STANDARD OPERATING PROCEDURE NO. 24

PETROGRAPHIC ANALYSES

REVISION LOG		
Revision Number	Description	Date
24.0	Original SOP	
24.1	Revisions by PJP	1/14/04
24.2	Revisions by PJP	5/19/2004
24.3	Revisions by EHP	12/12/2005
24v4	Edits by LMK	12/14/2005-1/11/06
24v5	Changes accepted, sent to EHP to approve, LMK	1/19/06
24v5	Finalized, sent to Jack Hamilton to post on Utah site, Ginger McLemore, and posted to Granite FTP server, LMK	1/24/06
24v6	Procedure addendum added by DCS, edited by LMK,, SOP 24 Spreadsheet also modified by DCS to SOP 24 v2 spreadsheet.	1/26/07
24v6	Finalized by LMK, to send to Jack Hamilton to post on project website and to George Robinson for lab audit	1/29/07
24v7	Editorial by SKA	10/23/08

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure describes the method for petrographic analyses involving optical examinations and mineral identification, which are the basis for all geologic models and characterization, specifically in differentiating various rock units, determining rank and intensity of alteration, determining chemistry of alternating fluids, describing cementation, and determination of paragenesis of mineralization, alteration, and cementation. Mineralogical data is required in selecting samples for weathering cells,

developing geotechnical models, weathering models, and geologic (mineralogy, stratigraphy, internal structure) models of the rock piles. Alteration rank is based upon the mineral assemblages, which infers temperature, pressure, and permeability conditions at the time of formation. Forms are in Appendix 1. Digital photographs will be taken (SOP 4) of thin sections and of mine soils under the binocular microscope.

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The Team Leader and Characterization Team will have the overall responsibility for implementing this SOP. They will be responsible for assigning appropriate staff to implement this SOP 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 SOP, and to receive specific training regarding these procedures, if necessary.

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

3.0 DATA QUALITY OBJECTIVES

This SOP addresses objectives 2-7 and 9 in the data quality objectives outlined by Virginia McLemore for the "Geological and Hydrological Characterization at the Molycorp Questa Mine, Taos County, New Mexico".

- Determine how mineralogy, stratigraphy, and internal structure of the rock piles contribute to weathering and stability.
- Determine if the sequence of host-rock hypogene and supergene alteration and weathering provides a basis to predict the effects weathering can have on mine rock pile material.
- Determine how weathering of the rock pile affects the geotechnical properties of the rock pile material.
- Determine if cementation forms in the rock piles and the effect of such cementation on the stability of the rock piles.
- Determine the concentrations of pyrite and carbonate minerals so that a representative sample goes into the weathering cells.
- Determine how the concentration and location of pyrite and its weathering products in the waste rock piles affect the weathering process.
- Determine if the geotechnical and geochemical characteristics of the bedrock (foundation) underlying the rock piles influences the rock pile stability.

4.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this SOP are intended for use with the following SOPs:

- SOP 1 Data management (including verification and validation)
- SOP 2 Sample management (including chain of custody)
- SOP 4 Taking digital photographs
- SOP 5 Sampling outcrops, rock piles, and drill core (solid)

- SOP 6 Drilling, logging, and sampling of subsurface materials (solid)
- SOP 8 Sample preparation (solids)
- SOP 9 Test pit excavation, logging, and sampling (solid)
- SOP 26 Electron microprobe
- SOP 27 XRD
- SOP 28 XRF
- SOP 29 Clay mineralogy
- SOP 78 Weathering cell sample selection
- SOP 79 Weathering cell tests
- SOP 80 Mineralogy by Rietveld analyses
- SOP 91 Geological sample color naming

5.0 EQUIPMENT LIST

The following materials are required for petrographic analyses:

- Petrographic microscope
- Electron microprobe
- Binocular microscope
- Digital camera
- Forms/spreadsheet
- Dilute HCl (10% HCl in Deionized water)
- Glass funnel and beakers
- Filter paper
- Indelible pen
- Hand lens

6.0 PROCEDURES

6.1 Soil Petrography

Soil petrography will be used to describe the lithology, alteration, and mineralogy of mine soil samples through the use of a binocular microscope. The following section describes soil petrography sample preparation, analysis, and calculation of modal mineralogy based on soil petrography and other analytical methods.

6.1.1 Sample preparation

Mine soils are rinsed in cool tap water to remove adhering fine material and to aid in the examination of rock fragment lithology and mineral identification. Examine approximately 10g of a representative portion of mine soil sample prior to rinsing. Place this same split in a glass beaker, add enough water to cover the sample, and swirl beaker. Decant water, which will include some clay and silt sized material, if present. Repeat this procedure until water is relatively clear and adhering fines are mostly removed. To limit the dissolution of gypsum and soluble salts, do not repeat rinsing more than 10 times or

leave mine soil immersed in water for extended periods of time. Write the sample number on a piece of filter paper with indelible ink. Place the filter paper in the funnel and pour mine soil and any remaining water into the funnel. Rinse the beaker repeatedly until all material is removed and deposited on the filter paper in the funnel. Drain any water from the funnel and air-dry the sample on the filter paper.

6.1.2 Soil petrography analysis

Examine unrinsed mine soil sample under the binocular microscope and note the abundance and color (SOP 91) of any fine material present, describe cohesion and/or cementation, and note grain shape based on AGI data sheet 18. Test for calcite by placing dilute HCl on a representative portion of sample. Note if there is any reaction to HCl and how vigorous the reaction. Take a general photo of unrinsed sample and any other pertinent features. Document these and any other observations of the unrinsed sample on the petrography form and subforms.

After rinsing (see section 6.1.1), examine rinsed and dried mine soil under the binocular microscope. Enter observations and measurements on the petrography form and subforms. It is important to estimate the proportions of rock fragment types (i.e., andesite, Amalia Tuff, intrusives). This is often difficult if the rock fragments have undergone high intensity hydrothermal alteration. Indicators of Amalia tuff include flattened pumice (fiame) and quartz phenocrysts, although quartz may also be present in other rock types. The Amalia tuff is rarely propyllitically altered. Most andesite fragments are gray-green in color. Andesite of the Latir volcanics spans a large age range and therefore it varies in appearance from very aphanitic to fairly course-grained. Intrusive rock fragments are also variable in appearance, but can usually be identified by their courser-grained texture and veining of various minerals.

Describe the rank and intensity of hydrothermal alteration. Alteration is a general term describing the mineralogical, textural, and chemical changes of a rock as a result of a change in the physical, thermal, and chemical environment in the presence of water, steam, or gas (Bates and Jackson, 1980; Henley and Ellis, 1983). The nature of the alteration depends upon (a) temperature and pressure at the alteration site, (b) composition of the parent rock, (c) composition and temperature of the alteration (invading) fluids, (d) permeability of the parent rock, and (e) duration of the alteration process. Recognition and genesis of alteration are important in mineral exploration and understanding the formation of ore deposits because specific alteration types are associated with specific ore deposits. Furthermore, alteration halos surrounding ore deposits are typically more widespread and easier to recognize than some of the orebodies themselves (Guilbert and Park, 1986).

Intensity of alteration is a measure of how much alteration has occurred that can be estimated by determining the percentage of newly-formed secondary minerals by visual examination (McLemore, 1993). For example, a parent rock that has not been affected by any alteration would have zero intensity of alteration, whereas a parent rock in which all primary minerals have been replaced by secondary minerals would have an alteration intensity of 100%.

Alteration rank is based upon the identification of new secondary minerals and their significance in terms of alteration conditions such as temperature, pressure, and permeability. The intensity of alteration is independent of the rank of alteration (McLemore, 1993). It is possible to have rocks with a high rank but low intensity (hot, impermeable zones) or other rocks of low rank but high intensity (cooler, permeable zones; McLemore, 1993).

Each alteration rank is associated with a particular mineral assemblage. The term mineral assemblage implies mutual equilibrium growth of mineral phases, whereas mineral association implies that the mineral phases are only in physical contact. A number of terms are applied to various alteration assemblages.

- Deuteric alteration refers to the interaction between volcanic or magmatic rocks and magmatic-hydrothermal fluids during the cooling of the igneous rocks. A variety of alteration minerals may be produced during deuteric alteration.
- Propyllitic alteration is identified by the presence of epidote and chlorite. Carbonate is also part of this alteration assemblage, but is often not present due to prior dissolution.
- Sericitic alteration is defined by the dominance of illite, sericite, and/or muscovite. The major difference between these three K-micas is grain size: illite is a clay-size K-mica, whereas muscovite is larger. Sericite is of intermediate size. Some minor compositional differences also occur between the three minerals.
- Argillic alteration consists of kaolinite, smectite (montmorillonite clays), chlorite, and sericite. Advanced argillic alteration consists of kaolinite, quartz, alunite, pyrophyllite, and other aluminosilicate minerals.
- Silicic alteration is produced by the addition of silica, predominantly as quartz.
- QSP alteration is identified by the mineral assemblage of quartz-sericite-pyrite. However, pyrite is often partially or wholly replaced by Fe-oxides or Fe-oxyhydroxides.

Alteration of parent rock occurs by several processes: (1) direct deposition, (2) replacement, (3) leaching, and (4) ejecta (Browne, 1978). Evidence of all four processes is found in the Questa district.

Direct deposition occurs by precipitation of new minerals in open spaces, such as vugs or fractures.

Replacement occurs when one mineral is converted to a new mineral by fluids entering the rock. These two processes are common and depend upon permeability and duration of the process. Complete fluid/mineral equilibrium is rarely achieved because of these factors.

Leaching and supergene enrichment occurs locally where steam condensate reacts to form acidic solutions by the oxidation of H_2S or CO_2 which then attacks the parent rock and dissolves primary or secondary minerals. Silica residue is a common result of leaching and is a spongy or vuggy altered rock predominantly consisting of quartz, iron

and titanium oxides. Direct deposition or replacement may occur after leaching, thereby producing overlapping alteration types.

Ejecta, hydrothermal brecciation, and hydrofracturing are another form of alteration where hot water and/or steam physically break apart the parent or altered rock. If this forceful ejection of fluids occurs at or near the surface, hydrothermal eruptions of water, steam, and rock can occur. Silicification following the brecciation is common.

After hydrothermal alteration, the rocks and minerals may be subjected to supergene alteration (long-term weathering). The term "weathering" is used in this document to describe chemical and physical changes that have occurred since the material was emplaced in rock piles, a process which continues today. However, distinguishing between supergene alteration and modern weathering may be difficult.

The mineralogy subform is to be used to record initial estimates of the abundances of visible minerals and rock fragments using comparison charts from AGI data sheet 15. If possible, also note whether minerals are primary, secondary, alteration, and/or weathering, . Final modal mineralogy (calculations described in section 6.1.3) will be recorded in the modal mineralogy subform.

Provide detailed descriptions of pyrite, carbonate, and gypsum in the appropriate petrographic subforms. These minerals are important because of their role in generating or preventing acid drainage and because they provide information about weathering of the rock pile material. Note whether pyrite occurs as individual grains or within rock fragments or clasts. Test for calcite with dilute HCl after rinsing and note where calcite occurs (e.g., within fine material, as discrete grains, or within altered rock fragments). Use a hand lens or binocular microscope to observe fizzing. Describe any other carbonate minerals present. Note the proportions of different forms of gypsum.

The form and texture of gypsum indicate its origin as being either detrital (incorporated before material was emplaced in the rock pile) or authigenic (grown in the rock pile as a result of in-situ weathering). Some soil samples contain both detrital and authigenic gypsum. It is important to describe the types of gypsum within each sample and estimate the relative percentages of each type.

Four different types of gypsum are included in the gypsum subform. The first is "clear" gypsum. This is authigenic gypsum that grew in the rock pile. Crystals are euhedral and clear and have a prismatic habit. The second is "milky" rounded grains of gypsum. This gypsum is detrital, or brought into the rock pile from outside. The third is "fuzzy" authigenic gypsum, which is usually found adhering to the outside of rock fragments or clasts. It has a delicate texture, which indicates that it formed in the rock pile (authigenic) because it would not have survived transport. The fourth type of gypsum is "platy" detrital gypsum, which is found adhering to the outside of rock fragments and tends to break off in brittle plates.

Take photographs of the rinsed sample and record information in the thin section photos subform (refer to SOP 4). Include at least one general photo of a representative portion of the rinsed sample, one of each type of gypsum present in the sample, and any other pertinent features.

*6.1.3 Modal mineralogy calculation (**NB: This procedure was used at the beginning of the project and found to be unsatisfactory and replaced by Hulk mineralogy method Appendix 1)***

Modal mineralogy is the abundance (in volume %) of all minerals found in a rock based on observations and measurements. For mine soil samples, several analytical techniques are used to estimate the modal mineralogy, including soil petrography, electron microprobe, clay analysis (XRD), Reitveld analysis, and whole rock geochemistry. Modal mineralogy for mine soils is an estimation only, because it is not determined by point counting due to the unconsolidated nature and heterogeneity of the material.

Soil petrography is used to estimate the amounts and types of rock fragments, the rank and intensity of alteration, and the abundance of visible and identifiable minerals including detrital and authigenic gypsum, pyrite, carbonate, Fe/Mn/Ti oxides, and clays. Normative mineralogy is used as a comparative tool to substantiate observations made by soil petrography (see section 6.3). The electron microprobe is used to identify mineral phases not found in soil petrography, to estimate the mineralogy of different types of rock fragments, and to validate soil petrographic data. XRD clay analysis is used to identify specific types of clays, including kaolinite, chlorite, smectite, illite, and mixed layer clays. Reitveld analysis provides precise measurements of the abundance of pyrite, copiapite, jarosite, goethite, hematite, molybdenite, fluorapatite, fluorite, and sphalerite.

A Microsoft Excel spreadsheet is used to calculate estimated modal mineralogy based on petrographic and other analyses. The following instructions (also included on the spreadsheet) correspond to steps in the spreadsheet:

Step 1: Determine the composition of average rock fragments. This is required for all types of rock fragments present. If appropriate, rock fragment compositions can be used in the modal mineralogy calculation for multiple samples. This is accomplished by performing image analysis on back-scattered electron (BSE) images and X-ray maps of rock fragments from the electron microprobe.

a.) Use Si map to determine quartz %

b.) Use Si map to determine total feldspar %

c.) Use BSE image to determine K-feldspar %

d.) Subtract K-feldspar % from total feldspar % to obtain plagioclase %

e.) Use Fe map to determine epidote + clay %

f.) Use Ca map to determine epidote %

g.) Subtract epidote % from (epidote + clay %) to obtain clay %

f.) Normalize to 100% (most images include approximately 20% void space)

Step 2: Determine alteration assemblages and the proportions of minerals within each assemblage. The alteration intensity for any given alteration type (or rank) is defined as

the percentage of primary minerals that have been replaced by alteration minerals. Therefore, it is necessary to determine the proportions of alteration minerals within a 100% altered sample. For example a 100% argillic-altered rock fragment would consist of 100% clay, and a 100% QSP-altered rock fragment might consist of 75% quartz and 25% sericite (pyrite estimated separately). This information must be entered into the alteration assemblage section of the spreadsheet. It can be estimated by petrography, electron microprobe imaging, the literature, or a combination of techniques. If appropriate, the same values can be used for multiple samples.

Step 3: Estimate the percentage of carbonate, pyrite, Fe/Mn/Ti oxides, gypsum (enter the proportions of authigenic and detrital gypsum; e.g., 40% authigenic and 60% detrital), molybdenite, phlogopite/biotite, organic material, fluorite, magnetite, apatite, hornblende, total clay, plus the total percentage of rock fragments. This is accomplished using the binocular microscope, but the electron microprobe and/or thin sections can also be used as aids. Enter 9999% for minerals that are present in trace amounts (note: do not enter 9999 for trace amounts in steps 1, 2, or 6).

Step 4: If pyrite reserve data are available, enter values for goethite, hematite, molybdenite, fluorite, apatite, copiapite, jarosite, and sphalerite. If values for goethite and hematite are entered, the spreadsheet will subtract these from the original Fe/Mn/Ti oxides value to calculate the new Fe/Mn/Ti oxides value in section 7. If pyrite reserve data are available, these data should override estimates made by petrography. If adding pyrite reserve data causes the total estimated modal mineralogy (section 7) to be greater than 100%, the data must be normalized to 100%.

Step 5: If clay XRD data are available, enter values for kaolinite, chlorite (2), illite, smectite, and mixed-layer clays. These values must be recorded in "parts in ten" of total clay. Spreadsheet will use total clay if these values are not entered. Note: In the final output (section 7) illite and sericite values are combined.

Step 6: Determine the types of rock fragments and their proportions (e.g., 80% andesite, 20% Amalia Tuff) and their types (ranks) and intensities of alteration (see definitions above; e.g., 20% QSP, 5% propyllitic).

Step 7: This section contains the final estimated modal mineralogy. Examine values and compare to electron microprobe data and add any mineral phases that are present in the microprobe data but absent in the modal mineralogy. Re-examine rinsed mine soil under a binocular microscope and make necessary adjustments to estimated modal mineralogy. If whole rock geochemistry is available, calculate normative mineralogy (see section 6.3 below) and compare to modal mineralogy. It is useful to compare a related group of samples. Qualitative positive correlations should exist between normative and modal minerals. If any changes are made to estimated modal mineralogy, enter the new data into step 9a (see below).

Values estimated from petrography are reported with 0 decimal places with the exception of authigenic and detrital gypsum, which are reported to 2 decimal places. Pyrite reserve data are also reported to 2 decimal places.

Step 8: Spreadsheet will format the final database input based on "final estimated modal mineralogy". Non-mineral fields (e.g,. petrographer, comments) can be modified here.

Step 9: Optional: To be used if changes are made to final modal mineralogy after spreadsheet calculations.

a.) Enter revisions to "final estimated modal mineralogy" here. Include values for all minerals, including "9999%" for trace amounts.

b.) Spreadsheet will normalize data from section 9a to a total of 100%.

c.) Spreadsheet will format the final database input based on revised and normalized modal mineralogy. Non-mineral fields (e.g., petrographer, comments) can be modified here.

Addendum to procedure, to be followed after January 25, 2007

Clay mineralogy is very important to understanding the stability of the rock pile. During petrographic analysis, the abundance of certain phyllosilicates, chlorite, and the micas are visually estimated using the AGI volume percentage diagram. However, clay abundances for minerals like illite, smectite, and kaolinite are more difficult to ascertain for several reasons. First, clay sized particles often form a layer over the entire sample. Since abundances are reported in volume percent, it is almost impossible to determine a volume percent for clays covering other particles. Second, clay mineral identification (i.e. illite vs. kaolinite vs. smectite) in hand sample is very difficult and other methods must be used to determine abundances. Degree of alteration is one way of estimating the amount of clay in a sample. As Donahue (2007) state, the clay mineral abundances have not changed since the rock piles formed. Therefore, we can use the relative abundances obtained from the X-ray diffractometer (XRD) data as a multiplier to the volume percent of total clay predicted in the SOP 24 spreadsheet (included here as a separate file – SOP24spreadsheet.xls) written by Erin Phillips. This spreadsheet was updated to include these new calculations; it is now called SOP 24 v2 spreadsheet (Fig 1).

Step 5: If clay XRD data are available, enter values for kaolinite, chlorite (2), illite, smectite, and mixed-layer clays. These values must be in "parts in ten" of total clay. Spreadsheet will use total clay if these values are not entered. Note: in final output (section 7) illite and sericite are combined.

Kaolinite	Chlorite	Illite	Smectite	Mixed_layered	other

clay	
0%	For calculations only; do not enter value here.

Figure 1: This figure shows where the XRD data would be imported into the SOP 24 v2 spreadsheet. Beneath the imported data is where the spreadsheet predicts the amount of clay present in the sample, based on alteration intensity.

For GHN-KMD-0088 (see spreadsheet SOP24spreadsheetv2.xls), this spreadsheet predicted 2% clays from 60% QSP and 10% propyllitc alteration. XRD data (in parts in ten) show that kaolinite is 2, illite is 1, smectite is 2, chlorite is 3 and mixed layer is 2. Using the XRD data as a multiplier will result in an estimated clay abundance with kaolinite = 0.4%, illite = 0.2%, smectite = 0.4%, chlorite = 0.6%, mixed layer = 0.4%. Use the calculated abundance when chlorite is observed during petrographic analysis. Clay values estimated using this procedure are reported with 0 decimal places.

For geotechnical studies, which do not take into account the clays found in rock fragments, we use a different method. Particle size distribution is the method which provides a maximum wt % of available clay-sized particles. Theoretically, volume % can be obtained with the wt% and the density of the sample. Using this information along with the XRD information to obtain relative abundances of different clays, we can obtain an estimate of clays available in the rock pile. When particle size distributions are not available for a sample, we use LOI and nearby sample data to approximate a particle size distribution.

For example, if a sample has 1.4% clay particles, we use the XRD as a multiplier to obtain the estimated clay abundances (i.e. 0.014 clay * 0.2 (kaolinite) = 0.28% kaonlinite). The same procedure can be used with other clay minerals analyzed with XRD. This calculation can be performed using the GeoTech Clay Abundance worksheet of the SOP 24 v2 spreadsheet. Clay values estimated using this procedure are reported to 4 decimal places.

6.1.4 QA/QC

The methods outlined in section 6.1 of this document are used to obtain an estimation of the mineralogy of each sample. It is emphasized that this is a qualitative to semi-quantitative method and that the relative abundance of minerals within a suite of samples is likely to be more reliable than the absolute abundance of minerals within isolated samples.

The use of multiple analytical techniques (soil petrography, electron microprobe, Reitveld method, clay XRD analysis, and whole rock geochemistry) serves to validate data. The accuracy of modal mineralogy is difficult to assess because of the lack of established standard samples of mine soils. The best estimates of accuracy are obtained by comparing estimated modal mineralogy to whole rock chemistry and electron microprobe results.

Precision is estimated by analyzing duplicate samples. For every tenth sample, a duplicate should be examined and modal mineralogy calculated following the procedures outlined in section 6.1.

6.2 Thin section petrography

Standard thin section petrographic methods will be followed (Williams et al., 1954). Thin section petrography can be used as a supplement to soil petrography and other methods described in section 6.1.

6.3 Normative mineral calculations

Normative mineralogy is a theoretical modal mineralogy that is calculated by using mathematical equations that partition elements from whole rock chemical analyses into a group of pre-determined minerals. In his book Basic Analytical Petrology, Ragland (1989) wrote, "It has been said that the norm is a list of minerals that might have crystallized from the magma, whereas the *mode* is the group of minerals that actually did crystallize." Cross et al. (1903) devised the first weight percent norm, known as the CIPW norm. Normative mineralogy was originally developed for use with fine-grained igneous rocks because minerals were too small to identify with petrographic microscopes.

The application of traditional normative mineralogy to rock pile material is compromised by the presence of hydrous minerals, as well as the presence of multiple alteration assemblages, many of which include minerals unaccounted for in the normative mineralogy. Nonetheless, calculation of normative minerals is useful for comparison of groups of rock pile samples and as a semi-quantitative verification of soil petrographic data. For example, within a group of rock pile samples, a positive correlation should exist between % Amalia Tuff and normative quartz, because the Amalia tuff contains more quartz than does andesite. However, hydrothermal alteration complicates this relationship. For example, samples with a high degree of QSP alteration will likely have higher normative quartz values than expected for non-QSP altered samples. In general, a positive correlation should exist between normative and modal mineral values within a suite of samples. However, these relationships must be evaluated on a case-by-case basis considering hydrothermal alteration, degree of weathering, and the presence of minerals that are not accounted for in the normative mineralogy. Norms are calculated using the MINPET program (version 2.02) and/or a spreadsheet obtained from the following website: http://www.union.edu/PUBLIC/GEODEPT/COURSES/petrology/norms.htm.

7.0 COLLECTION OF SAMPLES

Samples are collected according to the sample plan and to SOPs 5, 6, and 9 and prepared according to SOP 8.

8.0 QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES AND SAMPLES

See section 6.1.4.

9.0 SAMPLE HANDLING

Thin sections, grain mounts, rinsed and unrinsed mine soil samples, and other samples are archived after petrographic description.

10.0 DOCUMENTATION

Database forms and subforms will be used to record petrographic data (eg. Appendix 2).

11.0 REFERENCES

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APPENDIX 1. Spreadsheet for calculation of estimated modal mineralogy

See SOP 24 Excel Spreadsheet in separate document (SOP24spreadsheetv2.xls) and see below for images of pieces of that Excel Document

J	K	L	M	N	O
			Color Key		
	Values to be entered by user. The same values may be used for multiple samples, if appropriate.				
	Values to be entered by user. Values for each sample will be unique. Enter 9999% for trace amounts of minerals in steps 3, 4, and 5 (*not* in step				
	Estimated modal mineralogy calculated by spreadsheet				
	Input data for database (modal min table). Data is formatted for direct entry into database.				
	Optional: Values to be entered by user if revisions to "estimated modal mineralogy" in step 7 are necessary.				

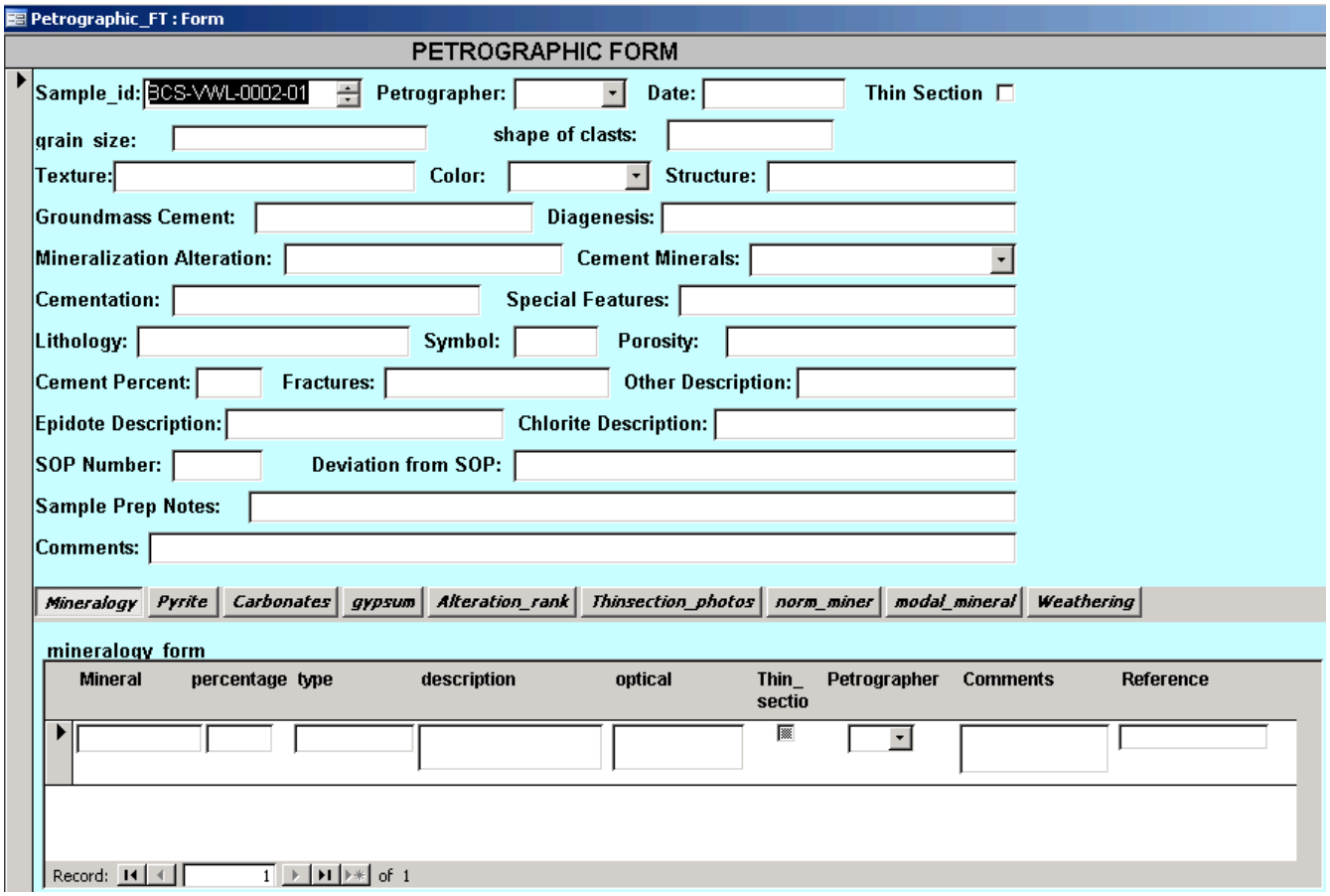
SOP24spreadsheet.xls

	A	B	C	D	E	F
1–6	**Step 1**: Determine the composition of average rock fragments. This is required for all types of rock fragments present. If appropriate, rock fragment compositions can be used in the modal mineralogy calculation for multiple samples. This can be accomplished by performing image analysis on back-scattered electron (BSE) images and X-ray maps of rock fragments from the electron microprobe. a.) Use Si map to determine quartz %; b.) Use Si map to determine total feldspar %; c.) Use BSE image to determine k-feldspar %; d.) Subtract k-feldspar % from total feldspar % to obtain plagioclase %; e.) Use Fe map to determine epidote + clay %; f.) Use Ca map to determine epidote %; g.) Subtract epidote % from (epidote + clay %) to obtain clay %; f.) Normalize to 100% (most images include approximately 20% void space)					
7						
8	Rock Type	Ave. moderately alt andesite	Amalia tuff			
9	Quartz %	36.4%	50.0%			
10	K-feldspar %	28.7%	31.3%			
11	Albite %	23.6%	18.8%			
12	Clay %	6.6%	0.0%			
13	Epidote %	4.8%	0.0%			
14	Total	100.0%	100.0%			
15						
16–21	**Step 2**: Determine alteration assemblages and the proportions of minerals within each assemblage. The alteration intensity for any given alteration type (or rank) is defined as the percentage of primary minerals that have been replaced by alteration minerals. Therefore, it is necessary to determine the proportions of alteration minerals within a 100% altered sample. For example a 100% argillic altered rock fragment would consist of 100% clay and 100% QSP altered rock fragments might consist of 75% quartz and 25% sericite (pyrite estimated separately). This information must be entered into this section of the spreadsheet. It can be estimated by petrography, electron microprobe imaging, the literature, or a combination of techniques. If appropriate, the same values can be used for multiple samples.					
22						
23	Alteration type (rank)	QSP (pyrite estimated separately)	Propylitic (carb estimated separately	Argillic		
24	Quartz	75.0%	0.0%	0.0%		
25	Sericite	25.0%	0.0%	0.0%		
26	Epidote	0.0%	60.0%	0.0%		
27	Chlorite	0.0%	40.0%	0.0%		
28	Clay	0.0%	0.0%	100.0%		
29						

43–45	**Step 6**: Determine the types of rock fragments and their proportions (e.g., 80% andesite, 20% Amalia Tuff) and the types (ranks) and intensities of alteration (see SOP for definitions; e.g., 20% QSP, 5% propyllitic).				
46					
47		proportion of rock frags andesite ('	proportion of rock frags Amalia (%)	proportion of rock frags intrusive (%)	QSP %
48					
51–56	**Step 7**: This section contains the final estimated modal mineralogy. Examine values and compare to electron microprobe data and add any mineral phases that are missing. Re-examine rinsed mine soil with microscope and make necessary adjustments to estimated modal mineralogy. If whole rock geochemistry is available, calculate normative mineralogy and compare to modal mineralogy. It is useful to compare a related group of samples. Qualitative positive correlations should exist between normative and modal minerals. If any changes are made to estimated modal mineralogy, enter new data into step 9a (see below). Values estimated from petrography are reported with 0 decimal places, with the exception of authigenic and detrital gypsum, which are reported to 2 decimal places. Pyrite reserve data are reported to 2 decimal places.				
57					
58					
59	Sample ID	quartz	k-feldspar	albite	epidote
60	0	0%	0%	0%	0%

65	**Step 8**: Spreadsheet will format the final database input based on "final estimated modal mineralogy". Non-mineral fields (e.g,. petrographer, comments) can be modified here.					
66						
67						
68	Sample_id	Petrographer	Laboratory_id	SOP_number	Deviation_SOP	qtz
69	0 EHP		NM16	24		0

APPENDIX 2. Forms



Note: The petrographic subforms are reached by clicking on the tabs at the bottom of the Petrographic_FT form. The mineralogy subform has been selected for this illustration.