EFFECT OF WEATHERING ON THE STABILITY OF THE QUESTA ROCK PILES

GEOLOGIC MAPPING PLAN

Prepared by the Characterization Team

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REVISION LOG		
Revision Number	Description	Date
GMP1.0	Original Geologic Mapping Plan	1/24/04
GMP2.0	Modified by VTM	5/19/04
GMP3.0	Modified by VTM, KMD	10/1/04
GMP 3v1	Edited by LMK	9/13/05 – 9/20/05
GMPv4	Edited by VTM	1/28/09

1.0 INTRODUCTION

In order to evaluate the stability of the Questa rock piles, surface geologic mapping is needed. This Geologic Mapping Plan describes the mapping and analyses that will be conducted as part of studies for the Rock Pile Weathering Stability study. The geologic mapping program will be carefully planned to meet the Data Quality Objectives (DQOs) outlined in the Quality Assurance Project Plan (QAPP), minimize cost, and minimize the potential conflicts between the numerous investigations. Appendix 1 is a list of personnel and emergency phone numbers.

2.0 DATA QUALITY OBJECTIVES

The proposed investigation will focus on the following interrelated critical issues:

1) Understanding weathering processes, both at the surface and within the mine-rock piles.
2) Measuring the rate at which such weathering processes occur within the rock piles over time.

3) Determining the effect of these processes on the long-term physical stability of the rock piles.

The key question to be addressed is, "Will the rock piles become gravitationally unstable over time?"

The characterization portion of this research project has identified ten DQOs, described in the QAPP that must be addressed in order to solve this problem. The geologic mapping plan specifically addresses four of the DQOs:

- Determine how the hydrogeochemistry and water balance dynamics influences rock pile weathering and stability.
- Determine how mineralogy, stratigraphy, and internal structure of the rock piles contribute to weathering and stability.
- Determine if cementation forms in the rock and alteration scars and how does the cementation contributes to the stability of the rock piles.
- Determine how much and where the pyrite is in the waste rock piles and how does the pyrite concentration affect the weathering process.

To meet these DQOs, the Characterization Team will implement this geologic mapping program in the GHN, Sugar Shack South, Middle, and Sulphur Gulch rock piles.

3.0 STUDY AREA

The Questa molybdenum mine is located on the western slope of the Taos Range of the Sangre de Cristo Mountains, Taos County, northern New Mexico. The current mine is an underground, molybdenum disulfide ("moly") mine that currently uses a block caving mining method to extract ore. Pit production began in 1969 and ended in 1981, when 81 million tons of ore with an average grade of 0.185 % MoS_2 had been processed. During the open pit period of mining 350 million tons of overburden rock were stripped and deposited onto mountain slopes and into tributary valleys forming the rock piles for this study.

4.0 INVESTIGATION APPROACH

The purpose of the Rock Pile Weathering Stability study is to develop a model to assess and identify the future risk of physical failure of the existing rock piles, based on the physical, chemical and mineralogical composition and weathering of the waste rock at Molycorp's Questa mine, in Taos County, New Mexico. **The key question to be addressed is, "Will the rock piles become gravitationally unstable over time?"** Molycorp further indicated that the "proposed investigation should focus on 1) understanding weathering processes, both at the surface of and within the rock piles, 2) the rate at which such processes occur over time, and 3) the effect or influence of these processes on the overall mass stability of the rock piles."

Weathering can have at least two counter influences on slope stability. First, dissolution of feldspars, biotite and other silicate minerals results in reduction of the silicate mineral

grain size and generation of clay minerals, both of which can adversely affect rock-pile stability. Second, iron oxyhydroxides generated by pyrite oxidation, as well as other reaction products, can aid in the cementation of soil grains. Formation of such aggregates will tend to increase rock-pile stability. Generation of water-soluble cements from the oxidation of pyrite also can adversely affect rock-pile stability. Both of these processes appear to be operational at the Questa site and have been observed at many mining sites.

Thus the first step in assessing the stability of the Questa rock piles is a complete physical, mineralogical, and chemical characterization of approximately 350 million tons of rock present in nine rock piles at the site utilizing new and existing data. This report addresses the geologic mapping plan required to characterize the rock piles.

5.0 RESPONSIBILITIES AND QUALIFICATIONS

The Characterization Team members will supervise the geologic mapping activities.

The Team Leader and Characterization Team will have the overall responsibility for implementing this geologic mapping plan. They will be responsible for assigning appropriate staff to implement this geologic mapping plan and for ensuring that the procedures are followed accurately.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this geologic mapping plan, and to receive specific training regarding these procedures, if necessary.

All environmental staff and assay laboratory staff are responsible for reporting deviations from this sampling field plan to the Team Leader.

6.0 PERMIT REQUIREMENTS AND NOTIFICATION

Molycorp and its drilling contractor(s) are responsible for securing all necessary permits and meeting all local, state, and federal regulations applying to all sampling and drilling activities, including, but not limited to, site access, waste disposal, operator health and safety, etc.

7.0 LIST OF EQUIPMENT

See SOPs for list of equipment. In addition the following equipment is needed:

- Graph paper preferably water proof
- Colored pencils
- Scales or rulers
- Flags
- String (orange or another visible color)
- Measuring tape

- Brunton compass
- Hand lens

8.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this plan are intended for use with the following SOPs.

- SOP 1 Data Management
- SOP 2 Sample Management
- SOP 3 Surveying (GPS)
- SOP 4 Taking Photographs
- SOP 5 Sampling Outcrops, Rock Piles and Drill Core
- SOP 6 Drilling, logging, and sampling of subsurface materials (solid)
- SOP 7 Decontamination of Sampling Equipment
- SOP 9 Trench and Test pits excavation, logging and sampling.

9.0 FIELD ACTIVITIES

This section describes field activities that will be performed for the Questa Weathering Project, that consist of the following activities:

- Premobilization and site reconnaissance
- Surveying, including taking and recording accurate GPS coordinates and systems
- Geological mapping of the rock piles
- Characterization sampling
- Quality control and quality assurance procedures

Instructions for implementing these tasks are given in standard operating procedures (SOPs), which are indicated in this plan. Field audits, as described in the quality assurance project plan (QAPP), will be performed to verify that approved methods and procedures are followed during the field investigations. Any identified deviations from this plan or any SOPs will be documented and the Team Leader and Principle Investigators will be informed. Procedures for corrective action are described in the QAPP.

Molycorp or their contractors will be responsible for the containing and disposal of all wastes incurred during the field investigation, as well as be responsible for procedures for utility clearance.

9.1 Premobilization and site reconnaissance

One or more reconnaissance trips may be needed to plan mapping activities and address any potential safety issues. All trips to Questa must be scheduled with Virginia McLemore and Bruce Walker.

9.2 Surveying

Conventional land and GPS survey techniques will be used to survey data locations and elevations, sampling locations, sampling grid locations, elevations, and orientations, utility clearance (as applicable), and other surface and subsurface features. GPS operators must also record the coordinate system used when taking GPS meaurements. Molycorp, Inc. will be responsible for all surveying other than GPS locations of samples. SOP 3 describes the procedures for GPS surveying.

9.3 Geological mapping and modeling of the rock piles

The first step in geological mapping of the rock piles will be to identify existing data and maps (Lahee, 1961). The maps will be incorporated into GIS as separate layers and other graphic programs as needed. The following is a partial list of GIS layers and models needed:

- Surface Geology
- Current topography
- Original topography (pre-rock pile surface)
- Remote sensing (by Peters)
- Underground workings
- Drill holes, test pits locations
- Sample locations (proposed and already collected)
- Photograph locations
- Surface and borehole geophysical profiles
- Pyrite reserve model to provide a view of the pyrite distribution within the rock piles (SOP 34) (by Brimhall)
- Stratigraphic columns of drill holes and test pits (by Characterization team)
- Cross sections and longitudinal sections of the rock piles (by Characterization team)
- Geologic models of the rock pile (mineralogy, internal structure, stratigraphy) (by Characterization team)
- Hydrologic and hydrostratigraphic models to investigate hydrologic processes within the framework of our geologic models (by Characterization team)
- Heat flow/temperature/two-phase water flow models will help determine the degree to which heat can drive liquid and vapor-phase water flow within the piles and identify hot spots within the piles (by M. Reiter)
- Infiltration models will aid in estimating the range of liquid-phase water inflows to the rock piles using estimated, measured, or simulated climatologic inputs (by Sigda)
- A water balance model for each rock pile is critical to determining rock pile stability because it will predict how water content and matric potential are distributed within the pile as well as how they will evolve dynamically through time. Applying different future climate conditions to the water balance model will produce the matric

potential distributions needed by the geotechnical models to predict long-term stability.
- Climatic models (by Characterization team)

Parameters that will be mapped include:
- Estimate of lithology
- Estimate of pyrite distribution and other mineralogy at the surface
- Orientation of layers and other structures at the surface (strike, dip, UTM northing and easting)
- Estimate ranges in grain size and texture
- Color (Munsell, 2000)
- Paste pH, conductivity, moisture content
- Location surface features, including rills, fractures, vents, cracks, etc.
- Soil consistency (sticky, hard, soft, not sticky)

9.4 SAMPLING

Characterization sampling (rock outcrops, soil, other) (see SOP 5 – Sample Management) will occur during mapping using these SOP 5 Trench Mapping procedures:

1. The trench/test pit must be inspected for safety and stability before mapping or any trench activities can commence.
2. Measuring tapes must be laid out from the surveyed stakes along each bench to get the length of each bench and the thicknesses of the units.
3. Using a Brunton compass, record the bearing of each trench wall.
4. Clear the bench walls to expose a fresh surface for identification of the units. Stand on the opposite wall to be able to get a good perspective of the entire trench wall including a view of all of the benches inorder to identify the units and to look for continuations of units through multiple benches. One person stands on the opposite wall looking for the distinction between units while another person on the wall being mapped uses flagging to mark the boundaries between the units using string to delineate the boundaries. The units are to be correlated through each bench where possible or to identify if layers pinch out between benches.
5. Once the unit boundaries have been identified, a detailed description of each unit it made. The descriptions are used to correlate the units to units mapped in previous trenches or to units exposed on the surface.
6. The strike, dip and true thickness of each unit are measured by correlating units from one side of the trench to the other.
7. A sketch of each bench should be drawn to scale on grid paper, both individually and from map view of the entire trench correlating units on both sides of the trench.
8. The units are named the letters A-Z with small units within layers being named A_1, A_2, etc. Once the letters have all been assigned to units, the letters will be doubled, e.g. AA, BB, etc.

9.5 Surface mapping (Lahee, 1961)

1. Identify surface units visually

2. Examine and describe each unit measuring the dip, strike, and true thickness of each unit.

3. Identify each unit boundary and record it on the map (Use a topographic map or air photograph as the base.

9.6 Check list for unit/sample description

The characteristics of the units were determined using standard geological and soil science procedures described below (National Soil Survey Center, 2002) and fill in the trench/test pit logging form (Appendix 2).

1. Look at the overall appearance of the unit, note if there are variations or changes within the unit.
2. Take a small portion (about a handful) of the unit to determine the moisture content of the sample (wet, damp, moist, dry) and examine the color. The color should be linked to moisture of the sample. Record the information on the sample record form and in the field log book.
3. Estimate the range of particle sizes and record them. Look at the grading (sorting) of the sample (do the particle sizes increase or decrease from the top of the unit?).
4. Look at the angularity of the grains and record it for all of the grain sizes observed, starting with the smallest grain size.
5. Feel the sample to see if it sticks together, record that it feels soft or feels gritty, indicating the presence of clay or the presence of silt, sand, and larger gravel particles.
6. Press your thumb against the face of the unit to test the consistency. Record whether or not you can push your thumb into the face.
7. Using a handful of sample material, test the plasticity by attempting to roll the sample into a 1/8 inch ribbon. Record the results as plastic (the material does roll into a ribbon) or non-plastic (the material breaks up when you try to roll it)
8. Examine the face of the unit and record any structures observed.
9. Look for and record any signs of alteration and cementation in the overall unit. including the cementation mineralogy and the amount and type of alteration.
10. Determine the lithologies of the larger clasts and estimate the percentages of each lithology using a hand lens. Record the lithologies and percentages.
11. Using the particle size charts determine the USCS classification of the unit and record it for each unit.
12. Look at the contact between the units, is it a clear boundary or does it grade into the next unit? Record the characteristics of the boundaries with the description of each unit.

10.0 QUALITY CONTROL AND QUALITY ASSURANCE PROCEDURES

Only geologists and engineers trained to use these exact procedures should map the rock piles to avoid variations between mappers.

11.0 DATA MANAGEMENT

All forms completed by hand and all field forms will be archived in a binder for future reference. Copies of the database forms will also be stored in binders after the completion of mapping..

12.0 MAPPING SCHEDULE

May-July 2004 geologic mapping of Goat Hill North

13.0 FIELD DOCUMENTATION

Documentation of field observations and data acquired in the field will provide information on the activities concluded and also provide a permanent record of field activities. The maps will be placed in a bound book, and the unit descriptions will be recorded on field data sheets in the database. Forms will be used to record field data (Appendix 2, see database). These forms include:

- Sample description form
- Photograph form
- Chain of custody and request for analysis
- Geologic mapping forms

Geologic observations and site description are recorded on the **sample description form**. Each site is located on a topographic map and a GPS reading taken (NAD 27, UTM) (SOP 3) and entered on the **sample description form.**

Photographs are taken of sample site (SOP 4; information recorded on **photograph form**). The numbering system for the photograph will be the field identification number (three components, see Table 1 for numbering convention) or sample number (four components) followed by a letter representing type of image (F-field, T-thin section, P-probe, H-test pit, D-drill core/cuttings, G-general, O- historic) 001 sequentially (Table 1). For example SSW-HRS-001-F001 is the photograph #1 that HRS took at sample site #1. Photographs will be taken at highest resolution as jpeg or tif and stored in separate folders corresponding to their image type.

Table 1. Photograph Number (Photo no).

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), followed by a sequential three number designation, 001.

14.0 HEALTH AND SAFETY

The site health and safety plan (HASP) will be followed by all contractors and subcontractors working on the site. It is the policy of New Mexico Tech to provide a safe and healthful work place for all employees, subcontractors, and clients in compliance with Molycorp and MSHA requirements. Telephone contacts are in Appendix 1.

Safety shall take precedence over expediency or short cuts. It is a condition of employment that all employees and subcontractors work safely and follow established safety rules and procedures. All injuries, vehicle accidents, and incidents with potential for injury or loss will be investigated. Appropriate corrective measures will be taken to prevent recurrence, and to continually improve the safety of the work place. Molycorp has a mandatory drug testing program that all personnel working on the property must follow.

Molycorp and its drilling contractor(s) will identify and rectify all subsurface and overhead hazards at each drilling or other construction site in accordance with the site Health and Safety Plan (HASP). Molycorp also will identify other hazards associated with mining activities including, but not limited to, ore haulage, slope stability, high walls, open pits, blasting areas and any other potential mining and/or drilling hazards. The characterization team will notifiy Molycorp of movements about the site and personnel locations. Communications will be conducted using two-way radios and other signals specified by Molycorp.

The characterization team will comply with all of Molycorp's notification, communication, and specific permit requirements at all times while working on site in accordance with the QAPP. Some of the rock pile slopes will require the use of ropes and harnesses to navigat them.

14.0 REFERENCES

AGI, 1982, AGI data sheets: American Geological Institute.
Lahee, F.H., 1961, Field geology: McGraw-Hill Book Company, New York, 926 p.

Munsell, 200, Munsell Soil Color Charts.
National Soil Survey Center, 2002, Field book for describing and sampling soils: National Soil Survey Center.

APPENDIX 1. Telephone Contacts

Team Project Manager:	Dr. Terry Chatwin Team Leader	
Characterization Team Leader	Dr. Virginia T. McLemore	505-835-5521 (office) 505-835-3823 (home) 505-838-6040 (cell)
Molycorp Guard Station:		(505) 586-7640
Molycorp Geologist:	Bruce Walker	(505) 586-7628

FIRE, POLICE, SHERIFF, AND AMBULANCE EMERGENCIES ONLY: 911

Ambulance: Taos County Non-Emergency: (505) 758-9591
Animal Control: Taos Animal Control: (505) 758-2981

Health Care:

Holy Cross Hospital, Taos: (505) 758-8883
Hospital Address:
1397 Weimer Road
Taos, NM, 87571
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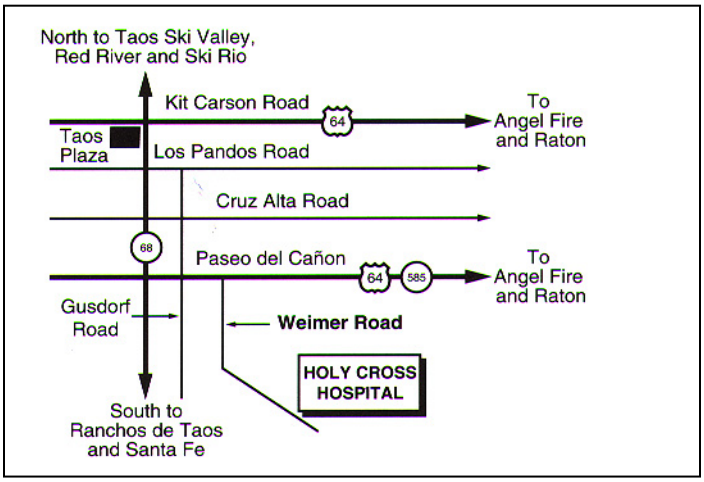
map at right)



Questa Health Center: (505) 586-0315
Red River Medical Office: (505) 754-2379

Poison And Drug Information Center: 1-800-432-6866

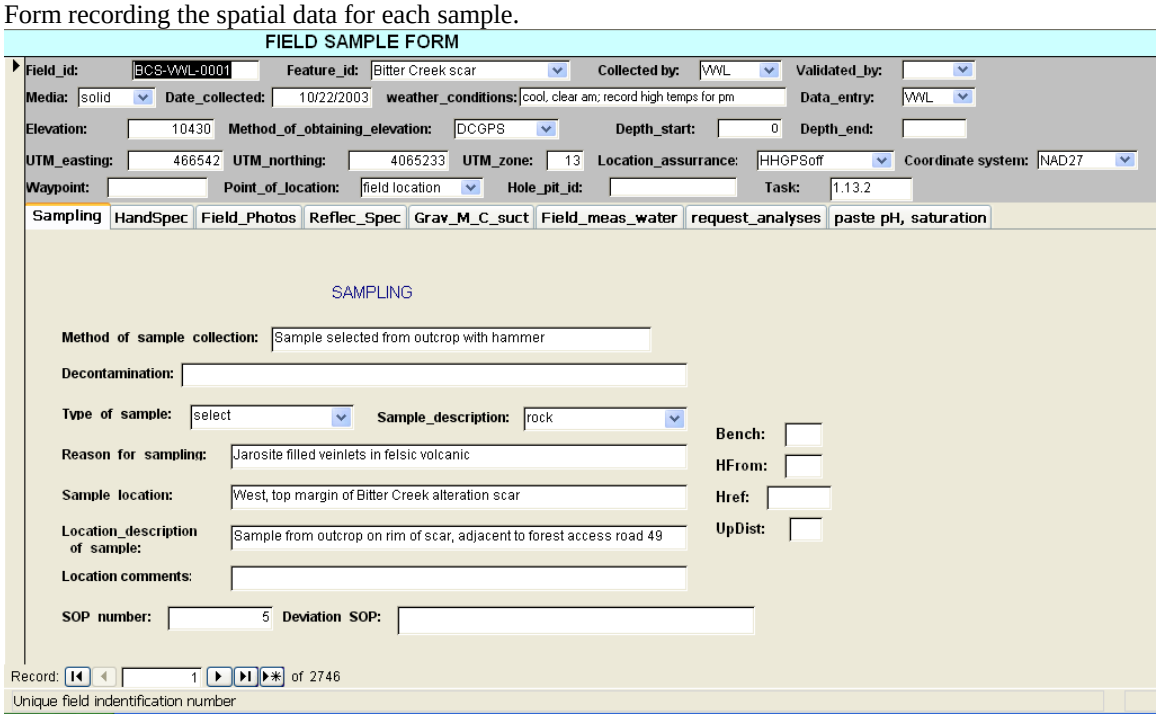
Police - Non Emergency:

Questa: (505) 586-1196
Red River: (505) 754-6166
Taos: (505) 758-4656
Sheriff - Non Emergency: (505) 758-4709
State Police - Non Emergency: (505) 758-8878

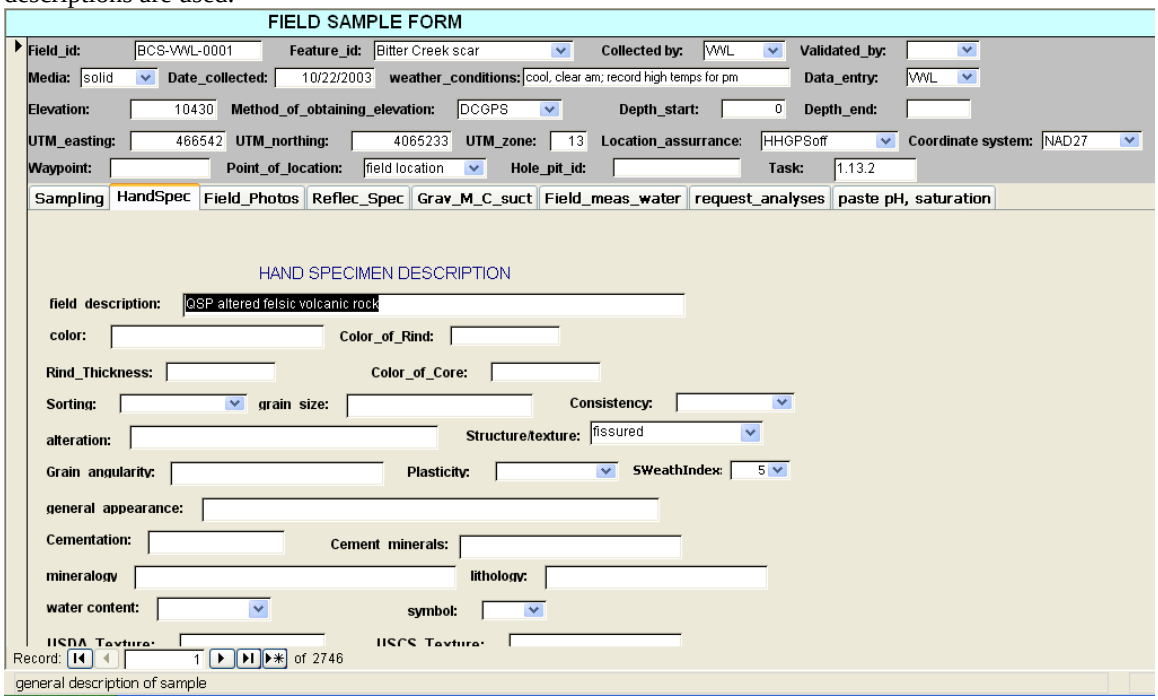
Note: Cellular telephones often do not work at the field site. If necessary, use telephones located at the Red River Waste Water Treatment Plant, the Town of Red River, or the Molycorp mine offices.

APPENDIX 2. Field sample forms in the database used to record field location and descriptive data obtained in the field during sample collection. Field ID described in Table 2-1.

Form recording the spatial data for each sample.



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



Form recording information on photographs taken in the field.

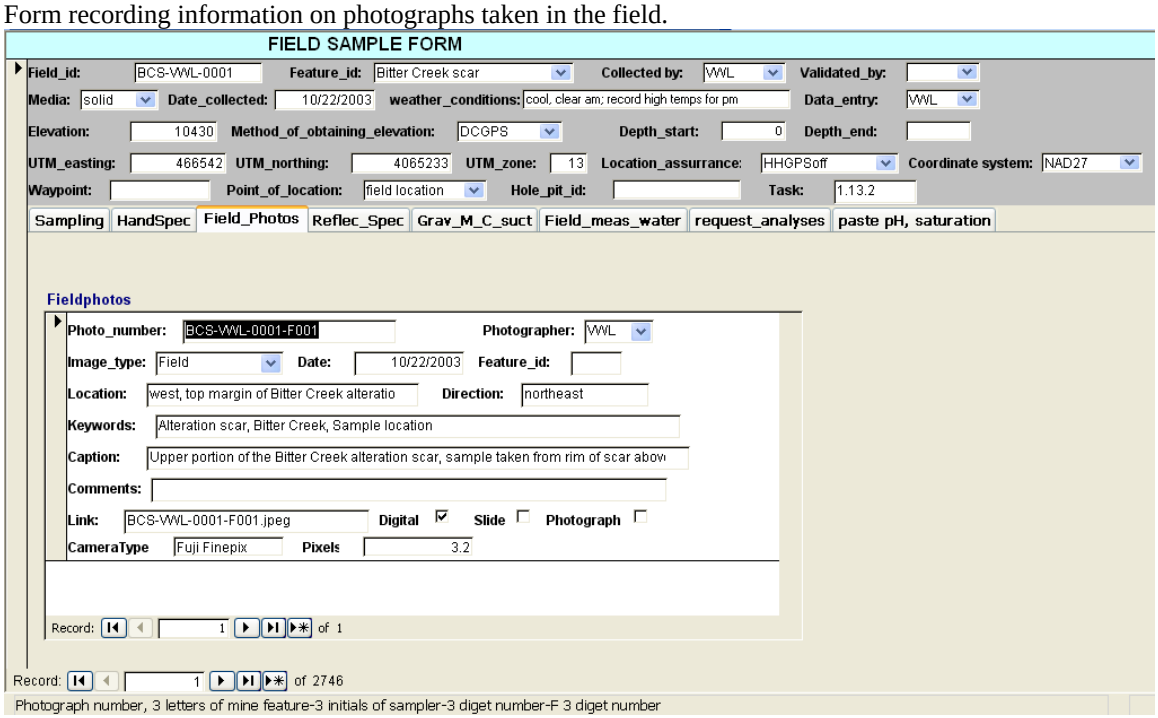


TABLE 2-1. Description of Sample description field in the sample form.

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 2-2. 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	
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	TBD

TABLE 2-3. 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	geotech 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 NMIMT
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 NMIMT
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