Department of Energy
Yucca Mountain Project Office
P. O. Box 98608
Las Vegas, NV 89193-8608

WBS 1.2.5.2.5
QA: N/A

OCT 02 1990

John J. Linehan, Director
Repository Licensing and Quality Assurance
Project Directorate
Division of High-Level Waste Management
U.S. Nuclear Regulatory Commission
4-H-3
Washington, DC 20555

TRANSMITTAL OF PROCEDURES FOR STUDY PLAN 8.3.1.8.5.1 "CHARACTERIZATION OF VOLCANIC FEATURES"

As requested in your letter of August 20, 1990, we are transmitting the following procedures referenced in Study Plan 8.3.1.8.5.1:

1. Drilling Program: TWS-INC-7-3/86-5
2. Preparation of Powders from Rock, Cinder, and Ash Samples: TWS-N5-DP-605, R0
3. Sample Collection Procedure for Rock Varnish Studies: TWS-ESS-DP-114, R1
4. Fission-Track Dating: USGS-GCP-08, R2
5. Procedure for Volcanism Field Studies: TWS-EES-13-DP-606, R1
6. Petrography Procedure: TWS-ESS-DP-03, R3
7. Volcanic Hazard Investigations Work Plan: TWS-INC-WP-12, R0

This transmittal partially satisfies your request. The remaining documents are being assembled and will be sent in the near future. It should be noted that some of the enclosed approved procedures were developed prior to the implementation of the current Yucca Mountain Project Quality Assurance (QA) Program. All procedures will be evaluated for consistency with the current QA Program prior to their use in the collection of site characterization data.

If you have any questions concerning the references, please contact David C. Dobson of my staff at (702) 794-7940 or FTS 544-7940.

Carl P. Gertz, Project Manager
Yucca Mountain Project Office

RSED:DCD-5152

Enclosure:
References for Study Plan 8.3.1.8.5.1

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WM-11 PDC

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OCT 02 1990

cc w/encl:
T. A. Grant, SAIC, Las Vegas 517/T-13

cc w/o encl:
L. J. Desell, HQ (RW-30) FORS
B. M. Crowe, LANL, Las Vegas, NV

RMS NUMBERS
LA001082

Los Alamos
Los Alamos National Laboratory
Los Alamos, New Mexico 87545

memorandum

TO Don Oakley, ES-NP, MS-F619

DATE March 17, 1986

FROM Bruce Crowe, INC-7 BC

MAIL STOP/TELEPHONE J514/7-3965

SYMBOL TWS-INC7-3/86-5

SUBJECT DRILLING PROGRAM FOR VOLCANISM DRILL HOLES

Enclosed is the drilling program for the volcanism drill holes, currently scheduled for June, 1986. The package needs to be sent to WMPO for approval and to meet a Level II milestone in the Tectonics and Volcanism WBS 2.3.2.2.1 (the milestone has a due date of 5/86 to your office and 6/86 to WMPO). Your assistance is required on two items:

1. Determine if a formal meeting is required with Don Vieth to obtain permission to proceed with the drilling (according to Dudley, this has often been the case with the more recent drill holes of the U.S.G.S.).

2. Keep me informed of the possible impact of the current QA problems with core handling on the drilling schedule. Based on conservations with Joe D'Lugosz (3/14), it appears that we may be able to proceed with our drilling by writing minor changes to the current core handling procedures. However, I am not willing to invest time into these modifications until the current situation is more clear.

I received a phone call from a F&S drilling person asking if we could proceed immediately with the volcanism holes. I would like to stay with our planned schedule. We still need to complete ground magnetic work and calculations to locate the drill sites and I do not want to make any errors on QA procedures. My feeling is that if we try to rush the holes, we run the risk of making errors that could compromise the scientific objectives of the drilling program.

BC:er

cy: F. Perry, INC-7, MS-J514
B. Barraclough, ESS-1, MS-D462
E. Bryant, INC-7, MS-J514
TWS File

ENCLOSURE

Los Alamos

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DATE March 11, 1986
IN REPLY REFER TO TWS-ES-NP-2-86-33
MAIL STOP J514
TELEPHONE (505) 667-1310

Dr. Donald L. Vieth, Director
Waste Management Project Office
US Department of Energy
P. O. Box 14100
Las Vegas, NV 89114-4100

ATTN: J. D'Lugosz

DRILLING PROGRAM FOR VOLCANISM TEST HOLES USW V#1 AND USW V#2

Enclosed is the drilling, sampling, and logging program for USW V#1 and USW V#2. These holes will be located in Crater Flat, a few kilometers east of Steves Pass and in the Amargosa Valley, a few kilometers southwest of the town of Lathrop Wells. The main purpose for drilling the holes is to determine the source of two prominent aeromagnetic anomolies. These anomalies are inferred to be caused by shallow buried volcanic rocks. If this inference proves to be true, the volcanic rocks will be cored and recovered core will be dated using the K-Ar dating method and analyzed geochemically for major and trace element constituents. These data will be used to: 1) Refine magma volume versus time curves used in volcanic probability calculations (Crowe and others, 1982), 2) Investigate further the possibility of future bimodal volcanism in the Yucca Mountain vicinity (Crowe and others, 1986) and 3) Test established geochemical patterns in the basalt episodes of the Nevada Test Site region (Vaniman and others, 1982, Crowe and others, 1986). Data from these holes will be used to help resolve Information Needs 1.7.1, 1.7.4, and 1.7.5.

The location of the holes has been established by transfer of aeromagnetic data to topographic quadrangle maps and by ground magnetic traverses over the anomaly sites. The drilling will be relatively inexpensive. Core recovery will be required only through thin (30 to 50 meters) basalt or silicic volcanic rocks. No core will be taken in alluvium unless the USGS requires core for Tectonic studies. No extensive drill hole logging will be required. Quality assurance procedures related to the drilling, sampling and logging of these holes are listed in the attached program. Quality assurance levels have been assigned for the subactivities/items and are attached. The development of the drilling plans and Quality Assurance plans have been coordinated with the USGS. This coordination will continue through the actual drilling and during data evaluation.

An Equal Opportunity Employer/Operated by University of California

Questions regarding technical justification for the drill holes should be directed to Bruce Crowe, Los Alamos (FTS 843-3965). Questions concerning the drilling program should be directed to Frank Perry, Los Alamos (FTS 843-0967) or Dick Blankennagel, USGS (FTS 776-5194).

Pending necessary approvals, the drill holes have tenatively been scheduled for June, 1986. Please let us know if it will be necessary for LANL or USGS scientists to meet with you to discuss the drilling program in greater detail.

Sincerely,

Don Oakley

DO:lmm

cy: F. Perry, INC-7, MS-J514
B. Crowe, INC-7, MS-J514
W. Dudley, USGS
D. Blankennagel, USGS
D. 'Lugos, WMPO
TWS File
CRM-4(2)

DRILLING PROGRAM FOR LOS ALAMOS VOLCANISM TEST HOLES USW V-1 AND V-2

OBJECTIVES:

1. To investigate the origin of aeromagnetic anomalies in Crater Flat and the Armagosa Valley.
2. To determine the thickness of and recover core from basaltic or silicic volcanic rocks encountered in the drill holes.
3. To determine the volume of inferred buried volcanic rocks in Crater Flat and in the Armagosa Valley.

LOCATIONS:

	Approximate Nevada central zone coordinates		
USW V-1	N. 729,600	E. 518,000	(Crater Flat)
USW V-2	N. 682,450	E. 572,900	(Lathrop Wells)

GROUND ELEVATIONS:

USW V-1	±2890 ft
USW V-2	±2605 ft

TOTAL DEPTHS:

±500 to 1,000 ft (Total depths will be determined in field by the Los Alamos representative)

ANTICIPATED LITHOLOGIES:

USW V-1	USW V-2
0 - ±500 ft Alluvium	0 - ±200 ft Alluvium
±500 - ±600 ft Basalt	±200 ft - ±400 ft Basalt
±600 - ±800 ft Alluvium or Tuff	±400 - ±600 ft Alluvium or Tuff

PROGRAM:

1. Prepare minimum access road and grade location as required.

2. Move in failing rig or equivalent, and using air soap, drill a 12-3/4-in. hole from surface to ±50 ft to a competent casing point. Take 10-ft cuttings samples from surface to total depth (±500 to 1,000 ft). Five-foot samples may be required in selected intervals.

3. Run and set 8-5/8-in. O.D., 32.00 #/ft, casing to ±50 ft and cement to the surface.

4. Drill a 6-3/4-in. hole from base of 8-5/8-in. O.D. surface casing to the first basalt layer by using air soap as the circulating medium. The basalt will be identified by the Los Alamos representative in the field, based on examination of rock cuttings and penetration rate.

5. Continuously core basalt layer in 10' intervals using wireline HCQ-3 core barrel and diamond-set bit. Air soap will be the circulating medium. The Los Alamos representative shall determine depth at which coring should be stopped.

6. Ream cored interval to 6-3/4-in. and drill to second basalt layer or to total depth as determined by Los Alamos representative. If a second basalt layer is encountered, core as in Item 5.

7. Demobilize rig and move to USW V-2 location. Proceed as in Items 1 through 7.

NOTES:

A. The Los Alamos representative shall note lithologic changes as they are encountered in the hole.

B. The hole shall be left in such condition that future water-level measurements can be made.

C. NTS contractors shall provides on-site, sufficient replacement bits, core catchers, and other expendable parts for the HCQ-3 core barrel.

RESPONSIBILITIES:

A. Fenix & Scisson, Inc. Responsibilities

1. Prepare the necessary procurement authorizations for off-site procurements.

2. Provide one or two trained geologists during drilling and coring operations to support the user. These geologists will work with the user to help achieve the scientific goals of the drilling program.

3. Monitor drilling operations.

B. REECo Responsibilities

1. Conduct rig operations on an 8-hour, 5-day week basis.

2. Provide capability to drill with air soap (foam) as the circulating medium.

C. Los Alamos (User) Responsibilities

1. Note lithologic changes (from cuttings) as they are encountered in hole.

2. Determine depth at which coring of volcanic rocks will begin and end, based on cuttings, core, and penetration rate.

3. Collect and process, i.e., sort, package, and label cuttings and cores.

4. On-site monitoring of any procedures that will affect scientific objectives of drill hole.

WORKING RELATIONSHIPS OF PARTICIPATING PARTIES:

1. The following people will represent the participating parties on location.

   A. Los Alamos (User)—LANL/F&S Geologists. Frank Perry is the responsible LANL representative for this program.

   B. REECo—REECo Drilling Superintendent

2. All changes originating from the User will be requested through DOE. DOE/NTSO will inform F&S Drilling of all approved changes. F&S Drilling will inform REECo Drilling and F&S field operations of the approved changes. F&S field operations and REECo Drilling will implement approved changes. F&S will document all changes.

Quality Assurance Requirements for Drilling, Sampling, and Testing

1. Each participating organization shall perform its activities in accordance with its Quality Assurance Program Plan. Official, controlled copies of these QAPPs shall be available for reference either at the work site or at the participant's office in Mercury.

2. Information copies of participants' procedures shall be distributed to those NNWSI personnel that perform activities, coordinate work, and provide interface for the activities described in those procedures.

3. The USGS/Los Alamos and F&S geologists assigned in direct support of USGS/Los Alamos shall conduct USGS/Los Alamos parts of these activities in accordance with USGS/Los Alamos Quality Assurance Program. Appendix A lists the applicable QA procedures that will be available at the work site. QA procedures are available at the work site or at Los Alamos, TA-48, Bldg. RC-1, Room 408A.

4. A communications procedure, or other written instructions, prepared by the USGS shall describe communication responsibilities and documentation requirements for F&S geologists assigned to assist the USGS/Los Alamos. This document shall be distributed and posted in a manner that makes it available to all participating F&S and USGS/Los Alamos personnel. The communication procedure and all resulting documents shall be included in the records of these activities.

5. Quality assurance requirements for drilling, sampling, and testing USGS/Los Alamos test holes are listed in Appendix A. Only those plans and procedures applicable to this program shall apply.

APPENDIX A

DOCUMENT INDEX FOR QUALITY ASSURANCE REQUIREMENTS FOR DRILLING AND SAMPLING LOS ALAMOS VOLCANISM TEST HOLES USW V-1 AND V-2

A. Fenix & Scission, Inc., Operating and Quality Assurance Procedures:

DOP-001	Procedure for the development of drilling programs
DOP-004	Procedure for the documentation of approved changes in drilling programs
DAP-9.16	Logging surveillance procedure
DOP-003	Drilling Specialist's surveillance procedure: Unit Price Contractor Operations
DOP-002	Drilling Specialist's surveillance procedure: Cost Plus Fixed Fee Contractor Operations
QAP-13.1	Handling, Storage, and Shipment
QAP-15.2(N)	Procedure for reporting nonconformance
QAP-16.1(N)	Corrective Action Procedure
QAP-17.1	Quality Assurance records procedure

B. The following DOE/NTSO plans and procedures shall be on file.

1. NNWSI Quality Assurance Plan (NVO-196-17, Rev. 4).
2. Engineering, Construction, and Support Services at NTS (NNWSI-SOP-03-01).
3. NNWSI Nonconformance Control System (NNWSI-SOP-15-01).

C. REECo FOD/Drilling Department Procedures:

201	NNWSI Measurement of Drilling Fluid Quantities and Determination of Drilling Fluid Loss	05-04-84
203	NNWSI Taking and Handling of Cores	05-04-84
204	Calibration of Equipment	02-28-85
205	Measurement of Depth of Hole	
206	Qualification of Core Drill Operations	05-04-84
207	NNWSI Pressure Testing of Drill Rod	05-04-84
208	NNWSI Nationally Accepted Drilling Practices and Standards	
211	High Pressure Air Operations	05-04-84
217	Action Required in Response to Spills and/or Leaks of Hazardous Materials	03-20-84
219	Procedure for Drilling in Casing or Pulling Stuck Casing with Air Assist	05-04-84

D. USGS/Los Alamos-NNWSI Quality Assurance Document Index

<u>Organization</u>	
NNWSI-USGS-QMP-1.01, R0	QA Organization Procedure
NNWSI-QP-01, R0	Los Alamos QAPP for NNWSI
<u>Quality Assurance Program</u>	
NNWSI-USGS-QMP-2.03, R0	Certification of USGS Technical Personnel for the NNWSI Project
NNWSI-USGS-QMP-2.04, R0	Certification of Fenix & Scisson Geologists
TWS-MSTQA-QP-08, R0	Certification of Los Alamos National Laboratory Personnel
<u>Design</u>	
NNWSI-USGS-QMP-3.02, R0	USGS Quality Assurance Levels Assignment Procedure
NNWSI-USGS-QMP-3.05, R0	Work Request for NTS Contractor Services (Criteria Letter)
TWS-MSTQA-QP-18, R0	Assignment of Quality Levels for Los Alamos NNWSI Activities and Items
<u>Procurement Control</u>	
NNWSI-USGS-QMP-4.01, R0	Procurement Document Control
<u>Instructions, Procedures, and Drawings</u>	
NNWSI-USGS-QMP-5.01, R0	Preparation of Technical Procedures
<u>Document Control</u>	
NNWSI-USGS-QMP-6.01, R0	Document Control
TWS-MSTQA-QP-03, R5	Document Control
<u>Identification and Control of Materials, Parts, Components, and Samples</u>	
NNWSI-USGS-QMP-8.01, R0	Identification and Control of Geologic and Hydrologic Samples
<u>Inspection</u>	
NNWSI-USGS-QMP-10.01, R0	Surveillance Procedure
<u>Control of Measuring and Test Equipment</u>	
NNWSI-USGS-QMP-12.01, R0	Instrument Calibration
<u>Control of Nonconforming Items</u>	
NNWSI-USGS-QMP-15.01, R0	Procedure for Control of Nonconforming Items

Corrective Action

NNWSI-USGS-QMP-16.01, R0	Control of Correction Action Procedure

Quality Assurance Records

NNWSI-USGS-QMP-17.01, R0	Quality Assurance Records Management

Audits

NNWSI-USGS-QMP-18.01, R0	Auditing Procedure

Technical Procedures

NWN-USGS-MDP-01, R0	Identification, Handling, Storage, and Disposition of Drill-Hole Core and Samples

E. Holmes & Narver, Inc., Survey Department Procedures:

S.O.P. #1	Standard procedure for establishing drill hole locations with a Total Station Distance Meter.
S.O.P. #2	Standard procedure for establishing elevations with a Total Station Distance Meter.
S.O.P. #3	Standard procedure for establishing as-built coordinates with a Total Station Distance Meter.

F. The DOE/NTSO, REECo, USGS/Los Alamos, H&N (Surveying), and F&S Quality Assurance Procedures listed above shall be maintained on file at the drill site or at project participant's office. Each organization shall be responsible for maintaining its own procedures.

G. F&S shall inform DOE/NTSO if a project participant's or support contractor's procedures are not available prior to commencement of operations.

NNWSI QUALITY LEVEL ASSIGNMENT

APPROVALS (SIGNATURE & DATE)			WMPO (PQM)
PI	TPO	PQA	WMPO (TECH)

CTIVITIES	QA LEVEL	QA CRITERIA	TECHNICAL JUSTIFICATION
; & Coring Equipment (R)	III	*	Standard fabricated equipment; meets none of the attributes of levels I & II on logic diagram
(R)	III	*	Meets none of the attributes of levels I & II on logic diagram
ıtion (R)	III	*	Meets none of the attributes of levels I & II on logic diagram
ite Preparation & Rig Setup(R)	III	*	Meets none of the attributes of levels I & II on logic diagram
g, Casing, & Coring Methods for Circulating Medium (R)	III	*	Meets none of the attributes of levels I & II on logic diagram
ting Medium (R)	III	*	Meets none of the attributes of levels I & II on logic diagram
Transport	I	*	Logic Item #5 applies: Affects condition of samples and could affect sample analysis
uttings Collection	III	*	Meets none of the attributes of levels I & II on logic diagram
Handling/Preservation	I	*	Logic Item #5 applies: Affects condition of samples and could affect sample analysis
Identification	I	*	Logic Item #5 applies: Affects analysis of data and conclusions
Storage	I	*	Logic Item #5 applies: Affects condition of samples and could affect sample analysis.

NNWSI-USGS QUALITY LEVEL ASSIGNMENT

(Applicable QA Criteria)

lcanism Test Holes USW V-1 & V-2

(Investigation)

CTIVITY-ITEM/CRITERIA NUMBER	QUALITY LEVEL	1 ORGANIZATION	2 QA PROGRAM	3 DESIGN CONTROL	4 PROCUREMENT DOCUMENT CONTROL	5 INST. PROC. DRWG.	6 DOCUMENT CONTROL	7 CONT'L. OF PURCHASED EQUIP. MAT'L. SERVICE	8 IDENT. AND CONT'L. OF ITEMS	9 CONTROL OF PROCESSES	10 INSPECTION	11 TEST CONTROL	12 CONTROL OF M&TE	13 HANDLING, SHIPPING AND STORAGE	14 INSP. TEST AND OPERATIONS STATUS	15 NONCONFORMANCES	16 CORRECTIVE ACTION	17 QA RECORDS	18 AUDITS
illing & Coring Equipment	III																		
cess	III																		
bilization	III																		
ill Site Preparation & Rig tup	III																		
illing, Casing, and Coring thods	III																		
rculating Medium	III	X	X	X		X	X		X		X				X	X	X	X	X
mples Transport	I	X	X	X		X	X		X		X			X	X	X	X	X	X
ill Cuttings Collection	III	X	X	X		X	X		X		X			X	X	X	X	X	X
mple Handling/Preservation	I	X	X	X		X	X		X		X			X	X	X	X	X	X
mple Identification	I	X	X	X		X	X		X		X				X	X	X	X	X
mple Storage	I	X	X	X		X	X		X		X			X	X	X	X	X	X

PREPARATION OF POWDERS FROM ROCK, CINDER, AND ASH SAMPLES

Effective Date: 6/20/89

Preparer F. Perry	5/17/89 Date
Technical Reviewer D. T. Vaniman	6/12/89 Date
Quality Assurance Review A. M. Pendergrass	05/31/89 Date
Quality Assurance Project Leader H. P. Nunes	6/15/89 Date
Technical Project Officer R. J. Herbst	6/19/89 Date

PROCEDURE FOR PREPARATION OF POWDERS FROM ROCK, CINDER, AND ASH SAMPLES

1.0 PURPOSE

This procedure describes methods for splitting, crushing, and powdering rock, cinder, and ash samples to prepare them for geochemical analysis. This work is performed in support of the volcanism studies for the Los Alamos National Laboratory (LANL) Yucca Mountain Project (YMP or Project).

2.0 SCOPE

This procedure applies to LANL Project personnel and subcontractors who are splitting, crushing, and powdering rock, cinder, and ash samples for geochemical analysis in support of the volcanism studies for the Project. Geochemical analysis includes major-element analysis by X-ray fluorescence (XRF), trace-element analysis by XRF and instrumental neutron activation analysis (INAA), and radiogenic isotope analysis by mass spectrometry.

3.0 REFERENCES

3.1 Parts Manual—Model HCS 400 Hydraulic Core Splitter, La Font Corporation, Prentice, Wisconsin 54556.

3.2 Handbook of Sample Preparation and Handling (Second Edition), 1988. Spex Industries, 3880 Park Ave., Edison, New Jersey, 08820.

3.3 TWS-QAS-QP-02.2, Procedure for Personnel Training.

3.4 TWS-QAS-QP-17.1, Procedure for LANL Group Resident Files.

3.5 TWS-ESS-DP-04, Thin Section Preparation Procedure.

4.0 RESPONSIBILITIES

The principal investigator (PI) has the overall responsibility for ensuring correct performance of all procedures (including documentation and storage) involving the preparation of sample powders at the University of New Mexico (UNM). The PI may assign tasks described in this procedure to trained and certified Project personnel.

5.0 PRINCIPLE

A prerequisite for many types of geochemical analysis of rock samples is preparation of the sample in a manner that retains the characteristics of the original bulk sample while minimizing the effects of alteration caused by handling and introduction of foreign material. This preparation increases the probability that analytical results represent the original condition of the sample when it was deposited in the field. This procedure describes a method of preparing samples for analysis that minimizes alteration of the original sample characteristics.

6.0 DEFINITIONS

Not applicable.

7.0 PROCEDURE

7.1. Equipment Used

- La Font HCS 400 12.5-ton hydraulic core splitter, or equivalent;
- hardened steel mortar and pestle;
- hardened steel vial set; and
- mixer/mill.

7.2 Safety

Always wear eye protection when operating the hydraulic core splitter and keep hands clear of the splitting blades.

7.3 Documentation

Information about each sample processed is recorded in a scientific notebook. Recorded information includes complete sample identification number; date of splitting, crushing, and powdering; name of person preparing each sample; and comments on the general condition of each sample (e.g., degree of alteration, secondary minerals in vesicles). The preparer signs and dates each day's entry.

7.4 Sample Splitting

7.4.1 Preparing and Cleaning the Splitter

7.4.1.1 Before first use, read the section on "operating procedures" in the Parts Manual--Model HCS 400 Hydraulic Core Splitter (Section 3.1).

7.4.1.2 Samples to be split by the hydraulic core splitter (HCS) must fit between the splitter blades, which open to a maximum of 4 in. Reduce the size of samples that are too large by breaking with a rock hammer.

7.4.1.3 Clean the splitter blades and work area around the blades by wiping with a wet wipe and then wiping dry.

7.4.2 Operation of the Splitter

7.4.2.1 Place the plastic container over the lower splitter blade so that blade protrudes through the container opening. The container catches rock fragments split from the main sample.

7.4.2.2 Press the black "Start" button on the left side of the HCS.

7.4.2.3 Place the rock sample so that the lower splitter blade touches the point at which the rock is to be split.

7.4.2.4 Hold the rock sample in position and close the upper splitter blade by moving the control valve handle on the left side of the HCS to the left. Open the splitter blades by moving the control valve handle to the right.

7.4.2.5 Maintain blade pressure on the sample until the sample is split.

7.4.2.6 Repeat the last three steps, splitting succeeding half-samples and splitting off all external surfaces of the sample so that only fresh, internal surfaces remain. Discard or place in a properly labeled container and return to the sample storage area all external surfaces and any portion of the sample that is excessively altered.

7.4.2.7 Split internal portions of the sample into pieces of 1- to 1.5-in. avoiding, if possible, portions with vesicles. Eight to twelve internal sample pieces should be obtained.

7.4.2.8 Put sample pieces obtained in the preceding step into a clean ice cream container labeled with the sample identification on both the side and top of the container.

7.4.2.9 Press the red "Stop" button on the left side of the HCS to turn it off.

7.4.2.10 In preparation for the next sample, clean the splitting blades and the work area around the blades by wiping with a wet wipe and wiping dry. Rinse the plastic container with water until all rock fragments and powder are removed and wipe dry.

7.4.2.11 Record the date the sample was split, information specified in Section 7.3, and any comments in the scientific notebook.

7.5 Sample Crushing

7.5.1 Cleaning

Disassemble the mortar and pestle by unscrewing the base collar of the mortar and thoroughly clean all parts with water and a toothbrush. Dry with a wipe and reassemble.

7.5.2 Operation

7.5.2.1 Place mortar on a clean work space and place one or two sample pieces in the mortar.

7.5.2.2 Insert pestle in mortar, reassemble the apparatus, and crush sample pieces by striking the top of the pestle with a hammer several times. Ear protection may be necessary for this step.

7.5.2.3 Remove the pestle and carefully pour the crushed sample fragments from the mortar on a piece of weighing paper that has been placed on a large sheet of aluminum foil. Beginning at this point, the preparer should not directly touch the sample.

7.5.2.4 Using a clean pair of tweezers, examine the crushed fragments on the weighing paper and remove and recrush any fragments larger than 1 cm in diameter. Remove any fragments that show signs of alteration or secondary mineralization.

7.5.2.5 Pour the crushed sample fragments from the weighing paper into a clean ice cream container labeled with the sample identification number and the designation "Crushed" on both the side and top of the container.

7.5.2.6 Repeat these steps until 6 to 8 sample pieces have been crushed.

7.5.2.7 Disassemble and thoroughly clean the mortar and pestle (as described in Section 7.5.1) and clean the tweezers in preparation for the next sample. Discard aluminum foil and weighing paper.

7.5.2.8 Record the date the sample was crushed, information specified in Section 7.3, and any comments in the scientific notebook.

7.6 Preparation of Sample Powder

7.6.1 Cleaning

Disassemble and thoroughly clean all parts of the hardened-steel vial set with distilled water and a toothbrush. Dry all parts with a wipe and set on a clean wipe.

7.6.2 Operation

7.6.2.1 Split 20 to 30 gm of crushed sample from the crushed sample in the ice cream container by the following splitting method.

- On a large sheet of clean aluminum foil, lay a sheet of weighing paper. Lay a second sheet of weighing paper so that one-half of the first sheet is covered by the second.

- Pour the crushed sample from the ice cream container along the edge of the upper sheet of weighing paper so that one-half of the sample is on the upper sheet and one-half is on the lower sheet. The distribution of the sample should be approximately equal on both sheets of weighing paper.

- Carefully lift the upper sheet of weighing paper by the edges so that one-half of the original sample is taken. Set this half sample aside momentarily and return the half sample left on the bottom sheet of weighing paper to the ice cream container.

- Using the remaining half sample and two new pieces of weighing paper, repeat the splitting procedure as many times as necessary until a sample split to 20 to 30 gm is left. Examine the sample carefully and use clean tweezers to remove any fragments larger than 5 mm in diameter. The grain size distribution of this sample should be approximately the same as that of the original crushed sample. Return the remaining crushed sample material to the labeled container and place it in the sample storage area.

7.6.2.2 Split the sample obtained in the second step in halves by the method described and place one-half of the sample in the base of the hardened-steel vial set. This portion of the sample is discarded after powdering and will be used to "pre-contaminate" the steel vials with powder from the same sample.

7.6.2.3 Place the 1/2-in. steel ball in the vial and close the vial by seating the lid and screwing on the cover cap.

7.6.2.4 Place the steel vial in the vial clamp of the mixer/mill and seat the vial firmly by tightening the clamping screw.

7.6.2.5 Close the cover of the mixer/mill, set the timer to 5 min, and start the mixer/mill by pressing the red start button on the left side of the mixer/mill.

7.6.2.6 When powdering is complete, remove the steel vial and discard the sample powder. Wipe the inside of the steel vial clean of adhering powder with a clean wipe.

7.6.2.7 Place the remaining half sample in the base of the steel vial and repeat steps 7.6.2.3 through 7.6.2.5.

7.6.2.8 When powdering is complete, remove the steel vial from the mixer/mill, carefully open the vial, remove the steel ball with clean tweezers, and pour the sample onto a clean piece of weighing paper that has been placed on a sheet of clean aluminium foil. Pour the sample on the weighing paper into a 20-ml polyethylene scintillation vial that has been labeled on the top and sides with the complete sample identification number.

7.6.2.9 Discard all weighing paper and aluminum foil that has been used in the powdering procedure.

7.6.2.10 Disassemble and clean the steel vial using the method described in Section 7.6.1 in preparation for the next sample.

7.6.2.11 Enter the date the sample was powdered, information specified in Section 7.3, and any comments in the scientific notebook.

7.7 Preparation of Cinder Samples

7.7.1 Pick individual cinders from the bulk sample by hand, avoiding any that show visible alteration or inclusion of foreign material.

7.7.2 Have a thin section made following DP-04, which includes three or four of the hand-picked cinders and examine for alteration of glass and suitability for geochemical analysis.

7.7.3 If cinders are judged suitable for analysis, crush and powder them by the procedures described in Sections 7.5 and 7.6.

7.8 Preparation of Ash Samples

Basaltic ash is attracted to a magnet and can be efficiently separated from other foreign material in the bulk sample by magnetic separation.

7.8.1 Pour the bulk sample onto a large sheet of clean aluminum foil and spread into a thin layer so that the surface area of the sample is maximized.

7.8.2 Place a magnet in a plastic bag (use a new and clean plastic bag for each sample processed to prevent cross-contamination of samples and contamination of the magnet by ash) and pass the magnet closely over the bulk sample so that ash particles are attracted to the surface of the plastic bag.

7.8.3 Remove the magnet and accumulated ash particles to a sheet of weighing paper and dislodge the ash from the surface of the plastic bag by carefully removing the magnet and shaking the plastic bag so that the ash particles fall onto the weighing paper.

7.8.4 Repeat Steps 7.8.1 through 7.8.3 until 5 to 10 gm of ash is separated from the bulk sample.

7.8.5 Repeat the Steps 7.8.3 and 7.8.4 (using weighing paper instead of aluminum foil) for the newly separated ash batch as many times as necessary until careful examination shows that the ash is free of any visible foreign material. A stereoscopic microscope may be used at this point for examination of the ash.

7.8.6 Separate a small quantity of the ash obtained after the preceding step and mount the ash as a thin section following DP-04.

7.8.7 Examine the thin section of ash with a petrographic microscope and document, by quantitative point counting, whether the sample consists of >99% ash and <1% foreign material. Document the results of the point count in a scientific notebook.

7.8.8 If the ash sample is >99% ash, it is considered suitable for geochemical analysis. Powder the ash sample by the procedure described in Section 7.6.

7.9 Deviations

Any unplanned deviations from this DP are documented in the scientific notebook. These deviations are reviewed by the PI for acceptance and for their effect on the quality of the resulting sample.

7.10 Rejection of Material

The individual preparing the sample powders may reject any prepared material, based on good scientific and professional judgment. Any rejections are noted in the sample logbook and scientific notebook.

8.0 QUALITY ASSURANCE

8.1 Storage and Handling Requirements

Samples are stored in locked laboratory and storage facilities in the Geology Department at UNM. Only Project personnel may remove samples from storage for preparation of sample powders. Each time a sample is removed, the date of removal is recorded in the sample logbook.

Personnel should exercise extreme care in properly labeling and tracking all samples during sample preparation to avoid any switching or mislabeling of samples.

8.2 Records

Records of sample preparation (Section 7.3) are kept in the preparer's scientific notebook in accordance with QP-17.1. Photocopies of records will be kept in the Resident File at UNM or N-5, Las Vegas.

8.3 Acceptance Criteria

The records in the scientific notebook and sample logbook, generated by following this DP, demonstrate that the procedure has been successfully implemented.

8.4 Training to Use DP

Training and certification of Project personnel in the procedures set forth in this DP are the responsibility of the DP's preparer and/or technical reviewer. At a minimum, training will consist of reading this DP and demonstrating a working understanding of the steps to the satisfaction of the preparer or reviewer. Training and certification will be documented in accordance with the Los Alamos YMP training and certification procedure (QP-02.2).

9.0 ATTACHMENTS

Not applicable.

LOS ALAMOS NATIONAL LABORATORY

YUCCA MOUNTAIN PROJECT CHANGE REQUEST

CHANGE REQUEST No. 144

DATE 3/28/90

PROCEDURE No. TWS-ESS-DP-114, R1 Sample Collection Procedure for Rock Varnish Studies

CHANGE REQUESTED:

A. Insert after first sentence in Section 4.2:

"A geoscientist will be qualified to perform this field procedure only after training in rock varnish sample collection and field techniques by the PI or by another qualified geoscientist designated by the PI."

B. Rename Section 4.3 as "Sample Handling, Shipping and Storage."

C. Add signature lines for the Principal Investigator and QA reviewer on the cover page. (An amended cover page in included as Attachment 1.)

REASON FOR CHANGE:

A and B. For clarification.

C. As required in QP 5.2, CR 088.

These changes should be considered minor since they do not change how the procedure is implemented.

CHANGE REQUESTED BY Charles J. Harrington DATE 4/23/90

REVIEWED BY Stephen A. Bates DATE 4/24/90.

QAPL APPROVAL [illegible] DATE 5/3/90

TPO APPROVAL [illegible] DATE 6/5/90

EFFECTIVE DATE June 5, 1990

SAMPLE COLLECTION PROCEDURE FOR ROCK VARNISH STUDIES

Effective Date 6-5-90

Charles D. Harrington Preparer C. D. Harrington	April 23, 1990 Date
David T. Vaniman Technical Reviewer D. Vaniman	April 24, 1990 Date
Stephen L. Bolivar QA Reviewer S. L. Bolivar	4/24/90. Date
Charles D. Harrington Principal Investigator C. D. Harrington	4/24/90. Date
HP Nunes Quality Assurance Project Leader H. P. Nunes	5/3/90 Date
R. J. Herbst Technical Project Officer R. J. Herbst	6/5/90 Date

SAMPLE COLLECTION PROCEDURE FOR ROCK VARNISH STUDIES

Effective Date 2/27/90

Charles D. Harrington
C. D. Harrington
Preparer

Jan. 22, 1990
Date

Dave Vaniman
D. T. Vaniman
Reviewer

Jan. 22, 1990
Date

H. P. Nunes
Quality Assurance Project Leader

Jan 24, 1990
Date

R. J. Herbst
Technical Project Officer

13 Feb. 1990
Date

SAMPLE COLLECTION PROCEDURE FOR ROCK VARNISH STUDIES

1.0 PURPOSE

This procedure describes the methods to be used in the collection of rock varnish samples from geomorphic surfaces and deposits, on Yucca Mountain, on and near the Nevada Test Site, or other selected localities within the southern Great Basin. Rock varnish data are utilized for four types of geologic determinations. These are: (1) obtaining chronometric ages of geologic surfaces or deposits; (2) obtaining additional calibration points for the Yucca Mountain rock varnish dating curve; (3) the study of rock varnish development through time on stable geomorphic surfaces; and, (4) studying rock varnish chemistry. Selection of sampling locations, sample collection and identification, and documentation are described.

2.0 SCOPE

This procedure applies to all rock varnish samples taken for the YMP project. Data acquired from the analysis of samples obtained using this procedure will be used in site characterization and the activity is therefore Quality Level 1.

3.0 PRINCIPLES

Rock varnish coatings on cobbles from geomorphic surfaces and from exposed deposits in arid environments can be used to date these surfaces or deposits over an age range of several thousand to more than a million years. The ratio of mobile to immobile cations [(K + Ca)/Ti] has been found to decrease with time and provide a relative-age indicator for rock varnish from a given region. Calibration curves, constructed by determining varnish cation ratios (VCRs) on surfaces previously dated by isotopic techniques are used for the calibrated time interval to estimate the VCR age of unknown-age deposits within the region. Because of variations in climate, rates of dust deposition, and differences in dust chemistry a separate VCR curve is created for each specific region of study. VCRs are determined by SEM chemical analyses of varnish on disks (about 2.5 cm in diameter) cored from rock varnish samples. The VCR for each geomorphic surface or deposit to be dated is the average of the VCRs determined for the varnish on each sampled cobble.

Varnish characteristics and chemistry vary both across an individual rock surface and among a group of rocks taken from a single geomorphic surface. Therefore, collection of duplicate samples having identical chemistry is not possible. The SEM technique of rock varnish dating, however, analyzes *in situ* varnish on rock substrates. All collected rock samples and all varnish cores cut from rock samples are neither modified nor destroyed during analysis. All rock specimens and disks made from varnish cores are retained at Los Alamos, and thus are available for verification and reanalysis. All rock material collected during rock varnish studies and all disks made from these rock varnish samples will be archived in the YMP Sample Management Facility at NTS following the completion of YMP rock varnish studies.

4.0 PROCEDURE

4.1 Site selection and identification

Sample sites are located on rock outcrops, on desert pavements formed on geomorphic surfaces, or on other stabilized geomorphic deposits. The type of rock varnish samples collected as well as the characteristics of the sampling site are determined by the nature of the geologic problem being studied. The location of the sampling site will be recorded on an appropriate topographic, geologic, highway, or other map. The site location and description will be recorded in the collector's controlled field notebook. Photograph(s) of the site may also be taken and these will be labeled and dated and retained with the collector's controlled notebook.

4.2 Sample collection and identification

Rock varnish samples are selected at the site by qualified Los Alamos or U.S. Geological Survey staff geologists. Samples of rock varnish are either collected as whole varnish coated surface clasts or as chips of varnished rock broken from surface clasts or outcrops of rock. The number of samples acquired for a surface depends on the degree of complexity of the surface but generally equals or exceeds eight. Samples are not collected in close proximity to lichens and other vegetation; to varnish formed along cracks; or rock surfaces in contact with soil. Wind-abraded and spalled rock surfaces are also avoided. Photographs may be taken to show the character of the surface from which the samples are taken and that portion of the surface from which samples are collected. Rationale for sample collection is recorded in the investigator's notebook. Samples selected are those possessing the most mature varnish development on the geomorphic surface to be sampled. Each sample will be labeled with a sample identification number. Sample identification will be sufficient to trace a sample to its original field location and collector. Sample identification for one sample collected from each surface or deposit will include the collector's initials and a sequence number, in addition to a lab identification number, unique to that collector's YMP field notebook. For all additional samples collected from the same surface or deposit, the sample identification number will consist of the unique sequential lab identification number. The sample will be marked by a permanent marking pen either on the sample itself, or on tape wrapping the sample, or on the sample bag. The sample numbers, the underlying substrate, and a field description of the surface from which the samples are collected are recorded in the field notebook. Notations may be made on photographs taken of sampled surfaces.

4.3 Sample shipment

Rock varnish samples shall be packed for shipment to Los Alamos in a manner so as to preclude destruction of the varnished rock surface during transport. Each varnished clast will be individually wrapped in paper or other protective material and placed in a sample bag on which sample identification numbers will be marked by a permanent marking pen. Sample bags containing rock varnish samples will be hand carried to Los Alamos whenever possible. If sample bags containing rock varnish samples are shipped to Los Alamos, they shall be packed in heavy cardboard shipping containers sturdy enough to preclude crushing of samples during transport.

Rock varnish samples hand-carried to Los Alamos shall be recorded in the sample receiving/tracking logbook. Rock varnish samples shipped to Los Alamos from Mercury/NTS or from another locality shall be handled in accordance with the Procedure for Identification and

Control of Samples (TWS-QAS-QP-08.1, R1). Upon receipt, a copy of the shipping manifest or a memo verifying receipt shall be put in the EES-1 resident file along with a list of samples. Each shipment entry in the sample tracking logbook will be signed and dated by the recipient.

4.4 Acceptance/Rejection Criteria

If rock varnish samples are collected following the procedure described in Sections 4.1 - 4.3, the samples will be acceptable for preparation for rock varnish analysis.

5.0 QUALITY ASSURANCE

5.1 Personnel

This rock varnish sampling procedure shall be performed by qualified personnel with a geoscience degree or who can demonstrate an equivalent combination of education and experience. Evidence of qualification shall be documented according to the LANL Personnel Certification Procedure.

5.2 Calibration

Not applicable.

6.0 RECORDS

6.1 Documentation and traceability of samples are addressed in Sections 4.1 and 4.2.

6.2 Records will be controlled in accordance with the LANL YMP Records Control Procedure.

UNCONTROLLED COPY
CONTROLLED
Yucca Mountain Project
This is a RED stamp

Fission-Track Dating

1.0 PURPOSE.

1.1 To assure the accuracy, validity, and applicability of the methods used to determine the age of a sample using the fission-track technique of dating, this procedure provides a guide for U.S. Geological Survey (USGS) personnel and contractors to perform the described activity.

1.2 This procedure describes the components of the work, the principles of the methods used, and their limits. It also describes the detailed methods to be used for calibration, operation and performance verification of any equipment if needed. In addition, it defines the requirements for data acceptance, documentation, and control; and it provides a means of data traceability.

2.0 SCOPE OF COMPLIANCE.

2.1 This procedure applies to all YMP-USGS personnel and their contractors who may perform work referred to in Para. 1.1, or use data obtained from this procedure if the data will represent graded QA Level I or II activities.

2.2 For all graded QA Level I or II activities, data collected from using this procedure and any equipment calibrations or recalibrations that may be required shall be in accordance with this technical procedure. Variations are allowed only if and when this procedure is formally revised, or otherwise modified, as described in Para. 8.

3.0 PERSONNEL RESPONSIBILITIES. For the purpose of this procedure, The Principal Investigator (PI) delegates responsibility for assuring full compliance with this procedure to the Branch Chief of Isotope Geology. The Branch Chief shall require that all personnel assigned to work to this procedure shall have the necessary qualifications and training to adequately perform the procedure; and they shall have a working knowledge of the YMP-USGS QA Program. Responsibilities of others including the reviewer(s), contributing investigators, Geologic Division (GD) Branch/Nuclear Hydrology Program (NHP) Chief, QA Office, and the Technical Project Officer are as described in Para. 4, YMP-USGS-QMP-5.01. When procedure-specific responsibilities are to be delegated to contributing investigators or other personnel, the details of these responsibilities are as stated in this procedure. Special qualifications and/or training unique to the conduct of this procedure are professional experience in fission-track dating. All personnel shall flag ongoing or continuing processes that are not to be interrupted by placing a warning sign at the activity location identifying the activity(ies) taking place.

4.0 DETAILED PROCEDURE. Fission-track dating will provide information on the timing of geologic events that have occurred in the Yucca Mountain region. Examples include, but are not limited to ages of volcanic eruptions, uplift and cooling history, and detection of possible hydrothermal systems.

4.1 Objective: The fission track is formed by two nuclei of a fissioning heavy element such as uranium. The original nucleus breaks up into two lighter nuclei of approximately equal energy and liberating about 200 meV. The two nuclei recoil from each other in opposite directions.

The fragments formed at the time of fission are highly charged nuclei that disrupt the electron balance of the atoms in the mineral or glass along their path. As the fission fragment passes, it leaves a zone of positive charge in its wake. This causes the positively charged ions in the material to repulse each other and force themselves into the structure, forming the track. The track is only a few angstroms wide and 10-20 micrometers long.

A given mineral can be dated if enough time has elapsed since its formation to accumulate a significant number of tracks. The mineral or glass quantitatively retains tracks at ambient (surface) temperature. The track density or number of tracks per unit of surface area is a function of the age of the material and its uranium content.

4.2 Methods Used:

4.2.1 MOUNTING MINERALS (usually apatite and glass) IN EPOXY:

1) Clean surface of teflon mounting block and put a strip of opaque drafting tape (or equivalent) down along the edge of the block. Write sample numbers about 3 cm apart on the tape.

2) Write sample numbers on standard petrographic glass slides with diamond scribe and clean slides with alcohol solvent to remove fingerprints and oils.

3) Pour several hundred grains from sample bottle onto the mounting block to form a 1 cm diameter circle 1 grain thick. Do this with each sample to be mounted. Refer to Attachment 1 - Figure 1.

4) Ensure that the grain mounts are of a uniform thickness.

5) If apatite is being counted by the population method, now is the time to prepare the split to be irradiated. Number 3 cm squares of aluminum foil and record numbers in record book. Refer to Attachment 1 - Figure 2. Pour several hundred grains from the sample bottle onto the center of the foil. Fold the square to form an envelope and heat in oven at approximately 500°C for over 3 hours.

6) Mix the proper amounts of epoxy resin and hardener into a suitable container and stir until well mixed, clear, and nearly free of bubbles.

7) Use 4-6 drops of epoxy for each mount.

8) Place numbered slides over the epoxy.

9) Allow epoxy to cure. Most epoxies require about 18 hours at about 25°C to be hard enough for polishing. Curing can be speeded up by heating

the block under a heat lamp after the epoxy is stiff. The temperature shall not exceed 40°C.

10) After the epoxy is cured and hard, flex the mounting block to remove the slide mounts or use a knife to gently pry them off.

4.2.2 POLISHING MOUNTS (Epoxy or Teflon):

1) Place the slide from Para. 4.2.1 Step 10 in the slide holder. A drop of water on the back of the slide will hold it in place. A teflon mount is held in place with double-sided adhesive tape.

2) Place #600 silicon carbide papers on the glass plate or Handimet grinder.

3) Place the slide holder on the #600 paper and grind using a flow of water to flush the surface during grinding. The holder should be pushed away from the operator and after each pass rotate the holder 180° to help prevent the wafer from becoming wedge shaped. Grind only until the grains are exposed. Normally this is five or six passes.

4) Attach a piece of micro-cloth to a lap wheel and put it on the polishing machine.

5) Put a 1 cm bead of 6 micron diamond compound on the micro-cloth. Add extender fluid to smear the diamond compound out on the cloth.

6) Hold the sample holder so that the diamonds will pass under the epoxy perpendicular to the scratches from Step 3. Use a moderate amount of pressure to polish sample until the #600 silicon carbide scratches are gone.

7) After the #600 scratches are removed, circular movement of the holder may be used.

8) Attach a piece of micro-cloth to the second lap wheel and put it on the polishing machine.

9) Put a 1 cm long bead of 1 micron diamond compound on the micro-cloth. Add extender fluid to smear the d'amond compound out on the cloth.

10) Proceed with the polishing, making sure that the scratches go in only one direction. Keep the sample holder on a fixed radius and move it in and out along that radius. Do not go round and round because the fission tracks are easier to observe if the polishing scratches go in one direction rather than crossing.

11) After proper polishing, the mineral grains should be fairly flat and smooth and look very bright if light is reflected off of them.

12) The lap wheels with cloth should be stored in a clean area after polishing for use again.

4.2.3 ETCHING:

1) If external detector method is used, the wafer must be removed from the glass slide. Place a drop of water on the glass slide at the edge of the epoxy wafer. Using a sharp knife gently work the edge of the blade under the epoxy wafer at the drop of water. Carefully work the blade under the wafer until it comes free using the water to help prevent the wafer from breaking. Otherwise, go to Step 3.

2) Put the sample number on the back of the wafer. Save the glass slide because it will be used again after irradiation.

3) Etch apatite in 7% HNO_3 by completely submersing the sample at room temperature. Etch the sample long enough to ensure complete track development. This occurs when no faint tracks can be seen; normally 20-40 seconds.

4) Etch sphene in a 50M NaOH solution at approximately 130°C or a solution of $1HF:2HCl:3HNO_3:6H_2O$ at room temperature. Place mount, grain side down in the etch solution. Etch time for either etch solution is 10-60 minutes depending on the track density. High fossil track density (10^6 - 10^7) will etch much faster than low track density.

5) Etch garnet and epidote in a stainless steel vessel of 50M NaOH. Etch at approximately 130°C for over 1 hour until tracks are properly developed.

6) Etch mica in a plastic cup or beaker of 48% HF at room temperature for 5 seconds to 20 minutes. Biotite etches in about 5 seconds whereas muscovite may take as long as 20 minutes. After etching, heat the mica on a hot plate to about 100-150°C to drive off any HF which is adsorbed between the cleavage planes.

7) Etch natural glass in a plastic cup or beaker of either 48% or 24% HF at room temperature for 5 seconds up to 1 minute. For optimum track development, it is recommended that several trial runs be made of the glass prior to etching it for dating. Etch the mounts for the fossil and induced tracks at the same time by holding the two mounts back to back and then holding them in the solution. After etching let warm water run over the mounts for about 5 minutes, thereby removing the HF and preventing etching of the microscope objective.

4.2.4 MOUNTING ZIRCONS IN FEP TEFLON:

1) Heat a metal block on the hot plate to approximately 310°C. At the same time heat up a glass slide.

2) On another cold glass slide pour out about 100 zircons to cover an area greater than 1 cm^2.

3) Place this slide on the hot metal block and allow it to come to temperature.

4) Take two small pieces of 10 mil FEP Teflon and place them together, concave sides toward each other, or take one piece of 20 mil FEP Teflon and place on top of the zircon grains.

5) Place the heated glass slide from Step 1 and put it on top of the teflon.

6) Press the top of the slide down on the teflon and the zircons. The translucent teflon will become water clear as it starts to melt. Continue to press for several seconds after the teflon clears.

7) Remove both glass slides from the hot plate and allow to cool to room temperature.

8) When cool, remove the teflon wafer and scribe the sample number on the back side away from the zircons.

9) Proceed with polishing mounts as in Para. 4.2.2

4.2.5 ETCHING OF ZIRCONS IN FEP TEFLON:

1) Place NaOH pellets and KOH pellets (0.72 NaOH:1 KOH ratio) in a platinum (or teflon) crucible or evaporating dish.

2) Place dish in oven or on hot plate and heat to approximately 210-230°C. It is necessary to cover the dish to prevent a crust from forming around the top of the dish.

3) When the hydroxide flux is at temperature, place the polished teflon wafers in with the zircon side down. The wafers will float.

4) The etching time will vary depending upon the track density. Those with a high track density of $>10^6/cm^2$ may etch in several hours. Zircons with a density $<10^6/cm^2$ will require much longer times. When in doubt check etching progress after the first four hours.

5) After a satisfactory etch is obtained prepare the mount for irradiation as per Para. 4.2.6.

4.2.6 PREPARING SAMPLES FOR IRRADIATION:

1) Cleave muscovite into sheets between 0.05 and 0.1 mm thick.

2) Cut muscovite to a size that will cover the grains on the mount. The best shape to use is shown in Attachment 2 - Figure 1. Cut enough pieces to cover all mounts.

3) Lay out all mineral mounts in increasing order of sample number.

4) Wash one mount at a time in a mild soap solution then rinse with distilled water and alcohol. Use compressed air to blow off the alcohol or let the alcohol evaporate.

5) After washing each mount and drying, cover it with muscovite (Para. 4.2.6, Step 4). Attach an approximately 20 cm length of clear, one-sided adhesive tape to the work bench. Stick a piece of muscovite to the tape and, using tweezers, gently remove the muscovite from the tape. A thin layer of muscovite will remain on the tape, leaving a clean, fresh cleavage surface in the tweezers. Put the clean side of the muscovite down on the grains in the mount.

6) Place a 2-3 cm length of clear tape over the muscovite and mount; press down to hold the muscovite in place. Trim off excess tape around edge of mount with a sharp knife. DO NOT FOLD TAPE AROUND EDGES OF MOUNT.

7) Repeat Steps 4, 5, and 6 until all mounts are covered by a detector and tape.

8) Repeat Steps 1 through 6 with two pieces of standard glass instead of mounts. It may be necessary to wrap the tape around the glass to be sure the detector is held in place. Label one "T" and the other "B".

9) Number the mounts in the package. If some apatite population packages are included in the reactor package start with the next number after the last apatite package.

10) Record the irradiation number and sample number of each sample in the sample book.

11) Place the samples and standards in the irradiation tube in the order they are numbered. The B glass should be placed on the bottom of the tube muscovite side up. The T glass is placed on top of the last sample muscovite side down. Refer to Attachment 3 - Figure 2.

12) Add enough packing material so that when the top of the irradiation tube is screwed on, the samples are pressed together so that there will be no gaps between the mount and the muscovite.

13) The reactor package is delivered to a nuclear reactor suitable for performing the irradiation.

4.2.7 IRRADIATION: Determining the neutron dose for the reactor package prepared in Para. 4.2.6 is largely based on previous experience with specific samples. However, because some reactors have a gradient in their neutron flux, glass standards are placed at the top and the bottom of the irradiation tube. The dose for an individual sample can be interpolated from these standards. The glass standards can be used many times without using up the uranium in the glass. For a neutron dose of 10^{15} neutrons/cm^2 about 6×10^{-7} of the uranium present is used up. Typical neutron doses will be between 1×10^{14} neutrons/cm^2 and 1×10^{16} neutrons/cm^2.

4.2.8 POST IRRADIATION:

1) Wearing plastic gloves empty contents of irradiation tube out onto paper towels.

2) Separate the standards, mineral mounts, and the apatite packages; they will each be processed differently.

3) With a sharp knife cut a "T" through the tape into the back of the muscovite covering the top glass standard and a "B" through the tape into the back of the muscovite covering the bottom glass standard. Care should be taken not to cut through the muscovite. This identifies the "T" and "B" standards and identifies the front and back of the muscovite. The back has a scratched letter and the front has the induced tracks.

4) Using the sharp knife cut around the muscovite and gently lift it off both glass standards.

5) Place the two muscovite detectors in a small plastic cup tape side down and track side up. Pour in 48% HF and etch for 45 minutes to 1 hour at room temperature.

6) Rinse the muscovite well with distilled water and alcohol. Place it on a hot plate, track side up, to boil off any HF left.

7) Number a clean glass slide with the type of standard used, reactor run number, and a "T" or "B" along one side. Refer to Attachment 4 - Figure 1.

8) Put a small amount of epoxy cement, or double stick tape, on the slide and stick the muscovite detector to the slide with the track side up and matched to the appropriate slide.

9) Punch registration holes (4 - 6 holes) through muscovite into grain mount. Cut along the edge of the muscovite through the tape and into the plastic of a plastic grain mount to leave an outline of the muscovite in the plastic (Attachment 4, Figure 2).

10) Gently lift the muscovite off the mount and put it in a plastic cup for etching tape side down and track side up. Remove any excess tape from the edges of the plastic mount.

11) Etch the muscovite detector in 48% HF for 15 - 20 minutes at room temperature.

12) Rinse the muscovite as in Step 6 and place next to mount.

13) Repeat process until all detectors are etched.

14) Use the glass slides from Para. 4.2.3, Step 2 and add the reactor run number along one side.

15) Mix up enough epoxy to glue all the mounts and detectors to their respective slides. Take the numbered glass slide and smear out a thin film of epoxy on the side opposite the numbers. Put the mount and the muscovite on the epoxy with the track side up and the sides parallel. The detector should form a mirror image of the knife marks in the mount. Allow the epoxy to set. If too much epoxy is used it will flow

up through the punch holes and prevent the counting of tracks near the holes. Do not do anything about it except use less epoxy the next time. Refer to Attachment 4 - Figure 2. Double stick tape may be used instead of epoxy.

16) Carefully open an apatite package over a piece of smooth paper and empty the grains onto the paper.

17) Pour the grains from the paper onto the mounting block and proceed with Para. 4.2.1. Ensure that the block is properly marked so it is known which apatite went where. When numbering the glass slide use the sample number and the reactor run number. Repeat for all apatite packages.

19) Allow the epoxy to set, polish and then etch the apatite grains for the same length of time as the fossil tracks. It is best if the two are etched together.

20) Radioactive materials will be disposed of in accordance with the USGS nuclear byproduct license.

4.2.9 COUNTING OF FISSION TRACKS

4.2.9.1 Counting Population Mounts:

1) Always count the same area on each grain. The number of squares used will depend on the grain size, the track density, and distribution within the grain. Determine the area of the squares used in the grid reticle with a stage micrometer (ruler with 0.01 mm spacing). This determines the area each square covers on the sample being counted. Each person using the same microscope must determine their own interocular distance which affects the magnification.

2) If possible, a minimum of fifty grains should be counted for both the fossil and induced count.

3) Record counts and number of squares counted.

4.2.9.2 Counting External Detector Mounts:

1) If possible count at least six crystals. The area may vary from grain to grain, but count the same area on the detector as was counted on the grain.

2) Extreme care should be taken to count the exact area on the detector that was over the part counted on the grain because the uranium distribution is not uniform throughout most crystals.

3) The image in the detector is reversed along a vertical plane. If the upper left corner of a grain was counted, the upper right corner of the image in the detector should be counted.

4) The counting of tracks in mineral and the muscovite detector is done at a total magnification of greater than 800X.

5) On the data page record the following: sample number, mineral, grid size and size of area being counted, microscope magnification, location of grain on mechanical stage, reactor run date.

6) Counting tracks in glass and the muscovite detector over the glass standard is done best at 400-600X. Use a noncover-glass corrected objective with transmitted light.

4.2.10 FISSION TRACK AGE EQUATION: The age will be calculated from the age equations in Naeser (1979) or Hurford and Green (1983).

4.2.11 CALCULATION OF THE ERROR OF AGE: The error is to be calculated according to the equations in McGee and others (1985). If the age is less than 2 x 10^9 yr the correction term C need not be applied.

4.2.12 TRACK LENGTH MEASUREMENTS IN APATITE: If necessary, confined track lengths will be measured in apatite. The measurements can be made with a graticule in the eyepiece or with a digitizing pad and microprocessor.

4.3 Alternative Method(s) Considered: None available at present.

4.4 Materials/Equipment Required: (No special handling, storage and/or shipping is required unless otherwise noted.)

4.4.1 MOUNTING MINERALS IN EPOXY:

- Copy of current, approved NWM-USGS-GCP-08
- Sharp knife (such as Xacto)
- Alcohol solvent
- Plastic block, plastic sheet, or teflon coated surface
- Standard petrographic glass slides
- Small spatula
- Epoxy resin and hardener in a graduated syringe
- Small evaporating dish for mixing epoxy
- Scribe (diamond or tungsten carbide)
- Opaque drafting tape, or equivalent
- 3 X 3 cm square of aluminum foil
- Oven (20-220°C temperature range)
- Heat lamp

4.4.2 POLISHING MOUNTS:

- Double-sided adhesive tape
- #600 silicon carbide abrasive paper with adhesive backing
- 6 micron diamond polishing compound
- 1 micron diamond polishing compound
- Extender fluid for diamond polishing compound
- 30 X 30 cm plate glass or Handimet grinder
- Polishing machine with at least two lap wheels
- Plastic block milled to hold microscope slide
- Micro-cloth discs with adhesive backing

4.4.3 ETCHING:

- Sharp knife
- Hot plate
- 7% HNO_3 for apatite (1 part HNO_3 concentrate to 9 parts H_2O).
- 50M NaOH for sphene, garnet, epidote, and silicates (40 g NaOH to 20g H_2O).
- 48% HF for micas
- 48% or 24% HF for natural glass
- 1HF:2HCl:3HNO_3:6H_2O (all acid concentrated for sphene or glass)
- Stainless steel vessel
- Plastic cup or beaker

4.4.4 MOUNTING ZIRCONS IN FEP TEFLON:

- Hot plate
- Metal block
- Glass slides
- 20 mil, or two pieces of 10 mil, FEP Teflon

4.4.5 ETCHING OF ZIRCONS IN FEP TEFLON:

- NaOH pellets
- KOH pellets
- Platinum or teflon crucible or evaporating dish and cover
- Hot plate or oven

4.4.6 PREPARING SAMPLES FOR IRRADIATION:

- Distilled water
- Liquid soap
- Alcohol in wash bottle
- Clear adhesive tape
- Muscovite cleavage flakes
- Sharp knife
- Packing material (such as plastic foam)
- Tweezers
- Pin vise with sharp pin
- Irradiation container
- NIST or Corning Glass Works glass standards

4.4.7 IRRADIATION:

- Nuclear reactor

4.4.8 POST IRRADIATION:

- Plastic gloves
- Sharp knife
- Small plastic cup
- 48% HF
- Distilled water
- Alcohol

- o Hot plate
- o Glass slides
- o Epoxy
- o Plastic grain mount
- o Radiation waste container

4.4.9 COUNTING OF FISSION TRACKS AND LENGTH MEASUREMENTS IN APATITE:

- o Binocular petrographic microscope
- o Mechanical stage
- o Graticule or digitizing pad and microprocessor
- o Microscope reticles - 1 cm square divided into 25-2 mm squares, 1 cm square divided into 100-1 mm squares, and 1 cm square divided into 400-0.5 mm squares.
- o NIST glass standards SRM 961, 962, 963, and 964 or other appropriate standard.

4.4.10 SYSTEM CALIBRATION:

- o USGS apatite mineral standard - 27.8 Ma, ± 0.1 Ma; accuracy within 3 sigma
- o USGS zircon mineral standard - 27.8 Ma, ± 0.1 Ma; accuracy within 3 sigma

4.5 Assumptions Affecting the Procedure: It shall be assumed that all tracks are etched, orientation is random, and geometry of etched surface is either 4π or 2π.

4.6 Data Information: (All software developed for or applied to this procedure shall be in compliance with the requirements of YMP-USGS-QMP-3.03, Software Quality Assurance.) Reports should include the following information: fossil track density, induced track density, neutron dose or detector density, age, and error. All information is recorded in field or laboratory notebooks.

4.6.1 QUANTITATIVE/QUALITATIVE CRITERIA: This procedure is subject to a system calibration (see Para. 5.2.1) using known USGS mineral standards against which satisfactory data acceptance criteria shall be established. Measurement of the age of the known mineral standards shall be within 3 sigma for data acceptance. All fission-track data will be reported with two standard errors of the measurement assigned to each age.

Measurements of laboratory time and temperature within this procedure are approximate in nature and absolute determination of parameters is not necessary for successful performance of the analysis. Laboratory time and temperature measurement parameters are encompassed within the system calibration where proper operation of the system is validated by testing standards of known age.

4.7 Limitations: Apparent age is dependent upon thermal history.

1) A fission-track age can be partially to totally reset by exposing the mineral or glass to elevated temperatures. This is not an all or nothing process. There are combinations of temperatures and time that

permit the partial to total annealing of fission tracks. This annealing affects the fission-track age. If the tracks are totally annealed by an event, the resulting age will date the cooling of the rock following the event. If the tracks are only partially annealed the fission-track age will be intermediate between the age of the sample and the age of the mild heating event.

2) The mineral or glass must contain trace amounts of uranium (usually between ≈ 0.1 ppm and ≈ 10,000 ppm), to be dated. The fossil fission-track density upon which the fission-track age is based is a function of the uranium content and the length of time that the tracks have been accumulating. A high uranium content along with a long time span will result in a track density that cannot be counted. At the other extreme, too little uranium and a short time span will result in a track density that is too low to be measured.

3) The mineral or glass must be non-opaque. That is, it must transmit light. Opaque minerals such as some oxides and sulfides do not retain tracks and therefore cannot be dated.

4.8 Other: Data will not be released from the laboratory until all samples of a given set have been examined for internal coherence. This technical procedure interfaces with NWM-USGS technical procedures GCP-02 and GP-27.

5.0 CALIBRATION REQUIREMENTS. All instruments and methods shall be calibrated in compliance with the Instrument Calibration Procedure (YMP-USGS-QMP-12.01) prior to obtaining graded QA Level I or II data. Calibration is required as a part of this technical procedure.

5.1 Calibration Responsibility: The Contributing Investigator (CI) as assigned by the Branch Chief is responsible for calibrations required by this procedure. Calibration shall be in accordance with procedures described or referenced in Para. 5.2. Maintenance of all calibration records described in Para. 5.3 may be done by a contributing investigator under the direct supervision of the PI.

5.2 Calibration Procedures: All calibrations, unless otherwise specified, shall be performed according to manufacturer's range and accuracy specifications. Fission-track dating methods per Para. 4.2 are subject to a system calibration. There are no specific instruments within the system that require calibration.

5.2.1 SYSTEM CALIBRATION: Fission-track dating methods will be calibrated by running USGS standard minerals of known age through the steps outlined in Para. 4.2 of this procedure. The standards, apatite and zircon from the Fish Canyon Tuff of southwestern Colorado, have been calculated to be approximately 27.8 my in age (Naeser, et al., 1981). These standards shall be run prior to running any samples for the YMP or, at a minimum, once a year. If the results from the analyses of the standards are not within acceptable limits per Para. 4.6.1, laboratory operations will be suspended until problems can be identified and rectified.

5.3 Calibration Records: In compliance with YMP-USGS-QMP-12.01, calibration data will be entered, signed and dated, into a notebook or other organized

documentation. A scientific notebook will be used if the calibrated equipment is used in the field. Minimum data will include instrument type, identification, and location; calibration procedure used; the standard used, including range and accuracy; recalibration due date; any pertinent observations; and the name and signature of the person calibrating the instrument. If an outside organization performs the calibration, all applicable documentation will be entered into the calibration record. Computer software used in calibration exercises shall meet the requirements stipulated in YMP-USGS-QMP-3.03. Notebooks and other documents shall be protected and submitted to the LRC in accordance with YMP-USGS-QMP-17.01 (YMP-USGS Records Management).

5.4 Labeling of Equipment Calibration Status: In compliance with YMP-USGS-QMP-12.01, a sticker shall be affixed to each piece of equipment used in this procedure denoting the calibration status according to one of three categories: 1) equipment identification, date calibrated, date recalibration due, procedure number and calibrator; 2) equipment identification, "OPERATOR TO CALIBRATE", and the procedure number; or 3) equipment identification and "NO CALIBRATION REQUIRED". When any equipment is not in service, it shall have a sticker affixed denoting the equipment status.

6.0 IDENTIFICATION AND CONTROL OF SAMPLES. Samples will be collected or handled as part of this procedure (see technical procedure NWM-USGS-GCP-02, Labeling, Identification, and Control of Samples for Geochemistry and Isotope Geology).

6.1 Sample Identification: As part of the data records and documentation and in compliance with YMP-USGS-QMP-8.01, all samples shall be identified as follows: Unique numbers will be assigned to samples in the field in accordance with NWM-USGS-GP-27, Trench Wall and Natural Outcrop Sampling for Coordinated Studies. Samples may be subdivided in the laboratory on the basis of physical, chemical, or mineralogical composition. These component subsamples will be identified by suitable labeling and record keeping as suffix numbers or letters appended to the original sample numbers. After mineral separation, each mineral to be dated will be assigned a laboratory number.

6.2 Control and Storage: In compliance with YMP-USGS-QMP-8.01, the collected and identified mineral splits shall reside in the custody of the CI who shall store them in a secured area in his laboratory.

6.3 Special Treatment: None.

7.0 QUALITY ASSURANCE RECORDS. All information collected and recorded under this procedure shall be transmitted (per YMP-USGS-QMP-8.03) and submitted (per YMP-USGS-QMP-17.01) as part of the official YMP-USGS record. Input needed to process the information as a record includes: title or description, subject, originator, date of the document, and whether it is an original, a revision or an addendum.

Specific items from this procedure that shall constitute a record are bound notebooks. Field records will be kept in a bound field notebook, and laboratory data will be kept in a bound data book. The original notebooks are the property of the CI and the Branch of Isotope Geology. Pages of the notebooks relevant

to this procedure and the YMP will be photocopied and sent to the LRC. Secondary records may be stored on a computer disk or other form of data storage that can be read by a computer.

7.1 Notebooks, forms, or other organized documentation shall be prepared, as appropriate, by the PI or a contributing investigator to record data from this procedure and shall include any information considered by the originator to be pertinent. When in loose-leaf form, each page shall be numbered consecutively and chronologically. All documents shall be signed (or initialed) and dated by the investigator on a daily basis as entries are made. Any revisions shall be lined out, initialed, and dated. Any notation by pencil shall be submitted in legible photocopy form.

7.2 All data collected and the applicability of the methods used in obtaining it shall be reviewed and cosigned by a qualified technical reviewer (per YMP-USGS-QMP-3.07) as a verification of acceptable and meaningful data or calculations that meet appropriate quantitative and qualitative acceptance criteria. Unacceptable data shall be identified appropriate to the kind of the data.

8.0 MODIFICATIONS. When field modifications become necessary, per Para. 5.8.3 of YMP-USGS-QMP-5.01, the PI or assigned CI shall fully document the changes, submit the documentation for the same review signature and distribution process as for the original procedure, and indicate whether the change should result in a subsequent revision to the technical procedure.

9.0 REFERENCES.

Hurford, A.J., and Green, P.F., 1983, The zeta age calibration of fission-track dating: Chemical Geology (Isotope Geoscience Section), v. 1., p. 285-317.

McGee, V.E., Johnson, N.M., and Naeser, C.W., 1985, Simulated fissioning of uranium and testing of the fission-track dating method: Nuclear Tracks, v. 10, p. 365-379.

Naeser, C.W., 1979, Fission-track dating and geologic annealing of fission tracks. In: Jäger, E. and Hunziker, J.C. (eds) Lectures in Isotope Geology. New York: Springer-Verlag, p. 154-169.

Naeser, C.W., Zimmerman, R.A., and Cebula, G.T., 1981, Fission-track dating of apatite and zircon: an interlaboratory comparison: Nuclear Tracks, v. 5, Nos. 1/2, p. 65-72.

10.0 ATTACHMENTS.

Attachment 1:	Figure 1 - Grains on Mounting Block
	Figure 2 - Preparing Foil Packet
Attachment 2:	Figure 1 - Muscovite Detector Shape
	Figure 2 - Sample Listing of Irradiation Package
Attachment 3:	Figure 1 - Punch mark placement
	Figure 2 - Irradiation Tube
Attachment 4:	Figure 1 - Detector Slide for Standard
	Figure 2 - Mounting Detector and Mount on Slide

11.0 APPROVAL. This technical procedure shall become effective upon its approval as noted by completion of all the following signatures and dates.

Charles W Naeser 1-19-90
Prepared by: C.W. Naeser Date

John S. Stuckless 1/19/90
Technical Reviewer: J.S. Stuckless Date

Carl E Hedge 1/19/90
GD Branch Chief: C.E. Hedge Date

1/22/90
YMP-USGS QA Manager Date

1/22/90
Technical Project Officer Date

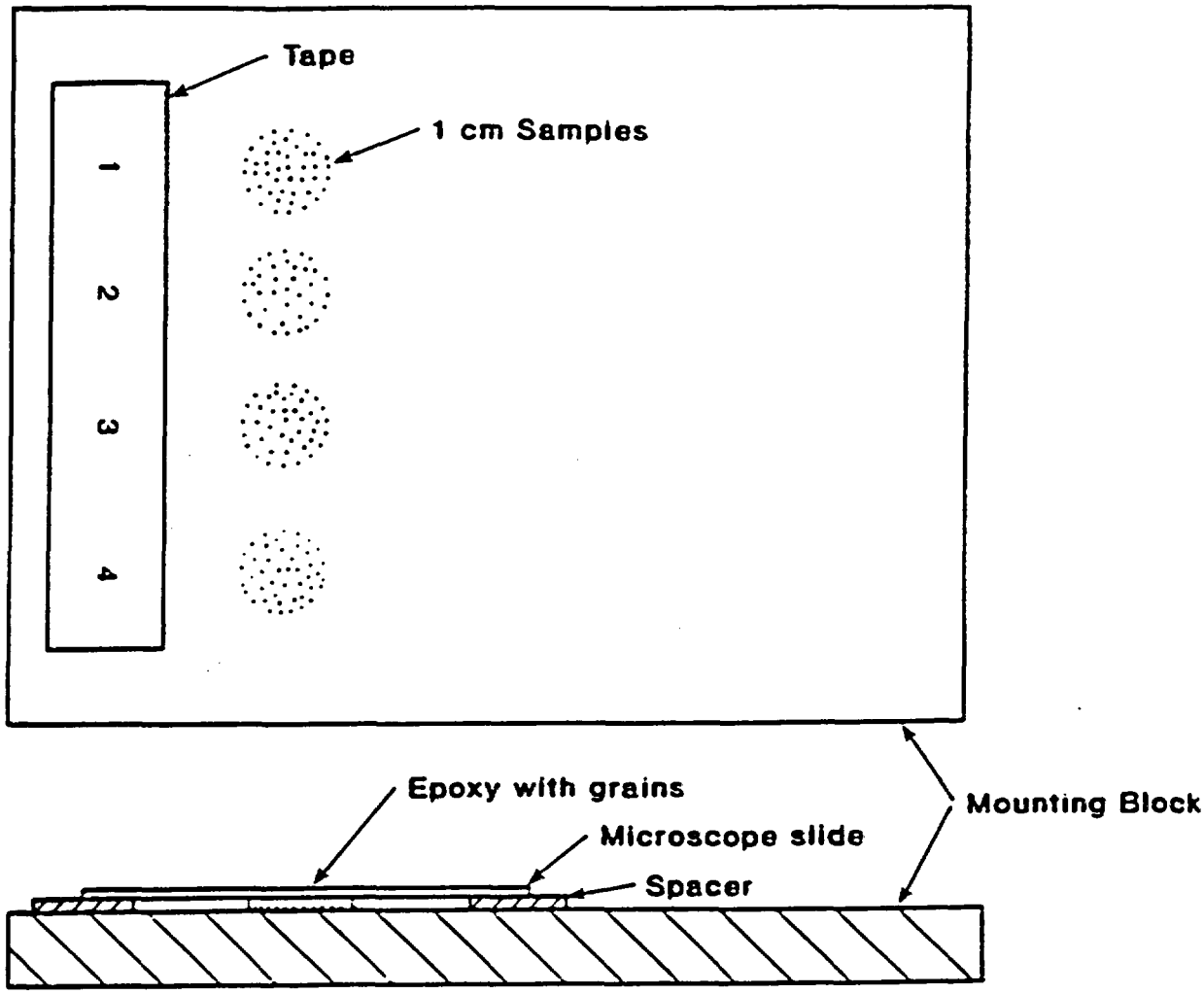


Figure 1

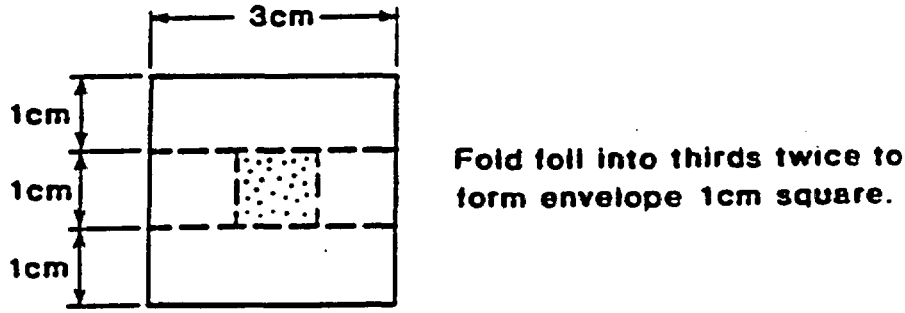
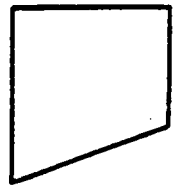


Figure 2



Muscovite Detector Shape

Figure 1

Reactor run 11-13-74 in Al tube

500KW for 30 min. (Lazy Susan)

Bottom

B USGS glass standard with muscovite

1 70L12 G (apatite in AL package)

2 B-78 (apatite in AL package)

3 KB-1 Sphene in epoxy

4 70L12 G zircon in lexan

5 B-24 zircon in lexan

6 #9 zircon in lexan

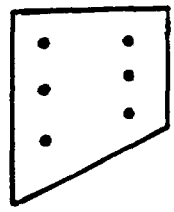
7 72052 zircon in lexan

8 72052 zircon in teflon

9 B-24 zircon in teflon

T USGS glass standard with muscovite

Figure 2 - Sample Listing of Irradiation Package



Punch mark placement

Figure 1

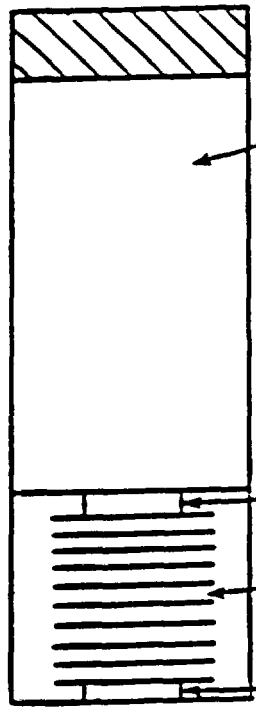


Figure 2 - Irradiation Tube

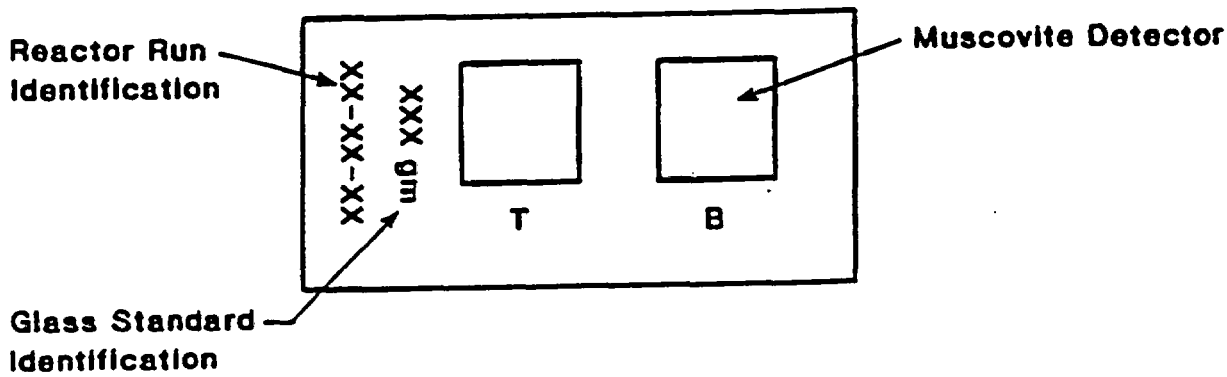


Figure 1 - Detector Slide for Standard

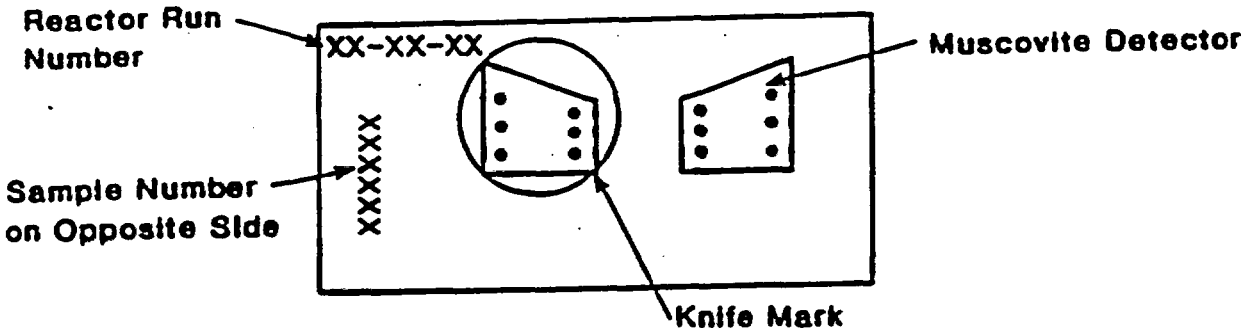


Figure 2 - Mounting Detector and Mount on Slide

LOS ALAMOS NATIONAL LABORATORY

YUCCA MOUNTAIN PROJECT CHANGE REQUEST

CHANGE REQUEST No. 145

DATE May 14, 1990

PROCEDURE No. TWS-EES-13-DP-606, R1

CHANGE REQUESTED:

1. Section 3.0, third item, replace "(in preparation)" with TWS-EES-13-DP-607
2. Section 6.6.2, first paragraph - Delete wording (inclusive) from "an SMF barcode affixed.." to "... SMF copy of the sample collection form is". Add to end of paragraph: "Use of SMF barcodes is discussed in the Procedure for Sample Storage and Control for Volcanism Studies."
3. Section 6.6.3, Shipment paragraph: Replace first sentence with: "After samples have been collected and marked for identification, a list of the samples shipped is made in the field notebook and also included in the shipment. Only the list in the field notebook is needed if the samples will be hand-carried. The samples are then sent to the appropriate volcanism sample storage facility, as described in the Procedure for Sample Storage and Control for Volcanism Studies, TWS-EES-13-DP-607."
4. Section 6.6.3, Storage paragraph: Replace "UNM" with "the storage facility."
5. Section 7.1 - Replace second sentence with "Training for this procedure is by reading and understanding it."

REASON FOR CHANGE:

Clarification of procedure and consistency with volcanism sample procedure.

1. Adds formal TWS # to procedure listing.
2. SMF barcode numbers are not required in field notebooks if the sample logbook establishes traceability between the barcode and the sample identifier.
3. This enables receiver to verify shipment contents.
4. Samples will be stored at locations besides UNM.
5. Change in training requirements is consistent with difficulty of procedure.

CHANGE REQUESTED BY [signature] DATE 5/16/90

REVIEWED BY SEE TWS-EES-13-LV-06-90-006 DATE 5/15/90
Dated: 6/18/90

QAPL APPROVAL [signature] DATE 5/22/90

TPO APPROVAL [signature] DATE 6/4/90

EFFECTIVE DATE June 4, 1990

PROCEDURE FOR VOLCANISM FIELD STUDIES

Effective Date: 3/7/90

Bruce M. Crowe — 2-23-90
Preparer — Date
B. M. Crowe

David Vaniman — 3/6/90
Technical Reviewer — Date
D. Vaniman

Richard Morley — 2/23/90
QA Reviewer — Date
R. A. Morley

Bruce M. Crowe — 2-23-90
Principal Investigator — Date
B. M. Crowe

H. P. Nunes — 3/6/90
Quality Assurance Project Leader — Date
H. P. Nunes

R. J. Herbst — 3/7/90
Technical Project Officer — Date
R. J. Herbst

PROCEDURE FOR VOLCANISM FIELD STUDIES

1.0 PURPOSE

This detailed technical procedure (DP) describes the methods for geologic, geomorphic, and soils field studies, and for obtaining geologic samples from volcanic centers of the Yucca Mountain region and adjoining areas of the southern Great Basin for the Yucca Mountain Project (Project or YMP). The range of activities covered under this DP is described in Study Plan 8.3.1.8.5.1, Characterization of Volcanic Features.

2.0 SCOPE AND PRINCIPLE

This DP applies to field studies of volcanic centers, including geomorphic studies of volcanic landforms, studies of soils developed on volcanic deposits and associated eolian and alluvial deposits, and the collection of samples for geochronology and geochemical studies. The emphasis of this procedure is to describe the field aspects of the above studies and to document sampling procedures.

3.0 APPLICABLE DOCUMENTS

Procedure for Geomorphic Analyses of Volcanic Landforms (DP in preparation).

Procedure for Soils Analysis (DP in preparation)

Procedure for Sample Storage and Control for Volcanism Studies (in preparation).

AP-6.3Q, Interaction of Participants and Outside Interests with Yucca Mountain Project Sample Management

4.0 RESPONSIBILITIES

The PI has the overall responsibility for overseeing, organizing, and documenting volcanism field studies. The PI may informally assign individual tasks described in the procedure to certified Project personnel. Because of the specialized training and experience required to describe and interpret volcanic features, correctly represent them on geologic maps, and ~~select~~ representative field samples~~, the~~ PI or assigned individuals will exercise professional judgement while implementing this procedure.

5.0 DEFINITIONS

5.1 Geologic Features

Geologic features include lithologic units, contacts between lithologic units, faults, strike and dip of lithologic units, and other similar elements of geologic importance.

5.2 Geologic Map

A geologic map is a topographic base map or aerial photograph upon which geologic features have been plotted.

5.3 Geologist

A geologist is the principal investigator (PI) for the Project or a YMP-certified individual designated by the PI.

5.4 Geomorphology

Geomorphology is the discipline concerned with the study of geologic processes and evolutionary development of landforms at the Earth's surface.

5.5 Landform

A landform is a morphological element of the Earth's surface that has been formed by constructional and/or destructional processes, such as a scoria cone or a stream channel.

5.6 Lithologic Unit

A lithologic unit is a distinctive body of rock or a deposit of unconsolidated alluvial, eolian, or colluvial material. Lithologic units are recognized and defined in the field on the basis of observable physical properties such as color, grain size, mineralogy, and morphology, as well as variations of these properties. Examples include separate lava flows, volcanic ash deposits formed during a single eruptive event, and volcaniclastic deposits formed by fluvial reworking of volcanic materials.

5.7 Morphometry

Morphometry is the measurement and analysis of landform shapes, sizes, and spatial patterns using topographic maps, surficial geologic maps, and field surveys.

5.8 Soil

Soil is a natural body consisting of layers, defined as horizons, of mineral and/or organic constituents of variable thicknesses, which differ in biological, morphological, physical, and/or chemical properties from the material in which the soil has formed, called parent material.

5.9 Soil Profile

A soil profile consists of a vertical arrangement of soil horizons extending down to the parent material.

5.10 Surficial Geology

Surficial geology is the discipline concerned with the geologic mapping of unconsolidated lithologic units (including soils) and their associated landforms at the Earth's surface.

6.0 PROCEDURE

The selection of significant geologic features to be included in a geologic field study will vary with the scope and purpose of the project. The geologist will use professional judgement to determine which types of features are germane to the study. The selection of features and the rationale for the selection is documented in the notebook if it is not already detailed in the governing study plan or other Project document. The rationale explains why various features were or were not included in the field study and what measurements and/or descriptive information will be taken for included features. Standard techniques for measurements such as strike and dip, and thickness will be used for the field geologic studies. These techniques are described in field geology texts such as Compton (1962) and Lahee (1961).

General field mapping techniques will be applied to the initial phases of soils and morphometric studies to establish the relationship of the features of interest to the geologic framework. Examples of data to be acquired by geologists conducting soil studies under this procedure are the occurrence, lateral distribution, and relationship of soil units to volcanic units defined from field mapping. Detailed description and analysis procedures are described in the Procedure for Soils Analyses (DP in preparation). Field measurements for geomorphic studies will correlate observations of the degree of erosional modification of volcanic landforms to the stratigraphy of volcanic units developed from geologic mapping. Detailed surveying and analysis of volcanic features is accomplished after field

geomorphic studies. This is described in a separate procedure (Procedure for Geomorphic Analyses of Volcanic Landforms, in preparation).

6.1 Geologic Mapping

Geologic mapping establishes the spatial and stratigraphic relationships between geologic features and provides the basis for understanding the evolution of a volcanic center or of a volcanic field which is composed of multiple volcanic centers. A geologic map is made by plotting geologic features, such as lithologic units and faults, on base maps or aerial photographs.

Geologic mapping will be done using aerial photographs, if they are available for an area, because: (1) they provide a larger scale than standard topographic base maps (up to 1:4000 for aerial photographs versus 1:24000 or smaller for topographic maps). This allows for more detailed mapping; (2) the increased resolution of aerial photographs allows more accurate plotting of geologic features; and (3) stereoscopic inspection of aerial photographs may reveal important geologic features which are not readily observable in the field. Topographic maps at the largest available scale will be used for mapping if suitable aerial photographs of an area are not available.

Geologists making a geologic map observe geologic features, landforms and geomorphic features, and contacts between lithologic units in the field and plot these features on a geologic base map or aerial photograph, as described in Section 6.2. The geologist enters descriptions and/or sketches of the mapped features in the field notebook. Descriptions, observations, and measurements such as strike and dip, thickness, age relationships, and areal extent are recorded on the map and/or notebook as appropriate. The descriptions are cross-referenced to the locations plotted on the geologic map. The name of the geologist making the entries is recorded in the notebook, along with the date.

Photographs of the geologic features may be taken at the discretion of the geologist. These photographs are not Project records unless they are used for direct plotting of data. These photographs have the date recorded directly on the film negative so that they can be readily cross-referenced to field notes. If the geologist chooses to make photographs Project records,

he will record descriptions of the photographs in a field or laboratory notebook and file a duplicate copy of the photograph in the volcanism resident file.

Samples are taken to characterize such parameters as the petrology, geochemistry, or geochronology of a unit. The sample collection plan is described in Study Plan 8.3.1.8.5.1 Characterization of Volcanic Features. Any deviations from that plan are described and recorded in the field notebook. Sample collection is discussed in section 6.3.

6.2 Plotting Locations on Maps and Aerial Photos

Locations are plotted on a base map or aerial photograph by comparing the configuration of features seen in the field with those shown on the base map or aerial photograph and plotting the location by inspection. Stereo pairs of aerial photos are often used, as they eliminate distortion caused by radial displacement when viewed stereoscopically. If a single aerial photograph is used for plotting features and locations, the nominal scale of the photographs should be such that individual features such as individual outcrops, roads, or vegetation can be readily observed. Triangulation using pocket transits can also be used to help plot a location on a topographic map.

Unique base map identifiers (aerial photograph numbers, topographic quadrangle descriptions, etc.) are recorded in daily entries in field notebooks during field geologic mapping. Locations are marked on the map or aerial photo with unique identifiers that are cross-referenced to the field notebook descriptions and sample identification system.

6.3 Samples

This section governs only surface sampling. Sampling of boreholes and core is governed by Project procedures.

6.6.1 Sample Collection

Samples of geologic units are collected according to the sampling plan, in order to characterize the petrologic and geochemical properties of units that have been identified by geologic mapping conducted as part of volcanism field studies. Samples are also collected to provide source material for geochronology studies. The

geologist collecting the sample must be trained in AP-6.3Q, Interaction of Participants and Outside Interests with Yucca Mountain Project Sample Management. When considering a surficial geologic unit or soil for sampling, the geologist inspects multiple outcrops of the unit to ascertain the degree of internal variability in the properties of the unit or soil horizon(s) developed within the unit. The geologist inspects a sufficient number of outcrops to ensure that the samples collected are representative of the unit. The purpose of these inspections is to insure that the samples are suitable for the anticipated analyses.

6.6.2 Sample Identification and Location

A sample identifier is marked on the sample, if it is consolidated, and on a sample bag, if it is unconsolidated, using a permanent marking pen. The identifier consists of the geologist's initials and a unique alphanumeric designator and is recorded in the notebook. The Sample Management Facility (SMF) Sample Collection Form is completed and an SMF bar code affixed to the sample or to the sample container after the geologist returns from the field. A copy of the bar code is also pasted into the field notebook to document the link between the SMF bar code and the sample identifier. The SMF copy of the sample collection form is submitted within 30 days of collection, as required by AP6.3Q.

Sample localities showing sample identifiers are recorded on topographic maps and/or aerial photographs. The geologist records this information in a field notebook, and when necessary adds a description of the locality in sufficient detail to permit tracing the sample and its processed derivatives to the original field location. A megascopic description of the sample, date, and the name of the geologist are also recorded.

6.6.3 Sample Handling, Storage, and Shipment

Handling

All collected and identified samples are packed in a manner that precludes physical damage during shipment and maintains the integrity and identity

of the sample. Samples are placed in a suitable container clearly marked with the name and address of the PI or certified project personnel.

Shipment

After samples have been collected and marked for identification, they are sent to the Department of Geology at the University of New Mexico (UNM) for analysis and storage. The method used to transport the sample must be documented in the field notebook to verify chain-of-custody. It is acceptable for the collector to transport the samples in the collector's vehicle or baggage, as long as adequate provision is made to protect the sample. If the sample is shipped by common carrier, the receipts are retained as records to verify chain-of-custody.

Storage

The Procedure for Sample Storage and Control for Volcanism Studies (in preparation) will used for sample curation once samples arrive at UNM.

6.7 Data Acceptance/Rejection Criteria

The PI has authority to accept, verify, or reject all data and samples collected under this procedure. The acceptance or rejection must be a matter of the PI's professional judgment, because the criteria may be subjective. The PI documents the reasons for rejecting data or samples in the field or lab notebook, as appropriate.

The plotting of features and sample locations on topographic maps or aerial photos results in standard uncertainties that depend on the scale of the base used. However, the procedures outlined in Section 6.2 will ensure that the field methods will not introduce any systematic errors.

7.0 QUALITY ASSURANCE

7.1 Personnel

Volcanism field studies are performed by qualified personnel with a geoscience degree (Bachelors degree minimum) and experience in field studies. Personnel are trained to this procedure by the Volcanism PI.

Documentation of training is sent to the Resident File and to the QAS Training File.

7.2 Calibration

Not applicable. Standard commercial measuring devices, such as tapes, are of sufficient accuracy. Pocket transits do not require calibration. The geologist sets the declination on the pocket transit to USGS topographic maps of the area and records this information in the field notebook.

7.3 Records

Originals of field notebooks, topographic maps and aerial photographs on which geologic features have been mapped, sample logbooks, and photographs are retained in the working files of the geologist until they are completed or are no longer needed for day-to-day use. Photocopies of these working materials are placed in the resident file for dual storage and protection. Details of aerial photos often do not photocopy clearly. Since the aerial photos can be easily replaced, this is not of concern as long as the photo identifier is clearly visible on the copy. However, the information marked on the aerial photo may be unique. Therefore, any information marked on the aerial photo should be clear on the copy. The geologist may need to manually copy some of the data onto the photocopy. If the original is lost, the information can then be traced onto a new print of the aerial photo. Completed maps, logbooks, photographs, and notebooks are placed in the resident file. SMF Sample Collection forms are filed in the resident file and with the SMF.

7.4 Deviations from this DP

Deviations from this DP are recorded in the lab or field notebook.

8.0 Attachments

None

9.0 References

Compton, R. R., 1962. Manual of Field Geology, John Wiley and Sons, Inc., New York.

Lahee, F. H., 1961. Field Geology, McGraw-Hill Book Company, New York.

PETROGRAPHY PROCEDURE

Effective Date 2/20/89

David Vaniman
Preparer

Feb. 3, 1989
Date

David Broxton
Technical Reviewer

Feb. 3, 1989
Date

Henry Paul Nunes
Quality Assurance Project Leader

2/9/89
Date

D.T. Oakley
Technical Project Officer

2/10/89
Date

PETROGRAPHY PROCEDURE

1.0 PURPOSE

The purposes of this procedure are (1) to standardize the petrographic descriptions used within mineralogy-petrology tasks through use of a set of primary reference books and (2) to assure adequate documentation of petrographic descriptions.

2.0 SCOPE

This procedure may be used for any petrographic descriptions made by standard optical methods (i.e., unaided visual observation, hand lens, binocular microscope, petrographic microscope) for the Yucca Mountain Project.

3.0 APPLICABLE DOCUMENTS AND REFERENCES

Petrographic studies within Work Breakdown Structure (WBS) element 2.3.4.2 (Mineralogy-Petrology) are defined in the Site Characterization Plan (SCP) and its updates. Quality procedures cited below (see section 8.5) are TWS-QAS-QP-03 [Document Control Procedure], TWS-MSTQA-QP-14 [Research and Development (Experimental) Procedure] and TWS-QAS-QP-16.1 [Procedure for Corrective Action]. Detailed technical procedures cited below are TWS-ESS-DP-07 [for electron microprobe analysis], TWS-ESS-DP-16 [for x-ray diffraction analysis], TWS-ESS-DP-101 [for sample tracking], TWS-ESS-DP-102 [for point-counting], and TWS-ESS-DP-112 [for scanning electron microscopy].

Published reference works applicable to this procedure are:

Bates, R.L. and Jackson, J.A. (editors) (1980) Glossary of Geology. American Geological Institute, Washington, D.C., 751 pp.

Ross, C.S. and Smith, R.L. (1961) Ash-flow tuffs: Their origin, geologic relations and identification. U.S. Geol. Survey Prof. Paper 366, 81 pp.

Smith, R.L. (1960) Zones and zonal variations in welded ash flows. U.S. Geol. Survey Prof. Paper 354-F, p. 149-159.

Williams, H., Turner, F.J., and Gilbert, C.M. (1954) Petrography. W.H. Freeman and Co., San Francisco, 406 pp.

4.0 RESPONSIBILITIES

The principal investigator (PI) for each subtask within WBS element 2.3.4.2 has the responsibility for organizing and overseeing petrographic studies and recording these in the plan of research in the relevant study plan. The PI is also responsible for insuring that this procedure is implemented. The individual analyst is responsible for recording his petrographic observations in a controlled field or laboratory notebook.

sought through electron microprobe analysis (TWS-ESS-DP-07) and/or x-ray diffraction analysis (TWS-ESS-DP-16).

The only significant source of uncertainty and error in petrographic description is mineral misidentification. Analysts are advised to refrain from making optical mineral identifications where the minerals are too fine-grained for adequate analysis or where the optical properties are ambiguous. Where mineral identifications must be ventured without certain optical identity, the notebook entry should be marked as "possible," "?," or otherwise queried. Uncertainties and errors in quantitative petrographic analyses are described in the relevant procedures (e.g., TWS-ESS-DP-102).

Petrographic descriptions are recorded in ink in a controlled laboratory or field notebook. Photographs may be attached as part of the description, and sketches may be used. It is advisable to mark or describe the scale of any photograph or sketch. Adequate notebook maintenance and review following TWS-QAS-QP-03 is required to determine that petrographic description activities have been adequately accomplished.

7.5 Sample/Site Traceability

Sample traceability is described in procedure TWS-ESS-DP-101. Site location traceability for field petrographic descriptions will be recorded in a controlled field notebook; field descriptions will reference map(s) or photograph(s) as appropriate. Copies of maps and photographs will be maintained by the investigator using them; upon task completion or departure of the investigator from the project, all records will be placed in the resident file and copied to the records processing center (RPC).

7.6 Verification of Key Actions

Key actions for this procedure are those that result in petrographic descriptions. Completed entries in controlled field or laboratory notebooks constitute verification.

8.0 . QUALITY ASSURANCE REQUIREMENTS

8.1 Handling, Shipping, and Storage

Handling, shipping, and storage requirements are described in procedure TWS-ESS-DP-101.

8.2 Records

Petrographic descriptions are recorded in controlled laboratory or field notebooks. Maps or photographs should be marked with sample or locality numbers that can be uniquely related to a notebook entry (sample numbering requirements are described in procedure TWS-ESS-DP-101).

8.3 Training

Completion of at least one college-level course in petrography is required to use this procedure. Researchers using this procedure must also certify that they have read and understood it and procedure TWS-ESS-DP-101.

8.4 Calibration Requirements

5.0 PRINCIPLES

The principles of petrographic analysis are learned through college-level course work. The standard reference for this procedure is Williams et al. (1954).

6.0 DEFINITIONS

There are no unique definitions in this procedure.

7.0 PROCEDURE

7.1 Adequate and Appropriate Equipment

Petrographic descriptions may be obtained by unaided visual observations, by hand lens, by binocular microscope, or by petrographic microscope. Any brand or model of lens or optical microscope may be used for petrographic analysis.

7.2 Preparatory Verification

No preparatory verification of equipment is necessary. Sample tracking is required and will follow procedure TWS-ESS-DP-101.

7.3 Controlled Environmental Conditions

No control of environment is necessary.

7.4 Data to be Recorded

Petrographic descriptions are either descriptive or quantitative. No two analysts will generate identical descriptions; for such descriptions, the recorded information will be traceable to a specific location in the field or to a specific sample in the laboratory to allow other petrographers to review the description. Photographs and drawings, appropriately keyed to specific field locations or samples, may be used to support petrographic descriptions. Quantitative petrographic analysis includes, but is not limited to, point counting and size measurement. Point counting is described in procedure TWS-ESS-DP-102. Coarse features may be measured by any standard scale, with metric units preferred; microscopic features may be measured by ocular scale. These scales are used for approximate and relative size classification only; thus calibration of the scales is not required. Examples of petrographic descriptions appropriate to this procedure can be found in the figure captions of Williams et al. (1954). The standard reference for petrographic terms will be Bates and Jackson (1980). Many of the terms used for textural features of silicic volcanic rocks are described in Ross and Smith (1961) and Smith (1960).

Petrographic analyses are considered acceptable as descriptive data. Rejection of certain parts of a petrographic analysis may be made by the same analyst or by another analyst based on reanalysis of the same sample; in such a case, the cause for the rejection should be described in the reanalysis and referred back to the original analysis. Since a wide latitude is possible in descriptive parameters, such rejections should be rare. The likeliest cause of a rejection is mineral misidentification based on optical properties; where mineral identity is optically ambiguous and important to the sample description, confirmation of mineral identity should be

Calibration is not required for the optical instruments covered by this procedure. Magnification scales and estimates are semi-quantitative. Where precise image measurements are required, it is recommended that the researcher use a procedure such as image analysis (see procedure TWS-ESS-DP-112).

8.5 Deviations and Nonconformances

Any special optical petrographic methods that might be used by a researcher shall be documented in a controlled laboratory notebook, following the requirements of TWS-MSTQA-QP-14. Any nonconformances will be handled according to TWS-MSTQA-QP-16.

9.0 APPENDICES

None.

VOLCANIC HAZARD INVESTIGATIONS
WORK PLAN

Effective Date ~~Nov 24 1982~~

SUPERSEDED

Bruce Crowe PREPARED BY	November, 1, 1982 DATE
Julian J. Fong TECHNICAL APPROVAL	18 Nov 1982 DATE
D T Dobley TPO APPROVAL	11/22/82 DATE
Peter L Bussolini QA APPROVAL	11/24/82 DATE

VOLCANIC HAZARD INVESTIGATIONS

1. PURPOSE

The principal objective of this work is to complete an assessment (begun in FY-1978) of the hazards of volcanism with respect to geologic isolation of radioactive waste in the southwestern region of the Nevada Test Site (NTS) for the NNWSI project.

2. WORK DESCRIPTION

Volcanic hazard investigations are concerned with identifying the potential for future volcanic activity and the possible range of disruptive effects on an underground repository due to silicic and basaltic volcanism. These studies are being conducted by the Los Alamos National Laboratory and the U.S. Geological Survey under the Tectonics, Seismicity and Volcanism work task. Los Alamos has the primary responsibility for volcanism studies. Major tasks of the volcanism investigations include:

- Geochemical comparison of the Black Mountain and Silent Canyon silicic volcanic centers.
- Evaluation of the geology, petrology, and history of Late Cenozoic basaltic volcanism in the south central Great Basin with emphasis on the NTS region.
- Assessment of the risk of volcanism with respect to the siting of a repository for storage of high-level radioactive waste at Yucca Mountain (Risk assessment is the product of probability times consequences).

3. FACILITIES AND EQUIPMENT

3.1 Polarizing microscopes

3.2 Sample preparation equipment (TWS-ESS-DP-04, Sample Preparation Laboratory Procedures; TWS-CNC-DP-23, Preparation of Thin Sections for Geologic Materials).

3.3 Electron microprobe (TWS-ESS-DP-07, Microprobe Operating Procedure).

3.4 X-ray fluorescence equipment (procedure to be developed)

3.5 Equipment for instrumental neutron activation analyses (procedure to be developed).

4. QUALITY ASSURANCE

4.1 The following detailed quality assurance and technical procedures apply to this work plan:

Document Control Procedure
TWS-CMBQA-QP-03

Handling, Storage, and Shipping Procedure
TWS-CMBQA-QP-04

NNWSI Procurement Procedures
TWS-CMBQA-QP-06

Procedure for Technical Review of Publications
TWS-CMBQA-QP-07

X-Ray Powder Diffraction Analysis
TWS-ESS-DP-01

NTS Core Petrography Procedure
TWS-ESS-DP-03

Sample Preparation Laboratory Procedures
TWS-ESS-DP-04

Operating Instructions for DV-502 Vacuum Evaporator Used in Carbon Coating Thin Sections for Microprobe Analysis
TWS-ESS-DP-06

Microprobe Operating Procedure
TWS-ESS-DP-07

Siemens X-Ray Diffraction Procedure
TWS-ESS-DP-16

Sample Preparation: Rock Powders
TWS-ESS-DP-19

Preparation of Fused Beads for Electron Microprobe Analysis of Rock Powders
TWS-ESS-DP-20

Preparation of Thin Sections for Geologic Materials
TWS-CNC-DP-23

SUPERSEDED

4.2 Only qualified personnel shall be allowed to perform this work. Evidence of qualification shall be documented in a certification record kept in the ESS-Division resident file and in the INC-Division resident file.

4.3 Identification and traceability is addressed in sections 5.1, 5.2, and 5.3.

5. REPORTING, REVIEW, AND RECORDS

5.1 Field Studies

Field studies including geologic mapping and sampling are conducted at sites of Late Cenozoic volcanism throughout the south central Great Basin. Field notes are recorded, and xerox copies are placed in the resident file. Results of geologic mapping and documentation of sampling sites are recorded on topographic quadrangle maps and aerial photographs, which are stored at Room 308, RC1, TA-48. Xerox copies of the aerial photographs including the date, scale, and photo number (source information recorded in field notes) and of the topographic quadrangle maps are placed with the xeroxed field notes in the resident file. Permanent maps are compiled and issued with formal publications.

5.2 Sample Selection and Preparation

Geologic samples obtained from field studies are shipped to Los Alamos following sample Handling, Storage, and Shipping Procedure (TWS-CMBQA-QP-04). The samples are logged into a Quality Assurance Notebook (Field Book #1, TWS-G6-5/79-16) stored at Room 308, RC1, TA-48. During the sample logging procedure, samples are screened for further studies in order to insure selection of a representative sample suite and to choose the most suitable samples for petrologic and geochemical studies. The major criteria used for the screening are a comparison of the sample suite with known geologic units to check for completeness and a megascopic examination of the degree of weathering and alternation of samples so that samples most likely to yield representative petrologic and geochemical data will be chosen. The samples selected for further studies (thin section, microprobe, and geochemical) are noted in the Quality Assurance Notebook

and the samples are prepared and analyzed following the procedures listed under section 4. Thin sections are labeled by etching the sample number on the back of the section. Thin sections are filed in a labeled container and kept in the offices of certified project workers. When not in use, they are stored at Room 308, RC1, TA-48.

5.3 Microprobe Analysis and Documentation

Electron microprobe analyses are completed for fused bead samples and individual mineral grains in thin sections following procedure TWS-ESS-DP-07. Analyses are screened for accuracy based on major-element totals and the chemical stoichiometry of mineral constituents. Probe results are documented in the form of computer print-outs. Working print-outs are maintained in a loose-leaf binder stored at Room 4, Bldg. 438, TA-33 (print-outs not in current use are placed in the resident file). Entries are dated and signed by project workers. Separate informal records of analyses are kept by individual workers in loose-leaf notebooks.

SUPERSEDED

5.4 Geochemical Studies

Major and trace element chemical analyses are made for selected samples using instrumental neutron activation and x-ray fluorescence techniques. These techniques will be described in separate procedures.

5.5 Probability Studies

Evaluations of the probability of disruption of an underground repository are made by applying standard probabilistic techniques to data from the geologic studies. The suitability of conditional probability techniques is tested for acceptance through publication of results in the open scientific literature and peer review.

5.6 Consequence Analyses

Consequence analyses of repository disruption include evaluation of the scenario development and of the potential radiological release levels due to a particular

scenario. The latter studies are conducted by Sandia National Laboratory. Scenario development studies involve prediction from the geologic data of the most likely type of effects due to future volcanism. These studies are speculative; therefore, the results are tested for acceptance through formal peer review and publication in the open scientific literature.

5.7 Publication of Results

Results of volcanic hazard studies are published routinely. These reports become formal compilations of the data gathered, interpretations, and conclusions of the work. Published reports are subject to independent review in accordance with the NNWSI Procedure for Technical Review of Publications (TWS-CMBQA-QP-07).

SUPERSEDED

6. REFERENCE

Not applicable.