile 2	South-Central East-West Soil Profile
Profiles 3 & 4	North-South Soil Profiles

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Table 1. Soil Core Log Summary

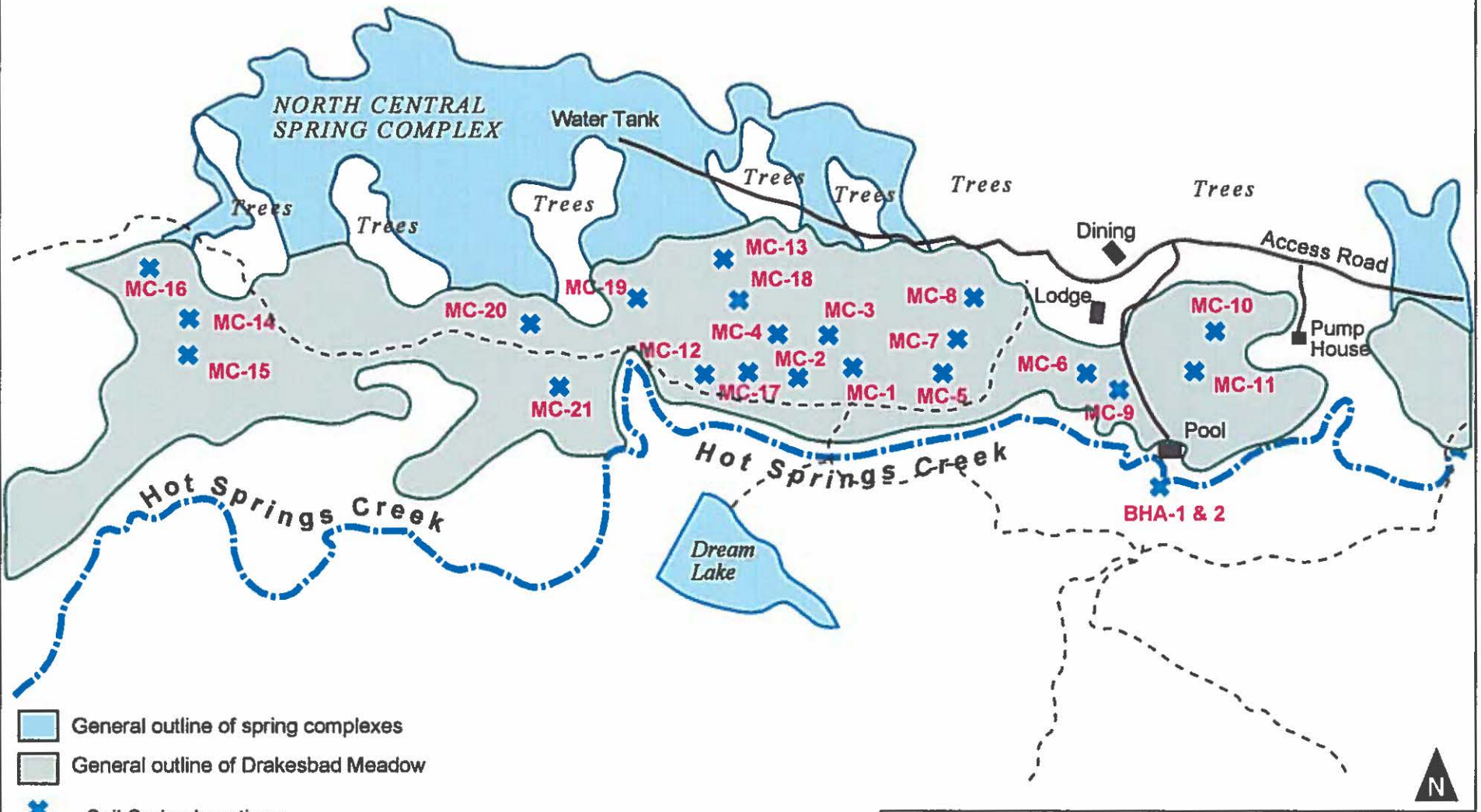
Core No.	Logging Status	Core Length (in.)	Max. Organic Interval (in.)	Organic-rich Soils (Y)	Paleosol P1 (Relic) Interval (in.)	Paleosol P2 Interval (in.)	Paleosol P3 Interval (in.)	Paleosol P4 Interval (in.)	Depth to C horizon (in.)	Tephra or Kaolin-rich Interval (in.)	Charcoal Interval (in.)	Laboratory Analysis
Middle Meadow												
MC-1	Draft	32	3		0-4.5"	4.5-10"	10-23"	23-31"	31"	29-32"	10-29"	
MC-2	Draft	25	2		0-4.5"	4.5-6"	6-16"	16-17.5"	17.5	17.5-25"	6-8, 10-14	
MC-3	Draft	22	2		0-2"		2-14"	14-21"	21"		4-14"	
MC-4	Draft	21	3		0-5"	5-11"	11-16"		16"		7-16"	
MC-5	Draft	39	2		0-4.5"	4.5-6"	6-14"	14-24"	24"		6-14"	
MC-6	Draft	32	2		0-4"	4-13.5"	13.5-27"	27-30"	30"		18-24"	
MC-7	Draft	34	13		0-3.5"	3.5-12"	12-22"	22-26"	26"			
MC-8	Draft	31	29	Y	0-2"	2-6"	6-20"	20-31"	31"		22-29"	TOC
MC-9	Draft	25	2		0-5"	5-10.5	10.5-21"	21-25"	25"			
MC-12	Draft	42	25	Y	0-5.5"	5.5-11"	11-31"		31"	25-37"	7-16", 25-42"	TOC, XRF
MC-13	Draft	37	18	Y	0-9"	9-22"	22-25"		25"	22-37"	11-18"	TOC, SEM
MC-17	Draft	19	13	Y	0-2"	2-4"	4-13"		13"	13-19"	4-13"	
MC-18	Draft	20	16	Y	0-8"	8-11"	13-16"	18-20"	20+"	11-13", 16-18"		TOC
MC-19	Draft	30	21	Y	0-5"	5-9"	9-21"		21"	21-28"	14-21"	TOC
Lower Meadow												
MC-10	Draft	13	2		0-7.5"	7.5-12.5"			12.5"			
MC-11	Draft	27	2		0-3"	3-5"	5-12"		12"	12-27"		
Upper Meadow												
MC-14	Archive											
MC-15	Archive											
MC-16	Archive											
MC-20	Archive											
MC-21	Archive											
Bathhouse Ash Site												
BHA-1	Draft	43	4		2.5-6.5"	6.5-17"	17-28"	28-31.5"	31"	12-17", 28-31"	26-28"	XRF
BHA-2	Archive	63										

Table 2. Physical Soil Boring Locations

Soil boring locations are given in relationship to Lassen Volcanic National Park's (LVNP) groundwater monitoring wells. Some measurements were approximated.

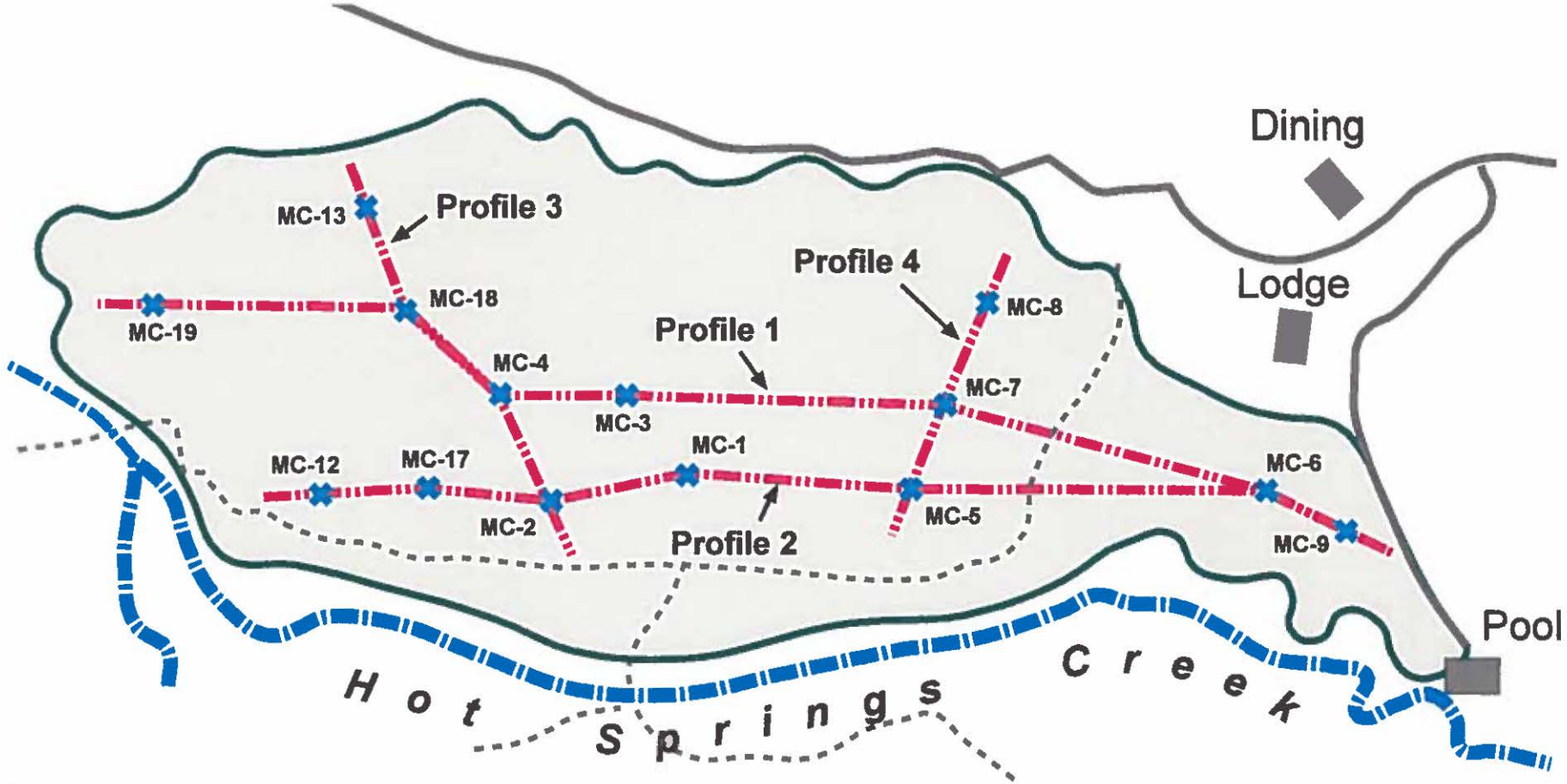
Boring	Location
BHA-1	2 m south of Hot Springs Creek near Drakesbad Bathhouse
BHA-2	2.5 m south of Hot Springs Creek near Drakesbad Bathhous
MC-1	2 m west of LVNP Well 30
MC-2	12 m southeast of LVNP Well 48
MC-3	14 m west of LVNP Well 28
MC-4	4 m southeast of LVNP Well 45 between two natural channels
MC-5	2 m south of LVNP Well 10
MC-6	22 m east of LVNP Well 2 in depression south of Drakesbad Lodge
MC-7	10 m north of LVNP Well 12
MC-8	between LVNP Wells 14 and 15, south of Drakesbad horse corral
MC-9	14 m west of gravel road to Drakesbad Bathhouse on small rise
MC-10	3 m east LVNP Well 147
MC-11	6 m north of LVNP Well 144
MC-12	16 m southeast of LVNP Well 63, west of row of trees in meadow
MC-13	22 m west of LVNP Well 36, center of prograding fan
MC-14	6 m west of LVNP Well 100
MC-15	13 m west of LVNP Well 102
MC-16	4 m northwest of LVNP Well 112
MC-17	9 m southwest of LVNP Well 48
MC-18	16 m west of LVNP Well 38
MC-19	12 m east of LVNP Well 70
MC-20	between LVNP Wells 73 and 72
MC-21	42 m east of LVNP Well 76

Figure 1. General Soil Core Location Map*
Hot Springs Creek Valley, Lassen Volcanic National Park



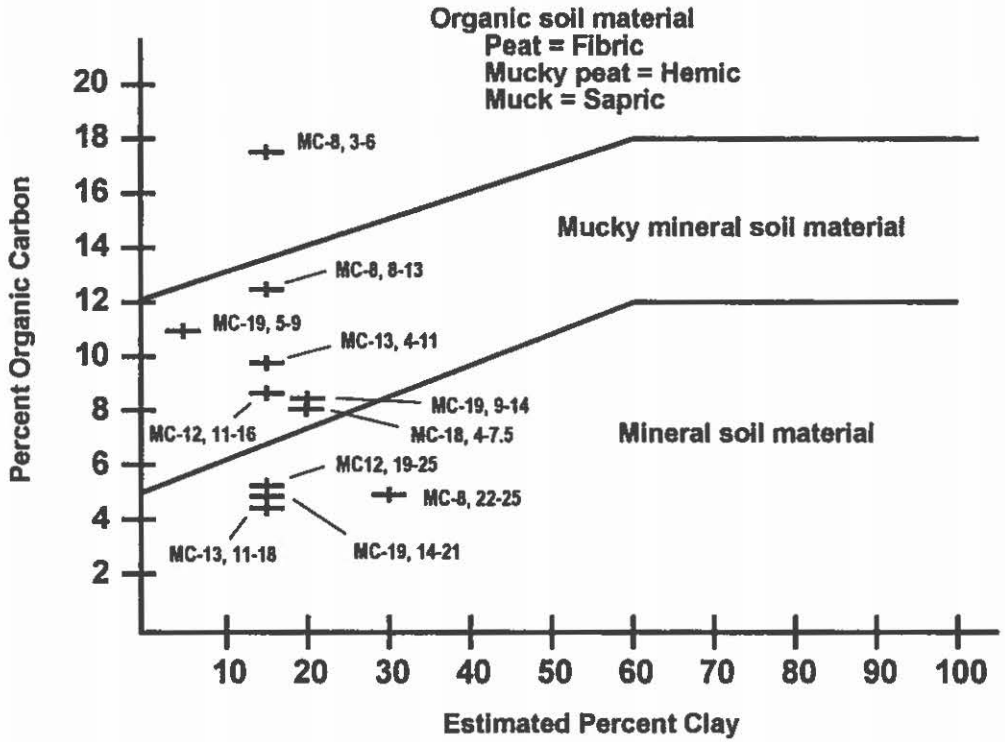
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 2. Soil Profile Location Map
Middle Drakesbad Meadow,
Hot Springs Creek Valley, Lassen Volcanic National Park



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

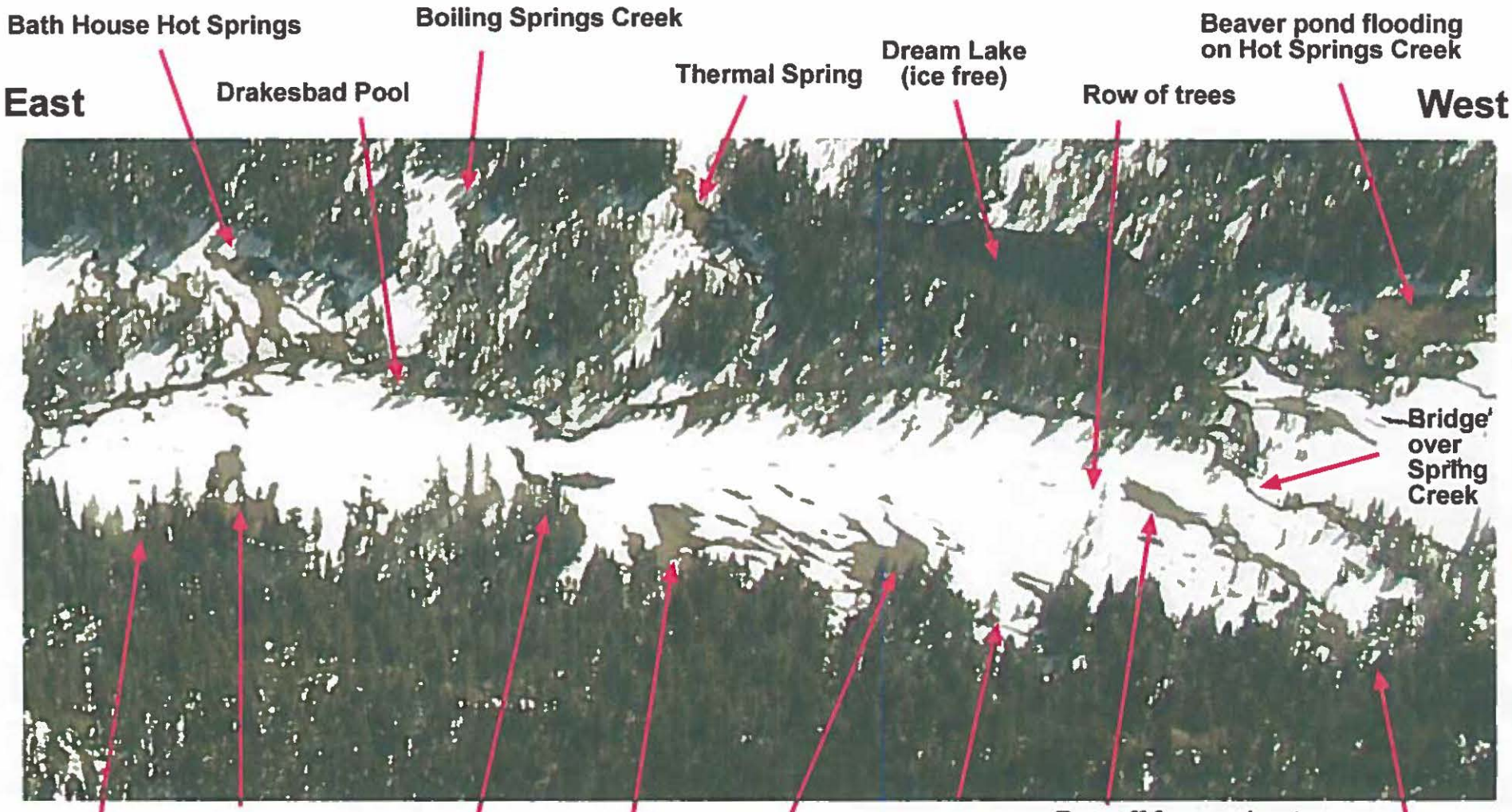
Figure 3. Percent Organic Carbon Versus Percent Clay, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



Source: G.W. Hurt, P.M. Whited, and R.F. Pringle (editors), Field indicators of Hydric Soils in the United States, Version 5.0, 2002. USDA, NRCS in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, TX

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

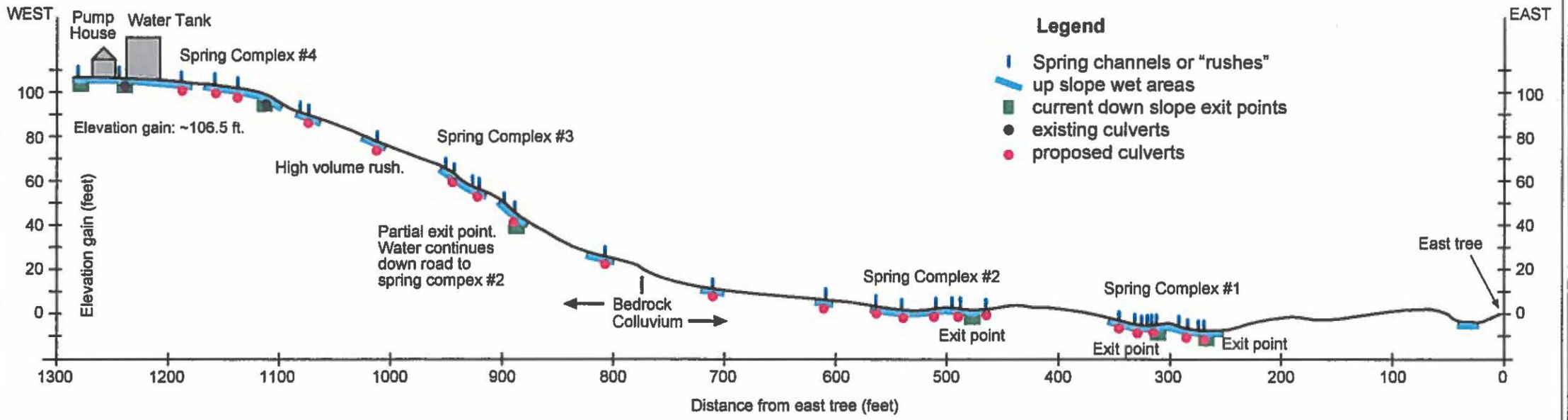
Figure 5. Aerial Photo Drakesbad Meadow, March 27, 2003



Notes: Geothermal fluids tend to melt snow quickly and help identify sources of warm ground, warm spring runoff, and ponding water. Notice the barren spots throughout the Lower and Middle Drakesbad Meadow area identifying of these fluids.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Figure 6. Drakesbad Water Tank Access Road Spring Complex, August 5, 2002
Hot Springs Creek Valley, Lassen Volcanic National Park
By Charles P. Watson



Discussion

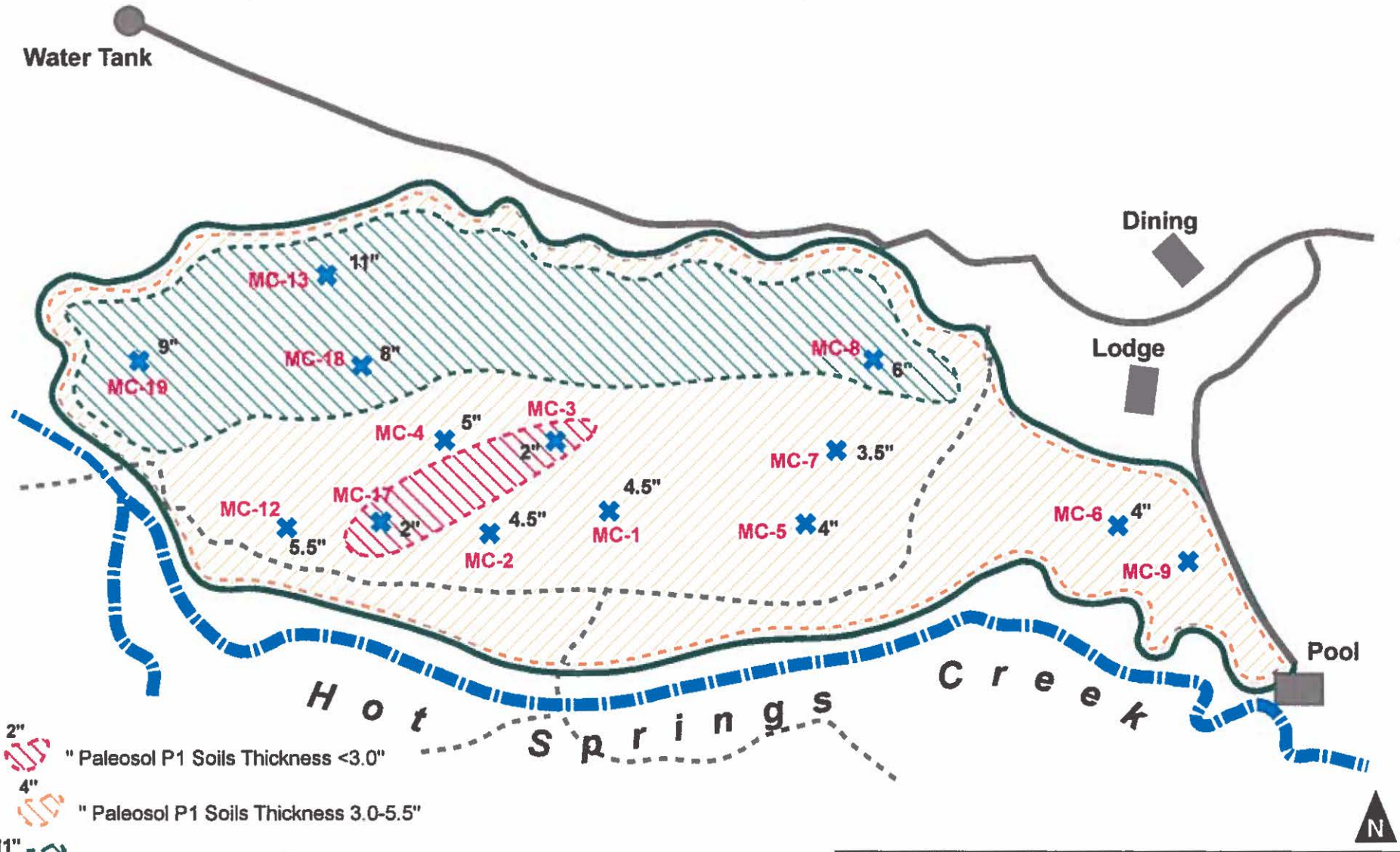
There are four major spring complexes along the Drakesbad water tank access road. Most (~80%) of the spring water comes down slope in channels or "rushes" and the remainder moves down in the subsurface, saturating the soils.

Currently, the access road intercepts all of this water and moves it down-road to various exits points. Ditches along the up-slope side of the road help move the water to these exit points. There are two existing culverts, both located at the top of the road. Bedrock crops out at the base of the steep incline; colluvium is to the east.

Twenty-one new culverts are proposed to put the spring water back onto the meadow in its natural position. Nine culverts are in bedrock; twelve in colluvium. This is a maximum number and could be reduced at selected locations. Road berms would also be placed at various location to capture runoff on the road. Maintenance of the culverts would be minor because little sediment moves down the rushes.

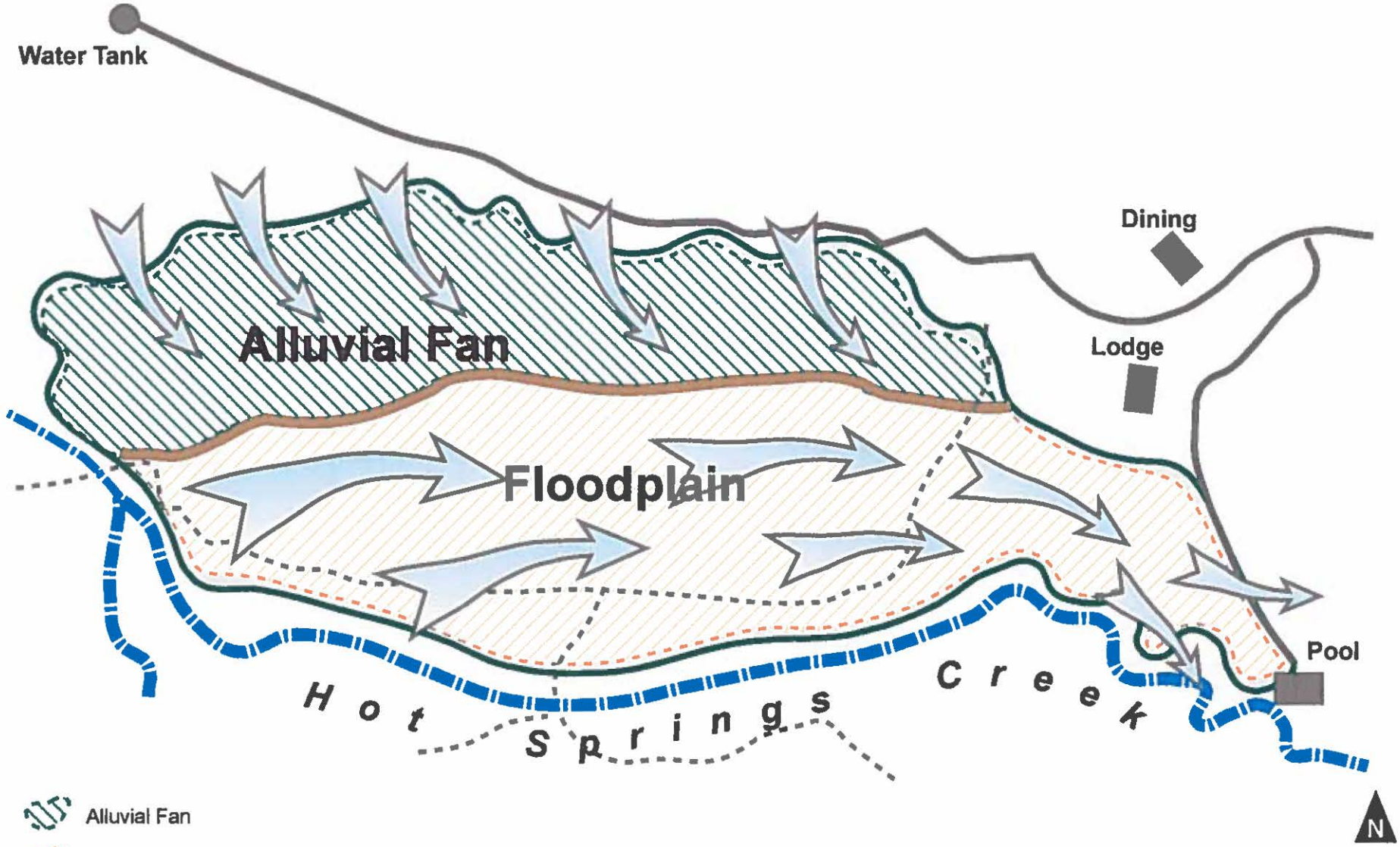
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89511-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 7. General Location and Thickness of Paleosol P1 (Relic) Soils, Middle Drakesbad Meadow, Hot Springs Creek Valley, LVNP



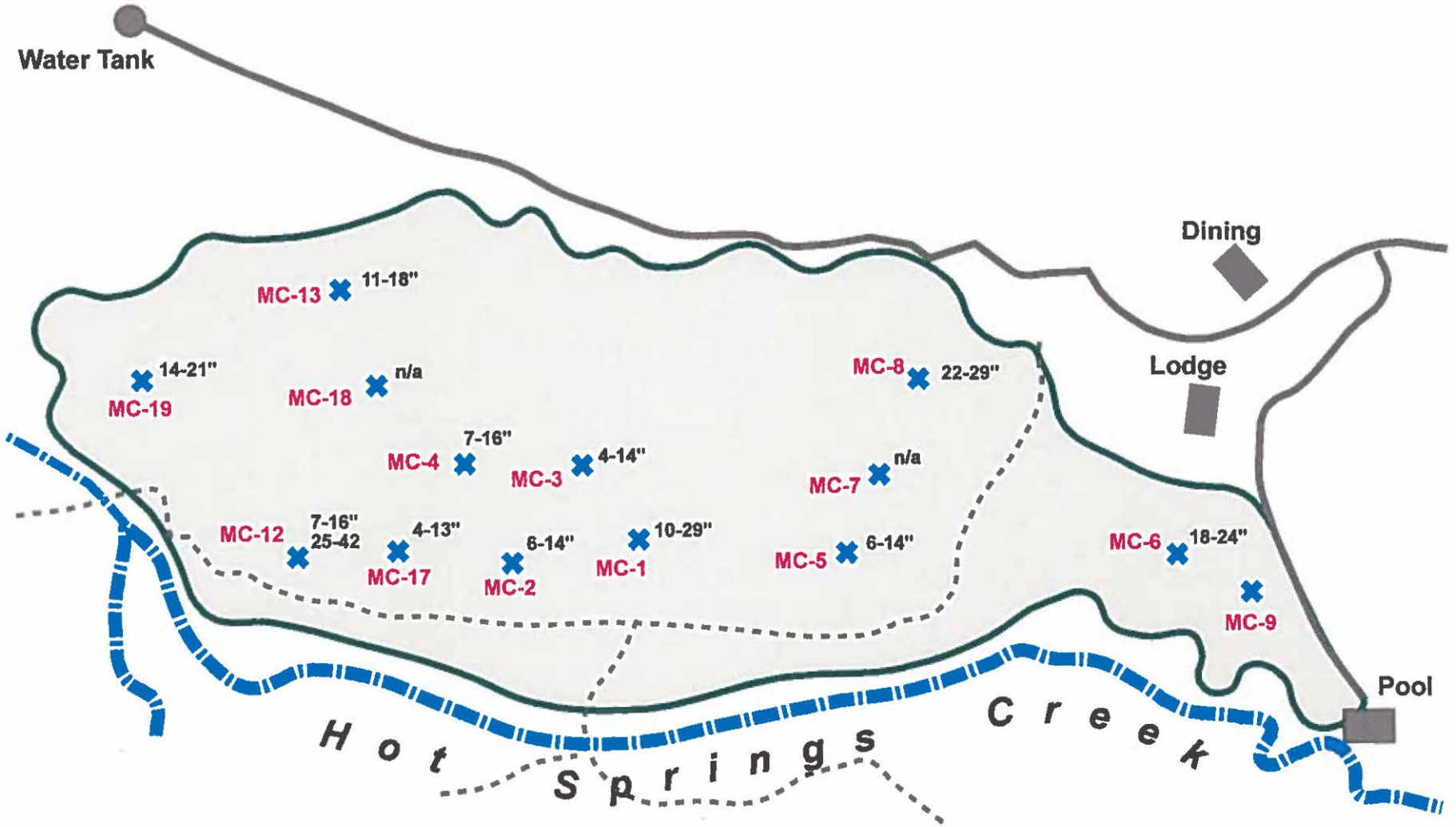
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 8. Schematic: Fan / Floodplain Deposits and Surface Flow
Middle Drakesbad Meadow, Hot Springs Creek Valley, LVNP



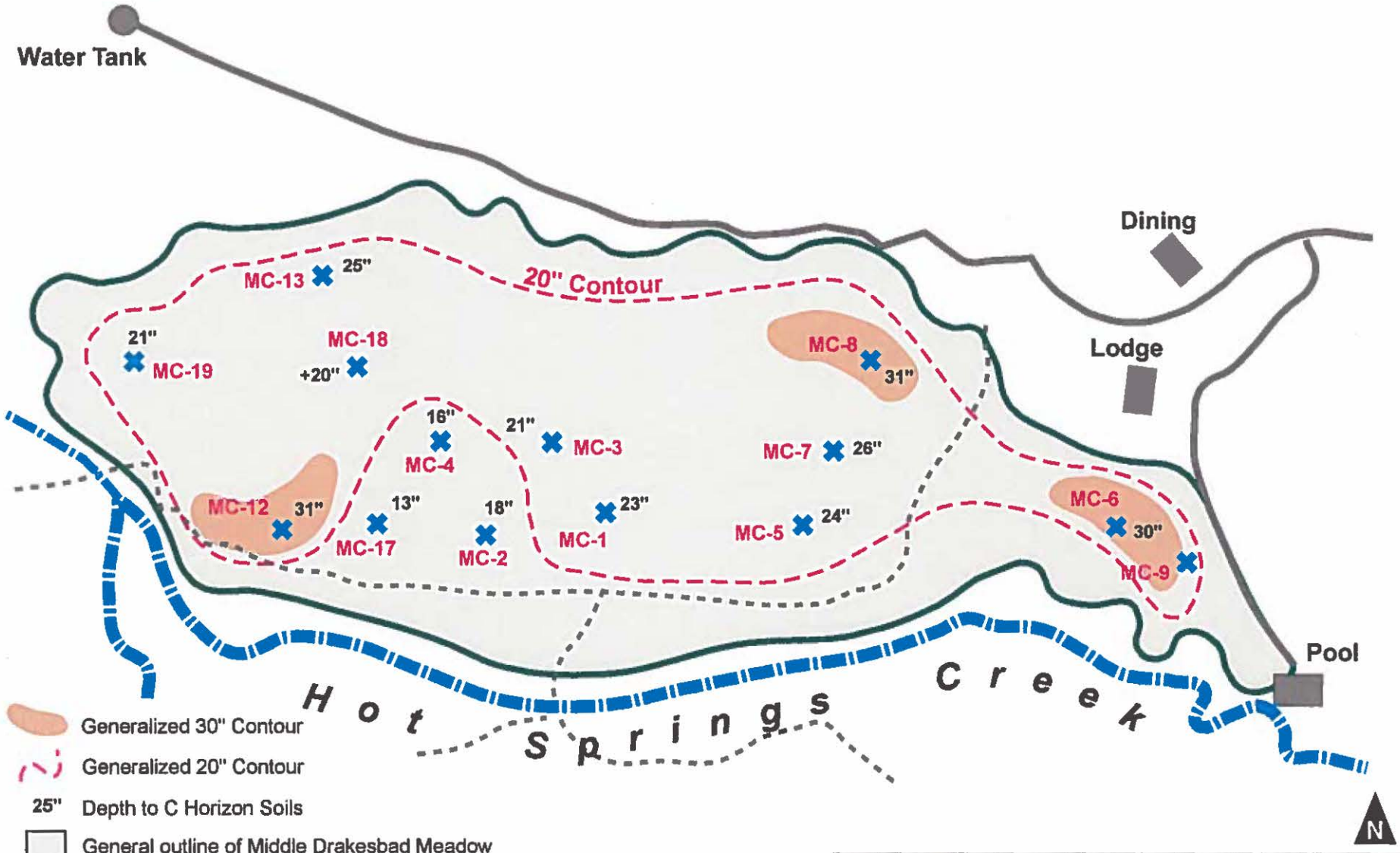
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 9. Charcoal-rich Horizon Map, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



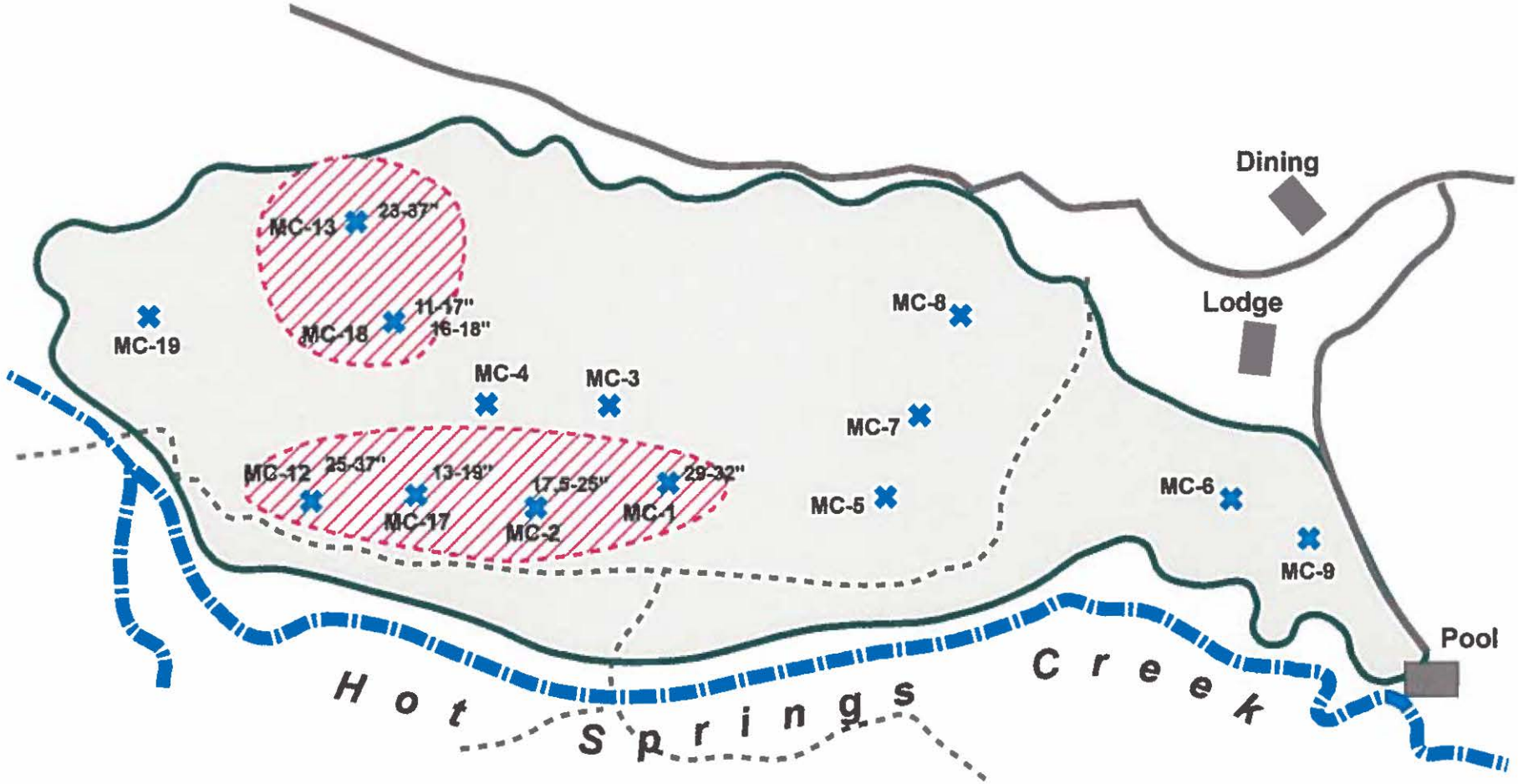
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 10. Depth to C Horizon Map, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 11. Tephra and/or Kaolin-rich Horizon Map, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



25" Interval containing Tephra and/or Kaolin-rich Soils

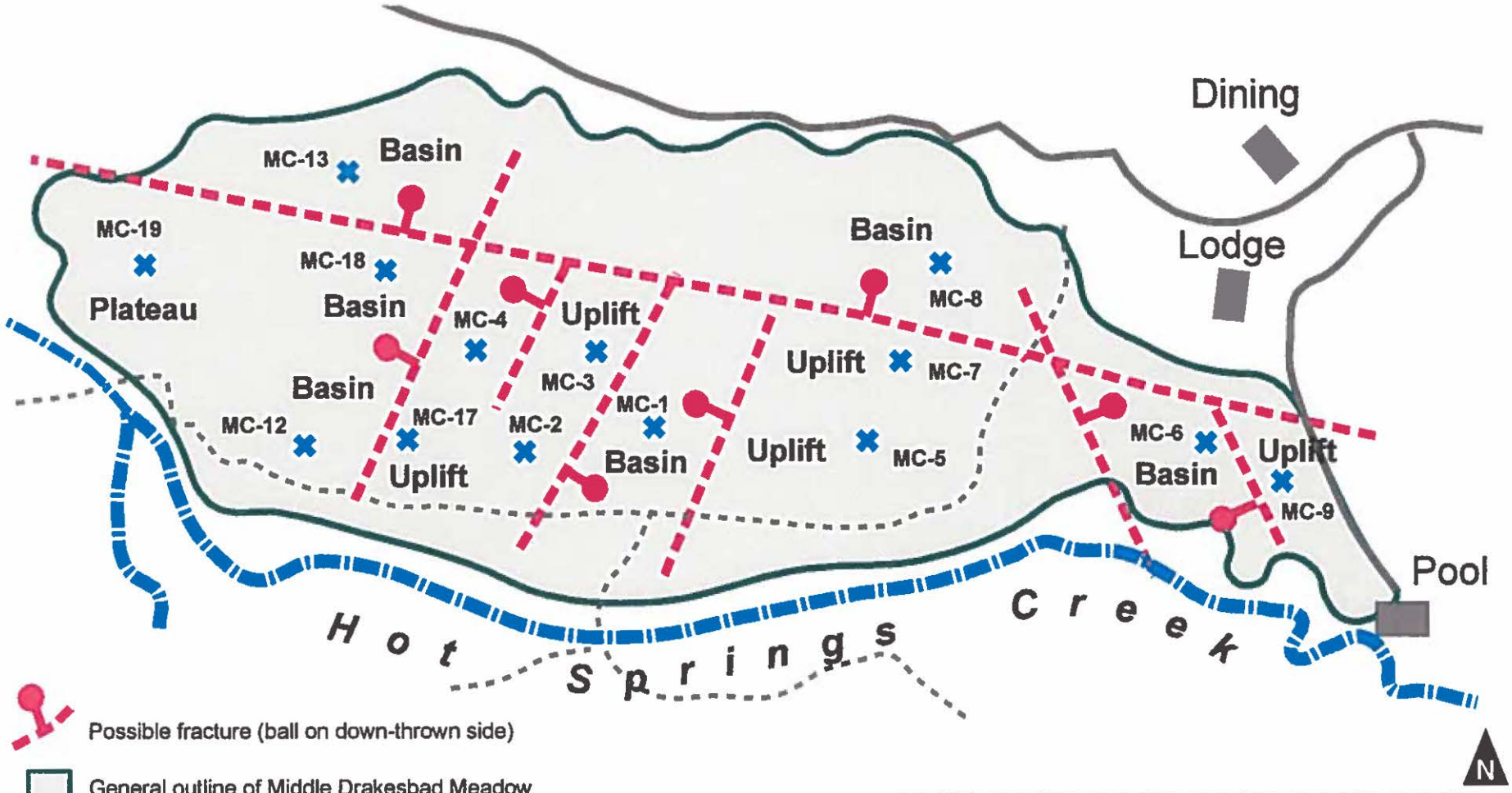
General outline of Middle Drakesbad Meadow

MC-15 Soil Coring Locations

Trails/roads/structure

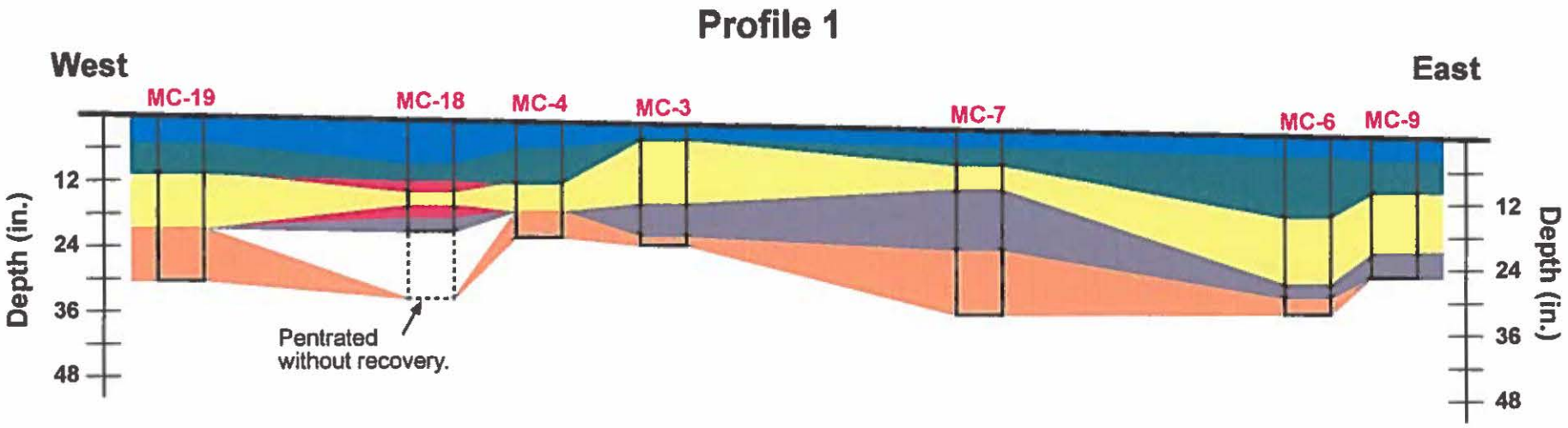
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Figure 12. Hypothetical Fracture and Paleo-Basin Map in Paleosol P-3 Time, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Profile 1 - Center East-West Soil Profile, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park



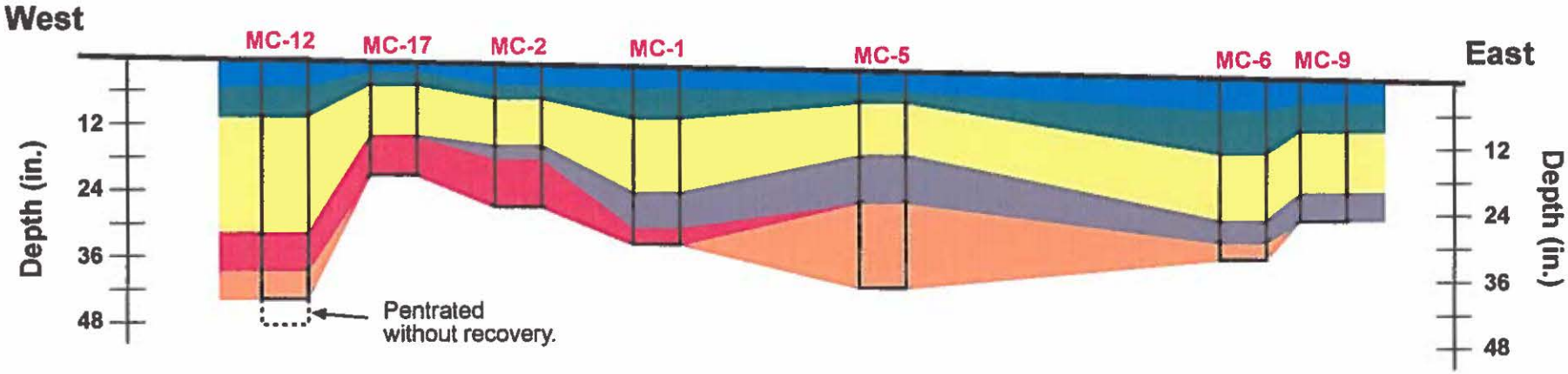
MC-18 Soil Core Locations

- Paleosol 1 (Relic)
- Paleosol 2
- Paleosol 3
- Paleosol 4
- Tephra and/or Kaolin
- C Horizon

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Profile 2 - South-Central East-West Soil Profile, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park

Profile 2



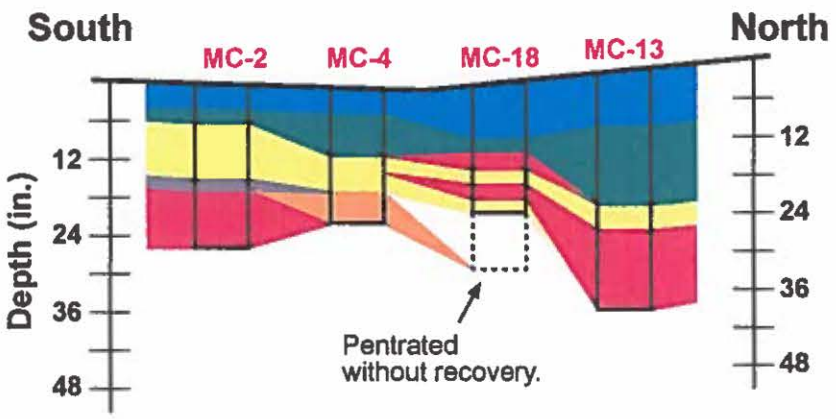
MC-17 Soil Core Locations

- Paleosol 1 (Relic)
- Paleosol 2
- Paleosol 3
- Paleosol 4
- Tephra and/or Kaolin
- C Horizon

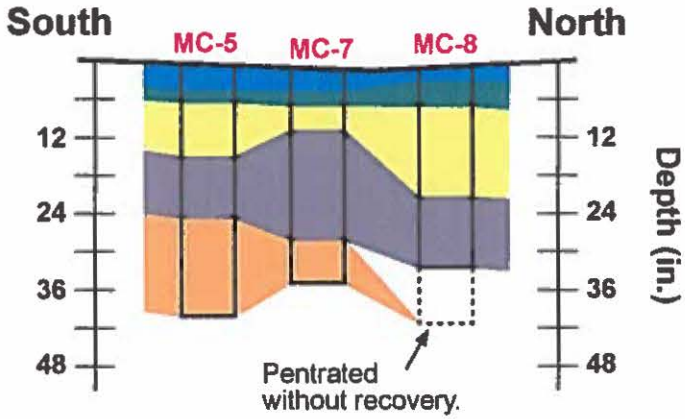
Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

North-South Soil Profiles, Middle Drakesbad Meadow, Hot Springs Creek Valley, Lassen Volcanic National Park

Profile 3
Western Middle Meadow Profile



Profile 4
Eastern Middle Meadow Profile



MC-18 Soil Core Locations

- Paleosol 1 (Relic)
- Paleosol 2
- Paleosol 3
- Paleosol 4
- Tephra and/or Kaolin
- C Horizon

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Appendix 1

Soil Classification

Appendix 1a.
Modified Core Logging Format

Appendix 1b.
Diagram of Soil Texture Classification
as per Percent Sand, Silt and Clay Ratios
as per
Field Book for Describing and Sampling Soils
Schoeneberger, Wysocki, Benham, and Broderson, 2002

Appendix 1a - Soils Description Guide

Soil horizon (O, A, E, AB, B, C, R sequenced 1, 2, 3, etc. With modifiers a (high), e (med), i (slight) = relative organic decomposition, h = illuviation of organics, b = buried, p disturbed, g = gleying, t = clay illuviation (coatings, skins, etc.)

Soil depth (interval from surface in inches)"

PALEOSOL(e.g: P1, P 2, etc)

Soil color name (dark gray, etc.) **Munsel color: hue** (e.g: 10 YR), **value/chroma** (e.g: 4/2)

Texture (Sand, Sandy Loam, Loam, Silt Loam, Clay Loam, Clay

Percent sand/silt/clay (SSC) : [sand]%/[silt]%/[clay]%

Moisture (dry, slightly moist, moist, wet)

Ped Structure (apedal, weak, moderate, strong)

Ped Size (fine, medium, course, very coarse)

Ped Shape (platy, prismatic, angular blocky, sub-angular blocky, granular)

Ped strength (loose, weak, firm, strong, ridgid)

Stickiness (non-, slightly, moderately, sticky, very)

Plasticity (non-, slightly, moderately, plastic, very)

Fine roots (trace, few, some, many, abundant), percent fine roots (e.g. 20%)

Large roots (no, trace, few, some, many, abundant)

Organic matter content (trace, few, some, many, abundant)

Porosity (low, medium, high)

Iron stains (trace, few, some, common, abundant; mottled?, root casts?)

Coarse Sand (trace, few, some, common, abundant) (angukar, sub-angular, sub-rounded, rounded)

Gravel (no trace, few, some, common, abundant) (angukar, sub-angular, sub-rounded, rounded)

Pebbles (trace, few, some, common, abundant) (angukar, sub-angular, sub-rounded, rounded)

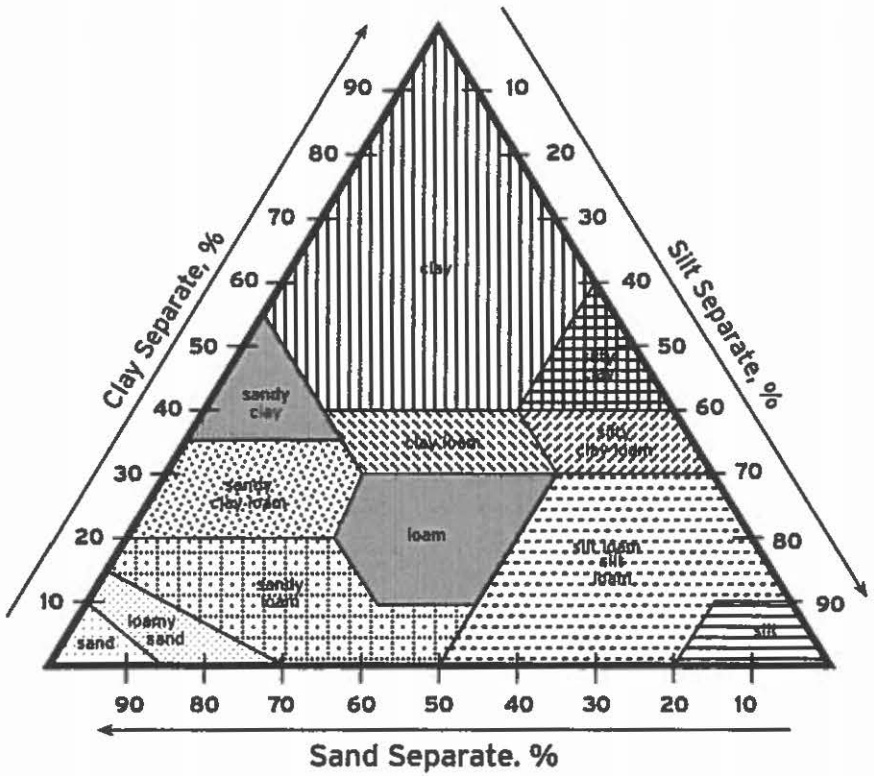
Charcoal fragments (trace, few, some, many, abundant).

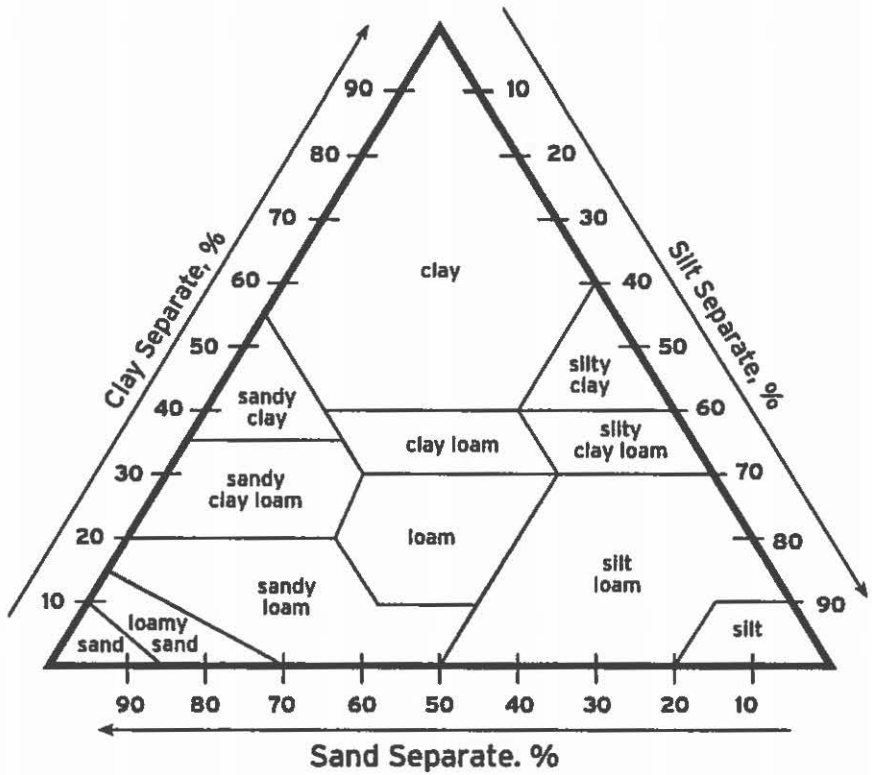
Other items of interest .

Lower boundary (sharp, gradual, irregular)

Soil origin comments .

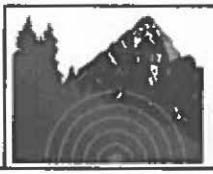
Appendix 1b. Soils Classification and Lithology





Other classifications and lithologies





Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Appendix 2

Laboratory Analyses

Letters of Request and Laboratory Analyses

for:

- Bulk XRF Analyses of Clay Samples;
  Franklin & Marshall College

- SEM Analyses of a Suspected Tephra Sample MC-13, 32-37"
  and Comparison of Regional Volcanic Sources;
  Western Washington University

- Total Organic Carbon Analyses of Organic Samples;
  Oregon State University

- Bulk XRF Analyses of MC-12, 31-33" Samples;
  Franklin & Marshall College

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
PO Box 18012, Reno, Nevada 89521 • Voice: (775) 852-0992 • Fax (775) 852-3226 • www.advancedgeologic.com

February 6, 2003

Dr. Stan Mertzman
C/O Warehouse
Franklin & Marshall College
501 Harrisburg Avenue
Lancaster, PA 17603

Stan,

Please find the enclosed samples for XRF analysis. The samples have been sieved to 40 mesh and I hope I have provided enough material for the runs. The sample numbers are:

- BHA-1
- BHA-2
- DK-1
- BSL-1

As per your instructions, enclosed is a check for $140 ($35 per sample) for the service.

If you could be so kind as to e-mail me the sample results at cwatson@addvancedgeologic.com and return any leftover material to the address above, along with a copy of the results.

Thank you for your assistance with these analyses. If you have any questions or if I can be of further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson
President / Chief Geologist

FRANKLIN & MARSHALL

Specimen	BHA-1	BHA-2	DK-1	BSL-1
SiO2	51.79	51.93	74.58	52.46
TiO2	4.40	4.53	1.16	3.84
Al2O3	36.27	37.27	16.75	39.49
Fe2O3T	4.20	3.04	4.05	2.11
MnO	0.04	0.03	0.01	0.02
MgO	0.53	0.43	0.53	0.40
CaO	0.68	0.56	0.27	0.22
Na2O	0.31	0.25	0.65	0.14
K2O	0.32	0.27	1.72	0.30
P2O5	1.06	0.99	0.22	0.83
Total	99.60	99.30	99.94	99.81
LOI	14.98	15.06	17.21	16.71
Rb	4.7	4	12.5	1.3
Sr	726	699	684	449
Y	28.9	27.8	11.2	22.9
Zr	388	409	290	369
V	230	211	104	181
Ni	12	12	14	17
Cr	101	99	31	103
Nb	30.4	35.6	11.2	31.9
Ga	40.9	42.7	25.3	38.6
Cu	11	4	24	27
Zn	24	20	15	31
Co	4	5	12	5
Ba	2582	2496	1433	2026
La	88	87	20	73
Ce	236	227	46	189
U	3.9	3.3	3.2	2.8
Th	10.9	10.9	9.1	10
Sc	30	30	12	27
Pb	21	20	17	23

DEPARTMENT OF GEOSCIENCES FRANKLIN & MARSHALL COLLEGE P.O. BOX 3003 LANCASTER, PENNSYLVANIA USA 17604-3003
TELEPHONE: 717.291.4133 FAX: 717.291.4186

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
PO Box 18012, Reno, Nevada 89521 • Voice: (775) 852-0992 • Fax (775) 852-3226 • www.advancedgeologic.com

Tuesday, April 15, 2003

Nick Foit
Department of Geology
Washington State University
Pullman, WA 99163

Nick,

Thanks for your offer to look at my suspected tephra. Enclosed is sample MC-13, 32-37" for your review.

If it is a tephra, I would like to go forward with a probe analysis, but let me know what you see first. Send me an e-mail asap.

Also, I was wondering once a tephra correlation is made, can XRF be used to verify additional samples?

I look forward to your results. If you have any questions or if I can be of further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson

June 19, 2003

Charles P. Watson
President / Chief Geologist
Advanced Geologic Exploration, Inc.
P.O. Box 18012, Reno, Nevada 89521

Dear Dr. Watson:

We have finished the analysis of the sample you provided our laboratory. The sample primarily consists of clays and detrital minerals with a lesser amount of volcanic glass. The composition of the glass (Table 1) is fairly uniform and its composition is a very good match (similarity coefficient = 0.97) to that found in the Rockland tephra which is believed to be from Mount Lassen. Recently reported ages (See search output) for this tephra range from 0.41 to 0.47 ma.

I trust this data will be useful in your studies. If you have any questions regarding these analyses please do not hesitate to call (509-335-3093) or email (foit@mail.wsu.edu) me.

I would appreciate it if you would provide us with location and depth information on this sample. Thank you for using our service.

Sincerely,

Franklin F. (Nick) Foit, Jr.
Professor and Director of Microbeam lab

TABLE 1. GLASS CHEMISTRY OF MOUNT LASSEN TEPHRA SAMPLE

Oxide	Sample MC-13
SiO2	77.83(0.37)
Al2O3	12.67(0.21)
Fe2O3	0.88(0.10)
TiO2	0.19(0.02)
Na2O	3.50(0.15)
K2O	3.81(0.15)
MgO	0.15(0.03)
CaO	0.88(0.12)
Cl	0.06)
Total**	100
Number of shards analyzed	16
Probable Source/Age	Rockland tephra 0.41-0.47 ma
Similarity Coefficient***	0.97

* Standard deviations of the analyses given in parentheses
** Analyses normalized to 100 weight percent
***Borchardt et al. (1972)

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
PO Box 2464, Lake Almanor, CA 96137 • Voice/Fax: (530) 596-3221 • www.advancedgeologic.com

Friday, September 12, 2003

J. H. Huddleston
Soil Science
3017 Ag and Life Science
Oregon State Univ.
Corvallis, OR 97331

Herb,

Enclosed are 11 soil samples from the Drakesbad Meadow at Lassen Volcanic National Park to be analyzed for total carbon content:

MC-8, 3-6"
MC-8, 8.5-13.5"
MC-8, 22-25"

MC-12, 11-16"
MC-12, 19-25"

MC-13, 4.5-11"
MC-13, 11-18"

MC-18, 4.0-7.5

MC-19, 5-9"
MC-19, 9-14"
MC-19, 14-21

I probably needed these results yesterday, but as soon as you can would be fine.

By the way, I have a tephra layer that underlies these soils and am having it looked at now. I believe we'll find these soils to be less than 3,500 years old. Remarkable, eh?

Thanks for your time on this and I look forward to your results. If you have any questions or if I can be of further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson

CENTRAL ANALYTICAL LABORATORY

Oregon State University Department of Crop and Soil Science

Herb Huddleston
Crop & Soil Science

SOIL

Submitted: 6/24/03
Gp 03427

Sample Number	Lab Number	C %	N %
1	03427.01	17.34	1.11
2	03427.02	12.07	0.76
3	03427.03	4.92	0.27
4	03427.04	8.49	0.75
5	03427.05	5.40	0.44
6	03427.06	9.85	0.73
7	03427.07	4.42	0.35
8	03427.08	8.07	0.66
9	03427.09	10.79	0.50
10	03427.10	8.13	0.60
11	03427.11	5.69	0.50

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
PO Box 18012, Reno, Nevada 89521 • Voice: (775) 852-0992 • Fax (775) 852-3226 • www.advancedgeologic.com

September 5, 2003

Dr. Stan Mertzman
C/O Warehouse
Franklin & Marshall College
501 Harrisburg Avenue
Lancaster, PA 17603

Stan,

Please find the enclosed sample MC-12, 31-33" for XRF analysis.

If you could be so kind as to e-mail me the results at cwatson@addvancedgeologic.com and send me a hard copy with letterhead to the address above.

Thank you for your assistance with these analysis. If you have any questions or if I can be of further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson
President / Chief Geologist

Major Element Chemical Analysis Via XRF For a Watson Sample.
Major Element Data Are in Weight Percent; Trace Element Data Are in PPM.
September 11, 2003.

	MC-12
Specimen	31-33
SiO2	57.14
TiO2	0.74
Al2O3	17.15
Fe2O3T	1.90
MnO	0.02
MgO	1.05
CaO	1.23
Na2O	1.09
K2O	1.35
P2O5	0.07
LOI	18.60
Total	**100.34**

Appendix 3

Soil Description Logs

(also see Table 1. Soil Core Log Summary)

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

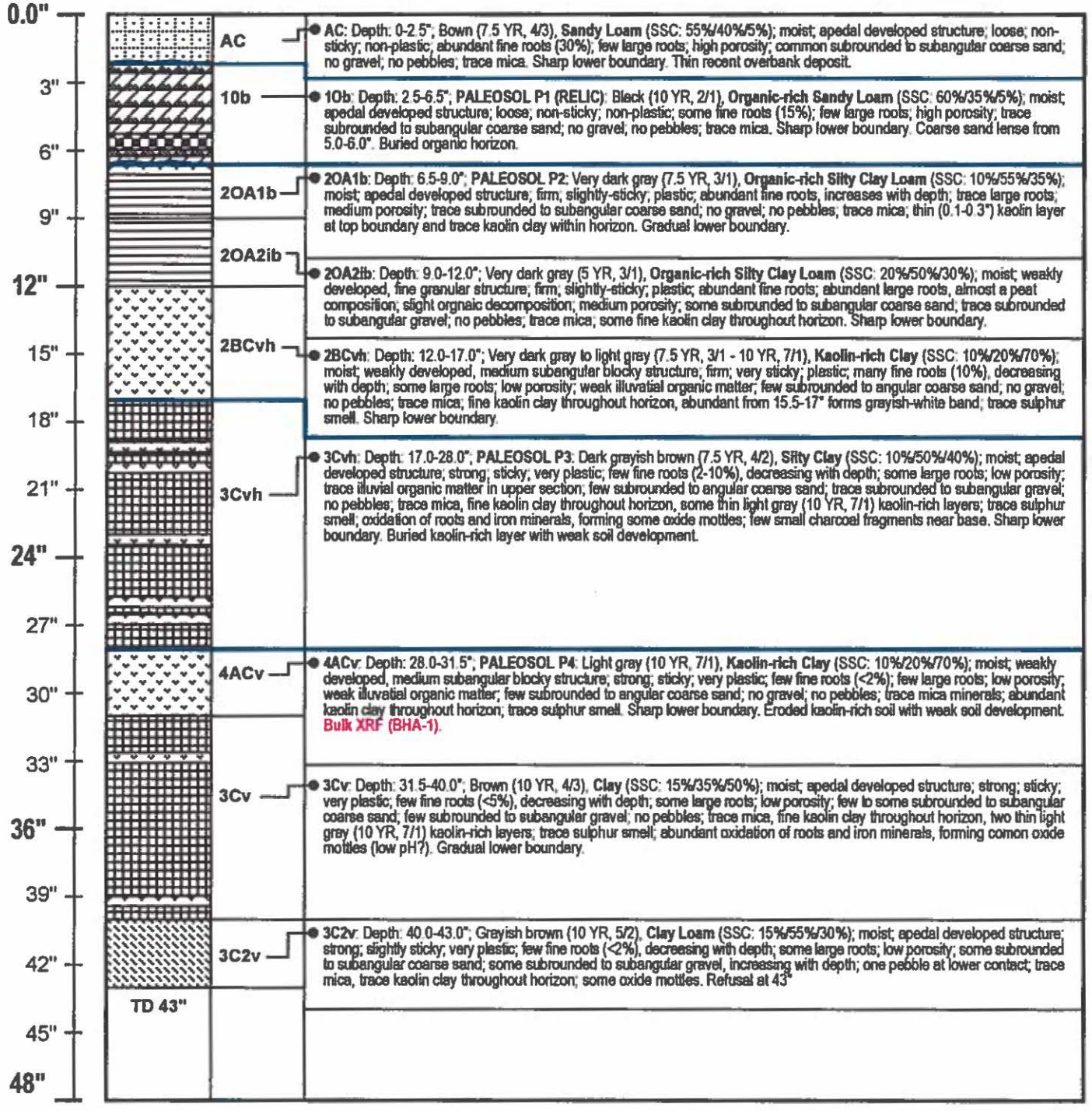
BORING NO. BHA-1 **TOTAL DEPTH:** 43" **DATE:** 9/10/02 **TIME:** Afternoon

BORING LOCATION: South of Drakesbad Bathhouse, south side of Hot Springs Creek at stream cut **ELEVATION:** 5570'

WEATHER: clear, hot

TEPHRA/KAOLIN: Yes **DEPTH:** Many **QUALITY:** good

CHARCOAL: Yes **DEPTH:** 26-28" **QUALITY:** good **SPECIAL NOTATIONS:** refusal at 43"



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89511-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-1 **TOTAL DEPTH:** 32" **DATE:** 8/02/02 **TIME:** Afternoon

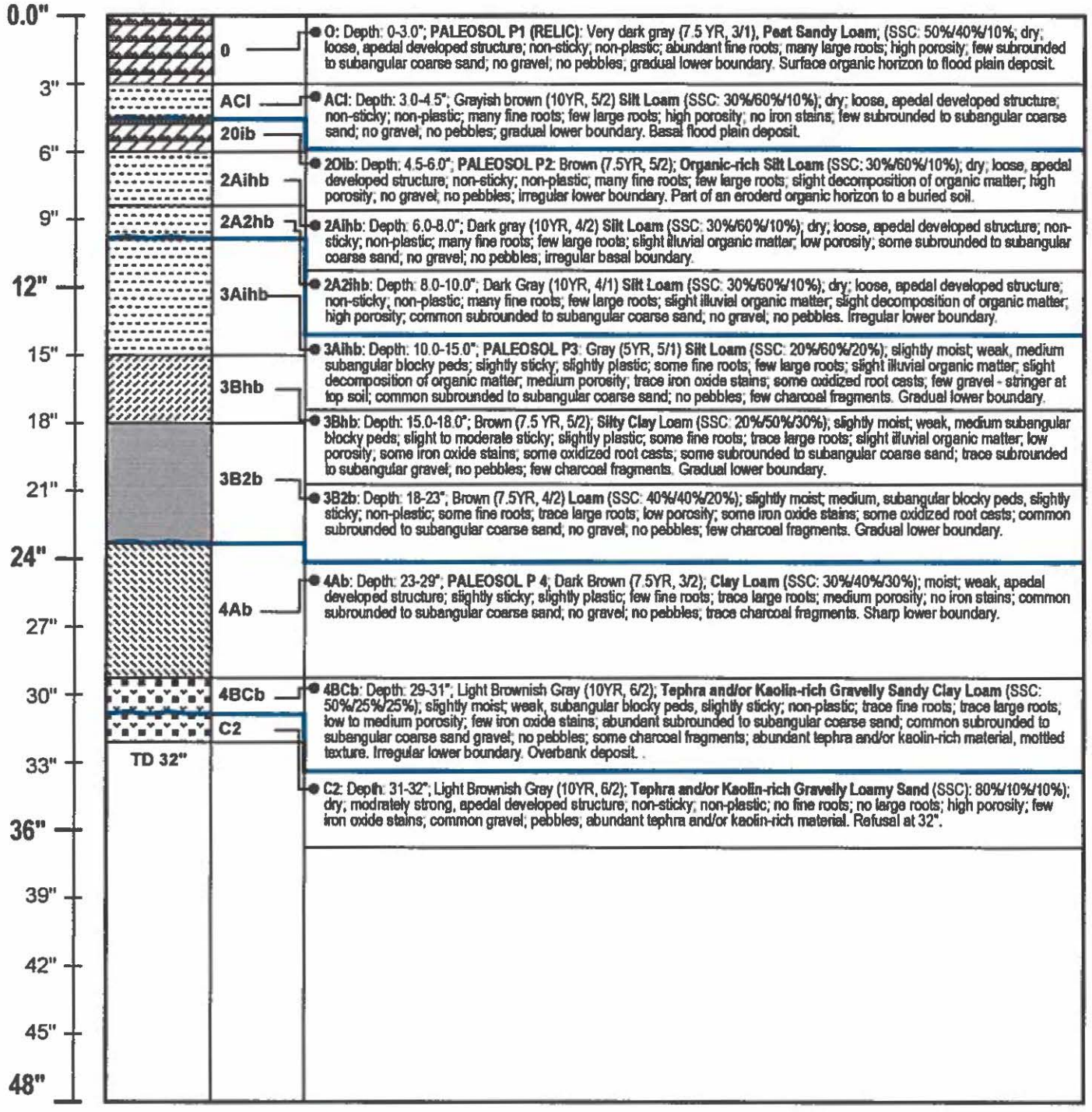
BORING LOCATION: Drakesbad Meadow, south side of valley, north of Dream Lake trail cutoff, near Well No. 135 **ELEVATION:** 5575'

WEATHER: clear, hot, smoky

TEPHRA/KAOLIN: Yes **DEPTH:** 29-32" **QUALITY:** poor

CHARCOAL: Yes **DEPTH:** 10-29" **QUALITY:** good

SPECIAL NOTATIONS: Refusal at 32".



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89511-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-2 **TOTAL DEPTH:** 25" **DATE:** 8/02/02 **TIME:** Afternoon

BORING LOCATION: Drakesbad Meadow, south side of valley, northwest of Dream Lake trail cutoff, east of row of trees **ELEVATION:** 5575'

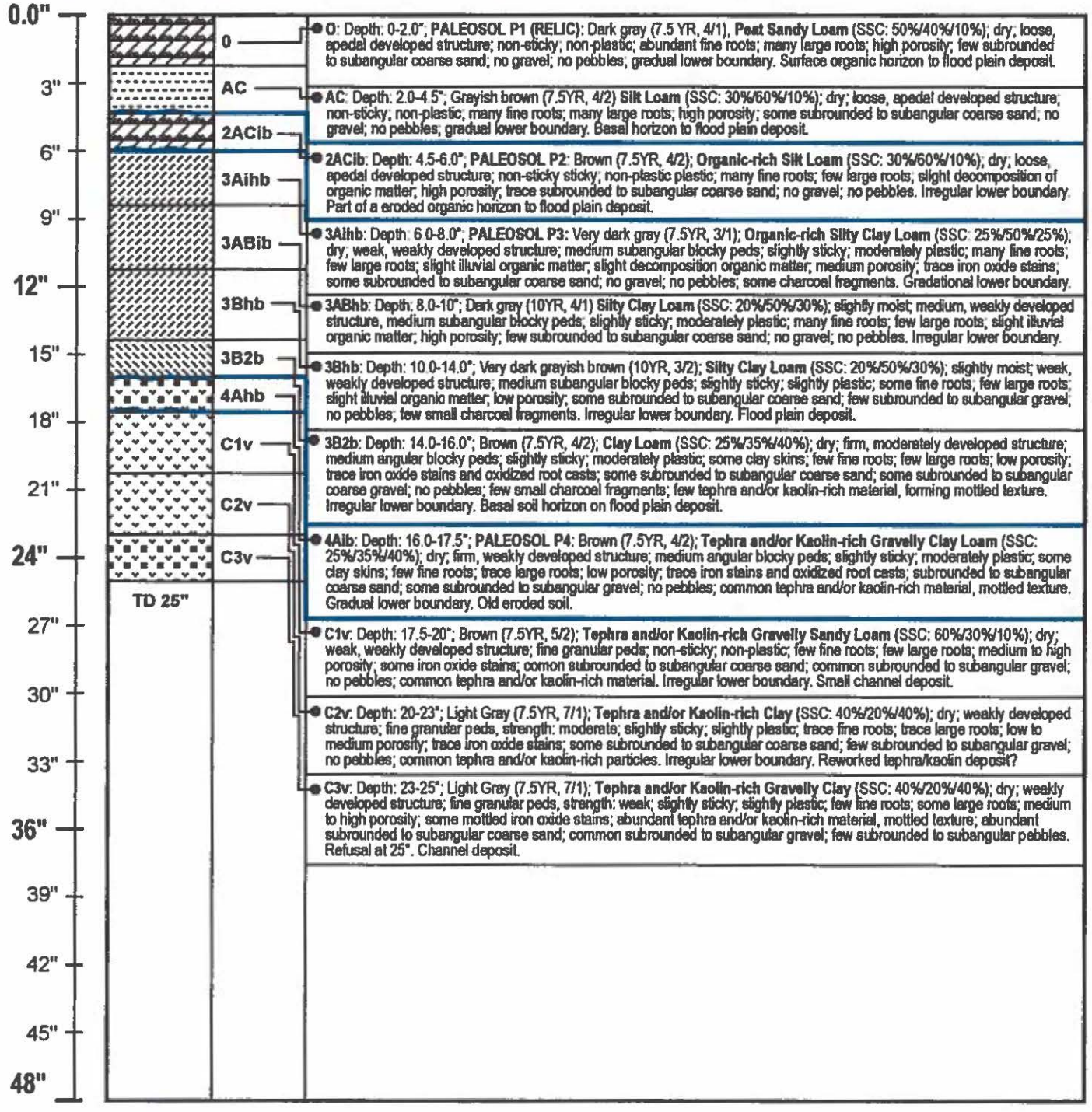
WEATHER: clear, hot, smoky

TEPHRA/KAOLIN: Yes **DEPTH:** 18-25 " **QUALITY:** good

CHARCOAL: Yes **DEPTH:** 6-8" & 10-14" **QUALITY:** good

SPECIAL NOTATIONS: Refusal at 25".

Tephra/Kaolin sample MC-2 22".



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-3 **TOTAL DEPTH:** 22" **DATE:** 8/13/02 **TIME:** Afternoon

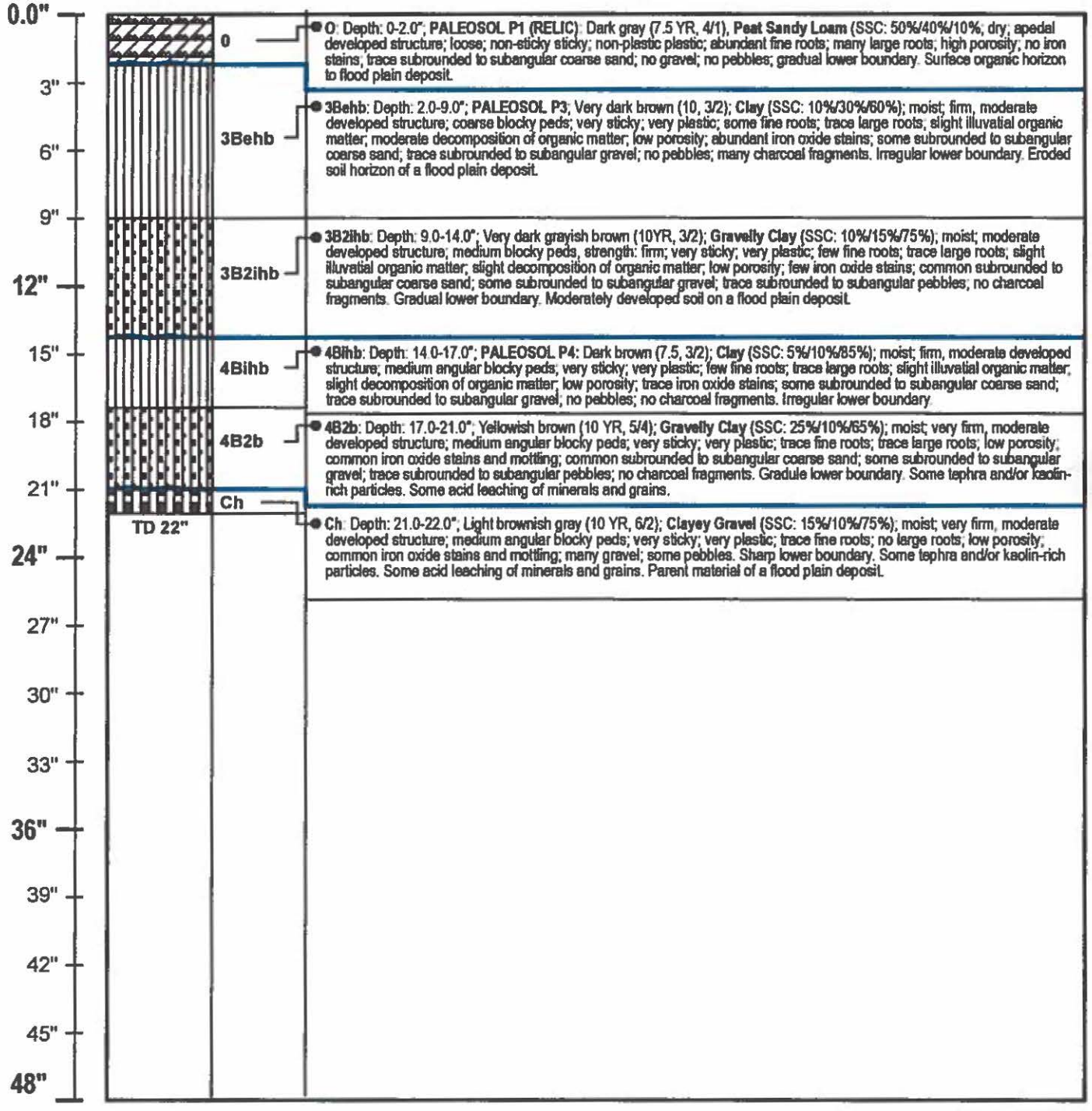
BORING LOCATION: Drakesbad Meadow, axis of valley, north of Dream Lake trail cutoff, east of row of trees **ELEVATION:** 5575'

WEATHER: clear, hot

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a

SPECIAL NOTATIONS: Refusal: 22".

CHARCOAL: Yes **DEPTH:** 4.0-14" **QUALITY:** good



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-4 **TOTAL DEPTH:** 21" **DATE:** 8/13/02 **TIME:** Afternoon

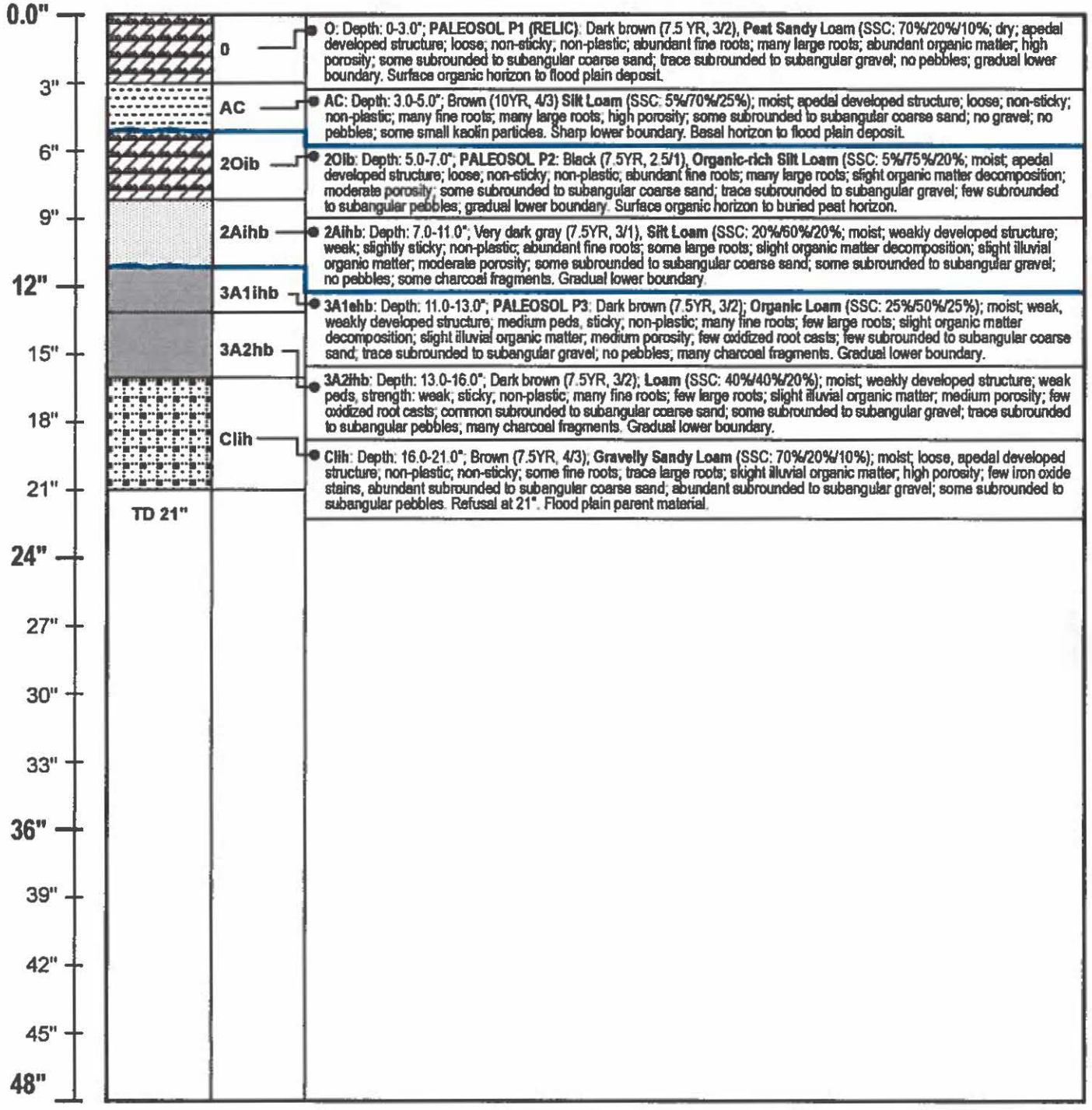
BORING LOCATION: Drakesbad Meadow, axis of valley, northwest of Dream Lake trail cutoff, west of row of trees **ELEVATION:** 5575'

WEATHER: clear, hot

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a

SPECIAL NOTATIONS: Refusal at 21".

CHARCOAL: Yes **DEPTH:** 7-16" **QUALITY:** good

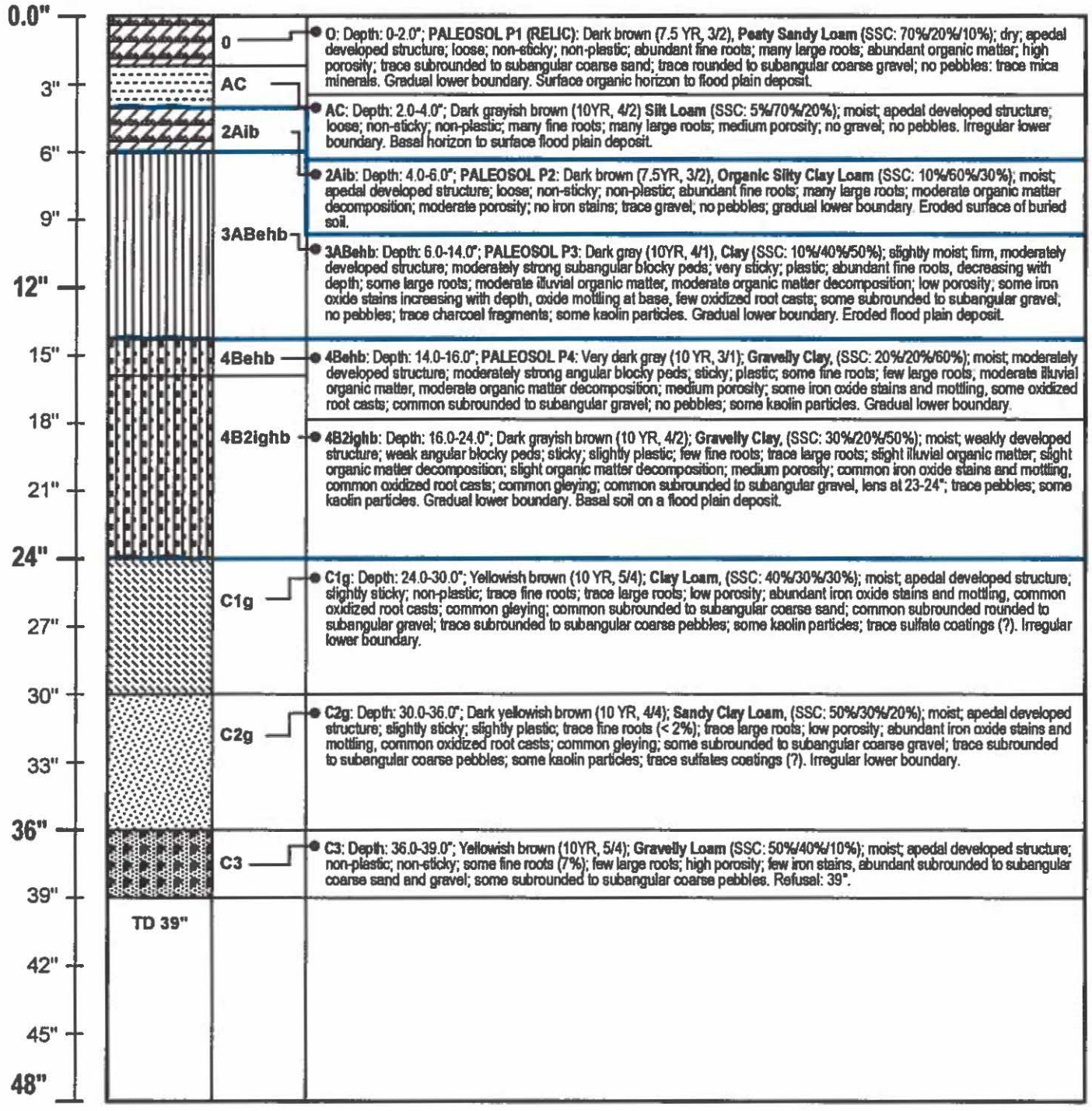


Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-5 **TOTAL DEPTH:** 39"
BORING LOCATION: Drakesbad Meadow, thalweg southwest of Drakesbad Lodge.
TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a
CHARCOAL: Yes **DEPTH:** 6-14" **QUALITY:** good

DATE: 8/15/02 **TIME:** Afternoon
ELEVATION: 5575'
WEATHER: clear, hot
SPECIAL NOTATIONS: Refusal at 39".



Depth	Lithology	Horizon	Description
0.0" – 3"		0	**O**: Depth: 0-2.0"; **PALEOSOL P1 (RELIC)**: Dark brown (7.5 YR, 3/2), **Peaty Sandy Loam** (SSC: 70%/20%/10%); dry; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; many large roots; abundant organic matter; high porosity; trace subrounded to subangular coarse sand; trace rounded to subangular coarse gravel; no pebbles: trace mica minerals. Gradual lower boundary. Surface organic horizon to flood plain deposit.
3" – 6"		AC	**AC**: Depth: 2.0-4.0"; Dark grayish brown (10YR, 4/2) **Silt Loam** (SSC: 5%/70%/20%); moist; apedal developed structure; loose; non-sticky; non-plastic; many fine roots; many large roots; medium porosity; no gravel; no pebbles. Irregular lower boundary. Basal horizon to surface flood plain deposit.
6" – 9"		2Aib	**2Aib**: Depth: 4.0-6.0"; **PALEOSOL P2**: Dark brown (7.5YR, 3/2), **Organic Silty Clay Loam** (SSC: 10%/60%/30%); moist; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; many large roots; moderate organic matter decomposition; moderate porosity; no iron stains; trace gravel; no pebbles; gradual lower boundary. Eroded surface of buried soil.
9" – 12"		3ABehb	**3ABehb**: Depth: 6.0-14.0"; **PALEOSOL P3**: Dark gray (10YR, 4/1), **Clay** (SSC: 10%/40%/50%); slightly moist; firm, moderately developed structure; moderately strong angular blocky peds; very sticky; plastic; abundant fine roots, decreasing with depth; some large roots; moderate illuvial organic matter, moderate organic matter decomposition; low porosity; some iron oxide stains increasing with depth, oxide mottling at base, few oxidized root casts; some subrounded to subangular gravel; no pebbles; trace charcoal fragments; some kaolin particles. Gradual lower boundary. Eroded flood plain deposit.
15" – 18"		4Behb	**4Behb**: Depth: 14.0-16.0"; **PALEOSOL P4**: Very dark grey (10 YR, 3/1); **Gravelly Clay**, (SSC: 20%/20%/60%); moist; moderately developed structure; moderately strong angular blocky peds; sticky; plastic; some fine roots; few large roots; moderate illuvial organic matter, moderate organic matter decomposition; medium porosity; some iron oxide stains and mottling, some oxidized root casts; common subrounded to subangular gravel; no pebbles; some kaolin particles. Gradual lower boundary.
18" – 24"		4B2ighb	**4B2ighb**: Depth: 16.0-24.0"; Dark grayish brown (10 YR, 4/2); **Gravelly Clay**, (SSC: 30%/20%/50%); moist; weakly developed structure; weak angular blocky peds; sticky; slightly plastic; few fine roots; trace large roots; slight illuvial organic matter; slight organic matter decomposition; slight organic matter decomposition; medium porosity; common iron oxide stains and mottling, common oxidized root casts; common gleying; common subrounded to subangular gravel, lens at 23-24"; trace pebbles; some kaolin particles. Gradual lower boundary. Basal soil on a flood plain deposit.
24" – 30"		C1g	**C1g**: Depth: 24.0-30.0"; Yellowish brown (10 YR, 5/4); **Clay Loam**, (SSC: 40%/30%/30%); moist; apedal developed structure; slightly sticky; non-plastic; trace fine roots; trace large roots; low porosity; abundant iron oxide stains and mottling, common oxidized root casts; common gleying; common subrounded to subangular coarse sand; common subrounded rounded to subangular gravel; trace subrounded to subangular coarse pebbles; some kaolin particles; trace sulfate coatings (?). Irregular lower boundary.
30" – 36"		C2g	**C2g**: Depth: 30.0-36.0"; Dark yellowish brown (10 YR, 4/4); **Sandy Clay Loam**, (SSC: 50%/30%/20%); moist; apedal developed structure; slightly sticky; slightly plastic; trace fine roots (< 2%); trace large roots; low porosity; abundant iron oxide stains and mottling, common oxidized root casts; common gleying; some subrounded to subangular coarse gravel; trace subrounded to subangular coarse pebbles; some kaolin particles; trace sulfates coatings (?). Irregular lower boundary.
36" – 39"		C3	**C3**: Depth: 36.0-39.0"; Yellowish brown (10YR, 5/4); **Gravelly Loam** (SSC: 50%/40%/10%); moist; apedal developed structure; non-plastic; non-sticky; some fine roots (7%); few large roots; high porosity; few iron stains, abundant subrounded to subangular coarse sand and gravel; some subrounded to subangular coarse pebbles. Refusal: 39".
39" – 48"	TD 39"		

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-6 **TOTAL DEPTH:** 32"
BORING LOCATION: Drakesbad Meadow, southwest of Drakesbad Lodge.
TEPHRA/KAOLIN: Yes **DEPTH:** 13-24" **QUALITY:** poor
CHARCOAL: Yes **DEPTH:** 6-14" **QUALITY:** good

DATE: 9/5/02 **TIME:** Morning
ELEVATION: 5570'
WEATHER: clear, hot
SPECIAL NOTATIONS: Refusal at: 32"



Horizon	Description
O	O: Depth: 0-2.0"; **PALEOSOL P1 (RELIC)**: Dark brown (7.5 YR, 3/2), **Peat Sandy Loam** (SSC: 70%/20%/10%); dry; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; many large roots; abundant organic matter; high porosity; some subrounded to subangular coarse sand; trace subrounded to subangular coarse gravel; no pebbles. Gradual lower boundary. Surface organic horizon to flood plain deposit.
AC	AC: Depth: 2.0-4.0"; Dark grayish brown (10YR, 4/2) **Silt Loam** (SSC: 5%/65%/25%); moist; apedal developed structure; loose; non-sticky; non-plastic; many fine roots; many large roots; medium porosity; no iron stains; some subrounded to subangular coarse sand; no gravel; no pebbles. Irregular lower boundary.
2Aehb	2Aehb: Depth: 4.0-7.0"; **PALEOSOL P2**: Dark brown (7.5YR, 3/2), **Silt Loam** (SSC: 25%/60%/15%); moist; weakly developed structure; weakly formed granular peds; loose; slightly sticky; non-plastic; abundant fine roots; many large roots; moderate illuvial organic matter; moderate decomposed organic matter; moderate porosity; subrounded to subangular coarse sand; trace subrounded to subangular coarse gravel; no pebbles; gradual lower boundary.
2A2ehb	2A2ehb: Depth: 7.0-10.0"; Dark brown (10YR, 3/3), **Silt Loam** (SSC: 25%/60%/15%); slightly moist; weakly developed structure; weakly formed granular peds; strength: weak, slightly sticky; non-plastic; abundant fine roots; few large roots; moderate illuvial organic matter; moderate decomposed organic matter; moderate porosity; few iron oxide stains increasing with depth, few iron root casts; some subrounded to subangular coarse sand; no gravel; no pebbles. Gradual lower boundary.
2Bahb	2Bahb: Depth: 10.0-13.5"; Dark reddish brown (5YR, 3/2), **Silty Clay Loam** (SSC: 20%/55%/25%); slightly moist; weakly developed structure; weak subangular blocky peds; moderately sticky; slightly-plastic; some fine roots; few large roots; some illuvial organic matter; moderate porosity; abundant mottled iron stains and common iron root casts; some subrounded to subangular coarse sand; no gravel, no pebbles; small charcoal fragments at 12", "sooty" basal section. Sharp lower boundary.
3ABehgb	3ABehgb: Depth: 13.5-18.0"; **PALEOSOL P3**: Dark reddish brown (5YR, 3/2), **Clay** (SSC: 10%/30%/60%); moist; moderately developed structure; medium angular blocky peds; firm; very sticky; very-plastic; some fine roots; trace large roots; moderate illuvial organic matter; abundant decomposed organic matter; low porosity; abundant mottled iron oxide stains and common oxidized root casts; common gleying; some subrounded to subangular sand; trace subrounded to subangular gravel; some pebbles; common kaolin particles. Gradual lower boundary.
3B2ihgb	3B2ihgb: Depth: 18.0-24.5"; Grayish brown (2.5YR, 5/2), **Clay** (SSC: 25%/15%/60%); moist; moderately developed structure; medium angular blocky peds; very sticky; moderately plastic; some fine roots; trace large roots; slight illuvial organic matter; moderate decomposed organic matter; low porosity; abundant mottled iron oxide stains and common oxide root casts; common gleying; some subrounded to subangular coarse sand; few subrounded to subangular coarse gravel; few subrounded to subangular pebbles; trace charcoal fragments; abundant kaolin particles. Gradual lower boundary.
3B3hgb	3B3hgb: Depth: 24.5-27.0"; Brown (7.5YR, 5/4), **Sandy Clay** (SSC: 45%/10%/45%); moist; moderately developed structure; medium angular blocky peds; moderately firm very sticky; moderately plastic; few fine roots; trace large roots; slight illuvial organic matter; low porosity; abundant mottled iron oxide stains and common oxide root casts; common gleying; abundant subrounded to subangular coarse sand; trace subrounded to subangular coarse gravel; no pebbles; some kaolin particles. Gradual lower boundary.
4BCgb	4BCgb: Depth: 27.0-30.0"; **PALEOSOL P4**: Light brownish gray (10YR, 6/2), **Sandy Clay Loam** (SSC: 65%/5%/30%); moist; weakly developed structure; medium blocky peds; moderately firm sticky; moderately plastic; trace fine roots; trace large roots; low porosity; common mottled iron oxide stains decreasing with depth, moderate iron oxide cementation, common gleying; some subrounded to subangular coarse sand; few subrounded to subangular coarse gravel; no pebbles; few kaolin particles. Gradual lower boundary.
C	C: Depth: 30.0-32.0"; Dark yellowish brown (10YR, 5/3); **Loamy Sand**, (SSC: 80%/5%/15%); moist; apedal developed structure; slightly sticky; non-plastic; some fine roots; trace large roots; high porosity; trace iron oxide stains, decreasing with depth; some subrounded to subangular gravel; some subrounded to subangular pebbles increasing with depth; trace kaolin particles. Refusal at 32".

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-7 **TOTAL DEPTH:** 34" **DATE:** 9/5/02 **TIME:** Afternoon

BORING LOCATION: Drakesbad Meadow, axis of meadow, south of Drakesbad horse coral. **ELEVATION:** 5575'

WEATHER: clear, hot

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a **SPECIAL NOTATIONS:** Refusal at 34"

CHARCOAL: No **DEPTH:** n/a **QUALITY:** n/a



Depth	Lithology	Horizon	Description
0.0" – 3"		0	**O**: Depth: 0-2.0"; **PALEOSOL P1 (RELIC)**: Dark Brown (7.5 YR, 3/2), **Peat Sandy Loam** (SSC: 70%/20%/10%); moist; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; many large roots; abundant organic matter; high porosity; some subrounded to subangular coarse sand; trace subrounded to subangular coarse gravel; no pebbles. Gradual lower boundary. Surface organic horizon to flood plain deposit.
3" – 6"		ACh	**ACh**: Depth: 2.0-3.5"; Brown (7.5YR, 4/2) **Silt Loam** (SSC: 5%/80%/15%); moist; apedal developed structure; loose; non-sticky; non-plastic; many fine roots; some large roots; slight illuvation of organic material; slight organic matter decomposition; medium porosity; some subrounded to subangular coarse sand; no gravel; no pebbles. Irregular lower boundary.
6" – 9"		2Aehb	**2Aehb**: Depth: 3.5-6.0"; **PALEOSOL P2**: Very dark brown (7.5YR 2.5/2), **Organic-rich Silty Clay Loam** (SSC: 10%/40%/50%); moist; apedal developed structure; loose; slightly sticky; moderately plastic; abundant fine roots; many large roots; slight illuvation of organic material; moderate organic matter decomposition; moderate porosity; trace subrounded to subangular coarse gravel; no pebbles. Gradual lower boundary.
9" – 12"		2B1ahb	**2Bahb**: Depth: 6.0-10.0"; **PALEOSOL P3**: Very dark brown (10YR, 2/2), **Organic-rich Clay** (SSC: 10%/20%/70%); slightly moist; weakly developed structure; weak subangular blocky peds; very sticky; very plastic; abundant fine roots; some large roots; abundant illuvial organic matter; abundant organic matter decomposition; low porosity; some iron oxide stains and mottling, increasing with depth, some oxidized root casts; some subrounded to subangular coarse sand; few subrounded to subangular coarse gravel; no pebbles. Sharp lower boundary.
12" – 15"		2B2ahb	**2B2ahb**: Depth: 10.0-12.0"; Black (7.5YR, 2.5/1); **Organic-rich Gravelly Clay**, (SSC: 30%/10%/60%); moist; moderately developed structure; weak angular blocky peds; very sticky; very plastic; abundant fine roots; some large roots; abundant illuvial organic matter; abundant organic matter decomposition; medium porosity; some iron oxide stains and mottling, some oxidized root casts; common subrounded to subangular coarse sand; common subrounded to subangular coarse gravel; no pebbles; common mica minerals. Sharp lower boundary. Sand lens with pedogenic over print. Sand blow? Small channel?
15" – 18"		3Aahgb	**3Aahgb**: Depth: 12.0-16.5"; **PALEOSOL P3**: Very dark grayish brown (2.5YR, 3/2); **Organic-rich Silt Loam**, (SSC: 5%/80%/15%); moist; weakly developed structure; weak angular blocky peds; slightly sticky; weakly plastic; some fine roots; some large roots; abundant illuvial organic matter; abundant organic matter decomposition, decreasing with depth, mottled appearance; low porosity; few iron oxide stains and mottling, few oxidized root casts; common gleying; trace subrounded to subangular coarse sand; no gravel; no pebbles; some mica minerals. Gradual lower boundary. Ponded water deposit (?) on flood plain.
18" – 21"		3Bihb	**3Bihb**: Depth: 16.5-22.0"; Dark Brown (10YR, 3/3); **Silt Loam**, (SSC: 15%/60%/25%); moist; weakly developed structure; weak angular blocky peds; slightly sticky; moderately plastic; some fine roots; few large roots; moderate illuvial organic matter; decreasing to zero with depth with mottled appearance; slight organic matter decomposition; low porosity; few iron oxide stains and mottling, some iron root casts; trace gleying decreasing to zero with depth; some subrounded to subangular coarse sand; trace subrounded to subangular coarse gravel; no pebbles. Gradual lower boundary. Ponded water deposit on flood plain.
21" – 24"		4Bhb	**4Bhb**: Depth: 22.0-26.0"; **PALEOSOL P4**: Brown (7.5YR, 4/2); **Loam**, (SSC: 30%/45%/25%); moist; weakly developed structure; weak angular blocky peds; slightly sticky; moderately plastic; few fine roots; trace large roots; slight illuvial organic matter; low porosity; few iron oxide stains and mottling increasing with depth, some oxide root casts; common subrounded to subangular coarse sand; few subrounded to subangular coarse gravel; no pebbles. Gradual lower boundary.
24" – 27"		C1	**C1**: Depth: 26.0-29.0"; Brown (7.5YR, 4/3); **Gravelly Loamy Sand**, (SSC: 80%/10%/10%); moist; apedal developed structure; *non-sticky; non-plastic; trace fine roots; trace large roots; high porosity; few iron oxide stains; abundant subrounded to* subangular coarse sand; abundant subrounded to subangular coarse gravel; few subrounded to subangular pebbles. Gradual lower boundary.
27" – 30"		C2	**C2**: Depth: 29.0-32.0"; Brown (10YR, 4/3); **Gravelly Sand** (SSC: 50%/40%/10%); moist; apedal developed structure; non-plastic; non-sticky; some fine roots; few large roots; high porosity; few iron oxide stains; abundant subrounded to subangular coarse sand; abundant subrounded to subangular coarse gravel; some subrounded to subangular coarse pebbles. Refusal at 34".
30" – 33"			
33" – 36"			TD 34"
36" – 39"			
39" – 42"			
42" – 45"			
45" – 48"			

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-8 **TOTAL DEPTH:** 31"

BORING LOCATION: Drakesbad Meadow, north side of meadow, south of Drakesbad horse coral.

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a

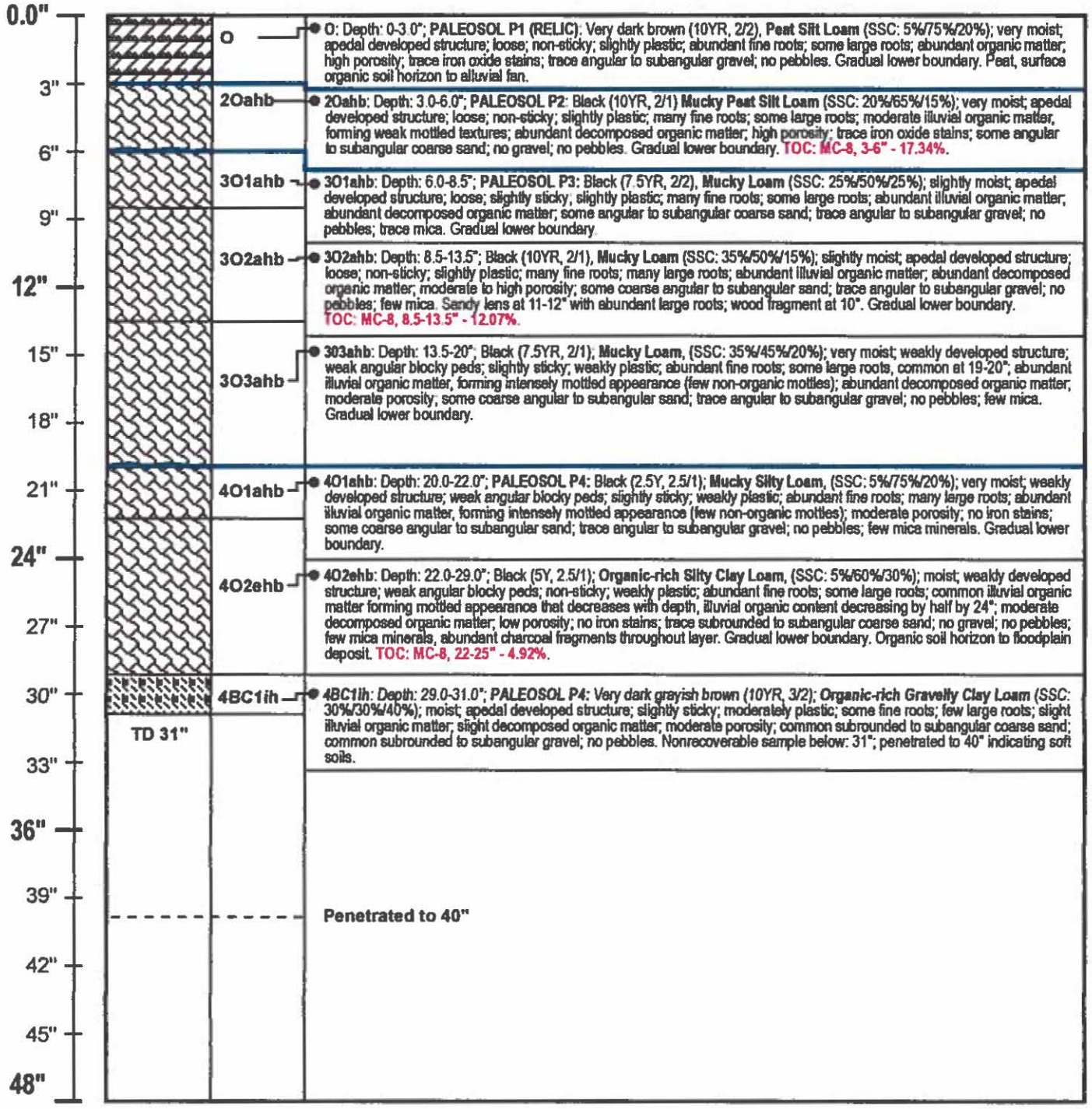
CHARCOAL: YES **DEPTH:** 10" & 22-29" **QUALITY:** good

DATE: 9/5/02 **TIME:** Afternoon

ELEVATION: 5575'

WEATHER: clear, hot

SPECIAL NOTATIONS: Penetrated to 40"; sample slipped out of corer >31"



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-9 **TOTAL DEPTH:** 25"

BORING LOCATION: Drakesbad Meadow, south of Drakesbad Lodge.

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a

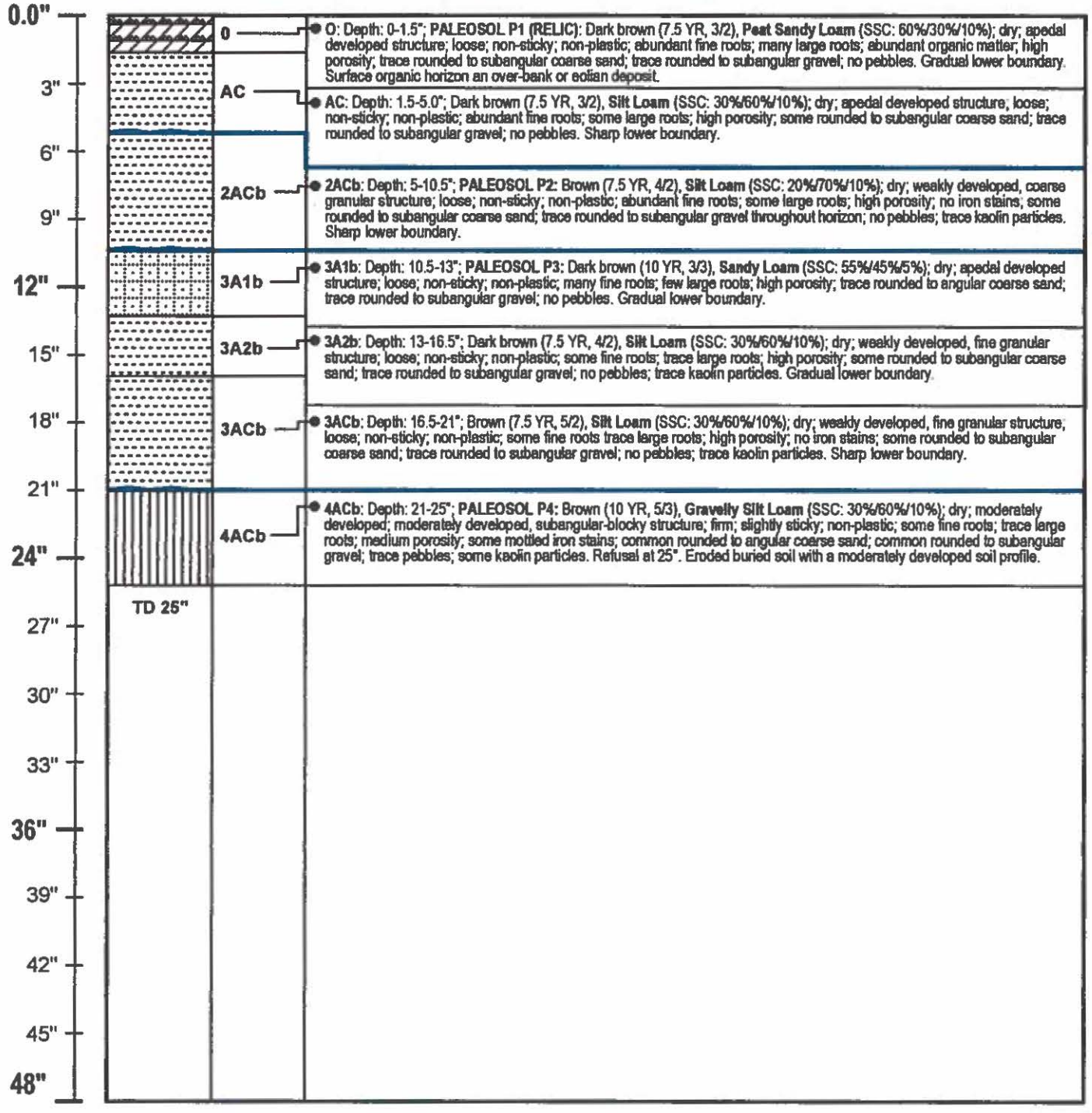
CHARCOAL: No **DEPTH:** n/a **QUALITY:** n/a

DATE: 9/5/02 **TIME:** Afternoon

ELEVATION: 5570'

WEATHER: clear, hot

SPECIAL NOTATIONS: Refusal at 25"



Depth	Lithology	Horizon	Description
0.0" – 1.5"		0	O: Depth: 0-1.5"; **PALEOSOL P1 (RELIC):** Dark brown (7.5 YR, 3/2), **Peat Sandy Loam** (SSC: 60%/30%/10%); dry; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; many large roots; abundant organic matter; high porosity; trace rounded to subangular coarse sand; trace rounded to subangular gravel; no pebbles. Gradual lower boundary. Surface organic horizon an over-bank or eolian deposit.
1.5" – 5.0"		AC	AC: Depth: 1.5-5.0"; Dark brown (7.5 YR, 3/2), **Silt Loam** (SSC: 30%/60%/10%); dry; apedal developed structure; loose; non-sticky; non-plastic; abundant fine roots; some large roots; high porosity; some rounded to subangular coarse sand; trace rounded to subangular gravel; no pebbles. Sharp lower boundary.
5.0" – 10.5"		2ACb	2ACb: Depth: 5-10.5"; **PALEOSOL P2:** Brown (7.5 YR, 4/2), **Silt Loam** (SSC: 20%/70%/10%); dry; weakly developed, coarse granular structure; loose; non-sticky; non-plastic; abundant fine roots; some large roots; high porosity; no iron stains; some rounded to subangular coarse sand; trace rounded to subangular gravel throughout horizon; no pebbles; trace kaolin particles. Sharp lower boundary.
10.5" – 13"		3A1b	3A1b: Depth: 10.5-13"; **PALEOSOL P3:** Dark brown (10 YR, 3/3), **Sandy Loam** (SSC: 55%/45%/5%); dry; apedal developed structure; loose; non-sticky; non-plastic; many fine roots; few large roots; high porosity; trace rounded to angular coarse sand; trace rounded to subangular gravel; no pebbles. Gradual lower boundary.
13" – 16.5"		3A2b	3A2b: Depth: 13-16.5"; Dark brown (7.5 YR, 4/2), **Silt Loam** (SSC: 30%/60%/10%); dry; weakly developed, fine granular structure; loose; non-sticky; non-plastic; some fine roots; trace large roots; high porosity; some rounded to subangular coarse sand; trace rounded to subangular gravel; no pebbles; trace kaolin particles. Gradual lower boundary.
16.5" – 21"		3ACb	3ACb: Depth: 16.5-21"; Brown (7.5 YR, 5/2), **Silt Loam** (SSC: 30%/60%/10%); dry; weakly developed, fine granular structure, loose; non-sticky; non-plastic; some fine roots trace large roots; high porosity; no iron stains; some rounded to subangular coarse sand; trace rounded to subangular gravel; no pebbles; trace kaolin particles. Sharp lower boundary.
21" – 25"		4ACb	4ACb: Depth: 21-25"; **PALEOSOL P4:** Brown (10 YR, 5/3), **Gravelly Silt Loam** (SSC: 30%/60%/10%); dry; moderately developed; moderately developed, subangular-blocky structure; firm; slightly sticky; non-plastic; some fine roots; trace large roots; medium porosity; some mottled iron stains; common rounded to angular coarse sand; common rounded to subangular gravel; trace pebbles; some kaolin particles. Refusal at 25". Eroded buried soil with a moderately developed soil profile.
25" – 48"	TD 25"		

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-10 **TOTAL DEPTH:** 12.5" **DATE:** 9/10/02 **TIME:** Morning

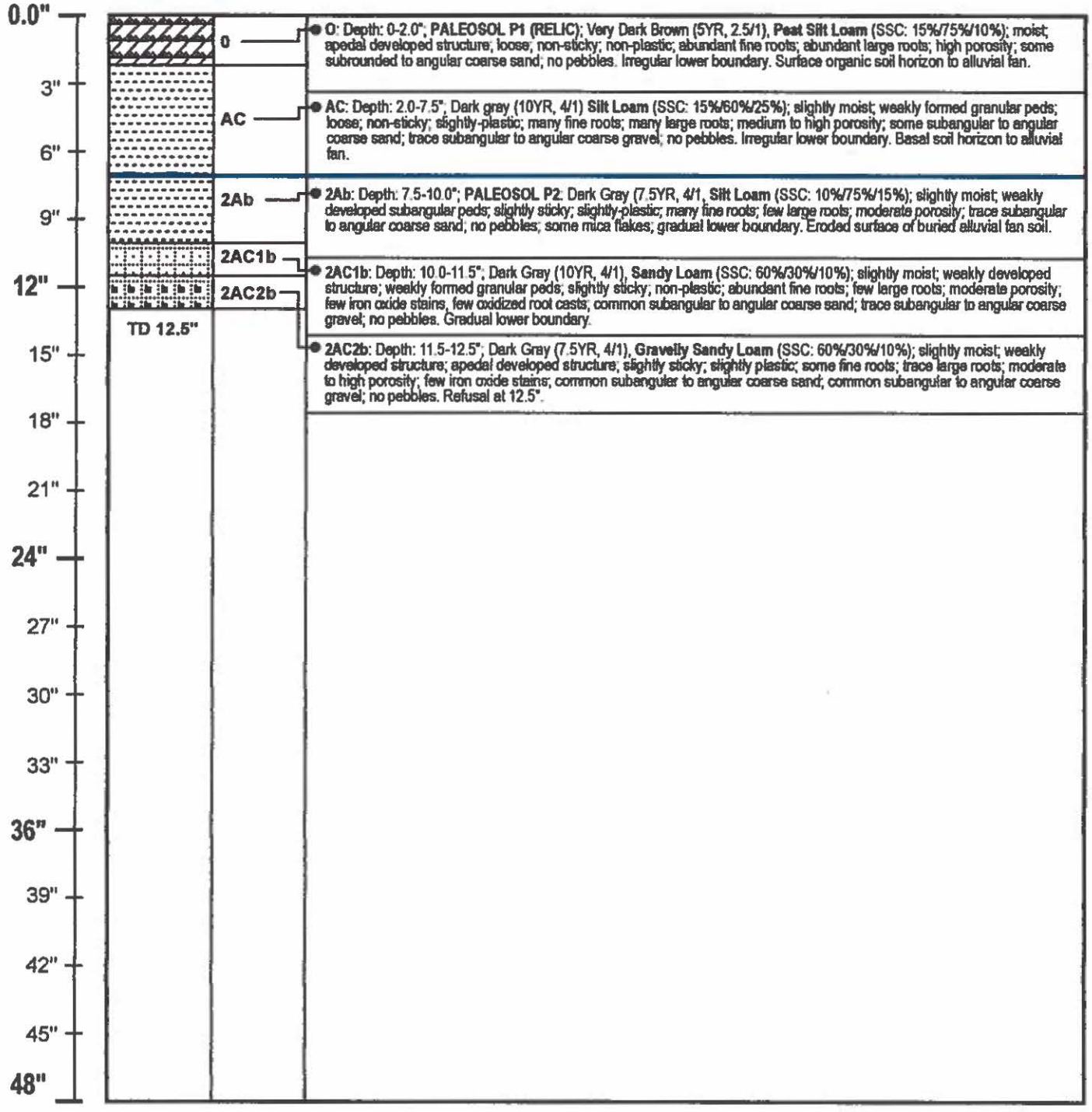
BORING LOCATION: Drakesbad Meadow, N lower meadow, between bungalows 3/4 and 5/6 on upper slope. **ELEVATION:** 5565'

WEATHER: clear, hot

TEPHRA/KAOLIN: No **DEPTH:** n/a **QUALITY:** n/a

CHARCOAL: No **DEPTH:** n/a" **QUALITY:** n/a

SPECIAL NOTATIONS: Dry surface conditions; refusal at 12.5; two cores.



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

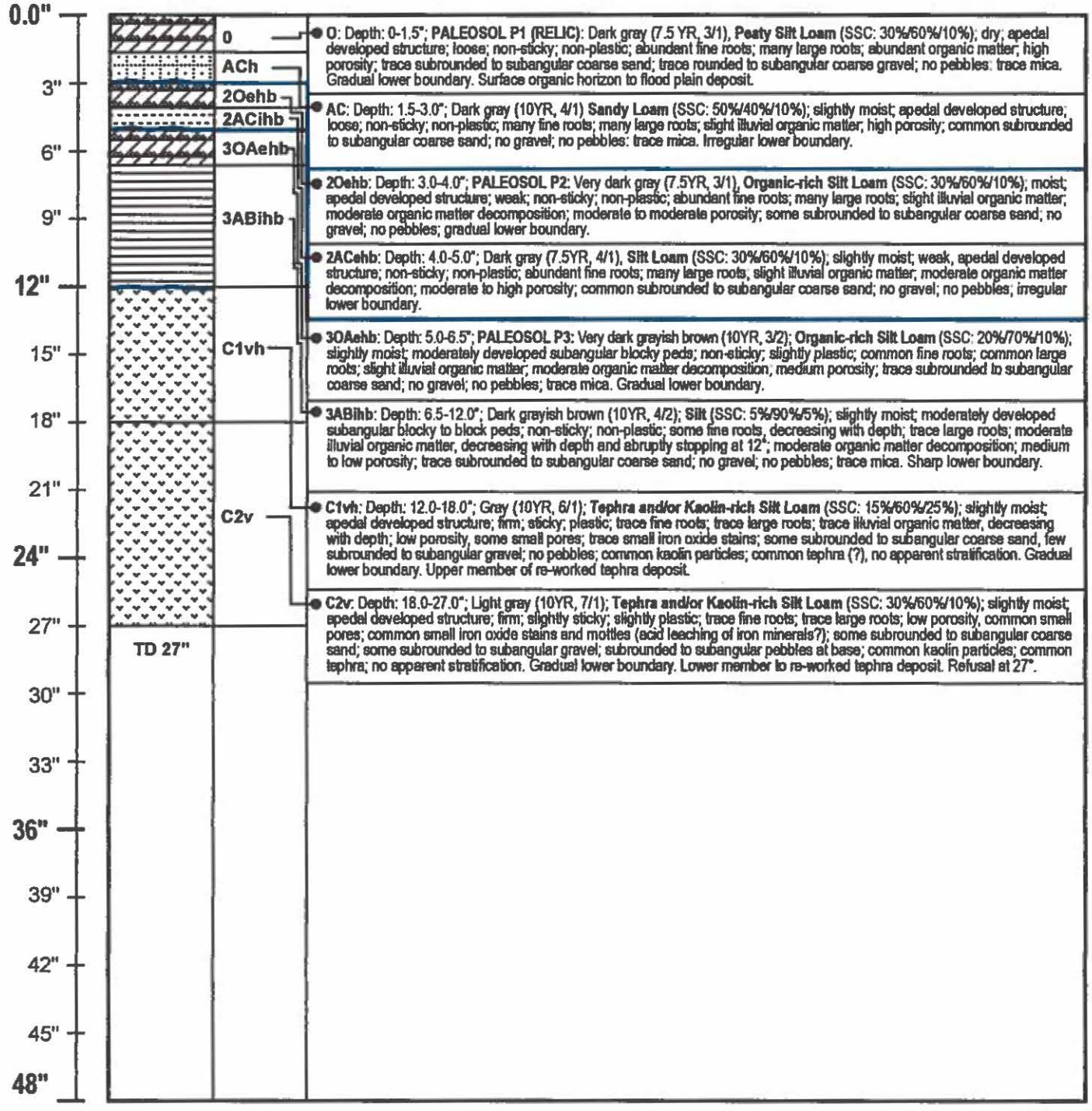
BORING NO. MC-11 **TOTAL DEPTH:** 27" **DATE:** 9/10/02 **TIME:** Afternoon

BORING LOCATION: Center of Lower Drakesbad **ELEVATION:** 5570'

Meadow, 20' north of Drake ditch, near well #144 **WEATHER:** clear, hot

TEPHRA/KAOLIN: Yes **DEPTH:** >12" **QUALITY:** poor **SPECIAL NOTATIONS:** Refusal at 27"

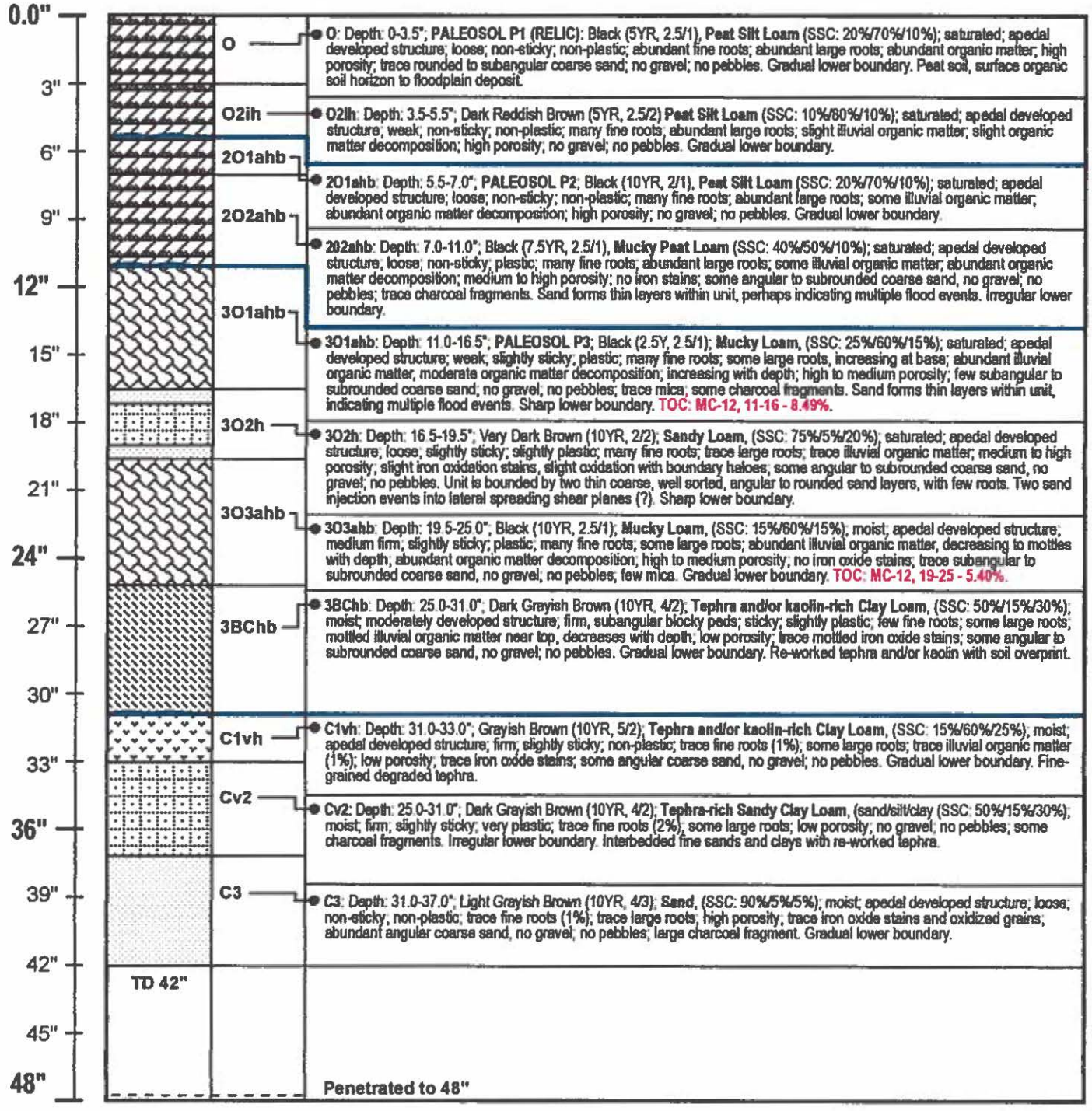
CHARCOAL: No **DEPTH:** n/a" **QUALITY:** n/a



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-12 **TOTAL DEPTH:** 42"
DATE: 9/10/02 **TIME:** Afternoon
BORING LOCATION: Drakesbad Meadow, northwest middle meadow, south of water tank, on prograding fan.
ELEVATION: 5580'
WEATHER: clear, hot
TEPHRA/KAOLIN: Yes **DEPTH:** 25-31" **QUALITY:** good
SPECIAL NOTATIONS: Penetrated to 48"; unrecoverable >42"
CHARCOAL: YES **DEPTH:** 7-16" & 25-42 **QUALITY:** good



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

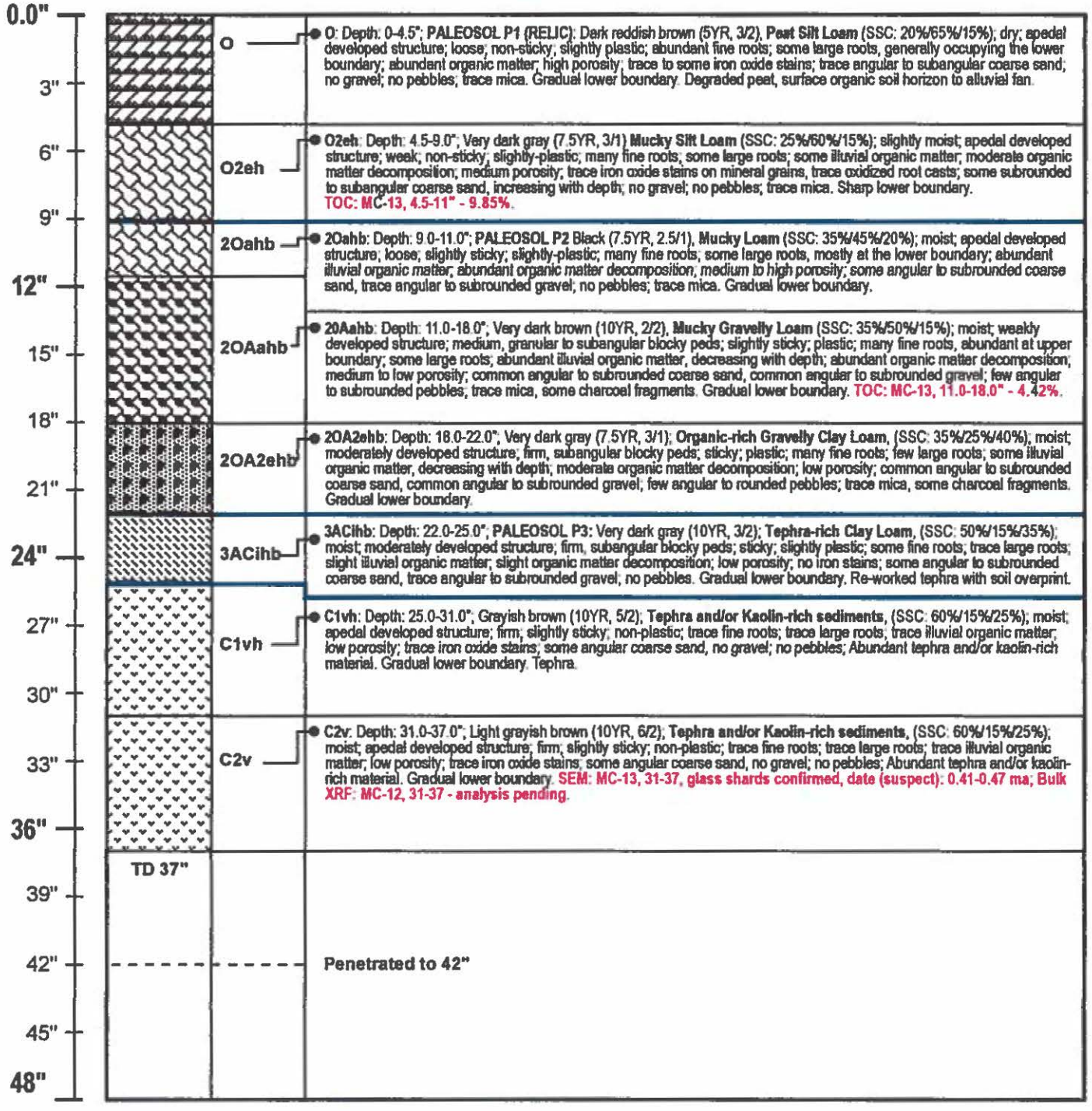
Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-13 **TOTAL DEPTH:** 37" **DATE:** 9/10/02 **TIME:** Afternoon

BORING LOCATION: Drakesbad Meadow, northwest middle meadow, south of water tank, on prograding fan. **ELEVATION:** 5580'

TEPHRA/KAOLIN: Yes **DEPTH:** >22" **QUALITY:** v.good **WEATHER:** clear, hot

CHARCOAL: YES **DEPTH:** 11-18" **QUALITY:** good **SPECIAL NOTATIONS:** Dry surface conditions; unrecoverable >37"



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-17 **TOTAL DEPTH:** 19" **DATE:** 9/24/02 **TIME:** Morning

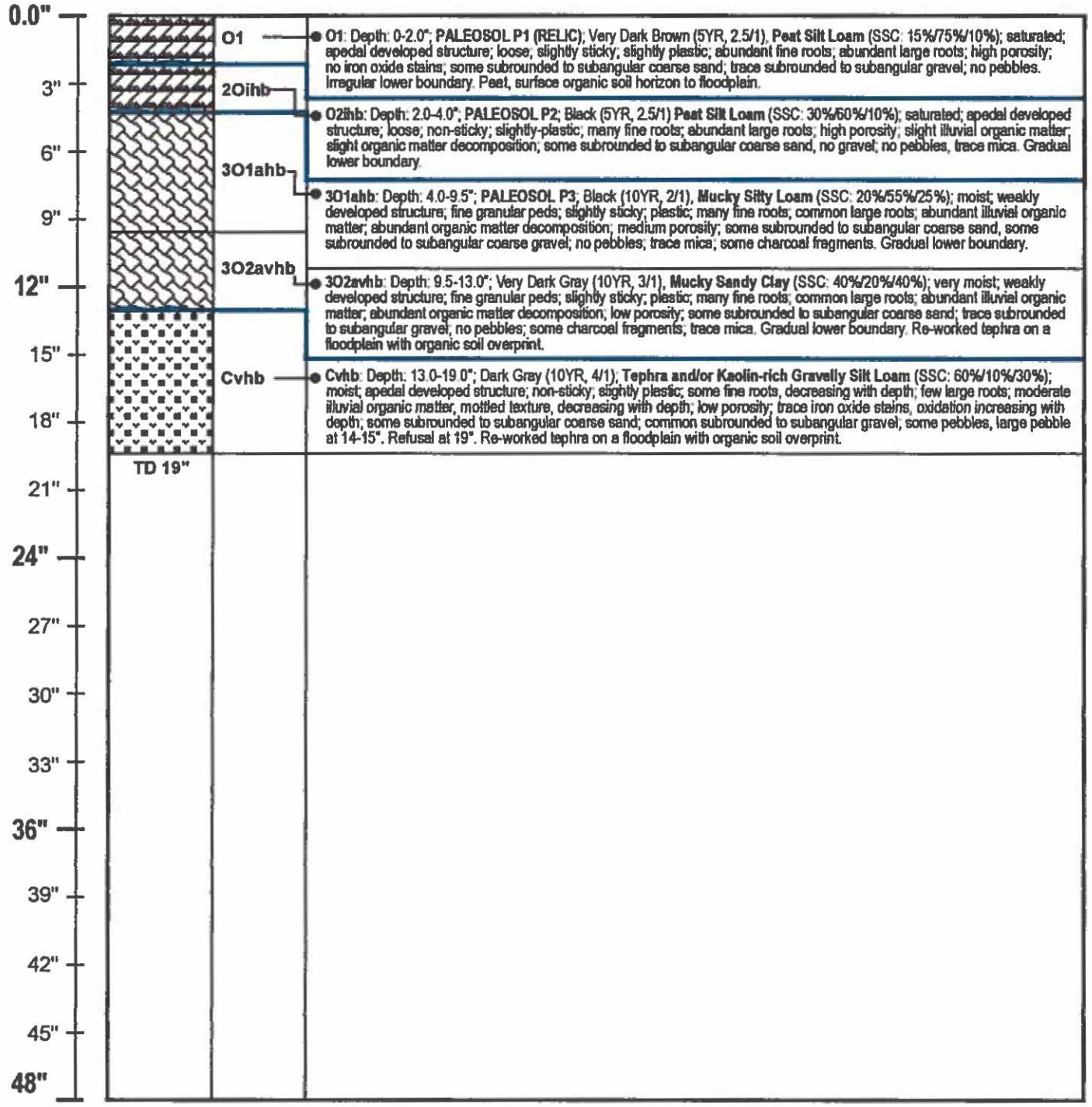
BORING LOCATION: Drakesbad Meadow, SW middle meadow, 20-30' W of row of trees. **ELEVATION:** 5575'

WEATHER: clear, hot

TEPHRA/KAOLIN: Yes **DEPTH:** >13" **QUALITY:** poor

CHARCOAL: Yes **DEPTH:** 4-13" **QUALITY:** good

SPECIAL NOTATIONS: Refusal at 17"; Two cores obtained.



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-18 **TOTAL DEPTH:** 20"

BORING LOCATION: Drakesbad Meadow, northwest middle meadow, south of water tank, near trees.

TEPHRA/KAOLIN: Yes **DEPTH:** 11-13" & 16-18" **QUALITY:** good

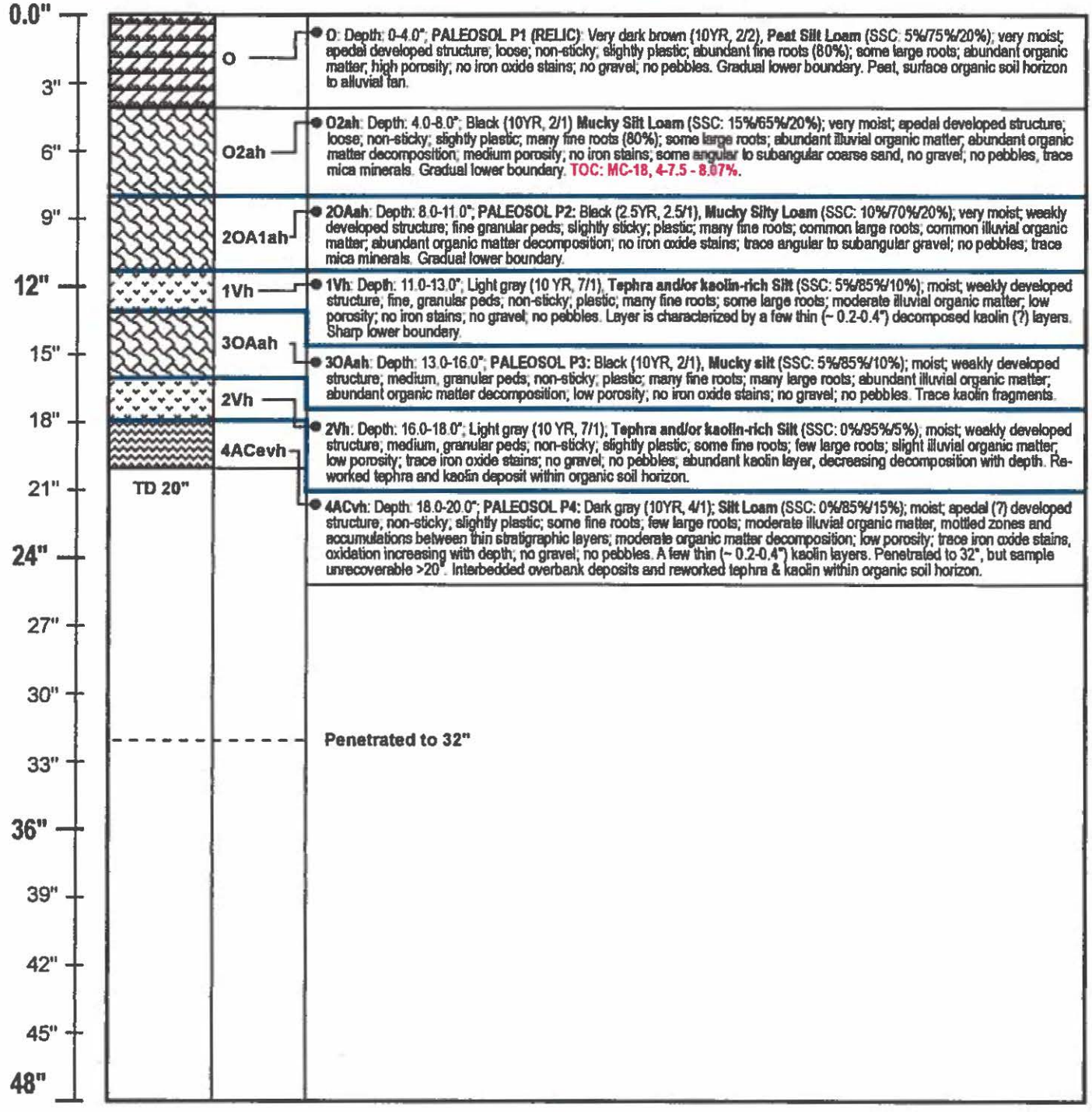
CHARCOAL: No **DEPTH:** **QUALITY:** n/a

DATE: 9/5/02 **TIME:** Afternoon

ELEVATION: 5575'

WEATHER: clear, hot

SPECIAL NOTATIONS: Saturated surface conditions; penetrated to 32", unrecoverable >20"



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Soil Description Log
Hot Springs Creek Valley, Lassen Volcanic National Park

BORING NO. MC-19 **TOTAL DEPTH:** 30"

BORING LOCATION: Drakesbad Meadow, middle-west meadow, West of MC-2, west of row of N-S trees.

TEPHRA/KAOLIN: Yes **DEPTH:** 21-28" **QUALITY:** poor

CHARCOAL: Yes **DEPTH:** 14-21" **QUALITY:** good

DATE: 09/24/02 **TIME:** Afternoon

ELEVATION: 5575'

WEATHER: clear, hot

SPECIAL NOTATIONS: Saturated surface conditions; non-recoverable >30"

Depth	Lithology	Horizon	Description
0.0" – 3"		O	**O**: Depth: 0-5.0"; **PALEOSOL P1 (RELIC)**: Black (5YR, 2/1), **Peat Sandy Loam** (SSC: 25%/55%/5%); saturated; apedal developed structure; loose; non-sticky; slightly plastic; abundant fine roots; some large roots; abundant organic matter; high porosity; trace angular to subangular coarse sand; no gravel; no pebbles; trace mica. Gradual lower boundary. Peat, surface organic soil horizon to alluvial fan.
3" – 6" – 9"		2Oeh	**Oeh**: Depth: 5.0-9.0"; **PALEOSOL P2**: Very dark gray (7.5YR, 2.5/1) **Mucky Loamy Sand** (SSC: 80%/15%/5%); saturated; apedal developed structure; weak; non-sticky; non-plastic; many fine roots; common large roots; moderate illuvial organic matter; abundant organic matter decomposition; high porosity; common subrounded to angular coarse sand; abundant in lower half; no gravel; no pebbles; trace mica. Irregular lower boundary. **TOC: MC-19, 5-9 - 10.79%.**
9" – 12"		3O1ahb	**3O1ahb**: Depth: 9.0-14.0"; **PALEOSOL P3**: Black (2.5YR, 2.5/1), **Muck Loam** (SSC: 25%/45%/20%); moist; apedal developed structure; loose; slightly sticky; slightly plastic; many fine roots; common large roots; abundant illuvial organic matter, abundant organic decomposition; medium-high porosity; some subangular to subrounded coarse sand; trace subangular to subrounded coarse gravel; no pebbles; trace mica. Gradual lower boundary. **TOC: MC-19, 9-14 - 8.13%.**
15" – 18" – 21"		3O2ahb	**3O2ahb**: Depth: 14.0-21.0"; Black (GLEY 1, 2.5/N), **Organic-rich Loam** (SSC: 15%/70%/15%); wet; apedal developed structure; medium density; slightly sticky; plastic; many fine roots; many large roots; abundant illuvial organic matter, mottling with depth, abundant organic decomposition, trace wood fragments; medium porosity; trace angular to subrounded coarse sand; trace angular to subrounded gravel; no pebbles; trace mica, trace charcoal fragments. Irregular lower boundary. **TOC: MC-19, 14-19 - 5.69%.**
21" – 24" – 27"		Cvh	**Cvh**: Depth: 21.0-28.0", Dark Gray (7.5YR, 4/1), **Tephra and/or Kaolin-rich Loam**, (SSC: 50%/10%/40%); moist; weakly developed structure; moderately firm, subangular blocky peds; very sticky; weakly plastic; some fine roots; few large roots; moderate mottled illuvial organic matter near top, decreasing rapidly with depth; low porosity; some angular to rounded coarse sand, fine sand layer, near bottom; some angular to rounded gravel; trace rounded pebbles. Abundant tephra and or kaolin particles. Gradual lower boundary. Reworked tephra or kaolin deposit.
30"		Ch	**Ch**: Depth: 28.0-30.0"; Very Dark Grayish Brown (2.5YR, 3/2), **Gravelly Loamy Sand** (SSC: 80%/5%/15%); moist; apedal developed structure; slightly sticky; moderately plastic; some fine roots; few large roots; trace illuvial organic matter; moderate porosity; no iron stains; common rounded to subangular gravel; some common rounded to subangular pebbles. Abundant tephra and or kaolin particles. Refusal at 30".
TD 30"			
33" – 36" – 39" – 42" – 45" – 48"			

Appendix 4

Geologic Research Project in the Warner Valley,

Phase II - Soils and Tephra Sampling

1. Contract with Lassen Park Foundation

2. Scope of Work Proposal

**3. Drakesbad Meadow Meeting Summary,
Drakesbad, California, October 29, 2001**

Advanced Geologic Exploration, Inc.
PO Box 2464, Lake Almanor, CA 96137 • Voice: (530) 596-3221 • Fax (530) 596-3221 • www.advancedgeologic.com

LASSEN PARK FOUNDATION

BOARD OF DIRECTORS
John W. Koeberer, Chairman
Susan J. Watson, Vice Chair
John Pelkan, Vice Chair
James L. Hazard, Vice Chair
Casie E. Hill, Chief Financial Officer

Dr. Arthur Bachelor
Cameron Baker
Karen Christensen
Trish Clarke
William N. Dennison
Arthur W. Feidler III
Nathan G. Hale
Judd Hanna
John E. Henning, Jr.
Gary Katz
Pam Koeberer Pitts
George Kutras
Judy Lalouche
Len McCandliss
Marilyn McGee
Barbara McIver
Robert C. Morrison
John E. Murray
Kevin L Murray
Nancy Nordensen
George Perkins
Nancy Piret
John A. Reis
Robert S. Reis
Bob Roberts
George Russell
Mazie Sanders
John Sharrah
Bob Simpson
Deborah Smith Wentworth
Briar Tazuk
David Trotter
Bob Warren
Nancy Weber
Donald Webster
Wallace Wertsch
Molly Wilson

HONORARY DIRECTOR
Mrs. Roy D. Sifford

AGENCY LIAISONS
Marilyn H. Parris
Superintendent
Lassen Volcanic National Park

Dan Jones
Chief of Maintenance
Lassen Volcanic National Park

Karen Haner
Chief of Interpretation & Cultural Res.
Lassen Volcanic National Park

Ed Cole
Forest Supervisor
Lassen National Forest

Elizabeth Norton
Public Service Program Manager
Lassen National Forest

STAFF
Jane Ziad, Executive Director

June 18, 2002

Charles P. Watson
Advanced Geologic Exploration, Inc.
P.O. Box 18012
Reno, NV 89511-8012

Dear Charles:

The intention of this letter is to specify the requirements for the receipt of payment for donation monies from the Lassen Park Foundation for completion of the project Geologic Research in Warner Valley as proposed in the funding proposal submitted and approved by the Foundation on May 17, 2002. Completion of this project will be under the direction of Lassen Volcanic National Park staff and will be conducted under a National Park Service Research and Collection Permit. Phase I and II will be conducted simultaneously.

Deliverables for the project Geologic Research in Warner Valley will include:

Phase I – Geologic Mapping

1) Detailed geologic map of the Warner Valley area – Map will identify bedrock geology, fluvial geomorphology, faults and fractures, and hydrologic and geothermal source areas. The area to be covered includes the Hot Springs Creek drainage basin upstream from the Kings Creek confluence. Scale will be at least 1:24,000 and map will be ready for scanning or digitizing.
2) Spring and geothermal source area map - Scale will be at least 1:24,000 and map will be ready for scanning or digitizing.
3) Perpendicular geologic cross sections.
4) Final report including methods, data and results.

Phase II – Soil and Tephra Sampling

1) Sediment cores and tephra samples from 40-60 auger borings. At least 10 tephra samples will be submitted for laboratory analysis.
2) Logs of the cores and profiles will be completed.
3) Sample location map
4) Final report including methods, data and results.

Payment for work on the project Geologic Research in Warner Valley will be made in installments based on the following schedule:

Phase I – Geologic Mapping ($11,600 LPF)

1) Initial payment to start work (50%)	$5800
2) Approval of draft maps by park (25%)	$2900
3) Approval of final maps and final report by park (25%)	$2900

Phase II – Soil and Thephra Sampling ($10,900 LPF)

1) Initial payment to start work (50%)	$5450
2) Approval of draft report and lab results by park (25%)	$2725
3) Approval of final report by park (25%)	$2725

Yours sincerely,

Jane Ziad
Executive Director

Charles P. Watson, President, Advanced Geologic Exploration, Inc.
Charles P. Watson

Please sign the letter as a sign of your agreement with the schedule of work.
Please make a copy of the signed letter and return the copy to us.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89511-8012 • Tel: (775) 852-0992 • Fax: (775) 852-3226
e-mail: info@seismo-watch.com • Web Site: http://www.seismo-watch.com

July 5, 2002

Jan Ziad
Executive Director
Lassen Park Foundation
P.O. Box 3155
Chico, California 95927-3155

Re: Geologic Research Project Contract Warner Valley, LVNP

Dear Jane,

Thank you for the opportunity to perform the work as per the enclosed signed agreement. This is an exciting area filled with natural and cultural values and the research shall contribute greatly to assisting the ongong research objectives of the park.

The agreement called for 50% of Phase I and II totalling $11,250. The initial payment check was for $11,600 or the total cost of Phase I. At the suggestion of Sara Koenig, LVNP, please deduct the difference of $350 from the final installment payment to cover the overage.

I will be preparing a number of items, like progress reports, rock chip display boards and soil profile displays, at various times of the project. I hope they will enlighten and educate the park visitors and the Foundation supporters as to the importance of this research. Some of this information will also be posted on our web site: www.advancedgeologic.com

I look forward to completing the project as per the requirements. If you have any questions or if I can be of further assistance, please feel free to contact me at your convenience.

Sincerely,

Charles P. Watson
President and Chief Geologist

enclosures.

c.c Sara Koenig, LVNP

Park Geology
The Lassen Volcanic Center, located in Lassen Volcanic National Park, is the southern most active volcanic region in the Cascade Range. It has had an extensive eruptive history during the last half million years and consequently, bedrock deposits consist mostly of lavas, ash flow tuffs, and tuff flow breccias. To a lesser extent, air fall ash layers (tephra) are preserved in lake, marsh, and other still water sedimentary environments. Tephra layers can be used for dating geologic events or determining rates of geologic processes. Tephra layers are also valuable in correlating geologic and palaeoenvironmental events from place to place and are also useful in collaborating soil stratigraphy and radiocarbon dating analyses.

In 2000, researchers identified a rare and possibly endangered fen deposit located in the Drakesbad Meadow of upper Hot Springs Valley in Lassen Volcanic National Park. While ongoing research establishes the extent and degree of preservation and/or restoration to be applied to the fen deposit, little is known about the geology that allowed the fen to develop. A detailed map of the bedrock geology, fluvial geomorphology, faults and fractures, and hydrologic and geothermal source areas is planned, but the relationships are complex and subsurface soil samples will be required to better correlate alluvial and fluvial stratigraphic units. The easiest and least invasive method for subsurface soil recovery is by a hand-operated split-spoon augur. Intact sediment cores retain enough qualities such that logs from a series of locations can be compared and correlated.

One of the advantages to working in a volcanic terrain is that there is a high likelihood of finding tephra layers in still water sedimentary environments. One such tephra layer has been discovered in the sediments exposed on south embankment to Hot Springs Creek near the Drakesbad Bath House in Lassen Volcanic National Park. Referred to as the "Bath House Ash", it is a thin grayish-white layer located in fine-grained sediments a few tens of centimeters below a rich organic soil horizon thought to be correlative to the rare fen deposit. This discovery represents an important "time-stratigraphic" marker in the valley and suggests that if this and other tephra layers could be traced throughout the valley, they would give valuable insights to the geologic development of the valley and more specifically, the formation of the fen.

Position Title: Senior Geologist

Position Description: Soil and tephra sampling project. Understanding the geologic framework of the Drakesbad Meadow is paramount to any meaningful, long-term management conclusions about the preservation and/or restoration of the fen deposit. Therefore, the goal of this project is to provide researchers of the Drakesbad Meadow Restoration Project with a valuable piece of the complex geologic story from which appropriate management decisions can be made.

The geologist will direct and participate in the recovery of soil and tephra samples from the Bathhouse Ash exposure site by two methods, 1) directly from the stream bank exposure, and 2) with a hand-operated a split-spoon augur of the soil deposits directly above the stream bank exposure. The split-spoon auguring will extract a complete sediment core from the organic horizon to below the tephra layer. A complete and

detailed log of the stream bank deposit will be compared to the split-spoon sediment core log. The sediment core will be boxed and stored for future analyses and a tephra sample will be submitted for laboratory analyses.

Additional split-spoon auger borings will be sited in strategic locations of Drakesbad Meadow and surrounding areas. Paramount will be recovering of subsurface soils and sediments from the active fen-forming terrace surfaces; however, operations will also target, non-fen soils and remnant fluvial terrace soils perpendicularly and longitudinally to the valley. The cores will the logged, sampled and appropriately archived for future analyses. It is anticipated that 40-60 cores will be recovered and 10 tephra samples will be submitted for laboratory analysis. Logs of these cores will be compared and profiles will be constructed. A report will outline the preliminary findings of the investigation and shall include a sample location map and suggestions for additional research.

Work could begin upon the melting of the snows.

Note that this project must run concurrently with the geologic assistant proposal but can run either concurrently with or sequentially after the geologic mapping project.

The Park could facilitate the project by providing assistance with basemap supplies, auguring tools and campsite accommodations.

Dates: Flexible for 8 weeks total. Time is split 1/2 field and 1/2 office/lab.

Qualifications: M.S. or higher in Geology and five years of experience in professional or academic related applications.

Park Contact: Sara Koenig
Lassen Volcanic National Park
P.O. Box 100
Mineral, CA 96063
(530) 595-4444
Sara_Koenig@nps.gov

Funding Amount Needed:

Technical services:	$8,900
Expenses	$1,200
Tephra Analysis	$2,000
Housing	n/a
	$12,100

Park: Lassen Volcanic National Park

Location: Mineral, California

Park Geology: The Lassen Volcanic Center, located in Lassen Volcanic National Park, is the southern most active volcanic region in the Cascade Range. It has an extensive eruptive history during the last half million years and consequently, bedrock deposits consist mostly of lavas, ash flow tuffs, and tuff flow breccias. To a lesser extent, air fall ash layers (tephra) are preserved in lake, marsh, and other still water sedimentary environments. Tephra layers can be used for dating geologic events or determining rates of geologic processes. Tephra layers are also valuable in correlating geologic and palaeoenvironmental events from place to place and are also useful in collaborating soil stratigraphy and radiocarbon dating analyses.

In 2000, researchers identified a rare and possibly endangered fen deposit located in the Drakesbad Meadow of upper Hot Springs Valley in Lassen Volcanic National Park. While ongoing research establishes the extent and degree of preservation and/or restoration to be applied to the fen deposit, little is known about the geology that allowed the fen to develop. A detailed map of the bedrock geology, fluvial geomorphology, faults and fractures, and hydrologic and geothermal source areas is planned, but the relationships are complex and subsurface soil samples will be required to better correlate alluvial and fluvial stratigraphic units. The easiest and least evasive method for subsurface soil recovery is by a hand-operated split-spoon augur. Intact sediment cores retain enough qualities such that logs from a series of locations can be compared and correlations applied.

One of the advantages to working in a volcanic terrain is that there is a high likelihood of finding tephra layers in still water sedimentary environments. One such tephra layer has been discovered in the sediments exposed on south embankment to Hot Springs Creek near the Drakesbad Bath House in Lassen Volcanic National Park. Referred to as the "Bath House Ash", it is a thin grayish-white layer located in fine-grained sediments a few tens of centimeters below a rich organic soil horizon thought to be correlative to the rare fen deposit. This discovery represents an important "time-stratigraphic" marker in the valley and suggests that if this and other tephra layers could be traced throughout the valley, they would give valuable insights to the valley's geotectonic development and the formation of the fen.

Position Title: Assistant Geologist

Position Description: Soil and tephra sampling project. Understanding the geologic framework of the Drakesbad Meadow is paramount to any meaningful, long-term management conclusions about the preservation and/or restoration of the fen deposit. Therefore, the goal of this project is to provide researchers of the Drakesbad Meadow Restoration Project with a valuable piece of the complex geologic story from which appropriate management decisions can be made.

The assistant geologist will aid a senior geologist in recovering soil and tephra samples with a hand-operated split-spoon augur. The split-spoon augur extracts relatively complete sediment cores from the subsurface and is an ideal method of sampling in sensitive areas; however, it is challenging for a single operator given a project of this

size. It is anticipated that 40-60 cores will be recovered for analysis. The geologic assistant will be involved in sediment logging and core storage procedures. They will also assist in core recovery from the field and processing the core at the laboratory.

Dozens tephra samples will be recovered, perhaps a few from each core. The geologic assistant will participate in tephra logging, sampling and cataloging procedures. They will also help evaluate and prepare samples prior to shipping to the analytical laboratory. It is anticipated that from the few dozen tephra samples recovered, ten will be submitted for laboratory analysis. Once the cataloging has been completed, the geologic assistant will be involved sample storage procedures. The geologic assistant will participate in the preparation and interpretation of stratigraphic profiles and compiling data for the final report.

Work could begin upon the melting of the snows.

Note that this project must run concurrently with the senior geologist proposal but can run either concurrently with or sequentially after the geologic mapping project.

Dates: Flexible for 8 weeks total. Time is split 1/2 field and 1/2 office/lab.

Qualifications: B.S. or higher in Geology and two years of experience in professional or academic related applications.

Park Contact: Sara Koenig
Lassen Volcanic National Park
P.O. Box 100
Mineral, CA 96063
(530) 595-4444
Sara_Koenig@nps.gov

Funding Amount Needed:

Technical services:	$3,000
Expenses	$800
Housing	n/a
	$3,800

Drakesbad Meadow Meeting Summary
Drakesbad, California, October 29, 2001

By: Charles P. Watson
President and Chief Geologist
Advanced Geologic Exploration, Inc.
Reno, Nevada

December 5, 2001

Executive Summary.

The National Park Service is on course to providing quality management decisions for the Hot Springs Creek wetlands, including the Drakesbad meadow, in Lassen Volcanic National Park. They have identified the need for long-term scientific research goals and have plans by which these studies will allow for meaningful recommendations for the preservation and restoration of this valuable natural and cultural resource.

Introduction.

Recent issues regarding management of the Hot Springs Creek wetlands has brought together a number of experts from government, academic, and professional areas to discuss how preservation of this valuable natural and cultural resource can best be achieved. The Hot Springs Creek wetland is located some 13 miles northwest of Chester, California, in upper Hot Springs Creek valley, within the boundaries of Lassen Volcanic National Park (LVNP). It is about 90 acres in size and is an area of a diverse mixture of biology, hydrology and geology. It also has been a popular destination area for people for over a hundred years. The Drakesbad meadow is part of the Hot Springs Creek wetlands. Prior to its incorporation into LVNP in 1958, it was first a homestead and then a guest ranch facility. Since 1958, a concessionaire under National Park Service control has maintained the facility.

Protection of the Hot Springs Creek wetlands was mandated after an inventory performed by the US Fish & Wildlife Service, as per the 1977 Presidential Executive Order 11990, identified Hot Springs Creek, the meadow, and all feeder streams and springs in the drainage as meeting criteria of potential wetlands. Executive Order 11990 was issued by the President "... to avoid to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and to avoid direct or indirect support of new constructions in wetlands wherever there is a practicable alternative..." Furthermore, release of National Park Service Director's Order 77-1 in 1998 established policies, requirements and standards for implementing Executive

Order 11990 in National Parks. In summary, Director's Order 77-1 directs the National Park Service (NPS) to: 1) provide leadership and to take action to minimize the destruction, loss or degradation of wetlands; 2) preserve and enhance the natural and beneficial values of wetlands; and 3) avoid direct or indirect support of new construction in wetlands unless there are no practicable alternatives to such construction and proposed action includes all practicable measures to minimize harm to wetlands.

Paramount to the Hot Springs Creek wetland management issue is the recently discovered and possibly rare and/or endangered fen, a unique peat soil, within the Drakesbad meadow. NPS indicated the wetlands and the fen have been "severely" degraded by cultural activities over the last 100 years, most of which occurred prior to Hot Springs Creek valley's incorporation into the National Park in 1958 and; therefore, actions must be taken to restore these unique wetlands to its pre-cultural characteristics, as per Executive Order 11990 and National Park Service Director's Order 77-1. In order to gain increased understanding of the wetland and fen ecosystem, a hydrologic monitoring program was implemented in 2000 to provide the basis determining what restoration, if any, should be implemented to preserve the Hot Springs Creek wetlands ecosystem.

A meeting was scheduled on October 29, 2001, between LVNP representatives and Lassen Park Foundation members to learn about and discuss the LVNP management plan for the Drakesbad meadow. Because of my professional geological knowledge, long family history in the area, and prior understanding of Hot Springs Creek valley and the Drakesbad meadow, I was asked by Susan Watson, Robert Morrison and John Pelkan of the Lassen Park Foundation to accompany them to the meeting.

The Meeting.

The purpose of the meeting was to discuss the NPS management plan for the Hot Springs Creek wetlands and tour the Drakesbad meadow. Since much of the basis for the management plan relies on field data, the meeting was coordinated at the meadow. A lengthy tour allowed the members to observe various aspects of the wetlands.

The following people attended the Drakesbad meadow meeting on October 29:

- Louise Johnson, Lassen Volcanic National Park
- Sara Koenig, Lassen Volcanic National Park
- Dr. David Cooper, Colorado State University
- Susan Watson, Lassen Park Foundation
- Charles Watson, Advanced Geologic Exploration, Inc.

Robert Morrison and John Pelkan of the Lassen Park Foundation were unable to attend the meeting because of prior commitments. Dr. David Cooper, a highly

regarded researcher of wetland environments, had been asked by the NPS to attend the meeting. He also assists the NPS in the Drakesbad meadow fen restoration project.

The weather was overcast and cool, with occasional drizzles of rain, but access to the wetlands was good. The Drakesbad Guest Ranch facility had recently closed for the season.

The Tour Route.

After first meeting in the lodge parking lot at about 9 a.m., the group moved down the main footpath to the center of the meadow where introductions continued. The initial discussions surrounded the monitoring well study and the criteria for fen identification. Dr. Cooper outlined the basic criteria for a fen was 40 cm (or roughly 16 in.) thick of actively growing peat in saturated soil conditions and gave a brief description fen research elsewhere in the United States. The excursion proceeded to the stream bank of Hot Springs Creek near the Boiling Springs Trail Bridge where a soil profile was examined. The group then looked at examples in the middle meadow of drainage channels and ditches, saturated versus non-saturated soils conditions, and exotic plant species. Flow rates for the "Spring Creek" tributary were observed, and a number of items were examined in the upper meadow, including surface soil conditions, fluvial-geomorphology, and possible fault offsets. A few monitoring wells were checked and groundwater levels were measured or estimated.

The excursion returned to the lower middle meadow area where Sara Koenig departed, and the remainder of the group continued across the meadow south of the Lodge to the Bath House where exposures of the "Bath House Ash" were examined. The group returned to the Lodge parking lot where Charles Watson distributed a handout and discussed the significance of geologic issues on fen development. The tour was completed around 1:00 p.m.

Discussions and Consensus.

The group displayed a spirit of cooperation in discussing and learning about the ecosystem of Drakesbad meadow. We all agreed that the ecosystem was a complex mixture of environmental factors that has been influenced, to some degree, by cultural activities. LVNP conveyed they were in the initial stages of identifying the baseline environmental factors and their plan included long-term scientific research goals. They conveyed that the key to managing the preservation and/or restoration of the wetlands is understanding, to the best extent possible, what the pre-cultural conditions were like and to what extent the cultural activities have affected the natural processes of the wetlands. The group recognized the need for these detailed, long-term studies and agreed that such research needed to be mature enough to allow for meaningful management recommendations to be proposed.

Fen Verification.

Based upon the criteria presented by Dr. Cooper, there was consensus by the group that fen soils occur within the meadow. Although no soil pits were dug or precise measurements taken, clearly many sections of the middle meadow showed at least 40 cm of saturated peat soils, and some areas may support even greater fen soil thickness. Not well understood was the quality of the fen soils and their distribution, and NPS explained that this was the focus of a recently acquired special studies grant.

Many areas of the meadow were dry and do not support either fen or wetlands criteria, and it was not clear if these conditions were due to cultural or natural influences. Some dry areas "graded" into wetland conditions, while others displayed abrupt boundaries. The group agreed that each area has it is own special circumstances and that detailed studies may be needed to understand the specific parameters.

Environmental Factors.

Four basic environmental factors were discussed by the group to have affected the Hot Springs Creek wetland ecosystem and are briefly discussed below:

- Cultural Activities. The levels of cultural and historic influences on the meadow are not well understood. European occupation of the valley occurred in the late 1800s and reports indicate various activities have occurred, including the following items:

    - Roads and trail system constructions;
    - Structures, buildings, and other constructions;
    - Construction of ditches, channels, leach fields and other runoff diversions;
    - Sowing of exotic plants, harvesting practices, and brush removals;
    - Grazing of livestock and other related activities.

    The group discussed the need of assembling historic records and eyewitness accounts of the cultural history and the high value these descriptions would be to the research body. Further discussions included how scientific data must correlate with historic accounts and show that these activities have adversely affected wetland quality and that restoration was necessary.

    Key to the discussions were ditches and channels, whether they were man-made or natural, and if man-made, what were their purposes - dewatering and/or irrigation, and did they have an adverse affect on

the wetland. The invasion of exotic plants was clearly shown to be affecting the quality of the natural meadow ecosystem, as were recent constructions of stone and gravel road and trail systems.

- Hydrologic. The hydrological source for Hot Springs Creek and the associated wetland is a complex network of springs and hydrothermal manifestations, which appear to supply relatively constant flows even after winter runoff is complete and in a low precipitation season, as was the case this year. This was remarkable information to the group and solidified the understanding that the ecosystem is much more complex than previously thought. It identified the need of detailed research into the hydrological parameters of the wetlands.

  The group noticed that mid-valley spring activity is substantial and in some locations saturates large areas of surface soil horizons, thus creating ideal conditions for the wetlands. Surprisingly, however, many parts of the valley were dry and add to the complexity of the valley's diverse properties and complex natural processes.

  The need for climatological regional groundwater aquifer studies was also recognized.

- Geologic. While the meadow and its wetlands are extraordinary, its geologic origins may be even more compelling. It was presented that although no detailed studies have been conducted, Hot Springs Creek valley is believed to be an east-west-trending tectonic depression or graben, bounded on both sides by active faults. A number of cross faults are suspected to dissect the valley into segments and may control not only the rates of deposition or erosion at various points, but also hot and cold water spring locations. Hot Springs Creek currently occupies a course almost entirely on the south side of the valley, which suggests regional tectonic tilting, and has left broad erosional surfaces marked by abandoned meanders and flood scours. Remnant fluvial terraces occur on both the north and south sides of the valley; however, it is unsure if they occupy paired elevations or are tectonically displaced.

  It was discussed that since the geologic processes were intrinsic to the formation of the valley, scientific research was needed to better understand the geological contribution to the ecosystem. Moreover, these geologic studies were considered as paramount to the ongoing fen preservation/restoration program.

- Biologic. A rare combination of geologic and hydrologic parameters has provided ideal conditions for a rare fen soil formation in Hot Springs Creek Valley. While the ongoing inventory defines its

quantitative and qualitative extent, other yet to be discovered bio-diverse aspects of the wetlands may come to the foreground upon further investigation. This lack of understanding was discussed, and it was recognized the importance of preliminary biological inventories being conducted as soon as possible. Possible areas of investigation were discussed and include unusual bryophyte and algae communities near both cold and hot springs sources.

Conclusions.

The National Park Service has acted wisely in identifying the special needs of the Hot Springs Creek wetlands and Drakesbad meadow. It is understood that NPS is in the preliminary stages of a long research program of a complex ecosystem. Furthermore, it is understood that these studies must be mature enough to allow for meaningful management recommendations to be proposed.

Supplement 1

Selected Photographs

Photographs 1 and 2.



Photo 1. Soil Core MC-1.

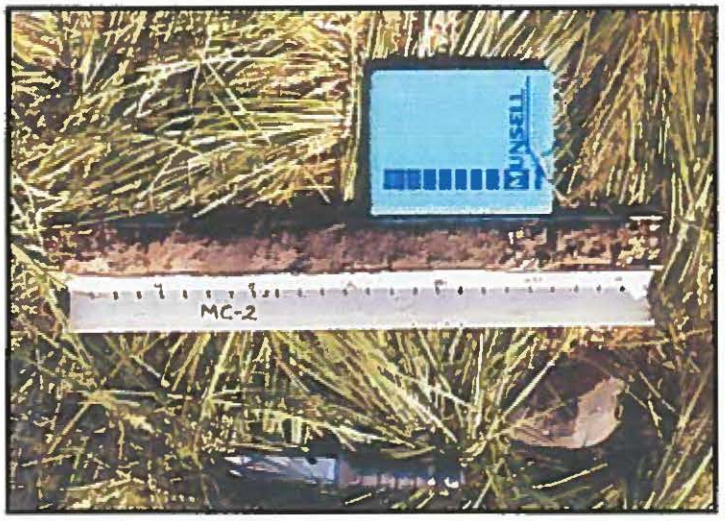


Photo 2. Soil Core MC-2.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 18012 • Reno • Nevada • 89521-8012
Tel: (775) 852-0992 • Fax: (775) 852-3226

Photographs 3 and 4.



Photo 3. Soil Core MC-3.

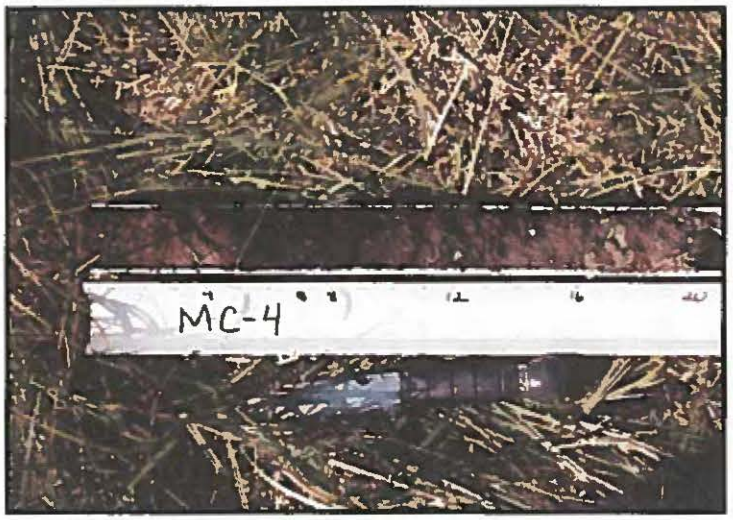


Photo 4. Soil Core MC-4.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 5 and 6.

N/A

Photo 5. Soil Core MC-5.

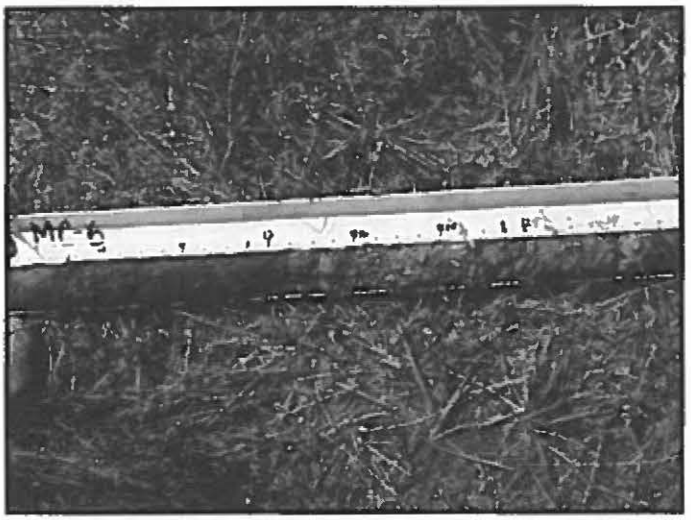


Photo 6. Soil Core MC-6.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 7 and 8.



Photo 7. Soil Core MC-7.

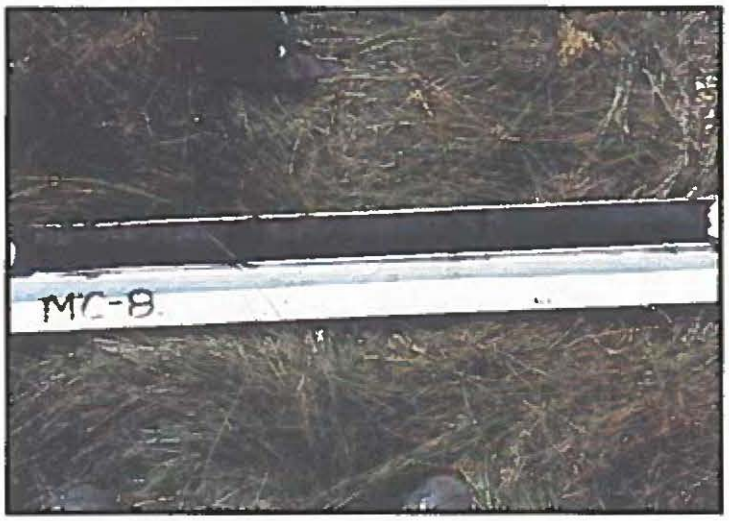


Photo 8. Soil Core MC-8.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 9 and 10.



Photo 9. Soil Core MC-9.



Photo 10. Soil Core MC-10.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 11 and 12.



Photo 11. Soil Core MC-11.



Photo 12. Soil Core MC-12.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 13 and 14.



Photo 13. Soil Core MC-13.



Photo 14. Soil Core MC-14.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 15 and 16.

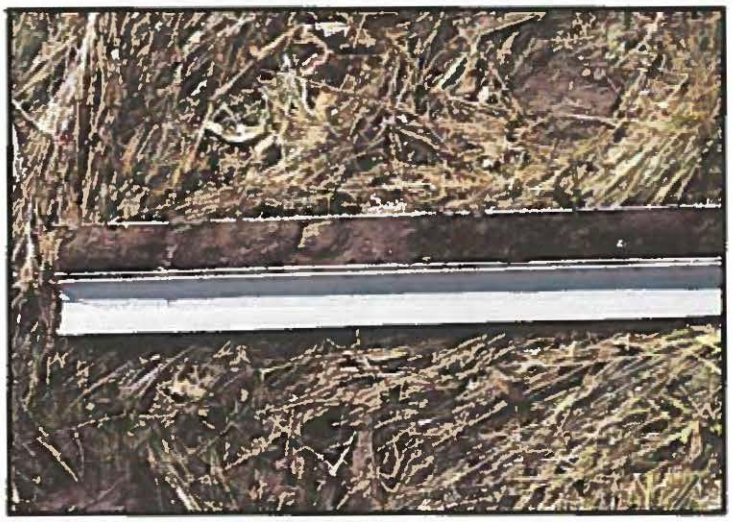


Photo 15. Soil Core MC-15.

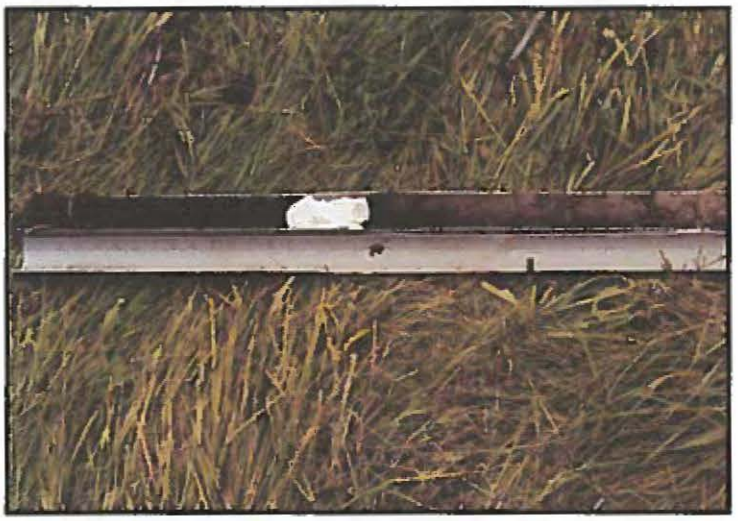


Photo 16. Soil Core MC-16.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 17 and 18.



Photo 17. Soil Core MC-17.



Photo 18. Soil Core MC-18.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 19 and 20.

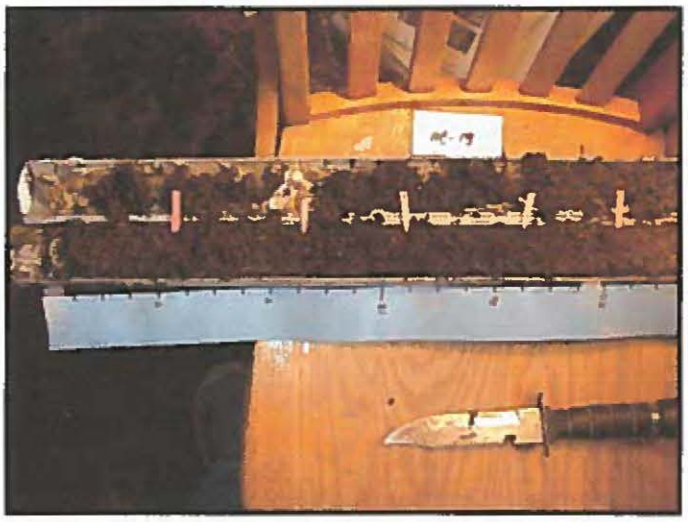


Photo 19. Soil Core MC-19.



Photo 20. Soil Core BHA-1.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 21 and 22.

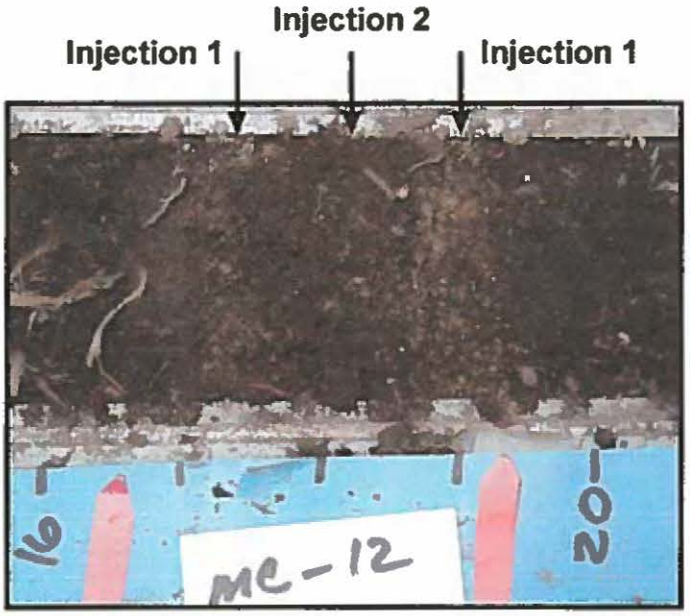


Photo 21. Soil Core MC-12. Two sand dike episodes probably caused by liquefaction.



Photo 22. Typical charcoal fragment in soil profile.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 23, 24 and 25.



Photo 23. Boiling Springs Lake

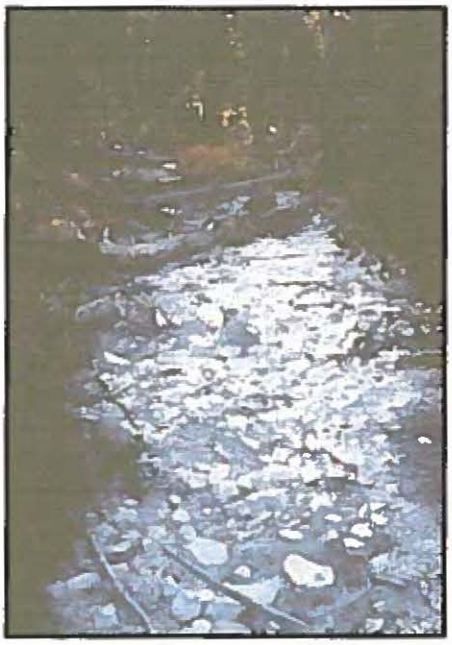


Photo 24. Boiling Springs Lake outflow channel.

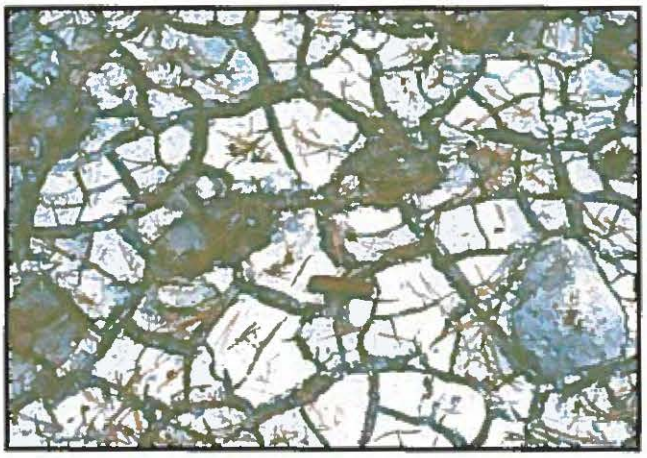


Photo 25. Dryed Kaolin clay in Boiling Springs outflow channel.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 26, 27 and 28.



Photo 26. While Kaolin clay in Hot Springs Creek, July 14, 2002.



Photo 27. Temperature reading of Hot Springs Creek at Stream Monitoring Station HSC-8, July 14, 2002. Air temperature is 85.1°F and stream temperature is 73.6°F.



Photo 28. While Kaolin clay in Hot Springs Creek, July 14, 2002.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 29 and 30.



Photo 29. Fumarole along Hot Springs Creek at Devils Kitchen responsible for kaolin outflow.



Photo 30. View of Devils Kitchen geothermal area.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 31, 32 and 33.

Photo 31. View looking southeast at the middle of Drakesbad Middle Meadow from water tank road. Date: Late May. Notice trees in meadow for reference.





Photo 32. View looking southeast at the middle of Drakesbad Middle Meadow from water tank road. Date: Late July. Notice trees in meadow for reference.

Photo 33. View looking southeast at the middle of Drakesbad Middle Meadow from water tank road. Date: Early October. Notice trees in meadow for reference.



Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221

Photographs 34 and 35.



Photos 34 and 35. View is looking west at Drakesbad Middle Meadow from horse path near the Drakesbad corral. Date: Early October.

Advanced Geologic Exploration, Inc.
Scientists of the Earth™
P.O. Box 2464 • Lake Almanor • California • 96137
Tel: (530) 596-3221 • Fax: (530) 596-3221