APPENDIX 8. QUALITY CONTROL AND QUALITY ASSURANCE REPORT (TASK B1)

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INTRODUCTION

The samples and field data (including field observations and measurements) are the basic component of the data collection and interpretation, which ultimately leads to the project conclusions. Therefore, it is important to understand the spatial and geological context and to describe the types of samples collected, sample preparation, and sample analyses. The purpose of this appendix is to present data to support the accuracy and precision for the geochemical, mineralogical, and geotechnical analyses obtained by NMBGMR. The QA/QC (Quality Assurance and Quality Control) procedures are summarized in the project work plan and described in the SOPs and the reader is referred to these documents for specific details. The data were obtained from the various laboratories and at least 10% of the data were validated or checked by an additional staff member to assure the data were entered into the Access database properly. If during validation, data were found to be entered incorrectly, the error was immediately corrected. This report only describes the sample collection and preparation for New Mexico Institute of Mining and Technology (NMIMT) laboratory analyses of samples collected during the Questa project (including analyses from New Mexico State University (NMSU), Washington State University (WSU), and ALS Chemex). The QA/QC procedures for the stable isotope, geochronology and electron microprobe laboratories at NMIMT are explained in the appropriate SOPs (listed in Appendix 8-1). This report does not include the QA/QC for the humidity cells analyses conducted at University of Utah, the geotechnical analyses conducted at University of British Columbia and Golder Laboratories, or any of the modeling activities.

TECHNICAL APPROACH

The QRPWASP was divided into specific tasks accomplished during several stages of study, and is only summarized here. The first stage of the project was to develop operational work plans and SOPs (Standard Operating Procedures listed in Appendix 8-1) to reduce error and to adopt proper and consistent procedures. A project Access database was developed to store collected data (McLemore et al., 2004a) and a project repository for all project data and reports was established. Data forms in the Access database were developed to ensure that all spatial (including detailed location data), geological, geochemical, geotechnical, hydrological, and other data, including field observations, were collected and documented (Appendix 8-2). Appendix 8-3 lists the abbreviations used to describe the various mine and geographic features in the Questa-Red River area. The parameters measured are summarized in Appendices 8-4-8-5. A summary of the geologic setting of the area is by McLemore (2008a). The amounts of sample required for each test is in Appendix 6. Sample location maps are in Appendix 8-7.

The first stage of field sampling was required to:

- Characterize the overburden, rock piles, underlying rocks, and other country rocks (i.e. the predominant sample populations of interest, other sample populations are described in Table 2-1, Appendices 8-2 and 8-4)

- Select humidity cells samples
- Select sites for in-situ shear testing
- Characterize the weathering of the rock-pile material
- Characterize the geotechnical parameters
- Determine the effect of weathering on slope stability.

Different types of samples (Table A2-1, Appendix 8-2), sample collection methods (Table A2-2, Appendix 8-2) and amount of each sample (Appendix 8-6) to obtain these objectives are described below and summarized in the appendices. These and subsequent data were used for the various geochemical, hydrological, and geotechnical models used in the project.

The exploratory stage of characterization followed, primarily to determine which samples were selected for humidity cell tests and to characterize the mined rock. The characterization results were used later to select sites for the in-situ shear tests and other selected studies (Appendix 8-4). During this exploratory stage, samples were collected for characterization of the material that went into the rock piles, rocks that underlie the rock piles, alteration scars, and debris flows. Samples of all of the major lithologic units were collected from outcrop localities, open pit, drill core and cuttings, rock piles, test pits/trenches, and pit high walls and included different degrees of hydrothermal alteration and weathering as defined by different mineral assemblages and alteration zonation (McLemore et al., 2008b). Additional samples were collected from throughout the rock piles as needed to characterize the rock piles since their formation. Mineral textures were described in order to define the paragenesis (i.e. the sequence in which minerals formed) of hydrothermal alteration and subsequent weathering (Delvigne, 1998; Jambor, 2003). The alteration scar areas were studied during this stage (Graf, 2008). Samples for geotechnical tests were selected and collected, not for typical stability analysis, but for determining the relationship between geotechnical parameters and changes in hydrothermal alteration and weathering intensity.

Additional field stages followed. The next stage of study involved characterization of GHN rock pile through trenches constructed during reclamation (Gutierrez, 2006; Shannon, 2006; Tachie-Menson, 2006; Viterbo, 2007; McLemore et al., 2004b, 2005, 2006a, b, 2008a; Gutierrez et al., 2008). Other rock piles were studied (McLemore et al., 2008c, f), but not in the detail that GHN was examined. Lithologic logs, trench maps, sample location maps, drill logs for GHN are in McLemore et al. (2008a). Sample locations are shown in Appendix 8-7 (Figure A7-2). The last stage of field data collection was to develop and perform in-situ direct shear tests to determine cohesion and friction angle directly in the field (Fakhimi et al., 2008; Boakye, 2008; McLemore and Dickens, 2008a). Other more specific samples and studies were conducted throughout the study to address specific questions and concerns and are described in the component DRAs (Appendix 8-8) and summarized in Appendix 8-4. Samples and other observational and measured data were collected and analyzed in the field during these phases. Other project tasks used these same samples and data obtained from the field study and are described in the component DRAs and project reports.

A *sample* is a representative portion, subset, or fraction of a body of material representing a defined population (Koch and Link, 1971; Wellmer, 1989; Rollinson, 1993; Davis, 1998; Schreuder et al., 2004; Neuendorf et al., 2005; Downing, 2008). A sample is that portion of the population that is actually studied and used to characterize the population. Collecting a representative sample of rock-pile material can be difficult because of the compositional, spatial, and size heterogeneity of the material. It also is necessary to define the particle-size fraction of the sample required and analyzed, because of the immense size heterogeneity in many rock piles (Smith et al., 2000). The sampling process is defined in the project sampling plan and SOPs (listed in Appendix 8-1), and is summarized below:

- Define the sample population
- Define the parameters to be measured
- Define the number of samples to be collected and where
- Define the sample collection method
- Define the quantity of sample collected
- Collect the sample according to the SOP
- Record field observations and sample description
- Review the sampling process and modify if needed.

The determination of total error of a measurement depends upon several parameters, including the sample error and analytical error (Rollinson, 1993; Schreuder et al., 2004). The sample error is the error that results from studying the collected sample instead of the entire population and depends upon completeness, comparability, and representativeness, as defined below:

- *Completeness*—the comparison between the amount of valid, or usable, data originally planned to collect, versus how much was collected.
- *Comparability*—the extent to which data can be compared between sample locations or periods of time within a project, or between projects.
- *Representativeness*—the extent to which samples actually depict the true condition or population being evaluated

Sample error is the error caused by observing a sample instead of the whole population and typically is dependent upon the sample-to-sample variation and is controlled by collecting a sample of suitable size relative to the heterogeneity of the sampled material, as well as a sufficient number of samples to characterize the population (Wellmer, 1989).

Basically, all analytical measurements are incorrect at some level and are measured against an agreed upon standard of analysis. It is just a question of how large the errors are compared to an agreed upon standard of accuracy and if those errors are acceptable; these are typically define in the original sampling plan. Analytical error is the error that results from laboratory analysis, is typically reported by the laboratory, and is defined by precision and accuracy, as defined below:

- *Precision* is the degree of agreement among repeated measurements of the same characteristic and is monitored by multiple analyses of many sample duplicates and internal standards. It can be determined by calculating the standard deviation, or relative percent difference, among samples taken from the same place at the same time (i.e. duplicates and triplicates, Fig. 8-1).
- *Accuracy* measures how close the results are to a *true* or accepted value and can be determined by analyzing certified reference standards as unknown samples and comparing with known certified values (Fig. 1).

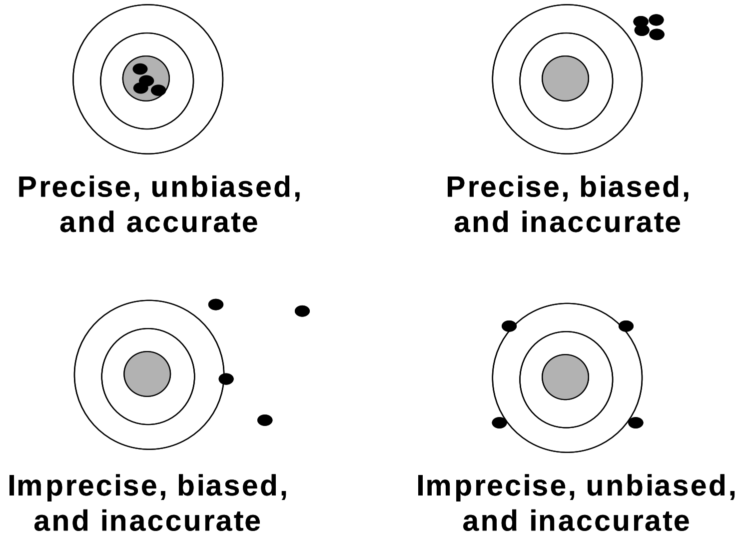


FIGURE 8-1. Diagram illustrating the difference between precision, bias, and accuracy.

All completed work plans, SOPs, project reports, theses, published papers, component DRAs, and the final programmatic DRA report are available upon request; many are available through the NMBGMR as open-file reports or published papers. The completed Access database and the project data repository also are available upon request. Most work plans and SOPs were reviewed by G. Robinson, J. Hamilton, and V.T. McLemore; some SOPs were reviewed by other specialists as specified in the SOP. Most component DRAs were peer-reviewed by non-author members of the QRPWASP team, as acknowledged in the final component DRA (summarized in Appendix 8-8). All published papers were reviewed by Chevron Mining Inc. and, in most cases, by two or more non-project reviewers, as credited in the acknowledgement section of the publications. All NMIMT student theses utilized existing SOPs (often included in the appendices of the theses), were reviewed by Chevron Mining Inc., and were reviewed and approved by a committee of three or more faculty members. Some theses also were reviewed by other QRPWASP members as acknowledged in the thesis.

FIELD PROCEDURES

A standardized protocol was followed for tasks employed in the QRPWASP (operating plans and Standard Operating Procedures, SOPs, listed in Appendix 8-1), including each collected sample (SOP 2, 5). Any deviations from the SOPs are documented in the project Access database for each specific sample or analysis. Chain of custody forms were completed for each sample and subsample split. Each laboratory manager was responsible for maintaining their records of chain of custody forms.

Different sampling strategies were employed based upon the purpose of each sampling task. Typically, at each site a grab, or bulk rock sample or other material was collected for petrographic study and geochemical analyses. A hand specimen was collected from some sites for thin section analysis. Each sample was stored in a separate bag or bucket, assigned a unique number (Table 8-2, 8-3, Field ID), logged on a field description form (Appendix 8-2), and entered into the project database. Other procedures are summarized in Appendix 8-5. Selected sample sites were marked in the field and a digital photograph (SOP 4) was taken at most localities. Photographs provide visual record of the sample site (Table 8-3). The photograph form identified site specifics, provided basic location and other data about the photograph (SOP 4). Location information obtained by global positioning system (GPS, SOP 3), type of sample, and field petrographic descriptions were collected. Geologic observations were recorded on the field description form and each site was located on a map, if possible (SOP 5). Hand specimen description provided a record of what was collected, which aided in petrographic descriptions and provided information on the sample for the laboratory analysis (for example, high pyrite samples may be treated differently than low pyrite samples). The hand specimen description was the preliminary data used to determine what samples required additional analyses. Several different types of samples were collected:

- Rock-pile material that includes both the soil matrix and rock fragments of mixtures of different lithologies and alteration assemblages (SOP 5)
    - Samples collected from the surface and from test pits throughout the rock piles
    - Samples of the rock-pile material collected from trenches in GHN (5 ft channel or composite of selected layers)
- Soil profiles of colluvium/weathered bedrock, alteration scar, and debris flows (SOP 5)
- Outcrop samples of unweathered (or least weathered) igneous rocks representative of the mined rock (overburden) (includes all predominant lithologies and alteration assemblages at various hydrothermal alteration and weathering intensities; SOP 5)
    - andesite
    - quartz latite
    - rhyolite tuff (Amalia Tuff)
    - aplite, granitic porphyry
    - miscellaneous dike, flow, and tuffaceous rocks
    - alteration scars
- Samples of the vein material within altered host rocks (typically veins are <2 cm; SOP 5)
    - quartz-molybdenite-pyrite (orthoclase flooding, biotite)
    - quartz-sericite-pyrite of rhyolite porphyry dikes
    - quartz-fluorite-sericite-pyrite-base metal sulfides (halo above mineral deposits)
    - calcite-gypsum/anhydrite
- Sections of drill-core samples of the mined rock (overburden) and ore deposit before mining (SOP 5, 6)
- Splits of drill cuttings from holes drilled into the rock piles and underlying colluvium/bedrock (SOP 5)
- Samples selected for specific analysis (age dating, stable isotopes, etc., Appendix 4, 5)

- Water samples from runoff, seeps, and springs (SOP 15)
- Leachate fluids from the humidity cells and column tests (SOP 78).

GHN rock-pile samples, drill cuttings from holes drilled into the rock piles, and samples collected from test pits throughout the rock piles represent varying degrees of hydrothermally-altered samples, some of which have been exposed to weathering since the construction of the rock pile (approximately 25-40 years). The collected samples from the rock piles consisted of a heterogeneous mixture of rock fragments ranging in size from boulders (0.5 m) to <1 mm in diameter within a fine-grained soil matrix. Most rock fragments were hydrothermally altered before mining occurred; some show signs of oxidization and weathering since emplacement in the rock pile. Outcrop samples of igneous rocks are critical to obtain the characterization of the material before it went into the rock piles (McLemore et al., 2008b). Drill-core samples represent hydrothermally-altered rocks of the pit deposit before mining that have not been exposed to post-mining surface weathering processes. Drill cores were stored in box cars or warehouses at the Questa mine and showed no visible signs of oxidation during storage. Alteration scar, debris flow, and colluvium/weathered bedrock samples represent hydrothermally-altered samples that have been weathered under similar surface weathering processes as the rock piles, but for significantly longer periods of time than the rock piles. These analog sites are analogous to the Questa mine site, because they are similar in lithology, hydrothermal alteration assemblages, mineralogy, chemistry, and clay types to the rock-pile samples, but represent long-term weathering (McLemore, 2008b; Graf, 2008). Sample location maps are in Appendix 8-7.

Sample and Photograph Nomenclature Scheme

Each sample was assigned a unique field identification (field ID) number by the field manager or sample collector (Table 8-1). The Field ID number for Questa samples comprises three components, separated by dashes, as described in Table 8-2 and SOP 2, for example SSW-HRS-0001.

TABLE 8-1. Scheme for identifying samples collected in the field, designated the Field ID. Description of mine-feature abbreviations is in Appendix 8-3.

Component 1	Component 2	Component 3
Three letter abbreviation for the mine feature, for example SSW for Sugar Shack West.	Three letter initials of the sample collector, for example HRS for Heather R. Shannon.	Sequential four number designation, for example 0001

Each sample is then assigned in the laboratory a separate sample identification number (Sample ID) designating the different sample preparation methods (Appendix 8-2, Table 2-3). The first part is identical to the Field ID number and is followed by a sequential two number, for example SSW-HRS-0001-01. The two digit lab sample can be correlated to sample preparation methods by Table 2-3 (Appendix 8-2). Figures showing sample locations are in the project reports.

TABLE 8-2. Scheme for identifying subsamples or splits of the collected field sample for specific laboratory analysis designated the Sample ID. Description of mine-feature abbreviations is in Appendix 8-3.

Component 1	Component 2	Component 3	Component 4
Three letter abbreviation for the mine feature, for example SSW for Sugar Shack West.	Three letter initials of the sample collector, for example HRS for Heather R. Shannon.	Sequential four number designation, for example 0001	Sequential two number designation, for example 01

Photographs are taken of most sample sites (SOP 4; information recorded on photograph form, Appendix 8-2). The numbering system for the photograph consists of the Field ID or Test Pit ID number followed by a letter representing the type of image (F-field, T-thin section, P-probe, H-test pit, D-drill core/cuttings, G-general, O- historic) 001 sequentially (Table 8-3). For example SSW-HRS-0001-F001 is the photograph no. 1 that HRS took at sample site no. 1. Photographs were taken at the highest resolution as jpeg or tif. Photographs are part of the project data repository.

TABLE 8-3. Scheme for identifying field photographs, designated the Photo no. Description of mine-feature abbreviations is in Appendix 8-3.

Component 1	Component 2	Component 3	Component 4	Component 5
Three letter abbreviation for the mine feature, for example SSW for Sugar Shack West.	Three letter initials of the sample collector, for example HRS for Heather R. Shannon.	Sequential four number designation, for example 0001.	Sequential two number designation, for example 01.	Letter of image type (F, T, P, H, D, G, O, M), followed by a sequential three number designation, 001.

SAMPLE SELECTION PROCEDURES FOR VARIOUS TASKS OF THE QRPWASP

This section describes the criteria for sample selection for each major project task. Additional information is in the cited project reports and component DRAs.

Characterize the overburden, underlying rocks, and other country rocks (lithologic atlas)

The purposes of characterizing the overburden, underlying rocks and other country rocks (lithologic atlas) were to:

- Familiarize workers with the lithologies that are most likely to appear in the Questa rock piles (i.e. the rocks that were mined from the open pit)
- Provide descriptions and photographs of these lithologies
- Describe the alteration assemblages
- Characterize the geochemistry of these altered lithologies.

McLemore et al. (2008b) includes descriptions and photographs of hand samples and thin sections of the lithologies and alteration assemblages. Some of these samples were used in the selection process for the humidity cells, as described below. Samples collected included:

- Outcrop samples of unweathered (or least weathered) igneous rocks representative of the mined rock (overburden), including all predominant lithologies and alteration assemblages at various hydrothermal alteration and weathering intensities.

    - andesite
    - quartz latite
    - rhyolite tuff (Amalia Tuff)
    - aplite, granitic porphyry
    - miscellaneous dike, flow, and tuffaceous rocks
    - alteration scars
- Samples of the vein material within altered host rocks (typically veins are <2 cm).
    - quartz-molybdenite-pyrite (orthoclase flooding, biotite)
    - quartz-sericite-pyrite of rhyolite porphyry dikes
    - quartz-fluorite-sericite-pyrite-base-metal-sulfides (halo above mineral deposits)
    - calcite-gypsum/anhydrite
- Samples of colluvium/weathered bedrock and alteration scars intended to identify weathering profiles.
- Sections of drill-core samples of the mined rock (overburden) and ore deposit before mining.

Sampling strategies varied according to the purpose of each sampling task. Typically, a select, grab, or bulk sample of rock or soil material was collected at each site for petrographic study and geochemical and geotechnical analyses. A hand specimen was collected from some sites for thin section analysis. The samples for this report consisted of grab samples of two or more pieces of outcrop or drill core samples (typically 3-8 cm in diameter). These samples are more homogeneous than rock-pile samples in that they are composed of one lithology and alteration assemblage, whereas the rock-pile material typically consists of multiple lithologies and/or alteration assemblages. A portion of the collected sample was crushed and pulverized for geochemical analysis. Thin sections were made of another piece of selected rock samples for petrographic analysis (including estimated modal mineralogical analysis). Some of the samples examined were obtained from the Chevron rock collection, and only hand specimen descriptions of these rocks were performed. Additional mineralogical and chemical analyses of rock types were obtained from the literature and Peter Lipman (USGS). More detailed petrographic data are in the project database.

Characterize the geologic, geochemical, hydrological, and geotechnical parameters of Goathill North (GHN)

The purpose of characterizing GHN was to describe the structure, stratigraphy, physical, chemical, mineralogical, hydrological, and geotechnical characteristics and extent of weathering of the rock pile. These characteristics were used to model the GHN rock pile and to model future weathering and slope stability of the Questa rock piles. Some of these samples were used in the selection process for the humidity cells, described below. Several types of samples were collected to characterize GHN (McLemore et al., 2008a):

- Rock-pile material that includes soil matrix and rock fragments of mixed lithologies and alteration assemblages
    - Samples collected from the surface and from test pits throughout the rock piles

    - Samples of the rock-pile material collected from trenches in GHN (5-ft channel or composite within a single, selected layer)
- Soil profiles of colluvium/weathered bedrock
- Splits of drill cuttings from the rock piles and underlying colluvium/bedrock
- Samples selected for specific analysis (age dating, stable isotopes, etc.).

Sample locations are in Appendix 8-7 and McLemore et al. (2008a). Project SOPs (Table 8-11) provide detailed descriptions of sampling methods and laboratory analysis methods for each type of sample.

Before re-grading GHN, composite surface samples were collected along the road cutting across GHN of each surface geologic unit for characterization. Tensiometer measurements were obtained throughout the surface of GHN (Shannon, 2007), and samples were collected at those sites as well. Splits of drill cuttings from drill holes in GHN were collected from 5-gallon buckets, representing 5- or 10-ft intervals collected during drilling.

During GHN re-grading, samples of each of the subsurface units were collected after the unit boundaries were identified. Samples were collected horizontally along the benches within the trenches which transect GHN rock pile, including near the base of the rock pile (Appendix 8-7, Figure A7-2). Although the entire rock pile was not completely sampled, the distribution of samples from the surface, trenches and drill holes is probably representative of the entire rock pile. Composite samples typically were collected from the north wall of the trench for characterization. If there was enough time, samples also were collected along the south wall of the trench as well. Additional samples were collected in 5-gallon buckets of each geologic unit within the trench for geotechnical testing. Samples were collected from each defined unit for geochemical analysis, geotechnical shear box tests, biological analysis, isotopic composition, and electron microprobe analysis. Most samples were channel composites collected along approximately 5-ft-long horizontal slots using a rock hammer to chip material from bench walls placed into a sample bag. Some samples were composites collected along specific layers that were less than 5-ft thick. The entire sample typically was analyzed by various techniques (Fig. 8-2), although selected analytical methods required smaller size fractions than normally collected (see SOPs). Sampling procedures, descriptions, and analytical analyses typically used for soil profiles were employed because the material in the rock piles appears to be soil-like (i.e. mine soils) (URS Corporation, 2003; Haering et al., 2004; Stormont and Farfan, 2005).

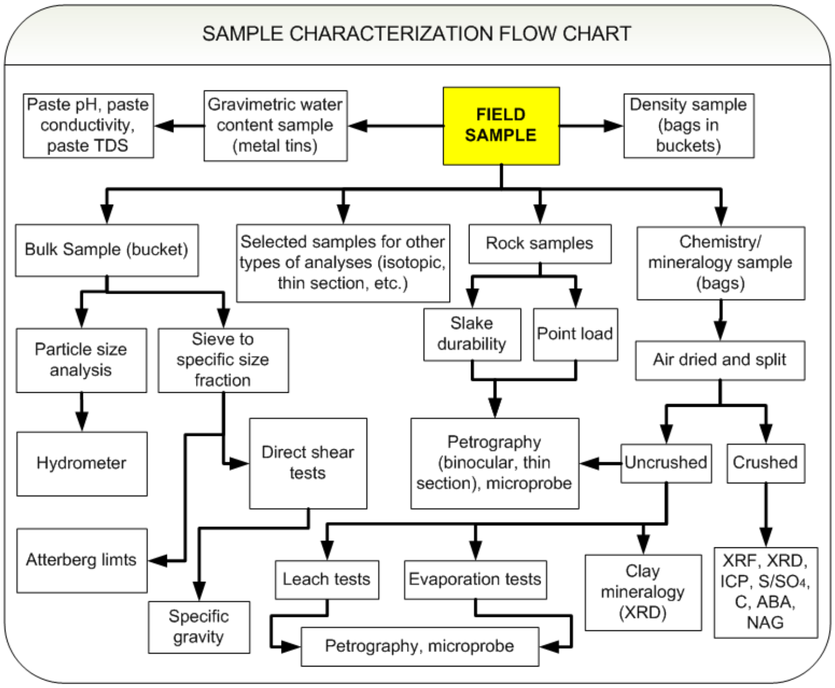


FIGURE 8-2. Flow chart showing analyses of selected samples, both soils and rocks. Not all analyses are performed on every sample. Bucket (5 gallons), metal tin, and bags (quart to gallon) refers to size of sample collected. XRF=X-ray fluorescence analyses, XRD=X-ray diffraction analysis, ICP=Induced-coupled plasma spectrographic analysis, NAG=net acid producing tests, ABA=acid base accounting tests. Specific details describing the sample preparation are in the project SOPs and summarized in Appendix 8-5.

Sampling strategies were based upon the purpose of each sampling task. Typically, at each site, a select, grab, or bulk sample of rock or other material was collected for petrographic study and geochemical analyses. A hand sample was collected from some sites for thin section analysis. Each sample was stored in a separate bag or bucket, assigned a unique number, logged on a field description form, and entered into the project Access database. Selected sample sites were marked in the field with flagging and a digital photograph (SOP 4) was taken at most localities. Location information obtained by a hand-held global positioning system (GPS) or surveyed by company surveyors (SOP 3), type of sample, and field petrographic descriptions were collected. Geologic observations were recorded on the field description form in the Access database and each site was located on a map (SOP 5). Hand-sample description provided a record of what was collected, which aided in petrographic descriptions and provided information on the sample for the laboratory analysis. The hand-sample description was the preliminary data required to determine what samples required additional analyses.

The following in-situ measurements were taken along either the horizontal or vertical surfaces of each exposed bench and along the base of each trench:

- Sand cone or sand or water replacement (density, SOP 65, 70)
- Tensiometer measurements (matric suction, SOP 64)
- Gravimetric water content (SOP 40)
- Particle size distribution (SOP 33)
- Infiltration tests (SOP 53, 71)

- Nuclear gauge measurements (density, moisture content, SOP 61).

Gravimetric water content samples were collected at many locations, including the locations selected for the measurement of matric suction and infiltration tests.

GHN rock-pile samples, drill cuttings from holes drilled into the rock piles, and samples collected from test pits throughout the Questa rock piles represented varying degrees of hydrothermally-altered samples that had been exposed to surface weathering since the construction of the rock pile (approximately 25-40 years). The collected samples from the rock piles consisted of a heterogeneous mixture of rock fragments ranging in size from boulders (0.5 m) to <1 mm in diameter within a fine-grained soil matrix. Most rock fragments were hydrothermally altered before mining occurred; some showed signs of oxidization and weathering since emplacement in the rock pile.

Characterize the Questa rock-piles

The specific purposes of the characterization of the Questa rock piles are to (McLemore et al., 2008f):

- Compare the geotechnical index parameters between the Questa rock piles (Atterberg Limits, particle size, shear, point load, slake, etc.)
- Compare the chemical and mineralogical composition among the Questa rock piles
- Describe the texture within the rock pile (e.g. particle size distributions, grain/clast shape, neighborhoods, shape/grain size, etc.)
- Identify any changes spatially and with time
- Identify the differences among the rock piles
- Identify the changes with depth within rock piles
- Differences between different laboratories testing sample splits for friction angle and cohesion.

Drill holes were selected throughout the rock piles for characterization sampling based upon:

- Availability of drill cuttings
- Includes both venting drill holes and non-venting drill holes
- Distributed on different rock piles and on different levels of the rock piles.

Surface samples were collected as part of the in-situ testing. The other rock-pile characterization study was not completed as planned because of focusing efforts on GHN and lack of funding, therefore, many of the samples collected were not studied.

Select humidity cells samples

Three sets of samples were used in the humidity cell tests and are characterized by McLemore et al. (2008e); 1) Robertson GeoConsultants Inc., 2) Golder Associates, and 3) University of Utah (UU) samples. In phase 1, the existing humidity cell data for six cells contained in Robertson GeoConsultants Inc. (2003) report were used to calibrate the Questa geochemical model. One problem in using these data to calibrate the geochemical model was that an extensive mineralogical analysis of the various rock types used for the humidity cells was not done. This makes model calibration difficult since a quantitative analysis of the actual rock particles used in testing our model is needed, but none of the original sample material remained for mineralogical testing. However, the NMIMT team was been able to analyze samples that are very close to those used in the Robertson

GeoConsultants study, and the results are presented in McLemore et al. (2008e). Two samples of potential cover material were selected by the Questa contractors and characterized from test plots in the rock pile material for the Golder Associates humidity cell tests.

Samples for the UU humidity cell tests were selected by the QRPWASP Weathering Committee based on differences in lithology and total sulfide content. Samples that were collected for characterization of the overburden, country rocks, underlying bedrock, alteration scars, GHN and other rock piles were used. The humidity cell experiments were used to model the pH, temperature, and availability of oxygen and water at various locations in the pile. This model allowed prediction of dissolution rates at specific locations within the pile given the spatial variation of composition within the pile. Therefore, the compositional variables and the effects of pH and temperature are of primary importance for the humidity cell testing. Key rock characteristics are the pyrite and Ca/Mg carbonate mineral surface area exposure and the extent of oxide coatings on the pyrite. Two representative lithologies were selected, and a fresh and a weathered example of each lithology tested, with weathering determined based on visual observation. Four fresh rhyolite, four fresh andesite, three weathered rhyolite, and three weathered andesite samples, each with varying amounts of pyrite, were selected. Choosing samples with varying pyrite concentration proved difficult because only total sulfur was measured initially, and, in general, the amount of pyrite in the GHN samples is low. A sample of crushed quartz with the same particle size distribution as the other samples was used as a control in the humidity cell experiments.

Appendix 8-7 includes sample location maps and a summary of the location and descriptions of humidity cell samples. The UU samples include:

- BCS-VWL-0004 - andesite from alteration scar, SWI 4 (note there is organic material in this sample)
- GHN-JRM-0001 - andesite from GHN rock pile, SWI 4
- GHN-JRM-0002 - andesite with minor amounts of intrusive granite from GHN rock pile, SWI 2
- GHN-JRM-0009 - andesite from GHN rock pile, SWI 4
- GHN-KMD-0057 - andesite from GHN rock pile, SWI 2
- GHN-KMD-0088 - rhyolite (Amalia Tuff) from GHN rock pile, SWI 2
- GHN-KMD-0096 - rhyolite (Amalia Tuff) from GHN rock pile, SWI 4
- MIN-VTM-0021 - andesite outcrop, SWI 3
- PIT-RDL-0005 - rhyolite (Amalia Tuff) outcrop from near the Questa pit, SWI 3
- PIT-RDL-0006 - rhyolite (Amalia Tuff) outcrop from near the Questa pit, SWI 4
- PIT-RDL-0007 - rhyolite (Amalia Tuff) outcrop from near the Questa pit, SWI 4
- PIT-VTM-0600 - andesite outcrop from near the Questa pit, SWI 2
- ROC-NWD-0002 - rhyolite (Amalia Tuff) outcrop, SWI 1
- SPR-JWM-0002 - andesite boulder from Spring Gulch rock pile, SWI 2

Crust study

Samples of the crust were collected from the surface of the Questa rock piles (Appendix 8-7; Giese et al., 2008) and Questa Pit and Southwest Hansen alteration scars (QPS, SWH, Appendix 8-7). Sample sites were selected from areas that were observed to have a fast-forming crust on the rock-pile slopes, that were near in-situ shear test sites

(Boakeye, 2008), and that were easily accessible. Two samples were collected at each site. The "top crust" sample was the top several mm to 1 cm of surface material, and the "subcrust" sample was collected directly from underneath the "top crust", collecting material from approximately 1-2 inches depth. Samples were collected by spade or shovel over an area of 1-3 meters square, were stored in zip lock bags, and were given separate field identification numbers. Although, it is recognized that these crustal materials can change by hydration and dehydration during sample transport and storage (Peterson and Grant, 2005), preservation methods to prevent changes to the mineralogy were not employed. Detailed mineralogy was not part of the objective of this task. A separate set of samples was collected for Soil Water Characteristics Curves (SWCC). Splits of these samples were sent to Mineral Services Inc. (2008) for mineralogy and chemical characterization; these samples were not available for characterization by NMIMT.

Water sample collection was not originally planned. However, runoff water samples were collected near the crust sample locations in the field from a rill, puddle, stream, or pond, immediately after a rain storm (SOP 68). Each water sample was allowed to sit for two days to let the larger particles settle to the bottom of the container. The water was poured off into another container and then filtered. Each water sample was filtered through a no. 4 filter, then vacuum filtered through a 0.45 μm filter and split between two 125 mL Nalgeene bottles. Subsequently, the water samples then were analyzed for general chemistry and trace metals.

Characterize the weathering

The questions to be addressed in the characterization of weathering include:

- What are the indications of weathering in the Questa rock piles?
- What are the physical and chemical weathering processes active at both the surface of and within the rock piles?
- How do the mineralogy, chemistry, and physical properties of the Questa materials change with weathering?
- Can the products of these processes be quantified and serve as one or more weathering indices?

The technical approach for examining the weathering processes involves an iterative and interactive process addressing both the geotechnical and geochemical characterization of materials (McLemore et al., 2008d). Samples selected from the above studies were used to determine the following parameters:

- Examine chemical compositions of water samples collected from seeps, trenches, surface and underground water samples, and runoff waters (McLemore et al., 2008a; Giese et al., 2008; E. Osantowski, in preparation).
- Determine geochemical trends for fresh outcrop samples, using published and new chemical analyses of outcrop, rock pile and drill hole (representing samples from the open pit, i.e. pre-mined overburden) samples (McLemore et al., 2008b).
- Characterize samples from GHN and determine weathering patterns and characteristics (McLemore et al., 2008a).
- Characterize samples from the hot zones on the front rock piles (McLemore et al., 2008g).
- Characterize samples of the rock pile crusts (Giese et al., 2008).

- Characterize weathered and unweathered boulders to understand short-term chemical effects on weathering (Sweeney et al., 2007).
- Characterize the samples before and after humidity cell testing (McLemore et al., 2008f).
- Establish and evaluate natural analogs to determine weathering products of similar rocks at a longer time scale (Graf, 2008; McLemore, 2008a, Ayakwah et al., 2008).
- Detailed geotechnical testing of a subset of samples for shear strength properties for internal angle of friction and cohesion. Evaluation of geotechnical data (McLemore et al., 2008e).
- Detailed characterization of in-situ samples and determine relationships between weathering and cohesion (McLemore and Dickens, 2008a).

Additional specialized studies in the QRPWASP

Additional samples and other data were collected for specific studies as summarized in Table 8-4. More details of the sample selection for these studies can be found in the associated SOPs and project reports.

TABLE 8-4. Summary of sample collection procedures for specific studies.

Study	Purpose	Method of selecting samples	Type of samples	SOP	Other reference
Isotope geochemistry of pore water	Compare isotopic signatures of pore water to other waters	Precipitation sites throughout the mine site; pore water samples collected of fined grained material within the trenches	Matrix-rich solid samples, collected precipitation and other water samples	39, 47	Campbell and Hedrickx (2008)
Sulfur and oxygen isotopes	Determine stable isotopes	Rock pile and analog samples	Selected samples of sulfide and clay minerals	25	Campbell and Lueth (2008)
Geochronology	Determine age	Alteration scar samples, ferricretes and wood material to obtain age of analog sites	Selected samples of specific minerals or wood material	44	
Tritium Analysis of bedrock	Use of tritium analyses to determine a hydraulic barrier	Drill core samples selected by K. Soloman	Selected samples	none	
Tritium analysis of clays	Tritium analyses	Screened split of megasamples and selected trench samples from GHN	Screened fine-grained samples	none	Marston (2009)
DI leach and column studies	Approximate pore water compositions	Selected GHN samples with mineralogy and chemistry completed	Selected samples	38	E. Osantowski, in preparation
Microbiology	Determine microbial populations	Selected GHN samples with mineralogy and	Selected samples of solid material for	55-60	

Study	Purpose	Method of selecting samples	Type of samples	SOP	Other reference
		chemistry completed	microbial analyses		

LABORATORY PROCEDURES

Samples were collected in the field and stored at NMIMT. Specific samples were subsequently selected for analyses depending on the purpose of the project tasks. Not all analyses were performed on each sample because only the specific analyses to address the task were performed. Not all samples collected were analyzed in the laboratory. Table 8-5 summarizes the laboratory procedures for the QRPWASP.

Sample preparation for solid materials

Samples collected in the field were selected and prepared for specific laboratory analyses. Sample selection procedures and sample descriptions are in the SOPs, project reports, and the data repository. A generalized flow chart of sample analyses is in Figure 8-2 and described in detail in the project SOPs (listed in Appendix 8-1). Many samples were split or separated from the original sample collected in the field for the specific laboratory analysis (generally by cone and quarter methods or using a sample splitter) as explained in the SOPs (Appendix 8-5) and project reports. A summary of the general sample preparation for laboratory analyses is in Appendix 8-5; more detailed procedures are in the project reports and theses. Each sample was homogenized at each crushing step by cone and quarter method. The samples were then sent to a laboratory (New Mexico State University, NMBGMR Chemistry Laboratory, Washington State University, AL Chemex) for analyses. Two internal standards (CAP-MLJ-0001, STD-DEW-0002 (Orogrande sample)) and/or numerous duplicates and triplicates were submitted blind to the laboratory and analyzed with each sample batch to compare and assess analytical precision, accuracy, representativeness.

Rock sample analyses

Whole rock chemistry data were obtained by X-ray fluorescence (XRF) for most elements (including La, Ce, and Nd) according to SOP 28 first at the NMSU facility. When the NMSU equipment was damaged, samples were sent to WSU for analyses. The Chemistry Laboratory at NMBGMR measured fluoride (F) by fusion and single-element electrode; beryllium (Be), arsenic (As) and rare earth elements (REE) by four-acid digest and inductively-coupled plasma mass spectrometry (ICP-MS); and ferrous iron by acid attack and titration. Total sulfur (S) was obtained on some samples by XRF at WSU and by acid attack and inductively-coupled plasma optical emission spectrometry (ICP-OES) at NMBGMR, and for other samples at AL Chemex, where SO_4 and total carbon (C) also were determined. Detection limits are in Table 8-6.

TABLE 8-5. Summary of laboratory analyses of Questa data at NMIMT or under NMIMT supervision. The data can be found in the project Access database or in separate excel datasheets in the project data repository as well as in project reports.

Analysis/ Media	Number of samples	Number of duplicates	Method SOP	Name of table in Access database or other location of data	Data Validated	Responsible Party
Humidity cell water samples	982	93	30, 31, 68, 78	Separate spreadsheets	Yes	NMBGMR ChemLab
water chemistry	51	7	30, 31, 68	Water chem	Yes	NMBGMR ChemLab
Fluoride/solid samples	616	93	69	Other chem solid	Yes	NMBGMR ChemLab
Ferrous iron/solid samples	547	55	69	Other chem Solid	Yes	NMBGMR ChemLab
Rare Earth Element / solid samples	405	40	31	Other chem solid	Yes	NMBGMR ChemLab
As, Be/solid samples	167	17	30, 31	Other chem solid	Yes	NMBGMR ChemLab
ICP/solid samples	318	32	30	ICP solids	Yes	NMBGMR ChemLab
Anions and major cations	266	22	30, 68	Osantowski (in preparation)	Eric Osantowski	NMBGMR ChemLab
Cations and general chemistry on 10 samples	71	9	30, 68	Donahue (2008)	yes	NMBGMR ChemLab
XRD, XRF for clay leachate studies	10	0	27, 28	Donahue (2008)	yes	Kelly Donahue/ Washington State University
paste tests	2089	175	11	Lab measurements solids	yes	Virginia McLemore
ABA (acid base accounting) tests	404	10	62	ABA	Yes	Virginia McLemore
NAG (net acid generating) tests	235	0	51	NAG	Yes	Virginia McLemore
bulk mineralogy	293	0	McLemore et al (2009)	Bulk mineralogy	Yes	Virginia McLemore
gravimetric moisture contents	743	0	40	Grav m c	Yes	Virginia McLemore
isotopes solids	161	39	25	Isotopes solids	yes	Andy Campbell
isotopes water	154	0	25, 39	Pore water, precip field samples	yes	Andy Campbell
modal mineralogy	101	McLemore checked approximately 10%, 0	24	Modal mineralogy	yes	Virginia McLemore

Analysis/ Media	Number of samples	Number of duplicates	Method SOP	Name of table in Access database or other location of data	Data Validated	Responsible Party
		duplicates				
Atterberg limits	249	47	54	GeoTech Atterberg header	Yes	Virginia McLemore
Particle size	211	27	33	GeoTech Sieve header	Yes	Virginia McLemore
Shear box	135	21	50	GeoTech ShearBox summary	Yes	Virginia McLemore
Density	762 nuclear gauge, 6 sand cone, 97 sand replacement	Golder, 0, 1	32, 61, 65, 70	Nuclear gauge header, sand cone, sand replacement	Yes	Virginia McLemore
pyrite	651	0	34	Pyrite reserve data	Yes	George Brimhall
hyperspectral analyses (mineralogy)	636	0	41	Reflect spectr	yes	Virginia McLemore/ Phoebe Hauf
clay mineralogy	432	30	29	Clay Mineralogy	yes	Virginia McLemore/ Kelly Donahue
slake durability index	229	0	76	Slake durability header	yes	Virginia McLemore
point load index	107	1	77	Point load header	yes	Virginia McLemore
specific gravity	104	0	75	Spec grav	yes	Virginia McLemore
sulfur, carbon chemistry	788	62	ALS Chemix	Sulfur chem	yes	Virginia McLemore/ ALS Chemex
XRF whole rock chemistry	1175	125	28	XRF	yes	Virginia McLemore/ NMSU/ Washington State University
XRD mineralogy	186	36	27	XRD	yes	Virginia McLemore
electron microprobe analysis	281	0*	26	petrographic eprobe	yes	Nelia Dunbar
field sample data	2747	0	5	sample, handspecimen	10%	Virginia McLemore
chip tray	65	0	49	Chip tray	10%	Virginia

Analysis/ Media	Number of samples	Number of duplicates	Method SOP	Name of table in Access database or other location of data	Data Validated	Responsible Party
description of drill cuttings						McLemore
SWCC	154	0	72	GeoTech SWCC	no	Ward Wilson
in situ direct shear testing data	52 test sites	14	Boakye (2008), Fakhimi et al. (2008)	In situ data, in situ samples, in situ shear	Yes	Virginia McLemore/Ali Fakhimi
gas data	44		66	Instrument gas data	yes	Virginia McLemore
geochronology			44	separate reports	yes	Virgil Lueth
hydraulic conductivity by guelph permeameter			71			Virginia McLemore/ Heather Shannon
hydraulic conductivity by tenisometer			53			Virginia McLemore/ Heather Shannon

TABLE 8-6. Detection limits for solid materials. XRF=X-ray fluorescence. Major element oxides are in weight percent and trace elements are in parts per million. These elements are the elements typically offered by XRF laboratories. The first set of samples did not include SO3 analyses; WSU added SO3 to their suite of elements after the Questa Rock Pile Weathering and Stability Project was underway.

Oxide weight %	detection limit XRF	trace element (parts per million, ppm)	detection limit XRF
SiO2	0.5	Ni	3.5
TiO2	0.02	Cr	3
Al2O3	0.2	Sc	1.6
FeOT	0.2	V	5
MnO	0.002	Ba	11.7
MgO	0.08	Rb	1.7
CaO	0.06	Sr	4.6
Na2O	0.05	Zr	3.9
K2O	0.03	Y	1.2
P2O5	0.005	Nb	1.2
LOI	0.001	Ga	2.7
SO3	0.07	Cu	7.4
		Zn	3.3
		Pb	2.6
		La	5.7
		Ce	7.9
		Th	1.6
		Nd	4.3

Oxide weight %	detection limit XRF	trace element (parts per million, ppm)	detection limit XRF
		U	2.7

Sample preparation for seep and runoff water samples

Collection of water samples was not part of the original sampling work plan. However, water samples were collected from seeps at the toe of GHN before reclamation, from trench LFG-021 from the colluvium/bedrock during reclamation of the unstable portion of GHN, and from rock pile runoff. These were samples of opportunity and proper filtration and measuring equipment was not available, therefore the samples were not filtered until the samples reached the NMBGMR Chemistry Laboratory. All other procedures detailed in SOP 15 were followed. These water samples were stored in coolers, transported to NMBGMR Chemistry Laboratory within one day of collection, and analyzed for major and trace elements (McLemore et al., 2008). A sample of the stream flowing through the Narrows of Goathill Gulch also was collected and analyzed for major and trace elements (McLemore et al., 2008).

Once in the laboratory, the water was poured off into another container and then filtered. Each water sample was filtered through a no. 4 filter, then vacuum filtered through a 0.45 µm filter and split between two 125 mL Nalgene bottles. Subsequently, the water samples were analyzed for general chemistry and trace metals and total dissolved solids.

The water samples from the toe of GHN are interpreted to represent combined flow from the colluvium/bedrock below the GHN rock pile and GHN rock pile. The sample from trench LFG-021 represents flow from the colluvium/bedrock beneath the unstable portion of GHN (McLemore et al., 2008a). The sample from the stream flowing through the Narrows represents combined seepage and runoff from the Capulin and GHN rock piles and runoff from the alteration scar area in Goathill Gulch. Runoff water samples were collected near the crust sample locations in the field from a rill, puddle, stream, or pond, immediately after a rain storm according to SOP 68 (Giese at al., 2008).

Analyses of water samples

Water analyses were completed by the NMBGMR Chemistry Laboratory following EPA methods and Standard Methods for the Examination of Water and Waste Water (Table 8-7). The required parameters were chosen by the investigator providing the samples according to SOP 15. All samples were logged into the Chemistry Laboratory Sample Log Book with a Lab ID number, with the exception of samples submitted by a few students who were completing their own work and whose data were reported in separate submissions other than the main project database. In the case of Humidity Cell samples, Ed Trujillo's University of Utah lab provided a temperature blank with every shipment of samples to allow the NMBGMR lab to check the temperature of the sample cooler upon arrival. These temperatures were reported to the Utah lab by email. Water analyses were reported to each investigator on the Chemistry Laboratory's standard spreadsheet forms with the exception of the Humidity Cell samples and a few samples from student investigators, which were reported on Excel spreadsheets specific to those parts of the project. With the exception of liquid samples that were returned to the investigator who provided them, all liquid samples were held for one year before disposal under the guidance of the NMIMT safety officer.

TABLE 8-7. Methods followed for water analyses in NMBGMR Chemistry Laboratory.

Parameter	Method	Holding times
pH	USEPA 150.1	NA*
Conductivity	USEPA 120.1	NA*
TDS	Calculation from Standard Methods	NA
Hardness	Calculation from Standard Methods	NA
Alkalinity	USEPA 310.1**	2 weeks
Trace metals by ICP-MS	USEPA 6020	6 months
Major and minor cations by ICP-OES	USEPA 200.7	6 months
Anions by IC	USEPA 300.0	1 month, except nitrate/nitrite +

* Laboratory SOPs assume that pH and conductivity were completed in the field, therefore, holding times do not apply to lab measurements of these parameters. Lab measurements of these parameters were intended to identify changes in the samples from the time they were collected. These measurements were made in the lab within 24 hours of receipt.

** Alkalinity was initially analyzed by an automated colorimetric method (USEPA 310.2), but after a number of measurements were found to be erroneous, the Chemistry Laboratory followed USEPA 310.1 exclusively.

+ No samples arrived in the NMBGMR Chemistry Laboratory with the nitrate/nitrite preservation described in SOP 68, therefore, Chemistry Laboratory measurements of nitrate/nitrite did not meet holding times.

ACCURACY AND PRECISION OF ROCK CHEMISTRY DATA (SOLIDS)

The accuracy of the data is how close the measured value is to the true value. Analyzing certified standards to unknown samples and comparing with known certified values monitors accuracy. Each laboratory is responsible for the accuracy and that data is available upon request from the laboratory manager (for XRF analyses see details in Johnson et al., 1999). The precision of an analysis is the repeatability of a measurement. Precision is the degree of agreement among repeated measurements of the same characteristic and monitored by multiple analyses of many sample duplicates and internal standards. It can be determined by calculating the standard deviation, or relative percent difference, among samples taken from the same place at the same time (i.e. duplicates and triplicates). In general, analyses obtained from the laboratories are in agreement with certified values of certified standards and precision is excellent between multiple analyses (see documentation in sections below).

However, differences between certified standards and duplicate pairs do exist. Generally no corrective procedures could be applied to solid samples. Variation in preparation of the bead used in the analysis is a major cause of these differences (Johnson et al., 1999). Nugget effects can account for variations in copper (Cu), iron (Fe), lead (Pb), sulfur (S), zinc (Zn), and zirconium (Zr), observed in some pairs of samples. A nugget effect is where a small grain of native gold or other minerals occurs in one split and not the other split and produces a higher concentration. Another variation between certified values and the results provided by the laboratories is a result of different analytical techniques. Washington State University and New Mexico State University used different fusion techniques. NMBGMR used inductively coupled plasma spectrometry (ICP) methods for several elements. ICP requires acid digestion and analyses of a liquid-base solution. In some cases, not all of the solid rock will be completely digested and can result in a lower value than that obtained by certified values typically done by XRF or instrumental neutron activation analysis (INNA).

X-ray fluorescence (XRF) Analyses

Accuracy data for WSU are in Johnson et al. (1999). The sum of major oxides (including SO3) totaled between 98.5 and 101% (Table 8-8 and Access database). Samples of NMBGMR internal standards were analyzed for most batches and the difference between analyses is acceptable, within 10% (Table 8-7). The precision of analyses is acceptable (within 10%) for samples where multiple analyses of the same sample were obtained (Table 8-9). For every 10 samples submitted, a duplicate sample was analyzed and for every 20 samples submitted triplicate samples were analyzed; these analyses compared within 10% (see project Access database for additional data).

There are numerous reasons why duplicate samples and/standards do not always agree. Some samples, such as rhyolite and basalt, grind into powder more easily than other samples, such as stream-sediment samples and nepheline syenites. Fusion techniques required for XRF analyses vary from lab to lab (Table 8-8) and also can differ between different personnel that could result in variations between sample pairs. Analytical error is higher for analyses with concentrations close to the detection limit. In addition, rock-pile samples and alluvium are very heterogeneous and difficult to completely homogenize. Most variations between duplicate samples are probably a result of sample inhomogenities and analytical errors related to low concentrations. Another problem encountered with rock-pile samples, is the variability of sample collection. Typically, eight people collected the Project samples using the exact procedures to minimize variations between sample collectors.

TABLE 8-8. Summary statistics for multiple analyses of internal standard STD-DEW-0002 2005-2008 (sample from Orogrande rock pile, Otero County, New Mexico). Oxides in percent, trace elements in parts per million. WSU= Washington State University (7 analyses) and NMSU=New Mexico State University (9 analyses). Data are in Access database.

Oxide/trace element	Theoretical value	Standard deviation	Mean	Maximum	Minimum	Standard deviation	error (difference/ accepted)*100
Laboratory	NMSU						
SiO2	55.20	0.19	55.43	56.24	54.90	0.49	-0.42
TiO2	0.39	0.01	0.38	0.40	0.37	0.01	0.98
Al2O3	10.30	0.13	10.28	10.50	10.10	0.12	0.22
FeOT	6.93	0.24	6.88	7.08	6.43	0.26	0.67
MnO	0.07	0.00	0.07	0.08	0.06	0.01	3.92
MgO	1.14	0.02	1.16	1.24	1.12	0.05	-1.98
CaO	12.24	0.23	12.13	12.50	11.93	0.20	0.89
Na2O	2.64	0.04	2.49	2.69	1.24	0.47	5.55
K2O	2.34	0.07	2.23	2.40	1.35	0.34	4.67
P2O5	0.16	0.00	0.15	0.17	0.12	0.02	5.70
LOI	7.94	0.09	7.74	8.05	7.04	0.40	2.51
Sum of oxides	99.35		98.94				
Ni	10	0.8	10	11	9	1	0
Cr	30	9.1	34	47	26	9	-14
Sc	5	0.1	5	5	5	0	-1
V	64	7.9	66	72	50	8	-3

Oxide/trace element	Theoretical value	Standard deviation	Mean	Maximum	Minimum	Standard deviation	error (difference/ accepted)*100
Ba	768	26.6	784	860	730	48	-2
Rb	65	4.4	65	73	60	4	1
Sr	395	6.6	395	401	384	6	0
Zr	201	6.9	200	210	190	6	1
Y	29	2.1	27	32	21	4	6
Nb	13	1.3	12	15	10	2	5
Ga			14	14	14	0	
Cu	111	9.6	115	119	101	6	-3
Zn	34	4.1	36	43	25	5	-6
Pb	18	4.0	29	70	13	23	-65
La	36	2.3	37	40	34	2	-1
Ce	65	3.5	65	70	61	4	0
Th	8	0.5	7	8	7	1	3
Nd	24	2.2	4	5	4	0	83
U	4	0.3	11	13	4	3	-158

Oxide/trace element	Theoretical value	Standard deviation	Mean	Maximum	Minimum	Standard deviation	error (difference/ accepted)*100
Laboratory	NMSU		WSU				
SiO2	55.20	0.19	55.09	55.36	54.71	0.26	0.20
TiO2	0.39	0.01	0.38	0.39	0.38	0.00	1.48
Al2O3	10.30	0.13	10.56	10.64	10.47	0.07	-2.57
FeOT	6.93	0.24	6.66	6.83	6.49	0.16	3.87
MnO	0.07	0.00	0.08	0.08	0.08	0.00	-7.45
MgO	1.14	0.02	1.14	1.16	1.13	0.01	-0.25
CaO	12.24	0.23	11.47	11.59	11.32	0.10	6.30
Na2O	2.64	0.04	2.66	2.71	2.64	0.02	-1.06
K2O	2.34	0.07	2.31	2.32	2.29	0.01	1.46
P2O5	0.16	0.00	0.16	0.16	0.16	0.00	0.44
LOI	7.94	0.09	7.58	7.58	7.58	0.00	4.48
Sum of Oxides	99.35		98.09				
Ni	10	0.8	18	23	16	3.0	-82.0
Cr	30	9.1	30	31	27	1.5	0.2
Sc	5	0.1	7	8	5	1.0	-37.7
V	64	7.9	70	72	66	2.1	-8.2
Ba	768	26.6	808	819	793	10.0	-5.2
Rb	65	4.4	64	65	62	1.1	1.8
Sr	395	6.6	395	398	391	2.2	0.0
Zr	201	6.9	212	217	206	3.6	-5.2
Y	29	2.1	22	23	21	0.9	24.1
Nb	13	1.3	9	10	9	0.3	25.5
Ga			13	15	12	1.1	
Cu	111	9.6	126	130	122	3.3	-13.3
Zn	34	4.1	41	43	40	1.3	-23.2
Pb	18	4.0	14	17	11	2.1	22.4

Oxide/trace element	Theoretical value	Standard deviation	Mean	Maximum	Minimum	Standard deviation	error (difference/ accepted)*100
La	36	2.3	34	35	33	0.9	7.7
Ce	65	3.5	58	62	55	2.6	9.9
Th	8	0.5	7	9	5	1.4	13.4
Nd	24	2.2	23	24	22	0.7	1.9
U	4	0.3	4	5	3	0.8	9.7

TABLE 8-9. Summary statistics for multiple analyses of internal standard CAP-MLJ-0001 2005-2008 (rock pile sample from Capulin rock pile, Questa mine). WSU= Washington State University (35 analyses) and NMSU=New Mexico State University (2 analyses of major oxides, 1 analyses of trace elements). FeOT is total iron calculated as FeO. Data are in Access database.

Oxide or trace element	Mean	Maximum	Minimum	Standard deviation	Error (max-min/mean)*100	Mean	Maximum	Minimum
Laboratory	WSU					NMSU		
SiO2	74.83	76.08	73.76	0.5885586	3.1003596	76.5	76.65	76.35
TiO2	0.21	0.212	0.2	0.0031134	5.7501481	0.22	0.22	0.22
Al2O3	11.81	11.97	11.69	0.0837692	2.3700758	11.885	11.91	11.86
FeOT	2.55	2.61	2.5	0.0347695	4.3127826	2.61	2.61	2.61
MnO	0.04	0.042	0.04	0.0005586	4.9275581	0.035	0.04	0.03
MgO	0.43	0.453	0.42	0.0110022	7.5882324	0.435	0.44	0.43
CaO	0.13	0.2	0.09	0.0315038	86.566838	0.125	0.13	0.12
Na2O	0.95	0.964	0.92	0.012499	4.6504432	1.015	1.04	0.99
K2O	4.81	4.88	4.74	0.04243	2.9132123	4.835	4.84	4.83
P2O5	0.05	0.06	0.049	0.0034528	20.719424	0.01	0.01	0.01
LOI	3	2.98	2.66	0.0796281	11.883639	2.665	2.74	2.59
Sum of oxides	98.81					100.335	100.63	100.04
Ni	37	45	30	3.8053304	40.546629	36		
Cr	97	100	94.5	1.3793949	5.692927	173		
Sc	2	3	0.3	0.6223547	121.65207			
V	20	22	18	0.9189366	20.111732	15		
Ba	340	347	332	3.4669723	4.4147584	369		
Rb	157	161	153	2.0564803	5.0856437	154		
Sr	72	74	69	1.3760768	6.9627108	66		
Zr	276	282.8	269	3.4911134	4.9983902	283		
Y	50	53.1	45.5	2.5262982	15.118528	46		
Nb	31	32.8	29.8	0.7174636	9.5940304	38		
Ga	23	25	21	1.0686106	17.448201	20		
Cu	39	42	35	1.8021856	18.082664	37		
Zn	52	54	49	1.4411278	9.6800215	49		
Pb	79	81.5	73	1.8687637	10.738726	103		
La	47	51	44	2.1170884	14.902425			
Ce	92	98.7	87	2.9415078	12.678727			
Th	13.286111	15	11	0.7772305	30.106628	12		
Nd	38.072222	40.6	36	1.3816369	12.0823			
U	5.3361111	7	3.5	0.8131606	65.590838	4		

Oxide or trace element	Mean	Maximum	Minimum	Standard deviation	Error (max-min/mean)*100	Mean	Maximum	Minimum
SO3	0.5250812	0.7	0.17	0.1103835	100.93678			

Fluoride analyses by alkaline fusion and fluoride ion electrode

The NMBGMR Chemistry Laboratory analyzed 616 solid samples for total fluorine using a fusion and electrode method by McQuaker and Gurney (1977) and documented in SOP 69. This highly robust method had an operating range of less than 200 mg/kg to 3000 mg/kg. Lower limits of the method varied from 104 to 180 mg/kg depending on the certified reference materials (CRMs) analyzed for detection limit purposes (Table 8-10). The only fluorine data falling in this range were control quartz blanks from the humidity cell solids (109 to 217 mg/kg); as a result all fluorine results were reported as above detection limits.

TABLE 8-10. Replicate fluorine measurements on various CRMs and the calculated method detection limit. USGS = U.S. Geological Survey. CCRMP = Canadian Certified Reference Material Project.

	Number of replicates	Average measurement (mg/kg)	Given value (mg/kg)	Standard deviation (mg/kg)	Method detection limit (mg/kg)
CCRMP LKSD-4	5	286	260	28	104
USGS QLO-1	3	301	280	22	154
USGS AGV-1	9	433	420	45	130
CCRMP LKSD-2	4	637	590	40	180
USGS STM-1	16	913	910	51	132
Average					140

Any samples with concentrations above 3000 mg/kg were reanalyzed at a 1:5 dilution with a CRM of 3000 mg/kg F (SOP 69). All samples that were more than 3000 mg/kg fluorine fell below 15,000 mg/kg (the upper limit for samples diluted 1:5), with the exception of one sample, PIT-VCV-0024, which had fluorine concentrations of more than 20,000 mg/kg. The data was submitted to the database with a note about the limitations of the CRM.

Of the 616 samples analyzed, 93 were run in duplicate. Most of these duplicates were within 10% difference of each other, although five were greater than 10% difference. Two of these were near the detection limit of the method. The remaining deviation can be expected within normal inhomogeneities of the preparation method.

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) Analyses

The ICP-OES at the NMBGMR Chemistry Laboratory analyzed mostly water and leachate samples during the course of the project, however, solid samples digested by acid attack were analyzed for the cations listed in Table 8-11 in 2005 and 2006. After 2006, these parameters were measured by other methods.

Quality control for the instrumental analyses was the same for solids as for waters with the addition of two types of solid standards: certified standards or certified reference materials (CRMs) and ongoing project control samples. These standards were digested and analyzed with the samples to support the quality of the digestions. The ongoing control standards were collected by the project manager's team and analyzed by all of the labs over several years time – mainly the CAP-MLJ-0001 from the Capulin rock pile.

CRM were analyzed with each batch of samples digested. If the standard reference material was within 15%, the data were accepted (SOP 30). If not, the samples were first reanalyzed. If the standards still failed, the standards and associated samples were redigested. Not all elements were reported for every digest. Results are summarized in Table 8-11.

TABLE 8-11. Results (mg/kg) for certified standard NIST 2780 Hard Rock Mine Waste and USGS GSP-2 Silver Plume Granodiorite. NIST = National Institute of Standards.

Analyte	**Al**	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**As**	**Cd**
Reference value 2780	88700	993	1950	44	216	27840	33800	5330	462	2210	49	12
Average	85314	973	1956	41	199	27606	33952	5623	432	2159	49	13
Number of analyses	11	17	19	13	13	19	19	15	19	17	7	19
Standard deviation	*3323*	*49*	*72*	*3*	*7*	*984*	*1659*	*244*	*20*	*135*	*4*	*1*
Average % difference	*4*	*5*	*3*	*9*	*8*	*3*	*4*	*6*	*7*	*5*	*7*	*7*
Analyte	**Al**	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**		
Reference value GSP-2	78800	1340	15000	20	43	34300	44800	5800	320	20600		
Average	77566	1344	14694	17	47	34625	44641	6263	310	19873		
Number of analyses	10	18	20	15	10	20	20	13	20	19		
Standard deviation	*1901*	*39*	*472*	*1*	*5*	*954*	*1747*	*239*	*14*	*1026*		
Average % difference	*2*	*2*	*3*	*17 **	*13*	*2*	*3*	*8*	*5*	*5*		
Analyte	**P**	**Pb**	**Sr**	**Ti**	**V**	**Zn**	**Ni**	**S**	**Sb**	**Se**		
Reference value 2780	427	5770	217	6990	268	2570	12	12630	160	5		
Average	416	5345	219	6169	266	2648	11	12915	168	5		
Number of analyses	10	10	19	8	11	19	3	19	19	2		
Standard deviation	*34*	*154*	*8*	*260*	*9*	*108*	*1*	*717*	*9*	*0*		
Average % difference	*7*	*7*	*3*	*12*	*3*	*4*	*10*	*5*	*6*	*4*		
Analyte	**P**	**Pb**	**Sr**	**Ti**	**V**	**Zn**	**Ni**	**Y**				
Reference value GSP-2	1300	42	240	4000	52	120	17	28				

Analyte	**Al**	**Ba**	**Ca**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Na**	**As**	**Cd**
Average	1357	27	240	3665	74	125	17	25				
Number of analyses	10	7	20	6	9	19	4	1				
Standard deviation	*53*	*2*	*5*	*87*	*5*	*6*	*1*	*NA*				
Average % difference	*5*	*37* **	*2*	*8*	*42* **	*5*	*7*	*12*				

* Although the percent differences for this analyte were high, the data were accepted as they were within the published error for the CRM.

** The data were accepted for these analytes because the analyses for standard 2780 passed and sample data were near the higher ranges of 2780 rather than the lower ranges of GSP-2. A note was added to comments in the database.

Detection limits for this instrument can be reviewed in SOP 30.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) Analyses

Two suites of elements were analyzed on the NMBGMR ICP-MS after a four-acid digestion: trace metals and rare earth elements (REE). From January to August 2006 a small group of solid samples were analyzed for vanadium, cobalt, nickel, gallium, arsenic, rubidium, molybdenum, silver, lead, thorium and uranium as the digestion method was being developed. After fall 2006, solid samples were only analyzed for arsenic and beryllium on the ICP-MS as the remaining elements in this group were analyzed by XRF.

The REE suite included lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, dysprosium, erbium, ytterbium and lutetium. Analyses of scandium and yttrium were included initially but were discontinued after XRF was found to produce more accurate results.

Quality control included an initial calibration, calibration checks every 10 samples, CRMs digested and analyzed with the samples, and duplicates. Calibration checks were accepted when within 10% of the target. CRMs were accepted within 15% of target or when within the published error of the analyzed CRM (Tables 8-12 and 8-13). Analyses that did not fall within these ranges were reanalyzed or redigested and reanalyzed. Analyses of CRMs consistently failed within about 30% for three REE elements – gadolinium, ytterbium and lutetium – but these elements were reported to the project manager with a flag that they did not pass quality control.

TABLE 8-12. Statistics for ICP-MS metals analyses (mg/kg) of certified standard USGS GSP-2 Silver Plume Granodiorite.

Analyte	**Be ***	**V**	**Co**	**Ni**	**Ga**	**Rb**	**Mo ***	**Pb**	**Th**	**U**
Published value	1.5	52	7.3	17	22	245	2.1	42	105	2.4
Published error	0.2	4	0.8	2	2	7	0.6	3	8	0.19
Mean	1.5	57	7.5	16	25	234	2.1	43	111	2.2
Number of analyses	35	25	25	25	25	25	25	25	25	25
Maximum	1.9	65	8.8	18	27	250	2.3	49	120	2.7

Analyte	**Be ***	**V**	**Co**	**Ni**	**Ga**	**Rb**	**Mo ***	**Pb**	**Th**	**U**
Minimum	1.3	51	6.8	15	23	210	1.8	40	105	2.0
Standard deviation	0.11	3.4	0.51	0.80	1.2	11	0.15	1.7	4.2	0.14
Average % difference	1.1	9.0	2.6	-5.9	15	-4.5	-0.8	1.3	5.8	-7.5

* Non-certified values

TABLE 8-13. Statistics for rare earth element analyses (mg/kg) for certified standard USGS GSP-2 Silver Plume Granodiorite.

Analyte	**Sc**	**La**	**Ce**	**Pr ***	**Nd**	**Sm**	**Eu**	**Gd ***	**Dy ***	**Er ***	**Yb**	**Lu ***
Published value	6.3	180	410	51	200	27	2.3	12	6.1	2.2	1.6	0.23
Published error	0.7	12	30	5	12	1	0.1	2			0.2	0.03
Mean	5.6	175	416	52	201	25	2.4	16	5.6	2.3	1.3	0.15
Number of analyses	28	28	28	28	28	28	28	28	28	28	28	28
Maximum	6.2	195	484	58	221	28	2.7	18	6.4	2.6	1.4	0.2
Minimum	5.2	159	369	48	183	23	2.3	15	5.0	2.1	1.2	0.1
Standard deviation	*0.20*	*6.6*	*28*	*2.0*	*7.5*	*0.93*	*0.12*	*0.83*	*0.26*	*0.10*	*0.063*	*0.013*
Average % difference	*11*	*4*	*6*	*3*	*3*	*8*	*6*	*31*	*9*	*5*	*22*	*33*

* Non-certified values

Ferrous iron measurements by acid digestion and titration

Ferrous iron measurements were made on 547 solid samples using a USGS method by Reichen et al. (1962) as detailed in SOP 69. Although the NMBGMR Chemistry Laboratory had very good recoveries on certified reference materials (Table 8-14), the stated limitation of the method is for samples without sulfides. All Questa samples were run with a standard reference for each batch, but sample reports were sent with a comment that a correction must be made to to results for samples containing sulfides. The objective was to rerun any batches with a certified reference materials with a percent difference of more than 10% (SOP 69). One batch had 18% difference. A comment was added to the Access database for the associated data points.

TABLE 8-14. Certified reference material results for percent ferrous iron. CCRMP = Canadian Certified Reference Material Project.

CRMs	Replicates (n)	Mean	Given value (%FeO)	Standard deviation	Relative standard deviation	Mean % difference
G-1	2	1.0	0.97	0.02	2.2	5.6
MRG-1	4	8.4	8.63	0.44	5.3	4.9
SY-2	25	3.5	3.62	0.12	3.5	4.2

SY-3	12	3.9	3.59	0.19	5.0	7.4
SY-4	44	2.9	2.86	0.12	4.0	4.0
Relative standard deviation = 100* standard deviation / mean						
G-1 = USGS Granite						
MRG-1 = CCRMP Mount Royal Gabbro						
SY-2, SY-3 = CCRMP Syenite 2,3						
SY-4 = CCRMP Diorite Gneiss						

Using a sample with a low % FeO (0.23 %), the method detection limit for six replicates was determined to be 0.05 % FeO. The published detection limit was 0.01 % FeO. Only one sample was found to be below detection limit.

Seventy-five duplicates were analyzed. Of these, 12 were above the 10% difference allowable. As only one of these 12 was a sample with concentrations above 1% FeO, this variability is seen as a function of concentration.

S, SO_4, and C (AL Chemex)

S, SO4 and C analyses were obtained by AL Chemex. Duplicate samples and standards were submitted and compared within 10% (see Access database).

ACCURACY AND PRECISION OF WATER CHEMISTRY DATA

All liquid samples submitted to the NMBGMR Chemistry Laboratory were analyzed with the quality control samples listed on Table 8-15. Analyses that did not fall within allowable results were reanalyzed.

TABLE 8-15. Quality Control samples analyzed at the NMBGMR Chemistry Laboratory.

	Frequency	**Allowable result**
Calibration	At the beginning of every run	Calibration verification standards must pass.
Duplicates *	Every 10 samples	Within 10%.
Blanks	Every 10 samples	Less than method detection limits.
Continuous calibration verification	Every 10 samples	Within 10%.
Independent calibration verification	At the beginning and end of each run	Within 10%.
Spikes	New matrices	Within 25%.

* Although several leach experiments provided enough solution to run Chemistry Laboratory duplicates, several did not, and in these cases duplicates were not run. However, most leach experiments included leach duplicates.

Samples that were submitted for general water chemistry were subjected to an ion balance calculation. An ion balance of up to 13% was allowable (SOP 68), however, any ion balances above 3% were subjected to reanalysis and if unresolved were brought to the attention (by email) of the investigator who requested the analyses and reanalyzed to the investigator's satisfaction. Sources of ion imbalance included low total dissolved solids and unanalyzed anions such as sulfides and silicon compounds.

ACCURACY AND PRECISION OF HYDROLOGICAL AND GEOTECHNICAL TESTS

Hydrological and geotechnical tests were conducted in the project included particle size, Atterberg, slake durability, point load, direct shear testing, and others. In order to determine the reliability of these test;

- standard hydrology and engineering procedures were employed as described in the SOPs, component DRAs, Gutierrez (2006), Shannon (2006), Viterbo (2007), Nunoo (2009)
- selected samples were analyzed by different laboratories
- the data were compared to reported analyses of Questa materials.

Samples for hydrological and geotechnical testing were collected specifically for examining relationships between friction angle and mineralogy, chemistry, lithology, geotechnical parameters, and weathering. Several different types of samples were collected:

- Samples of the rock-pile material (5 ft channel or selected layers), including 5 of the 9 rock piles (Goathill North, Sugar Shack West, Spring Gulch, Sugar Shack South, Middle) and analogs (Alteration scars and debris flow)
- Soil profiles and selected samples of colluvium, alteration scars, and debris flows (analog materials)
- Outcrop samples of unweathered (or least weathered) igneous rocks representative of the mined rock before emplacement into the rock piles.

Particle size distribution within the rock piles is an important component of the hydrological and geotechnical characterization evaluation. Two methods of particle size analysis can be performed; wet or dry sieving. Previous testing of Questa materials utilized dry sieving (URS Corporation, 2003; Norwest Corporation, 2004, 2005). Gutierrez (2006) and Nunoo (2009) performed both dry and wet particle size analysis on Goathill North rock pile material, one of the nine rock piles at the Questa mine site, in accordance to the ASTM standards (2002) and U.S. Army Corps of Engineers (1970) methodology. Gutierrez (2006) reported that there were differences in the percent fines i.e. the percentage passed sieve No. 200, when dry and wet sieving were performed on the same material. The percent fines for the sample tested changed from 2.5% in dry sieving to 17.8% when wet sieving was conducted. The wet and dry sieving test results by Nunno (2009) are summarized in Table 8-16 and 8-17. Table 8-18 compares the particle size analyses for splits of the same sample by two different laboratories. It was observed that the wet sieving resulted in higher percentages of fines compared to dry sieving. The increase in fines is a result of the presence of water in wet sieving that dissolves the cementation and cohesion between particles and disintegration of clumps. However, it is believed that the increased percentage of fines observed in the wet sieve analysis does not represent the true behavior of the unsaturated rock-pile material. Since the particle size analyses of samples analyzed by NMBGMR is within the same range as analyses conducted by other laboratories (Table 8-19), the particle size analyses by NMBGMR are representative of the particle size distribution of the Questa material.

TABLE 8-16. Summary table of particle size results conducted at New Mexico Tech. Note that two separate samples were collected from Sugar Shack West rock pile. The particle size ranges for gravel, sand, and fines are defined in Appendix 8-2.

SAMPLE ID	DESCRIPTION	PARTICLE SIZE, DRY SIEVING			PARTICLE SIZE, WET SIEVING		
		% GRAVEL	% SAND	% FINE	% GRAVEL	% SAND	% FINE
MIN-SAN-0001	Debris Flow	52.4	45.7	1.9	53.2	34.3	12.6
QPS-SAN-0001	Alteration Scar	64.9	33.1	2.0	62.0	29.1	9.0
SSW-SAN-0005	Sugar Shack West	56.7	40.2	3.1	49.8	32.2	18.1
SPR-SAN-0001	Spring Gulch	71.4	25.9	2.7	66.4	22.6	11.0
SSW-SAN-0001	Sugar Shack West	46.4	52.3	1.4	33.2	44.7	22.1

TABLE 8-17. Summary table of particle size results conducted by Golder Associates.

SAMPLE ID	DESCRIPTION	PARTICLE SIZE (GRADATION) (-1-INCH) WET SIEVING			PARTICLE SIZE (GRADATION) (-No. 4) WET SIEVING		
		% GRAVEL	% SAND	% FINE	% GRAVEL	% SAND	% FINE
MIN-SAN-0002	Debris Flow	62.3	20.7	17.0	0.0	72.6	27.4
QPS-SAN-0002	Alteration Scar	40.9	42.5	16.6	0.0	71.9	28.1
SSW-SAN-0006	Sugar Shack West	66.4	8.8	24.8	0.0	62.6	37.4
SPR-SAN-0002	Spring Gulch	41.8	44.9	13.3	0.0	68.2	31.8
SSW-SAN-0002	Sugar Shack West	39.2	43.5	17.3	0.0	71.6	28.4

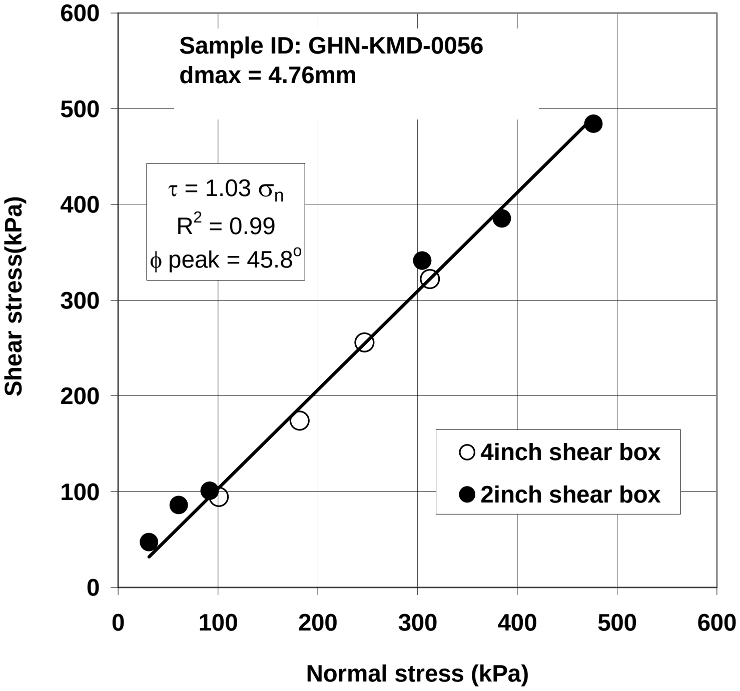
TABLE 8-18. Ranges and means of gravel, sand, and fines from wet sieving of Questa materials reported by different laboratories.

Laboratory	**% Gravel**		**%Sand**		**%Fines**	
	Range	Mean	Range	Mean	Range	Mean
Norwest	27-58	42.3	24-68	43.0	6-21	14.6
Golder	39.2-66.4	50.1	8.8-44.9	32.1	13.3-24.8	17.8
NMBGMR	33.2-66.4	52.9	22.6-44.7	32.6	9.0-22.1	14.6

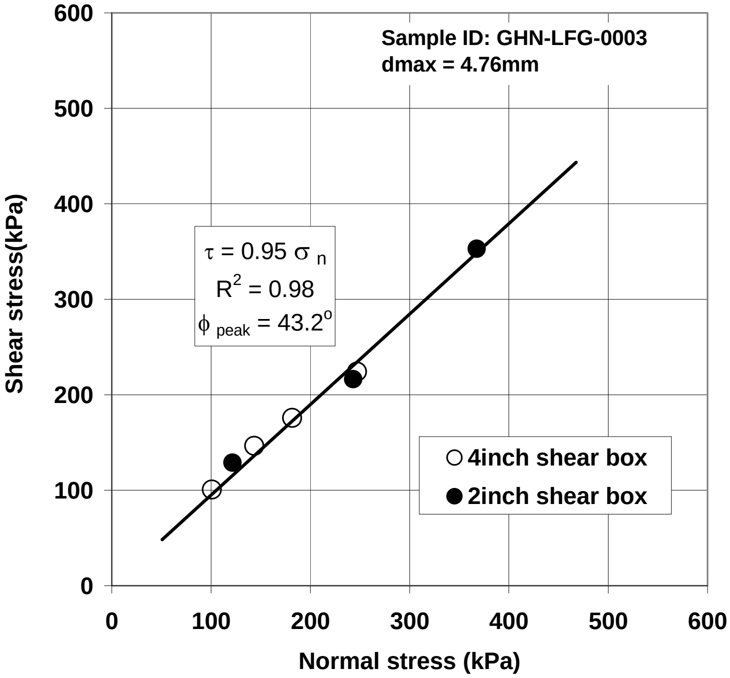
Direct shear testing of reconstituted samples provides friction angle and cohesion intercept, which are important geotechnical parameters that control the stability of the rock piles and is determined by the well known Mohr-Coulomb failure criterion to interpret the shear tests results (SOP 50; Gutierrez, 2006). One limitation of direct shear testing is the inability to control or monitor the pore water pressure. A few tests were performed with different water contents by Gutierrez (2006) and it was decided by the Questa Geotechnical Team to perform tests on air-dried samples at NMIMT.

Another limitation identified was the size of the shear box used. Gutierrez (2006) tested a few samples in both 5-cm (2-inch) and 10-cm (4-inch) boxes and determined that the results were relatively similar (no major size effect for changing the box size of 2 inch to 4 inch, Fig. 8-3). A 2-inch box was chosen because a wider range of normal stresses could be applied using this shear box.

In order to verify the accuracy of the adopted procedure, some samples were tested in duplicate or triplicate. In addition, tests were conducted using a 2.5-inch calibrated *ELE* direct shear testing apparatus at Kleinfelder Laboratory in Albuquerque, NM. The proving ring for this motorized apparatus is annually calibrated. The purpose of these tests was to validate the tests conducted with the manual *Soiltest* shear box machine in the NMT Soil Mechanics Laboratory. The Mohr-Coulomb diagrams for samples GHN-KMD-0014 and GNH-KMD-0017 tested using both machines are shown in Figures 8-4 and 8-5. The shear test results using the ELE machine fell along the trend lines defined by data generated with the machine at NMT. The addition of the corroborating data did not change the ϕ values. Five samples were tested at NMBGMR and at Golder Laboratory and the comparison is in Table 8-18. Therefore, these reliability procedures described above confirm that the direct shear test results obtained at NMT are considered to be reliable, representative and reproducible.



(a)



(b)

FIGURE 8-3. Shear box size effects on direct shear test (a) for sample GHN-KMD-0056 with dmax = 4.76 mm, (b) GHN-LFG-0003 with dmax = 4.76 mm.

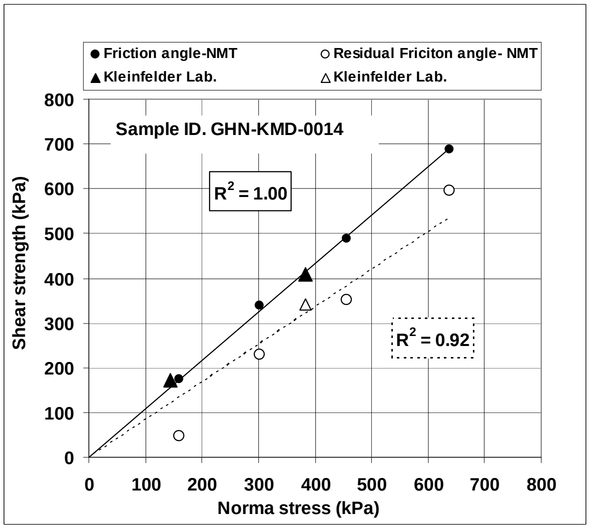


FIGURE 8-4. Mohr-Coulomb diagrams for sample GNH-KMD-0014 tested using both ELE machine at Kleinfelder Laboratory in Albuquerque , NM and Soiltest machine at the Mineral Engineering Department, NMIMT.

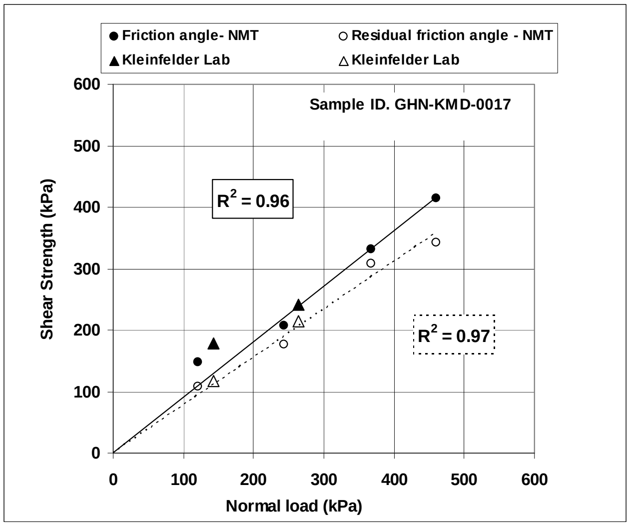


FIGURE 8-5. Mohr-Coulomb diagrams for sample GNH-KMD-0017 tested using both ELE machine at Kleinfelder Laboratory in Albuquerque , NM and Soiltest machine at the Mineral Engineering Department, NMIMT.

TABLE 8-19. Golder Lab (2.4-inch samples) and NMT (2-inch samples) shear test results for air-dried samples.

SAMPLE ID (GOLDER)	SAMPLE ID (NMT)	DESCRIPTION	2.4 inch DRY, GOLDER LAB RESULTS		2 inch DRY, NMT RESULTS	
			Normal Stress (50-700kPa)		Normal Stress (50-700kPa)	
			c (kPa)	φ (degrees)	c (kPa)	φ (degrees)
MIN-SAN-0002	MIN-SAN-0001	Debris Flow	32.2	39.3	26.1	39.7
QPS-SAN-0002	QPS-SAN-0001	Alteration Scar	54.4	38.5	33.4	38.4
SSW-SAN-0006	SSW-SAN-0005	Sugar Shack West	30.3	39.2	28.9	35.3
SPR-SAN-0002	SPR-SAN-0001	Spring Gulch	33.9	38.4	26.6	38.1
SSW-SAN-0002	SSW-SAN-0001	Sugar Shack West	64.4	35.8	17.7	41.6

SUMMARY

Samples were collected, prepared, and analyzed according to standard methods for each specific laboratory analysis and are described in the project SOPs, project reports, and Appendices 8-1, 8-4 and 8-5. Samples collected are complete, comparable, and representative of the defined population at the defined scale as documented in this report and the project reports. Precision and accuracy are measured differently for each field and laboratory analysis (parameter), and are explained in the project reports, SOPs, DRAs, and this report. Most geochemical laboratory analyses depend upon certified reference standards and duplicate and triplicate analyses as defined in the project Sops. The reliability of the hydrological and geotechnical tests was determined by employing standard engineering procedures, analyzing selected samples by different laboratories, and comparing the data to reported analyses of Questa materials. The sampling and analysis plans for each segment of the field program and the control of accuracy and precision as defined in the SOPs, provides a large high-quality set of observations and measurements that are adequate to support the interpretations and conclusions of the various technical studies documented in the individual project reports.

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APPENDIX 8-1. List of Standard Operating Procedures (SOPs)

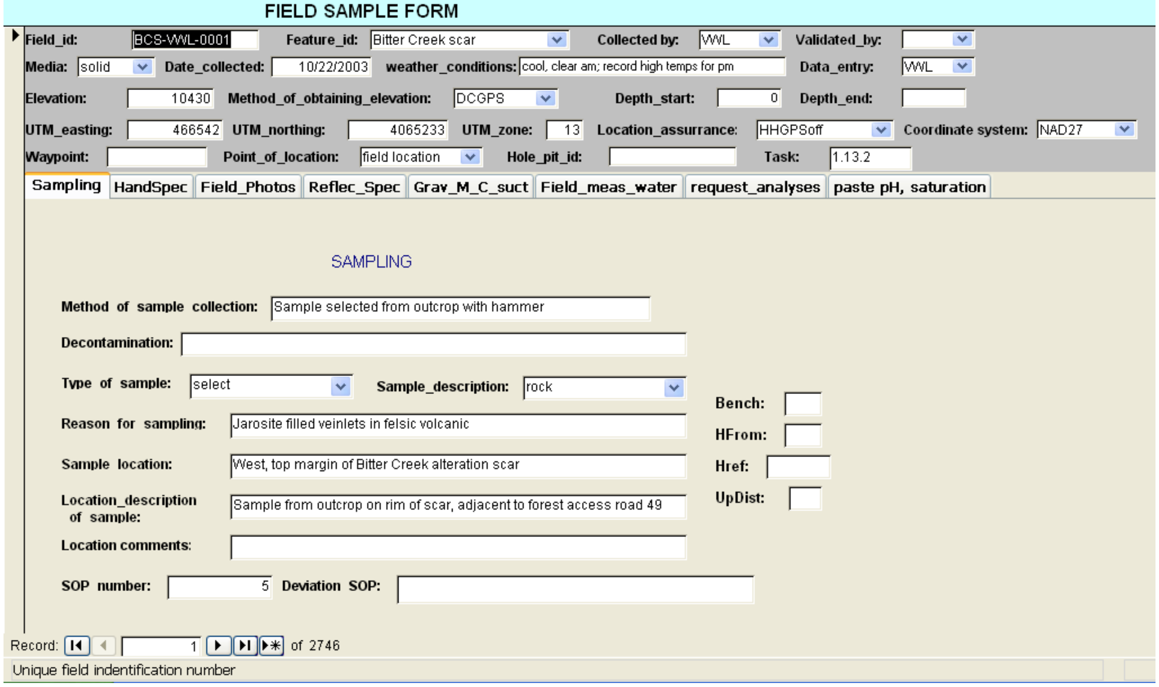
Number	Name	Description
MP	Project Management Plan	Overall project management plan
WP	Work plan	Work plan for the project
HASP	Health and Safety Plan	Health and safety plan for filed and laboratory work
QAPP	Quality Assurance Project Plan	Quality assurance and quality control plan
FSP	Field Sampling Plan	Field sampling plan
DP1	Drilling plan, phase 1	Drilling plan
DP2	Drilling plan, phase 2	Drilling plan
GMP	Geologic mapping plan	Geologic mapping plan
SOP 1	Data management	entering, reporting, verification, and validation of data to the database
SOP 2	Sample management	procedures of handling samples from field to laboratory to archive
SOP 3	Surveying (GPS)	field procedures using GPS and other surveying methods
SOP 4	Photography	procedures taking photographs in the field and laboratory
SOP 5	Sampling outcrops, rock piles, and drill core	field procedures for taking surface solid samples
SOP 6	Drill logging and sampling of subsurface	field procedures for drilling, logging, and sampling of subsurface samples (solids)
SOP 7	Sample equipment Decontamination	field procedures for decontamination of sampling equipment
SOP 8	Sample preparation	laboratory procedures for sample preparation (solids)
SOP 9	Test pit excavation, logging, and sampling (solid)	field procedures for test pit excavation, logging, and sampling (solid)
SOP 10	Met station maintenance	field procedures for maintaining meteorological station
SOP 11	Paste pH and paste conductivity	laboratory procedures for paste pH and paste conductivity
SOP 12	Field measurements of water	field procedures for measuring water flow, pH, conductivity, alkalinity, temperature when collecting water samples
SOP 13	Water elevation measurements	field procedures for measuring water elevations in drill holes
SOP 14	Field filtration of water samples	procedures for filtering water samples in the field
SOP 15	Surface water and seep sampling	field procedures for collecting samples of surface and seep water samples
SOP 16	Groundwater sampling	field procedures for collecting ground-water samples
SOP 17	Borehole logging	field procedures for borehole logging
SOP 18	Pump testing	field procedures for collecting information during pump testing
SOP 19	Geophysical logging	field procedures for borehole geophysical logging
SOP 20	Well development	field procedures for development of wells
SOP 21	Monitoring well installation	field procedures for installing monitoring wells and instrumentation
SOP 22	Analytical data validation	procedures for data validation
SOP 23	Geophysics with electromagnetic induction	procedures for geophysical surveys
SOP 24	Petrographic analysis	laboratory procedures for describing petrographic samples
SOP 25	Stable isotope analysis	laboratory procedures for stable isotope analyses
SOP 26	Electron microprobe analyses	laboratory procedures use for analyses using the electron microprobe
SOP 27	X-ray diffraction (XRD) analyses	laboratory procedures for mineralogical analyses by x-ray diffraction (XRD)
SOP 28	X-ray fluorescence (XRF) analyses	laboratory procedures for chemical analyses by x-ray fluorescence (XRF)
SOP 29	Clay mineralogy analyses	laboratory procedures for sample preparation and XRD analyses of clay minerals
SOP 30	ICP-OES analyses	laboratory procedures for chemical analyses using ICP-OES
SOP 31	ICP-MS analyses	laboratory procedures for chemical analyses using ICP-MS
SOP 32	Bulk density	laboratory procedures for determining bulk density
SOP 33	Particle size analysis	laboratory procedures for determining particle size analyses

Number	Name	Description
SOP 34	Sampling for the Remaining Pyrite Model	approach, collection of samples and laboratory procedures required for sampling for remaining pyrite model
SOP 35	Volumetric moisture content	collection of samples and laboratory procedures for determining volumetric moisture content
SOP 36	Sample preservation, storage, custody, shipping	procedures for sample preservation, storage, and shipment
SOP 38	DI leach	laboratory procedures for leaching solid samples by deionized water to provide for soluble material
SOP 39	Samples for Pore water measurements	laboratory procedures for collecting samples for pore water measurements
SOP 40	Gravimetric moisture content	collection of samples and laboratory procedures for gravimetric moisture content
SOP 41	Reflectance spectroscopy	field procedures for mineralogical analyses using reflectance spectrography
SOP 42	Porosity	laboratory procedures for determining porosity
SOP 43	Tensiometer and thermal conductivity thermal conductivity sensor installation	field procedures for installing tensiometers and thermal conductivity sensors procedures for argon/argon dating
SOP 44	Argon/argon geochronology	laboratory procedures for argon/argon dating
SOP 45	Moisture retention relation by hanging column	procedures for determining moisture relations
SOP 47	Rain and snow collection for isotope	field procedures for collecting rain and snow
SOP 48	Dye tracer studies	Tracer studies using dyes
SOP 49	Chip tray preparation	How to prepare chip trays of drill cuttings for examination
SOP 50	Direct Shear tests	How to do simple shear box tests
SOP 51	Collecting Thermal images	How to collect thermal images using thermal camera
SOP 52	Static Net Acid Generation (NAG) Test	Nag test for laboratory
SOP 53	Tension Infiltrometer	procedures for tension infiltrometer measurements
SOP 54	Atterberg Limits	procedures for Atterberg Limits
SOP 55	General Microbial Sampling - Solids	General Microbial Sampling - Solids
SOP 56	Classical microbial analysis - solids	Classical Microbial Analysis - Solids
SOP 57	Microbial laboratory safety	Microbial Laboratory Safety
SOP 58	Microbial metabolic profiles - biology	Microbial Metabolic Profiles - Biology
SOP 59	Microbial nucleic acid analysis	Microbial Nucleic Acid Analysis
SOP 60	Slurry pH-redox-condictivity-temperature	Slurry Ph – Redox – Conductivity - Temperature
SOP 61	Neutron density gauge	Describes measurements taken with the nuclear density gauge (density, water content)
SOP 62	Acid-base accounting (ABA)	Procedures for acid base accounting in laboratory
SOP 63	Kelway soil acidity and moisture measurements	Kelway Soil Acidity and Moisture Tester for field measurements
SOP 64	Portable tensiometer	procedures for using field portable tensiometers as opposed to in place monitoring
SOP 65	Sandcone	procedures for sand cone
SOP 66	Gas analyzer	procedures for gas analyzer
SOP 67	Solid sample collection and compound analysis	procedures for solid sample collection and compound analysis
SOP 68	Water analyses	water analyses in lab
SOP 69	Other chemical analyses on solids	other chemical analyses on solids (ammonia, nitrate, fluorine, etc)
SOP 70	Sand replacement	calculates volumetric moisture content and bulk density
SOP 71	Guelph permeameter	procedures for guelph permeameter measurements
SOP 72	SWCC	Soil water characteristic curve (UBC)
SOP 73	Falling head Permeability	Permeability by falling head method
SOP 75	Specific gravity	procedures for determining specific gravity

Number	Name	Description
SOP 76	Slake durability	procedures for slake durability tests
SOP 77	Point load	procedures for point load tests
SOP 78	Humidity cell testing	procedures for weathering cells tests
SOP 79	Sample preparation for humidity cell testing	procedures for weathering cells sample selection and preparation
SOP 90	XRD sample preparation for pyrite reserve model	XRD sample preparation for pyrite reserve model
SOP 91	Color	procedures for obtaining the color of a soil sample

APPENDIX 8-2. Field sample forms in the database used to record field location and descriptive data obtained in the field during sample collection (for both solids and waters). Field ID described in Table 2-1.

Form recording the spatial data for each sample.



FIELD SAMPLE FORM

Field_id: BCS-WWL-0001
Feature_id: Bitter Creek scar
Collected by: WWL
Validated_by:
Media: solid
Date_collected: 10/22/2003
weather_conditions: cool, clear am; record high temps for pm
Data_entry: WWL
Elevation: 10430
Method_of_obtaining_elevation: DCGPS
Depth_start: 0
Depth_end:
UTM_easting: 466542
UTM_northing: 4065233
UTM_zone: 13
Location_assurrance: HHGPSoff
Coordinate system: NAD27
Waypoint:
Point_of_location: field location
Hole_pit_id:
Task: 1.13.2

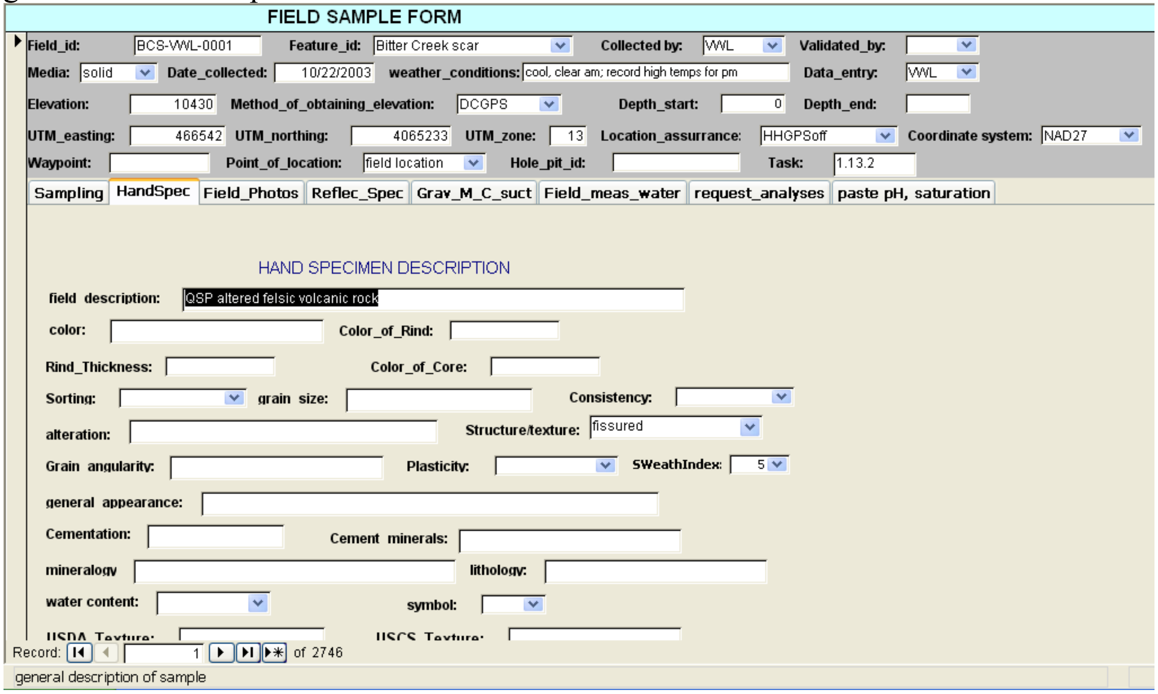
SAMPLING

Method of sample collection: Sample selected from outcrop with hammer
Decontamination:
Type of sample: select
Sample_description: rock
Reason for sampling: Jarosite filled veinlets in felsic volcanic
Sample location: West, top margin of Bitter Creek alteration scar
Location_description of sample: Sample from outcrop on rim of scar, adjacent to forest access road 49
Location comments:
SOP number: 5
Deviation SOP:
Bench:
HFrom:
Href:
UpDist:

Record: 1 of 2746

Unique field indentification number

Form recording the geological descriptions of the samples. A mixture of geological and geotechnical descriptions are used.



FIELD SAMPLE FORM

Field_id: BCS-WWL-0001
Feature_id: Bitter Creek scar
Collected by: WWL
Validated_by:
Media: solid
Date_collected: 10/22/2003
weather_conditions: cool, clear am; record high temps for pm
Data_entry: WWL
Elevation: 10430
Method_of_obtaining_elevation: DCGPS
Depth_start: 0
Depth_end:
UTM_easting: 466542
UTM_northing: 4065233
UTM_zone: 13
Location_assurance: HHGPSoff
Coordinate system: NAD27
Waypoint:
Point_of_location: field location
Hole_pit_id:
Task: 1.13.2

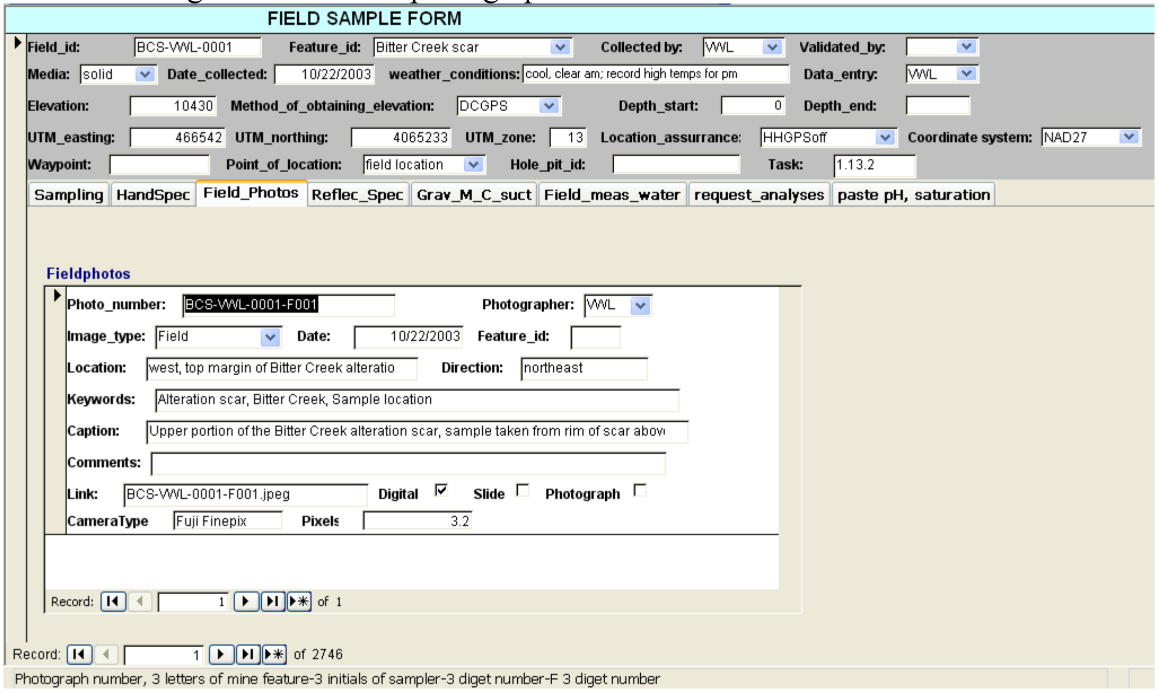
HAND SPECIMEN DESCRIPTION

field description: QSP altered felsic volcanic rock
color:
Color_of_Rind:
Rind_Thickness:
Color_of_Core:
Sorting:
grain size:
Consistency:
alteration:
Structure/texture: fissured
Grain angularity:
Plasticity:
SWeathIndex: 5
general appearance:
Cementation:
Cement minerals:
mineralogy
lithology:
water content:
symbol:
USDA Texture:
USCS Texture:

Record: 1 of 2746

general description of sample

Form recording information on photographs taken in the field.



FIELD SAMPLE FORM

Field_id: BCS-VWL-0001
Feature_id: Bitter Creek scar
Collected by: VWL
Validated_by:
Media: solid
Date_collected: 10/22/2003
weather_conditions: cool, clear am; record high temps for pm
Data_entry: VWL
Elevation: 10430
Method_of_obtaining_elevation: DCGPS
Depth_start: 0
Depth_end:
UTM_easting: 466542
UTM_northing: 4065233
UTM_zone: 13
Location_assurance: HHGPSoff
Coordinate system: NAD27
Waypoint:
Point_of_location: field location
Hole_pit_id:
Task: 1.13.2

Fieldphotos

Photo_number: BCS-VWL-0001-F001
Photographer: VWL
Image_type: Field
Date: 10/22/2003
Feature_id:
Location: west, top margin of Bitter Creek alteratio
Direction: northeast
Keywords: Alteration scar, Bitter Creek, Sample location
Caption: Upper portion of the Bitter Creek alteration scar, sample taken from rim of scar abov
Comments:
Link: BCS-VWL-0001-F001.jpeg
Digital ☑ Slide ☐ Photograph ☐
CameraType: Fuji Finepix
Pixels: 3.2

Record: 1 of 1

Record: 1 of 2746

Photograph number, 3 letters of mine feature-3 initials of sampler-3 diget number-F 3 diget number

TABLE A2-1. Description of Sample description field in the sample form.

Sample description	Description
well	water from well or drill hole
subsurface unsaturated/vadose zone	selected subsurface sample
waste water	waste water
mine drainage	water sample from mine drainage
rock	unaltered or slightly altered rock
mineralized rock	rock is altered or mineralized
ore	mined or extractable ore material
rock pile	rock material
soil	soil sample
sediment	stream or lake sediment
select	select sample for specific analysis
microbe	sample collected for microbe analyses
core	drill core
cuttings	drill cuttings

TABLE A2-2. Description of type of sample field in the sample form.

Type of sample	Description
drill cuttings	cuttings from reverse circulation
Becker cuttings	drill cuttings from Becker drill rig
sonic core	core obtained from sonic drilling
split spoon	sample collected from split spoon, indicate size in comments
drill core	diamond drill core
bucket	sample collected from backhoe bucket
grab	randomly collected sample by hand
hand auger	sample collected by hand using an auger
channel sample	continuous sample over a specified length and width
composite	sample collected from different locations and combined to form one sample
composite rock pile	sample collected from different locations and combined to form one sample in a rock pile
select	sample selected for specific analysis
screened	solid sample screened to specified size fraction, specify size in comments
pump sample	Sample obtained during pump tests
field blank	field blank, typically used for only water
field replicate	Field replicate sample
quality control sample	As required by SOP, generally 1 duplicate per 25 samples collected
biological	samples selected for biological purposes
Gas analyses	analysis of gas venting from drill holes

TABLE A2-3. Description of 2-digit sample preparation numbers (the last 2 digits in the Sample Identification Number). See SOPs for more details.

Sample Preparation Number	Definition
00	field sample as collected, moisture content, water
01	thin section
02	XRF, XRD
03	ICP
04	DI leach (uncrushed)

Sample Preparation Number	Definition
05	Moisture content, paste pH, paste conductivity
06	Clay mineralogy
07	Stable isotopes
08	Ar/Ar dating
09	Reflectance spectroscopy (uncrushed)
10	Powdered Archive
11	Aqueous pH, conductivity
12	geotechnical sample (shear box)
13	microprobe
14	ABA/NAG
15	pyrite reserve
16	paste pH, paste conductivity
17	biology
18	volumetric sample
19	sand cone
20	pea size, crushed for archive
21	sand replacement
22	bulk density
23	volumetric sample
24	bulk density
25	pore water
30	different samples taken in the field for microprobe, typically soil sample
31	different samples taken in the field for microprobe
32	different samples taken in the field for microprobe
33	humidity cell sample, after tests
34	humidity cell sample, after tests
35	humidity cell sample, after tests
36	humidity cell sample, after tests
37	humidity cell sample, after tests
38	humidity cell sample, after tests
39	humidity cell sample, after tests
40	humidity cell sample, after tests
41	duplicate isotope sample
42	duplicate isotope sample
43	duplicate isotope sample
44	duplicate isotope sample
45	duplicate isotope sample
46	duplicate isotope sample
47	duplicate isotope sample
48	duplicate isotope sample
49	duplicate isotope sample
50	duplicate isotope sample
51	particle size analyses (6in ASTM sieve opening)
52	particle size analyses (4in ASTM sieve opening)
53	particle size analyses (3in ASTM sieve opening)
54	particle size analyses (2in ASTM sieve opening)
55	particle size analyses (1.5in ASTM sieve opening)
56	particle size analyses (1in ASTM sieve opening)
57	particle size analyses (0.75in ASTM sieve opening)
58	particle size analyses (0.5in ASTM sieve opening)
59	particle size analyses (0.375in ASTM sieve opening)

Sample Preparation Number	Definition
60	particle size analyses (3mesh ASTM sieve opening)
61	particle size analyses (4mesh ASTM sieve opening)
62	particle size analyses (6mesh ASTM sieve opening)
63	particle size analyses (8mesh ASTM sieve opening)
64	particle size analyses (14mesh ASTM sieve opening)
65	particle size analyses (16mesh ASTM sieve opening)
66	particle size analyses (20mesh ASTM sieve opening)
67	particle size analyses (30mesh ASTM sieve opening)
68	particle size analyses (40mesh ASTM sieve opening)
69	particle size analyses (50mesh ASTM sieve opening)
70	particle size analyses (70mesh ASTM sieve opening)
71	particle size analyses (100mesh ASTM sieve opening)
72	particle size analyses (140mesh ASTM sieve opening)
73	particle size analyses (200mesh ASTM sieve opening)
74	particle size analyses (Pan)
75	GeoTech Atterberg Limits
76	GeoTech shear box
77	GeoTech drying
78	GeoTech extra
79	GeoTech extra
80	GeoTech extra
81	GeoTech extra
82	GeoTech extra
83	Ar/Ar dating
84	Ar/Ar dating
85	Ar/Ar dating
86	slake testing
87	slake testing
88	duplicate for boulder samples
90	coarse fraction, solid sample in the weathering cell
91	fine size material separated from humidity cell sample at NMT
92	fine size material washed/separated from humidity cell sample at Utah
93	water sample of DI wash from Utah
94	water sample of DI leach of fines at NMT
95	leachate sample from weathering cells collected at a specific date
96	biological sample
97	duplicate for boulder samples
98	duplicate analyses
99	duplicate analyses

APPENDIX 8-3. Description of mine-feature abbreviations used in sample nomenclature scheme (Tables 2-4).

Symbol	Site name	Type of feature
BIR	Birdfoot scar	alteration scar
BCS	Bitter Creek scar	alteration scar
CAP	Capulin	mine waste rock pile
CAS	Capulin scar	alteration scar
ERS	Eagle Rock scar	alteration scar
EJB	East June Bug scar	alteration scar
ELE	Elephant Rock campground	campground
FSR	Forest Service Ranger Station scar	alteration scar
GOH	Goathill	natural hill
GDF	Goathill debris flow	debris flow
GSR	Goathill Gulch scar	alteration scar
GHN	Goathill North	mine waste rock pile
GHS	Goathill South	mine waste rock pile
GOO	Goose Creek	alteration scar
ROC	Hand sample or nonmine samples	lithology
HAS	Hansen scar	alteration scar
HTS	Hottentot scar	alteration scar
JBS	June Bug scar	alteration scar
LEG	legacy data sample	legacy data
LHA	Little Hanson scar	alteration scar
LBS	Lower Bitter Creek scar	alteration scar
MCS	Mallette scar	alteration scar
MID	Middle	mine waste rock pile
MIL	Mill	mill
MIN	Mine	mine area, including underground workings
QPS	Pit scar	alteration scar
PIT	Questa open pit	open pit with pit lake
QAS	Questa scar	alteration scar
RED	Red River	river valley
SJB	South June Bug scar	alteration scar
SSC	South Straight scar	alteration scar
SHE	Southeast Hottentot scar	alteration scar
ESS	Southeast Straight Creek scar	alteration scar
SET	Southeast Truck Shop scar	alteration scar
SWH	Southwest Hansen scar	alteration scar
SPR	Spring Gulch	mine waste rock pile
SCS	Straight Creek Scar	scar
SSS	Sugar Shack South	mine waste rock pile
SSW	Sugar Shack West	mine waste rock pile
SGH	Sulphur Gulch North/Blind Gulch	mine waste rock pile
SGN	Sulphur Gulch North/Blind Gulch scar	rock pile
SGS	Sulphur Gulch South	mine waste rock pile

Symbol	Site name	Type of feature
TAL	tailings	tailings
WER	West Eagle Rock scar	alteration scar
WGH	West Goathill scar	alteration scar

APPENDIX 8-4. Additional specialized studies in the QRPWASP where samples and other field data were collected.

Study	Purpose	Type of samples	SOP	DRA	Other reference
Characterization of alteration scars	Describe a potential weathering analog	Bulk samples along weathered residual soil profiles	5	20	Graf (2008), McLemore et al. (in preparation)
Characterization of debris flows	Describe a potential weathering analog	Bulk samples along weathered residual soil profiles	5	22	Ayakwah et al. (2008)
Characterization of weathered bedrock	Describe a potential weathering analog	Bulk samples along weathered residual soil profiles	5	21	McLemore (2008b)
Characterization of the hot zones	Describe the material in the hot zones within the front rock piles	Rock-pile drill cuttings	5, 6	7	McLemore et al. (2008c)
Characterization of the crust	Describe the weathered crust that forms on the surface of the rock piles and the effect on	Selected samples of the crust, samples of precipitation runoff	5	8	Giese et al. (2008)
Characterization of humidity cells	Describe the samples before and after humidity cell tests	Selected samples based on total S concentration	5	34	McLemore et al. (2008e)
Characterization of weathered boulders	Describe weathered boulders at the surface	Large boulders	5	25	Sweeney et al. (2008)
Isotope geochemistry of pore water	Compare isotopic signatures of pore water to other waters	Matrix-rich solid samples, collected precipitation and other water samples	39, 47	12	Campbell and Hedrickx (2008)
Sulfur and oxygen isotopes	Determine stable isotopes	Selected samples	25	17	Campbell and Lueth (2008)
Geochronology	Determine age	Selected samples	44	18	
Tritium Analysis	Use of tritium analyses to determine a hydraulic barrier	Selected samples	none	11	
DI leach and column studies	Approximate pore water compositions	Selected samples	38	26, 23	
Microbiology	Determine microbial populations	Selected samples of solid material for microbial analyses	55-60	24	

APPENDIX 8-5. Summary of sample preparation for specific laboratory analyses. XRF–X-ray fluorescence analyses, XRD–X-ray diffraction analysis, ICP–Induced-coupled plasma spectrographic analysis, NAG–net acid producing tests, ABA–acid base accounting tests. Solid materials remaining after the tests were archived. Pulverized and crushing are the steps in SOP 5 that reduce the particle size to <35 µm required for chemical analysis.

Laboratory analysis	Type of sample	Sample Preparation	Method of obtaining accuracy and precision	SOP
Petrographic analyses	Collected in the field, used split from chemistry sample before crushing	Uncrushed, typically smaller than gravel size material used, thin sections made of selected rock fragments	Selected samples were analyzed by outside laboratory	24
Microprobe analyses	Collected in the field or split from chemistry sample before crushing	Uncrushed, generally 2 splits; rock fragments and soil matrix	Use reference standards	26
Whole-rock chemical analysis (XRF, S/SO4, C)	Collected in the field in separate bag, analysis performed on powdered sample	Crushed and pulverized	Use reference standards and duplicates and triplicates	8
Whole-rock chemical analysis (ICP-OES, ICP-MS, F, ferrous iron)	Collected in the field in separate bag, analysis performed on powdered sample	Crushed, pulverized, and dissolved in a liquid for analysis	Use reference standards and duplicates and triplicates	8, 30, 31
X-ray diffraction (XRD) analyses (including remaining pyrite analysis)	Used split from chemistry sample	Crushed	Compared to detailed analysis by electron microprobe	27, 34
Clay mineralogy analyses	Used split from chemistry sample before crushing	Uncrushed, typically smaller than gravel size material used, thin sections made of selected rock fragments, clay separation obtained by settling in a beaker of DI water	Use duplicate analysis, compared to other results performed by consultant companies, compared to detailed analysis by electron microprobe	29
Particle-size analysis	Bulk sample collected in the field	Sample sieved for each size fraction weighed	Use duplicate analysis, compared to other results performed by consultant companies	33
Paste pH and paste conductivity	Collected in the field, used split from chemistry sample or gravimetric sample	Uncrushed, typically smaller than gravel size material used	Use duplicates, compared with field measurements using Kelway instrument (SOP 63), compare to mineralogical analysis	11
ABA/NAG tests	Used split from chemistry sample	Crushed, typically smaller than gravel size material used	Use duplicate analysis, compared to other results performed by consultant companies	52, 62

Laboratory analysis	Type of sample	Sample Preparation	Method of obtaining accuracy and precision	SOP
DI leach	Collected in the field	Uncrushed, typically smaller than gravel size material used	Use reference standards and duplicate analyses	38
Gravimetric moisture content	Collected in the field in a sealed metal canister	Uncrushed, typically smaller than gravel size material used	Use duplicates	40
Atterberg Limits	Bulk sample collected in the field	Sample sieved to <0.425 mm	Use duplicate analysis, compared to other results performed by consultant companies	54
Bulk density and specific gravity	Collected in sealed buckets in the field	None, typically smaller than gravel size material used	Use duplicate analysis, compared to other results performed by consultant companies	32, 65, 70, 75
Direct Shear Test	Bulk sample collected in the field	Sieved to pass through the no. 6 sieve (<3.35 mm) for 2 inch shear test	Use duplicate analysis, compared to other results performed by consultant companies	50
Slake durability and point load index tests	Rock fragments 40 and 60 g for slake durability tests and approximately 4-10 cm in dimension for point load tests	None	Duplicate tests	76, 77
Stable isotope analysis	Selected mineral grains	See SOP 25	duplicate analysis and use of international standards	25

APPENDIX 8-6. Amounts of collected sample material required for the project.

Laboratory analysis	Amount of material to be collected
Archive sample	250 grams
Clay mineralogy	2200 grams
Leaching studies	50 grams
Whole rock chemical analysis	200 grams
Particle size	5 gallon bucket
Shear tests and Atterberg Limits	5 gallon bucket
Thin section	Rock fragments (>cm diameter)
Pore water chemistry	Mason jar
Stable isotopes and age determination	Few grams of select sample
Paste tests and gravimetric moisture content	Small tin (~200 g)
Biological samples	Small collection test tube of sample
Pyrite reserve analysis	1 kilogram
Bulk density	5 gallon bucket

APPENDIX 8-7. Location of samples examined in the Questa project. In addition, two GIS-ARC Map projects are attached that show the locations individual samples in the GHN trenches (GIS trenches) and throughout the Questa area (GIS_samples).

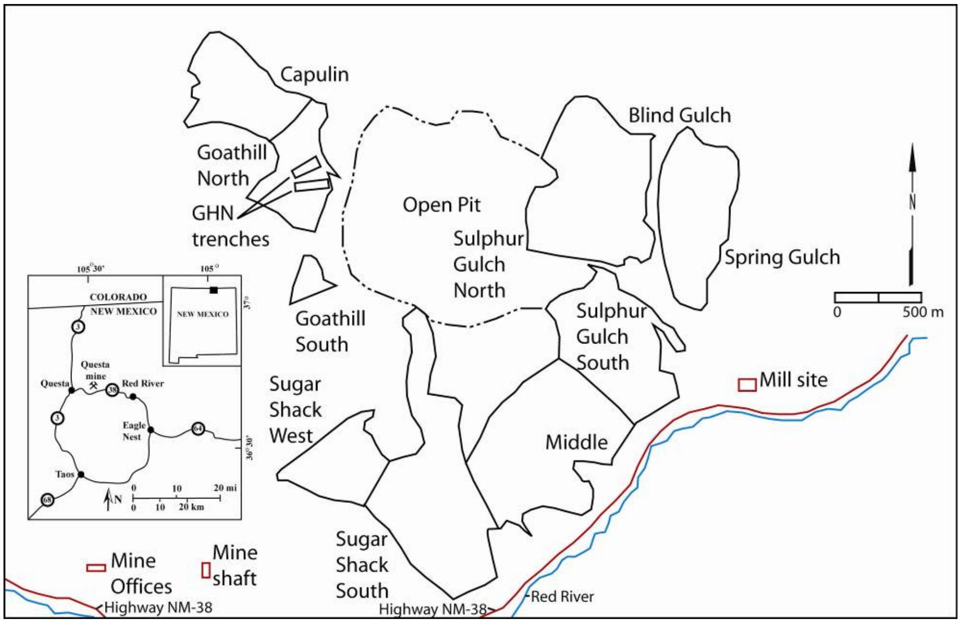


FIGURE A7-1. Questa rock piles and other mine features, including location of trenches constructed in GHN (DRA-2; McLemore et al., 2008f).

LOCATION OF GHN SAMPLES (more detailed locations in McLemore et al., 2008a, appendices 4-6) (Gutierrez, 2006; Gutierrez et al., 2008)

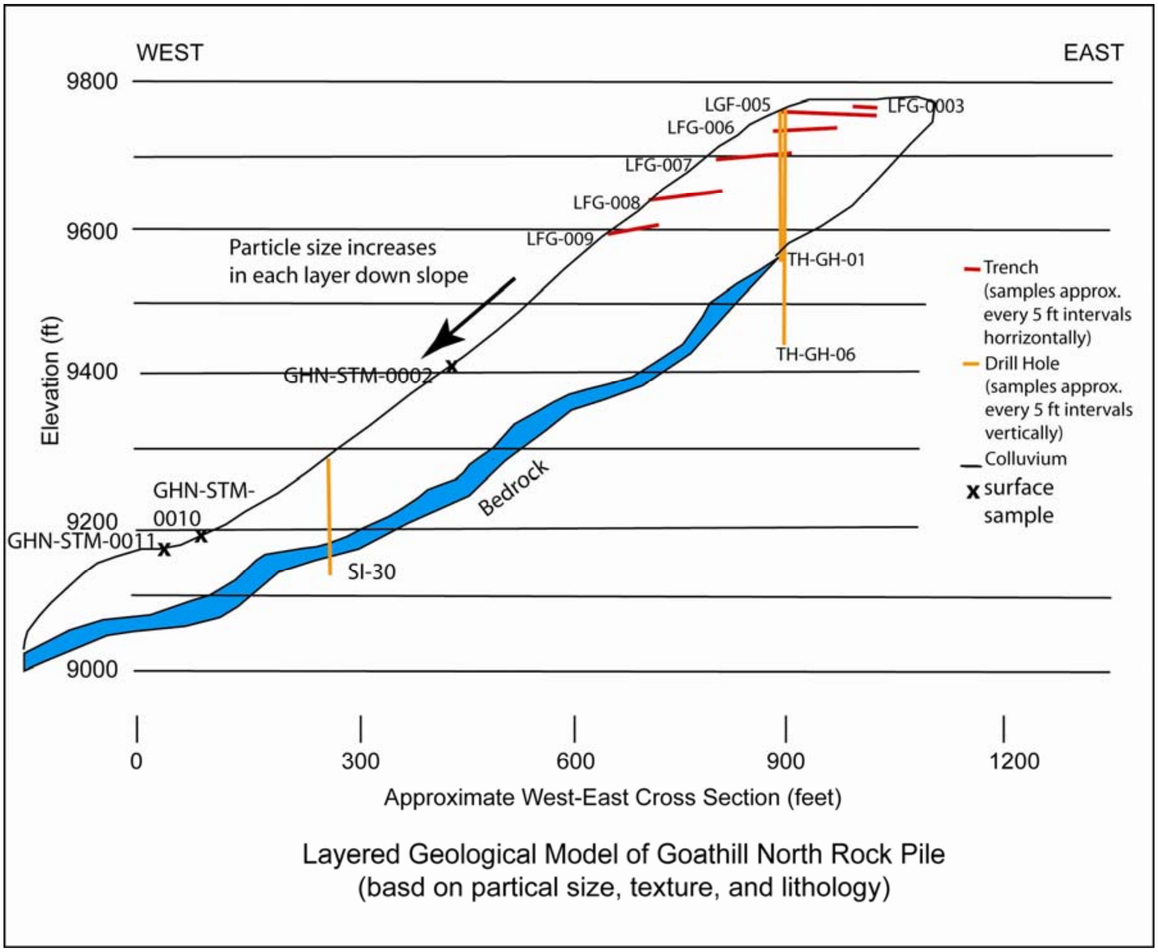


FIGURE A7-2. Approximate locations of samples in Goathill North rock pile. Samples were collected at approximately 5 ft intervals horizontally along the benches within each trench and at approximately 5 ft intervals vertically down each drill hole. See McLemore et al. (2008a, appendices 3, 4, 5, 6) for detailed maps showing locations of samples.

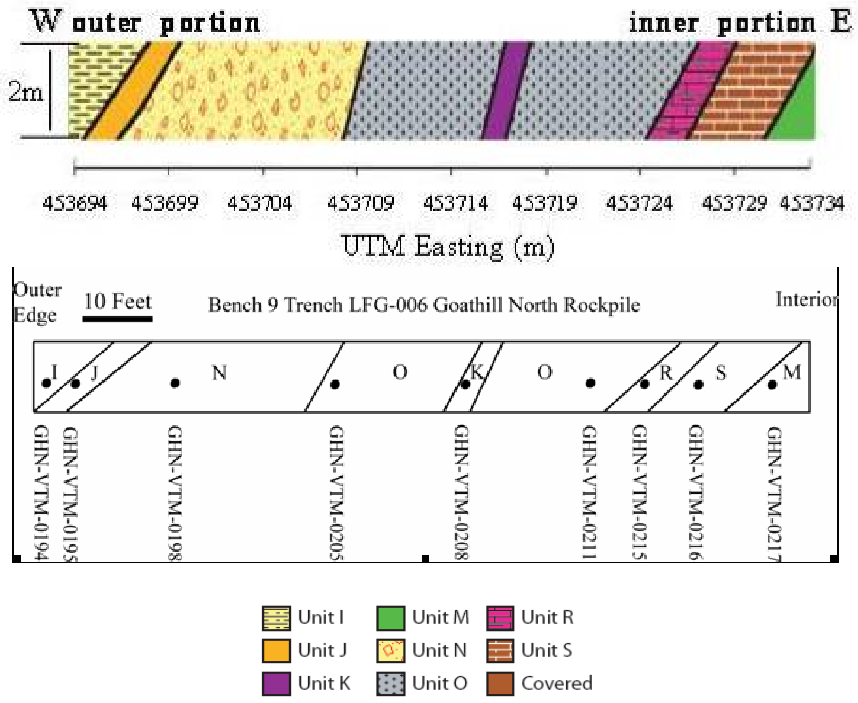


FIGURE A7-3. Geologic cross section of bench 9, trench LFG-006. Note that not all 18 geologic units are present in this bench. Note the vertical exaggeration; actual dips of strata were 20°-40°.

TABLE A7-1. Location of samples (surface, drill holes and trenches) in GHN rock pile as shown in Figure A7-2.

Drill hole or trench	Samples
TH-GN-01	GHN-ACT-0001 through GHN-ACT-0032
GHN-SI-30	GHN-PXW-0001 through GHN-PXW-0016
LFG-003	GHN-HRS-0001, 2, GHN-LFG-0018 through GHN-LFG-0024, 41
LFG-004	GHN-LFG-0037
LFG-005	GHN-LFG-0085 through GHN-LFG-0090, GHN-VTM-0035-GHN-VTM-0040 through GHN-VTM-0120
LFG-006	GHN-KMD-0013 though GHN-KMD-0027, GHN-VTM-0168 through GHN-VTM-0217
LFG-007	GHN-KMD-0048 through GHN-KMD-0065, GHN-VTM-0231 through GHN-VTM-0303
LFG-008	GHN-KMD-0072 through GHN-KMD-0100, GHN-VTM-0353 through GHN-VTM-0361
LFG-009	GHN-JRM-0001 through GHN-JRM-0027, GHN-VTM-0404 through GHN-VTM-0455
Traffic zone (top of GHN)	GHN-LFG-0018, 20, GHN-VTM-0053
Rubble zone	GHN-VTM-0598, 0607, 0624, GHN-EHP-0003, GHN-ACT-0023 through GHN-ACT-0032, GHN-LFG-0041, 57, 60, 89
colluvium	GHN-ACT-0033, 34, GHN-EHP-0004, 5, GHN-HRS-0095, 96, GHN-LFG-0001 through GHN-LFG-0006, 91, GHN-SAW-0200, 201, GHN-VTM-0500 through GHN-VTM-0502, 506, 507, 508, 509, 510, 553, 605, 606, 611

Drill hole or trench	Samples
	through 614
Surface samples	GHN-STM-0001 through GHN-STM-0005
Unstable GHN	GHN-EHP-0001, 2, GHN-HRS-0088 through GHN-HRS-0094, GHN-JRM-0037 through GHN-JRM-0047, GHN-SAW-0002 through GHN-SAW-0005m GHN-VTM-0003

LOCATION OF UBC SAMPLES AND STRAIGHT CREEK PROFILE (McLemore and Dickens, 2008b)

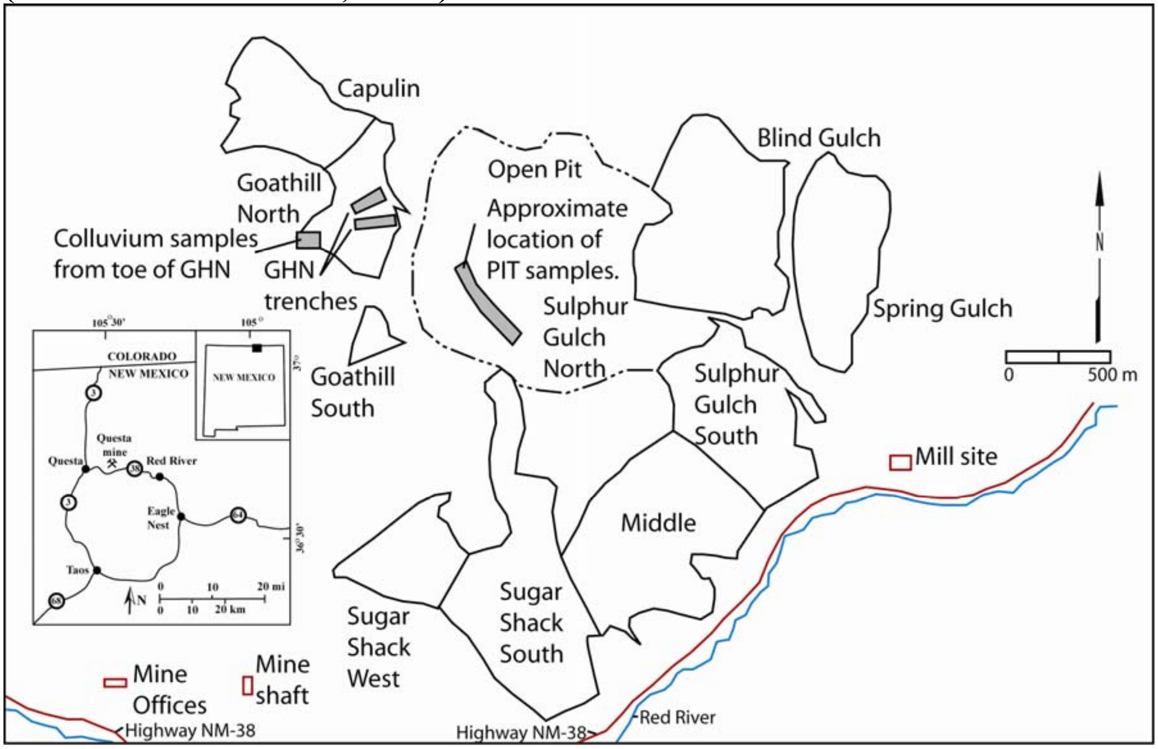


FIGURE A7-4. Questa rock piles and other mine features, including locations of UBC samples (trenches constructed in Goathill North (GHN) rock pile, colluvium samples from toe of GHN, and PIT samples from the open pit).

LOCATION OF HUMIDITY CELL SAMPLES (McLemore et al., 2008e)

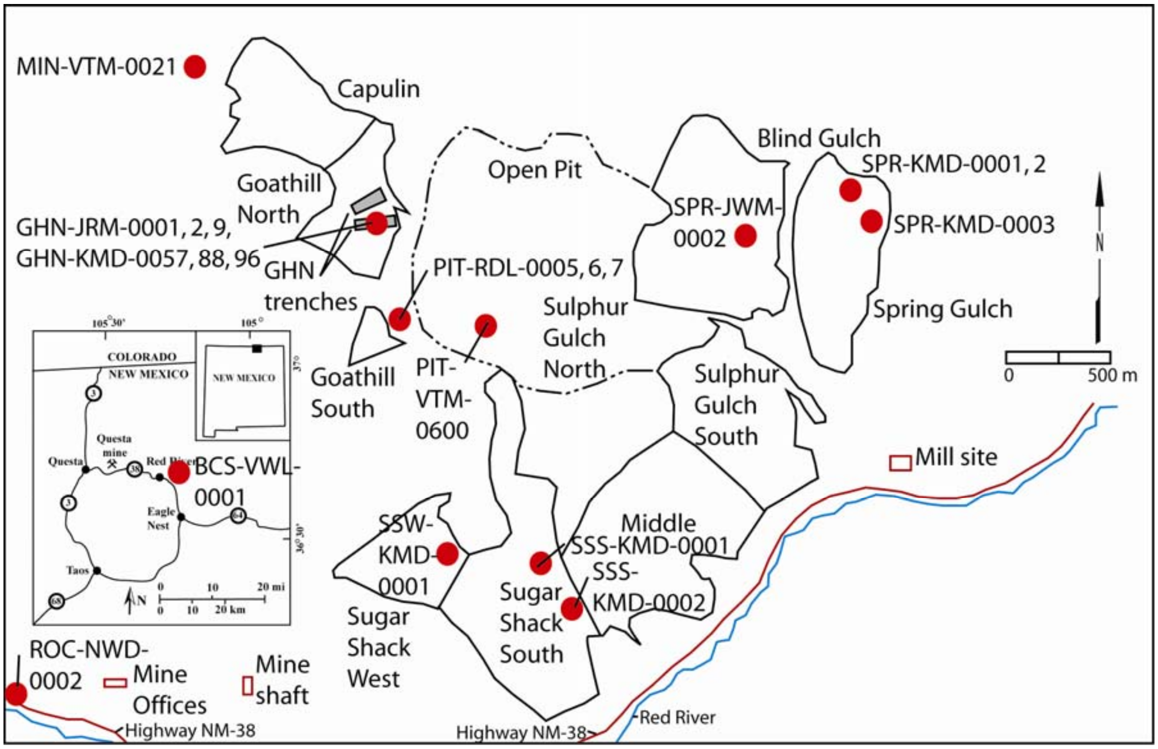


FIGURE A7-5. Location of humidity cell samples.

TABLE A7-2. Location and descriptions of samples used in the humidity cell tests. Three sets of samples of the humidity cell tests were by University of Utah (UU) samples (15 samples), Robertson GeoConsultants, Inc. (8 samples, RGC), and splits of the Golder humidity cell samples (2 samples). Detailed descriptions and chemical and mineralogical data of humidity cell samples are in Appendices 1 and 2. The two Golder samples SPR-OTH-0001 were composite samples from test plots from Spring Gulch rock pile and the exact locations are unknown.

Sample	unit	UTM easting (m)	UTM northing (m)	Elevation (ft)	Depth (ft)	Actual hole identification number	Correlates with sample identification number
UU samples							
BCS-VWL-0004	scar	466549	4065237	10340	0		
GHN-JRM-0001	Unit J	453642.2	4062137	9602			
GHN-JRM-0002	Unit N	453642.4	4062137	9601			
GHN-JRM-0009	Unit J	453634.2	406123	9585.8			
GHN-KMD-0057	Unit O	453695.8	4062140	9694			
GHN-KMD-0088	Unit O	453657.4	4062127	9635.4			
GHN-KMD-0096	Unit J	453658.4	4062119	9640.3			
MIN-VTM-0021	andesite	453817	4062418	9968	0		
PIT-RDL-0005	rhyolite	453822	4061505	9912	0		
PIT-RDL-0006	rhyolite	453822	4061588	9916	0		

Sample	unit	UTM easting (m)	UTM northing (m)	Elevation (ft)	Depth (ft)	Actual hole identification number	Correlates with sample identification number
PIT-RDL-0007	rhyolite	453822	4061588	9916	0		
PIT-VTM-0600	andesite	454215	4061522	9476	0		
ROC-NWD-0002	rhyolite	451697	4060400	8023.5	0		
SPR-JWM-0002	andesite	455254	4062384	9319	0		
RGC humidity cells							
SPR-KMD-0001		455795	4062171	9043.4	5-10	MMW-40A	WRD 1 (5-10 ft), cell 1
SPR-KMD-0002		455795	4062171	8998.4	50-55	MMW-40A	WRD 1 (50-55ft), cell 2
SPR-KMD-0003		455838	4062293	9017.7	45-50	WRD-20	WRD 2 (55-60ft), cell 3
SSS-KMD-0001		454181	4060503	9263	0-5	WRD-5	WRD 5 (5-10ft), cell 5
SSS-KMD-0002		45424.8	4060204	8692.3	25-30	WRD-3	WRD 3 (20-25ft), cell 4
SSW-KMD-0001		453872.1	4060686	9372.5	34-39	SI-1	WRD 6 (30-35 ft), cell 6
Golder humidity cells							
SPR-OTH-0001		unknown	unknown	unknown	surface		
SPR-OTH-0002		unknown	unknown	unknown	surface		

LOCATION OF CRUST SAMPLES (Giese et al., 2008)

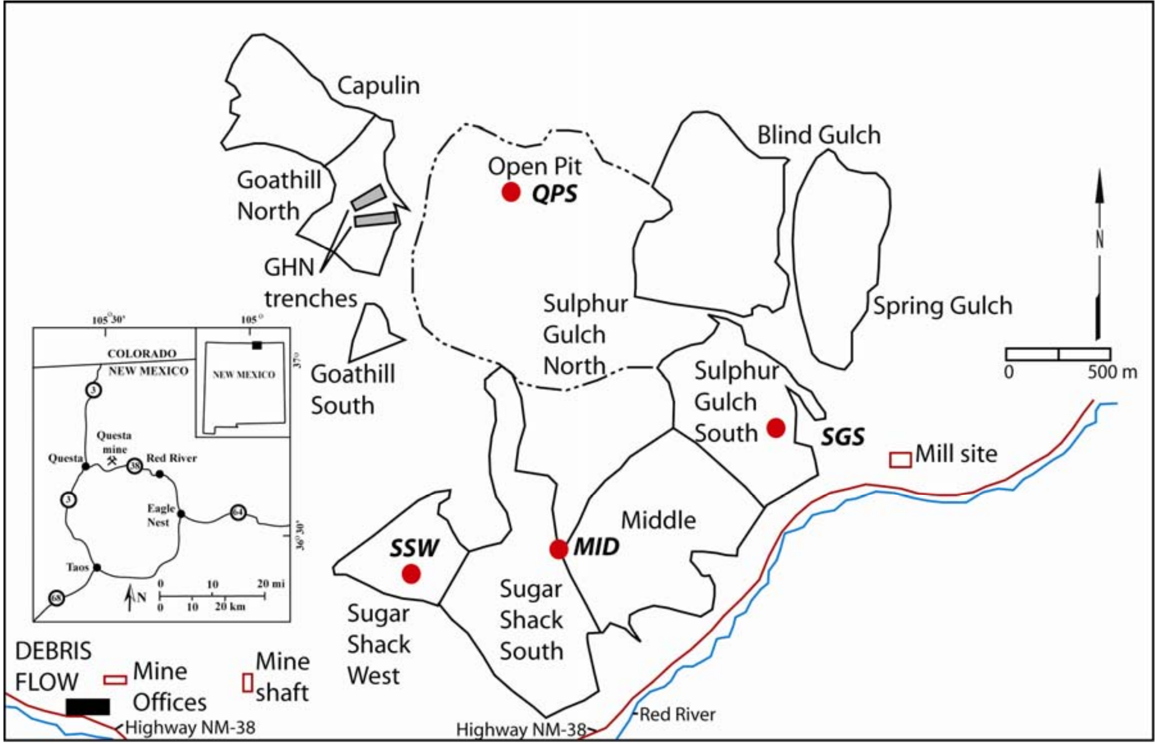


FIGURE A7-6. Questa rock piles and other mine features, including approximate locations of crust samples (Table A7-3).

TABLE A7-3. Location and sample type of crust samples. *Samples collected by D.C. Jacobs, approximate location taken near SSW-VTM-0010.

Sample Number	Sample type	UTM easting (m)	UTM northing (m)	Elevation (ft)
SSW-VTM-0006	Crust	453668	4060609	9054
SSW-VTM-0008	Sub-Crust	453668	4060609	9054
SSW-VTM-0010	Crust	453691	4060578	9015
SSW-VTM-0012	Sub-Crust	453691	4060578	9015
SSW-VTM-0013	Crust	453802	4060691	9319
SSW-VTM-0015	Sub-crust	453802	4060691	9319
SGS-VTM-0024	Crust	454271	4061364	9454
SGS-VTM-0026	Sub-Crust	454271	4061364	9454
QPS-VTM-4001	Crust Before (none taken after)	454155	4062554	9621
MID-VTM-4000	Runoff Jug	454277	4060551	9314
MID-VTM-4001	Crust before	454265	4060535	9293
MID-GJG-4001	Crust above MID-VTM-4000 After	454277	4060551	9314
SWH-VTM-4000	Runoff Jug	458734	4062430	8717
SWH-VTM-4001	Crust Before	458734	4062430	8717
SWH-GJG-4000	crust above SWH-VTM-4000 After	458734	4062430	8717
SSW-VTM-4001	Crust Before	453693	4060537	8977
SSW-VTM-4000	Runoff Jug	453699	4060533	9017
SSW-GJG-4000	Crust above SSW-VTM-4000 After	453699	4060533	9017
HAS-GJG-4000	creek drainage	458802	4061912	8425

Sample Number	Sample type	UTM easting (m)	UTM northing (m)	Elevation (ft)
SWH-GJG-4001	creek drainage	458696	4062385	8648
QPS-GJG-4000	puddle	454349	4062555	9524
MID-GJG-4000	puddle	455280	4061460	8846
MID-GJG-4002	puddle	454559	4060902	9320
MIN-GJG-4000	puddle	455741	4061450	8638
CAT-GJG-4000	Catchment pond	455455	4061676	8633
SSW-DCJ-0003*	Crust	453691	4060578	9015
SSW-DCJ-0004*	Crust	453691	4060578	9015
SSW-DCJ-0005*	Crust	453691	4060578	9015
SSW-DCJ-0006*	Crust	453691	4060578	9015

LOCATION OF HOT ZONE SAMPLES (McLemore et al., 2008c)

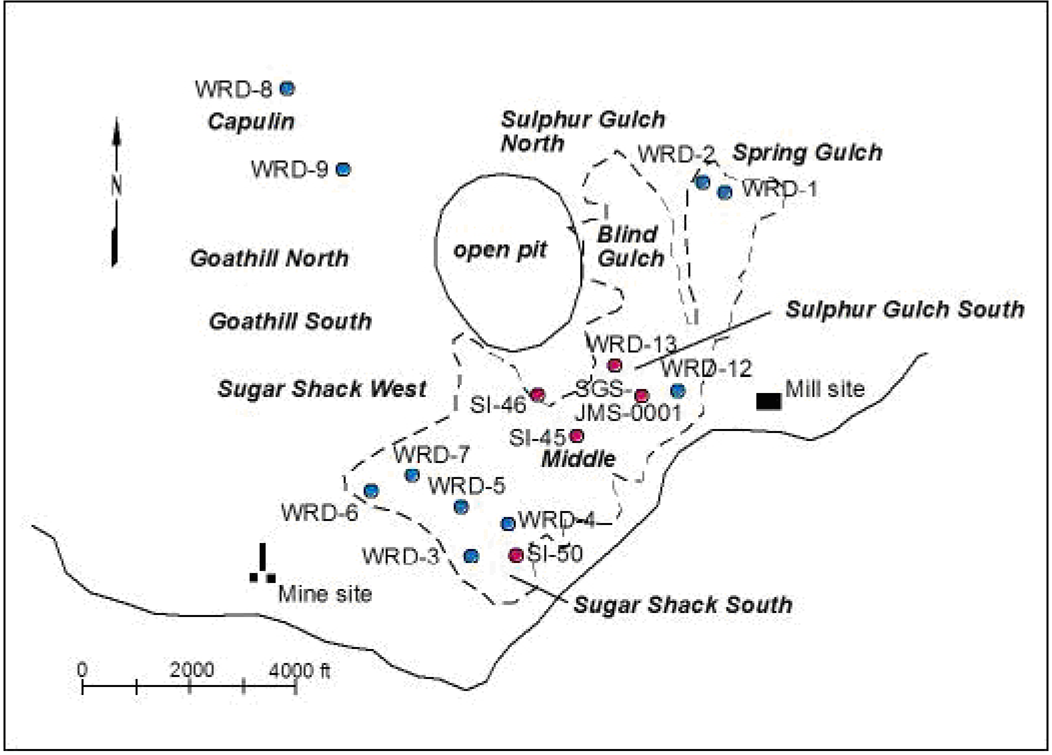


FIGURE A7-7. Location of venting drill holes (Table A7-5) and surface vent area (SGS-JMS-0001). Blue circles indicate drill holes drilled in 1999 that contain monitoring instruments for temperature, O_2 and CO_2. Red circles indicate drill holes and a surface vent area that do not contain temperature and gas instrumentation and are sites monitored by the NMIMT team.

TABLE A7-5. Drill holes through the hot zones (Robertson GeoConsultants, 1999; URS Corporation, 2003).

Drill Hole Number	Location	Total Depth (ft)	Date drilled	Type of thermal data	Depth rock pile (ft)	Depth colluvium (ft)	Depth weathered bedrock (ft)	Depth bedrock (ft)
WRD-1	SPR 4062356 N 455778 E 9076.8 ft	100	7/31/1999	Instrumented for temperature, O_2, and CO_2	100			
WRD-2	SPR 4062410 N 455619 E 9279.4 ft	75	7/31/1999	Instrumented for temperature, O_2, and CO_2	75			
WRD-3	SSS 4060204 N 454248 E 8717.3 ft	100	7/30/1999	Instrumented for temperature, O_2, and CO_2, gas analysis	120			
WRD-4	SSS 4060413 N 454506 E	75	7/29/1999	Instrumented for temperature,	75			

Drill Hole Number	Location	Total Depth (ft)	Date drilled	Type of thermal data	Depth rock pile (ft)	Depth colluvium (ft)	Depth weathered bedrock (ft)	Depth bedrock (ft)
	8908.79 ft			O_2, and CO_2, gas analysis				
WRD-5	SSS 4060510 N 454179 E 9267.3 ft	80	8/1/1999	Instrumented for temperature, O_2, and CO_2	80			
WRD-6	SSW 4060572 N 453698 E 8976.1 ft	60	8/4/1999	Instrumented for temperature, O_2, and CO_2	60			
WRD-7	SSW 4060680 N 453908 E 9433.8 ft	80	8/2/1999	Instrumented for temperature, O_2, and CO_2	80			
WRD-8	Capulin 4062975 N 453173.8 E 9816.6 ft	85	8/3/1999	Instrumented for temperature, O_2, and CO_2	85			
WRD-9	Capulin 4062581 N 453505 E 9790.6 ft	125	8/3/1999	Instrumented for temperature, O_2, and CO_2	120			
WRD-13	SGS 4061349 N 455109.6 E 9067.87 ft			gas analysis	199			
SI-1	SSW 4060693 N 453869 E 9429.7 ft	208	9/21/2002		197			197 - 208
SI-2	SSS 4060198 N 454228 E 8719 ft	140	9/23/2002		130.7			130.7 - 140
SI-4	Middle 4060594 N 454853.2 E 8663.0 ft	284	10/5/2002		272.25			272.25 - 284
SI-6	SGS 4060893 N 455116.9 E 8645.3 ft	298	10/3/2002		284			284 - 298
SI-36	SSW 4060682 N 453801.8 E 9301.3 ft	233			182	182 - 184	184 - 211	211-233
SI-37	SSW 4060645 N 453883.3 E 9429.1 ft							
SI-39	SSW 4060633 N							

Drill Hole Number	Location	Total Depth (ft)	Date drilled	Type of thermal data	Depth rock pile (ft)	Depth colluvium (ft)	Depth weathered bedrock (ft)	Depth bedrock (ft)
	453668 E 8955.3 ft							
SI-44	SGS 4061055 N 454913 E 9046.4 ft	255	7/25/2004	gas analysis	241	241-244 or 246	244 or 246 - 250	>250
SI-45	Middle 4060686 N 454750.2 E 8899.4 ft	145	8/7/2004	gas analysis	145			
SI-46	SSS 4060456 N 454340.3 E 9136.91 ft	437	8/12/2004	gas analysis	388			388 - 437
SI-47	SSS 4060690 N 454331 E 9420.7 ft	265.5	7/11/2004		134		134 - 165	165 - 265
SI-48	Middle 4061069 N 454410.5 E 9320.2 ft	273	7/16/2004		185	185-201	201-215	215 273
SI-49	SSS 4059932 N 454521.1 E 7991.9 ft	149	8/19/2004		159			
SI-50	SSS 4060246 N 454388.6 E 8710.1 ft	119	8/19/2004	gas analysis	304	304-400		400-453
SI-51	SGS 4060767 N 455319.7 E 8173.4 ft	187	8/19/2004		153			
SI-52	SGS 4061065 N 455349.5 E 8566.4 ft	237	11/15/2004		184	184-197		197-246
SI-53	4060452 N 455160 E 8054.4 ft							
SI-62								
MMW 37A	SSS 4060246 N 454400.1 E 8707.58 ft	360	10/12/2000		345	345-360		

LOCATION OF WATER SAMPLES (McLemore et al. 2008a)

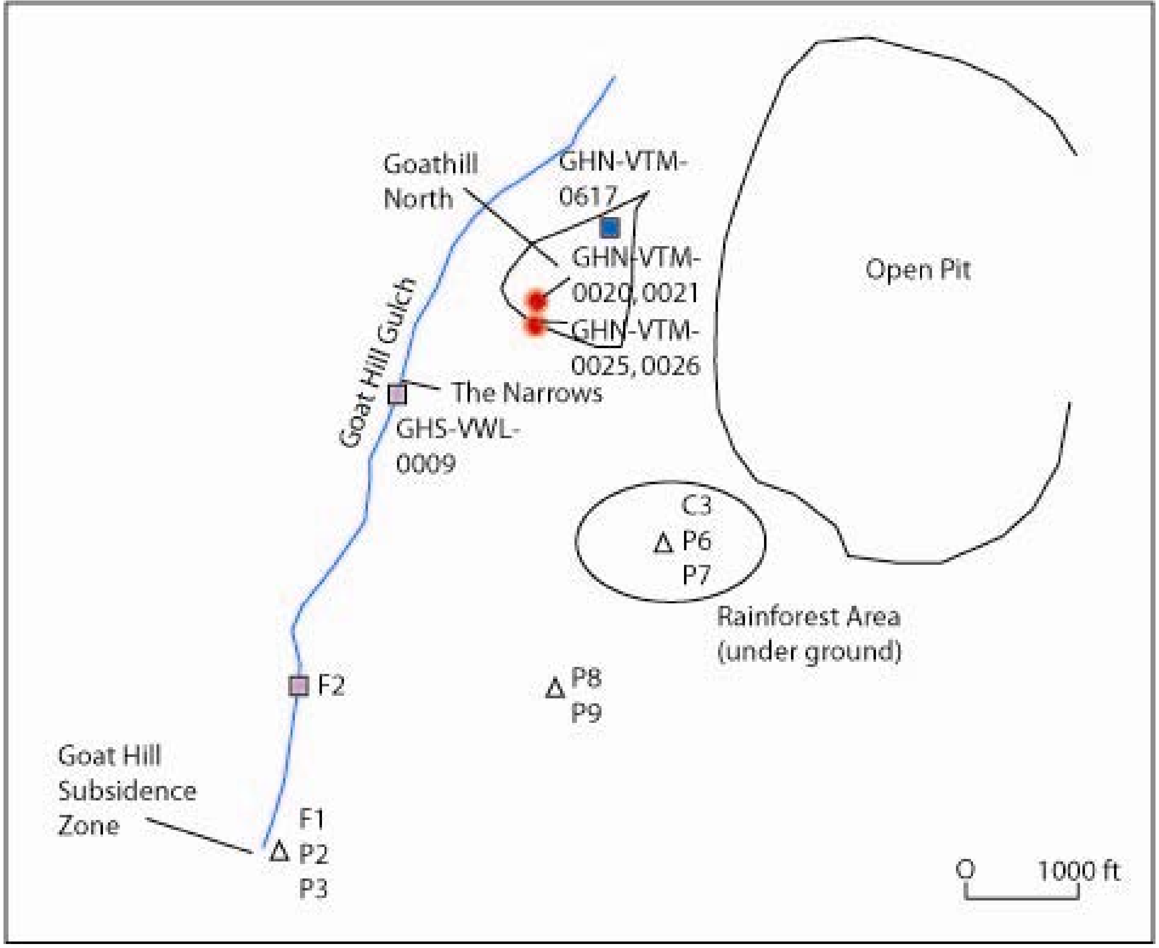


FIGURE A7-8. Location of water samples.

TABLE A7-7. Description of water samples shown in Figure A7-8 for this project.

Field_id	Area	Reference
GHN-VTM-0020	toe of GHN rock pile	NMIMT
GHN-VTM-0021	toe of GHN rock pile	NMIMT
GHN-VTM-0025	toe of GHN rock pile	NMIMT
GHN-VTM-0026	toe of GHN rock pile	NMIMT
GHN-VTM-0617	Trench LFG-021	NMIMT
GHS-VWL-0009	Narrows	NMIMT
F-2	Goathill Gulch surface flow	SRK (2004)
F-1	Goathill-below subsidence	SRK (2004)
P-2	Goathill-below subsidence	SRK (2004)
P-3	Goathill-below subsidence	SRK (2004)
P-8	old workings	SRK (2004)
P-9	old workings	SRK (2004)
C-3	rainforest	SRK (2004)
P-6	rainforest	SRK (2004)
P-7	rainforest	SRK (2004)