USGS TECHNICAL PROCEDURE GP-01, R1

Geologic Mapping

1.0 PURPOSE.

1.1 To assure the accuracy, validity, and applicability of the methods used to map geologic features, this procedure provides a guide for USGS personnel and contractors to perform the described activity. The procedure establishes requirements for the collection, plotting, recording, and interpretation of geologic data in order to produce a geologic map and associated cross sections. From this procedure, the Department of Energy (DOE) and the Nuclear Regulatory Commission (NRC) can evaluate these activities for meeting requirements of the NNWSI Project, and competent, trained personnel can reproduce the work.

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. 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 USGS personnel and their contractors who may perform work referred to in Para. 1.1, or use data obtained from this procedure if it is deemed to potentially affect public health and safety as related to a nuclear waste repository.

2.2 All data derived from this procedure that are presented to support licensing of the NNWSI Project repository, 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 Section 8.

3.0 PERSONNEL RESPONSIBILITIES. The Principal Investigator (PI) is responsible for assuring full compliance with this procedure. Per QMP-2.02 and QMP-2.03, the PI shall require that all personnel assigned to work under this procedure shall have the necessary technical training, experience, and personal skills, to adequately perform this procedure; and they shall have a working knowledge of the USGS QA Manual. Responsibilities of others including the reviewer(s), contributing investigators, Branch/NHP Chief, QA Office and the Chief, Branch of NNWSI are as described in Para. 4.3, QMP-5.01.

4.0 DETAILED PROCEDURE. The purpose of geologic mapping is 1) to identify geologic features including faults, stratigraphic units, and geomorphic features; 2) to define their distribution, contact relations, and internal variations; and 3) to determine their age and history. This information

contributes to an understanding of tectonic and geologic processes which could affect waste isolation at Yucca Mountain, and to an understanding of the geologic structure of the Yucca Mountain site area. This information is vital to the development of tectonic and geologic models of the Yucca Mountain site. Geologic mapping of surficial deposits, bedrock stratigraphy, fault systems, and zonal features in both the surficial units and the bedrock units will help provide an understanding of the geologic framework, history, and geologic processes at and near the potential repository site. Knowledge of the geometry and distribution of strata and faults within this framework is fundamental to all studies designed to evaluate natural geologic barriers to radionuclide migration.

4.1 Objective: To produce geologic maps at various scales of one or more of the following classes of features: landforms, surficial deposits, bedrock stratigraphic units, or geologic structures such as faults, folds, and fractures. Field observations and measurements will be synthesized to produce geologic maps and may be interpreted to produce cross sections.

4.2 Methods Used: Geologic maps are to be constructed through annotation of observations and interpretations pertaining to the geology of the area to be mapped (field area) at their appropriate locations on a previously prepared topographic base map.

Observations pertain to geologic features or relations which were observed at a specific place within the field area. Both the nature of the observation and the specific place at which the observation was made are to be recorded at the location on the map representing their actual location. For convenience, the details of the observation may be recorded in a field notebook. If so, the specific place, referred to as a field station, shall be numbered, the number recorded at the location on the map representing the actual location, and the same number with the corresponding observation entered in the field notebook. Interpretations shall be similarly recorded.

Interpretations are to be distinguished from observations through use of distinctive symbols on the map, and through clear written distinction in the field notebook.

Observations and interpretations may be made through visitation and examination (field mapping) of the actual geologic feature. Field mapping may be supplemented or aided through examination and interpretation of aerial photographs of the actual geologic features. In field mapping, observations, interpretations, and/or field stations are to be plotted on a version of the base map (field sheet) carried to the field area, and subsequently replotted on a version of the base map retained at the base camp, field office, or home office. If aerial photographs are employed, observations, interpretations, and field stations may be plotted directly on the aerial photographs and subsequently transferred to a field sheet or to a base map.

The geologic map shall be drawn on a version of the base map, and provided with an accompanying explanation. The geologic map and explanation shall present a synthesis of the geologic information

contained in the field notes, field sheets, other base maps, and such auxiliary information from aerial photographs, sample collections, previously published maps, and other relevant sources of data as may be available. In addition, the geologic map shall present an interpretation of the likely distribution, character and age relationships of the particular geologic features of interest (e.g., rock stratigraphic units, geologic structures, surficial deposits, geomorphic features) consistent with available observational data. Finally, the geologic map, explanation, and supporting documentation and illustrative material (e.g., text and cross-sections), if used, shall distinguish through appropriate symbols or other means that which was observed from that which was interpreted.

4.2.1 Map Scale - This method is applicable to geologic mapping at all scales. A mapping scale, or range of mapping scales, appropriate to the desired objectives may be called out by the Study Plan, or lacking that, established by the PI.

4.2.2 Base Maps - Base maps include either paper or mylar advance or edition copies of USGS topographic quadrangle maps. These maps may be used at publication scales of 1:24,000 to 1:100,000, or enlarged as required. Larger scale topographic base maps prepared for the NNWSI Project may also be used. Base maps may be cut into sections for convenient transportability. Overlays may be used in conjunction with base maps to record certain classes of data, i.e., field stations. Two versions of the base map may be employed, one of which is carried in the field area while mapping (field sheets), the other retained in the base camp, field office, or home office for compilation of data.

4.2.3 Sampling of Rock- and Soil-Stratigraphic Units - Hand samples should be collected from the outcrop or from artificial exposures (man-made cuts and pits) and retained in sufficient number to represent the dominant lithologies and significant variants of all mapped rock- and soil-stratigraphic units. Samples of rock stratigraphic units should normally be obtained by breaking the prospective sample from the outcrop, using a hammer or hammer and chisel. If the sample is taken from material previously separated from the outcrop (e.g., float or talus) that fact should be recorded in the field notebook. Samples may be bagged in plastic, cloth, or paper bags if necessary to prevent loss, damage or contamination of the sample during handling, transit, and storage.

Samples of friable materials (soils, uncemented aggregates) should be collected directly from the bed, stratum, or deposit they are to represent, using implements appropriate to the purpose (e.g., shovels, trowels), taking care to prevent contamination of the sample through accidental inclusion of foreign material, and bagged in plastic, cloth, or paper bags.

Processing of these samples is limited to preparation of thin-sections, polished sections, grain mounts, and measurement of physical attributes (e.g., specific gravity) or other nondestructive procedures. However, portions of a sample may be removed for destructive tests (e.g., chemical analysis) provided sufficient material remains, in the judge-

ment of the PI, to fulfill the primary purpose of the sample, as described above.

Sampling for other purposes (e.g., dating), which may be necessary or desirable, is outside the scope of this procedure.

4.2.4 Photographs - Aerial photographs (vertical or oblique, color or black and white) may be used as described above to observe, interpret, and plot geologic features and field stations. If annotated, the photographs become part of the formal data base. If not annotated, the photographs are regarded as part of the informal data base, requiring no special documentation or custodial care.

Photographs of specific geologic features may be taken using hand-held cameras as part of field data collection. The field location, frame number, azimuth (approximate), and object of the photograph are to be recorded in the field notebook. As soon as practical thereafter, a print or duplicate transparency of the photograph should be correlated with the information in the field notebook, the print or transparency labeled in such a way that this information can be recovered, and filed as part of the formal data base. Other prints, positives, and negatives of the same photograph may be retained by the PI as part of an informal data base, to be used for other purposes, and requiring no special documentation or custodial care.

4.2.5 Attitude of Planar and Linear Features - The attitude of planar and linear features may be measured using hand-held devices (e.g., Brunton compasses) at the discretion of the PI. The measurement may be entered directly on field sheets, aerial photographs, or in the field notebook. Magnetic declination will be compensated for by adjustment of the compass to the local declination, or through adjustment of the measurement.

4.2.6 Scientific Notebooks - One or more bound scientific notebooks shall be maintained, and observations, interpretations, and conclusions related to geologic mapping recorded therein. The primary scientific notebook shall be the field notebook. Supplementary notebooks (e.g., laboratory notebooks) may be maintained at the discretion of the PI. Logbooks, including sample logbooks and photograph logbooks, are not considered scientific notebooks. Logbooks, laboratory notebooks, field sheets, annotated aerial photographs, base maps, and finished geologic map are considered addenda to the field notebook. Prior to initiation of a mapping activity, the following entries, as a minimum, shall be made in the field notebook:

- Name, organization, and address of the individual maintaining the notebook;
- Title of the mapping activity (usually the title of an SCP activity or sub-activity);
- Description of the objective of the mapping activity (see SCP or Study Plan);

- Identification and scale of the field sheets and base map(s) used in the mapping;
- Identification and scale of aerial photographs to be used for annotation of data;
- Method to be used for compensating for magnetic declination;
- Name of supplementary logbooks and notebooks to be used (these items are considered to be addenda to the field notebook);
- List of equipment to be employed (optional equipment need not be listed, but if listed, should be so designated); and
- Dated signature of individual making the initial entries;

Space should be allowed for making additions and changes to the initial entries as mapping progresses. Any changes made should be dated and initialed.

In process entries are to be made in the field notebook as observations, interpretations, and conclusions are made. Entries for a given day should be preceded by an initial entry for that day containing the following information:

- Date and name of individual making the entries;
- Short description of the mapping project (activity or subactivity), including detailed step-by-step process to be followed (through reference to appropriate procedure i.e. "Surficial geologic mapping, Big Dune quad., GP-01, R1");
- Description of any conditions (commonly weather) that may have adversely affected the results of the mapping; and
- Subsequent entries for a given day should include identification of samples collected, all data collected, and a brief description of the results, including notation of any unexpected results; any deviations from the planned geologic mapping; and any interim conclusions. Samples and data are to be keyed to the location from which they were obtained through designation and plotting of field stations on field sheets or aerial photographs, as explained in Para. 4.2.

At the conclusion of the mapping, the final results and a summary of the outcome of the mapping shall be provided. This summary shall include a discussion of whether the mapping objectives, as outlined in the initial entries, were achieved. The summary shall also include a reference to a completed and published report or map; or the summary will be provided in the field notebook.

The final entries in the field notebook shall have the signature or the geologic mapper and the signature of a competent technical reviewer.

4.3 Alternative Method(s) Considered: The chief alternative to the general procedure outlined above is a method in which the geologic map and the topographic base map are constructed concurrently by the same field team utilizing plane-table surveying techniques. This method is appropriate where large-scale maps of small areas are required, as in mine and quarry mapping. However, the method is inherently slow, requires specialized equipment and training, and thus is not as cost-effective as the method described above when used for larger areas.

4.4 Materials/Equipment Required: The materials and equipment required are standard, off-the-shelf equipment which may include, but are not limited to the following:

- Brunton compass
- Aerial photos
- Topographic base map
- Pocket stereoscope
- Rock hammer
- Hand lens
- Field notebook
- Camera
- Scale
- Protractor
- Sample bags (if appropriate)

4.5 Assumptions Affecting the Procedure: A basic assumption is that the individuals applying this procedure are competent, well-trained geologic mappers.

4.6 Data Information: Data collected using this procedure is presented as a geologic map, with accompanying explanation and optional cross-sections, and character of rock- and/or soil-stratigraphic units, geomorphic features, faults, folds, and fractures, their age relationships, and their geologic history.

4.6.1 Quantitative/Qualitative Criteria - An acceptable general purpose geologic map should meet the following criteria:

1. The map should be on a base that meets National Map Accuracy Standards. A topographic base is essential except on small scale maps or in areas of such low relief that the absence of contours does not hinder geologic interpretation.

2. The completed map should be clearly readable and usable at publication scale. All symbols on the map should either be in common usage or be fully explained in the marginal material. The sources of geologic data should be indicated for all parts of the map; contacts inferred from geophysical, photogeologic, or remote sensing data should be identified and explained.

3. All geologically significant units mappable at the scale should be shown, and geologic features should be depicted uniformly throughout the area of the amp.

4. Mines, prospects, quarries, wells, trenches, test pits, and drill holes should be shown in so far as possible at the map scale.

5. Geologic interpretations should be internally consistent and plausible. Relations of normal contacts of geologic units to topography should be consistent with rock attitudes, stratigraphy, and structure shown on the map and in cross sections.

6. Structure should be adequately portrayed. Attitudes of significant structural features should be indicated wherever practical. Structure sections should be included if needed for clarity, and these should be consistent with relations depicted on the map.

7. Surficial units should be distinguished and, where possible, subdivided on the basis of age, origin, morphology and/or lithology. If the map meets all criteria but this, it should be termed as bedrock geologic map. If it meets this criterion, but does not portray the bedrock units, it should be termed a surficial geologic map. In some cases, several maps may be required to provide adequate general purpose coverage of an area.

8. Faults that display mappable offset of stratigraphic or lithologic units or which display evidence of recent movement, or are of some other special significance, should be mapped and classified as to type (normal, reverse, thrust, strike-slip, etc.), and dip and direction of relative movement should be shown wherever possible.

9. The explanation should be concise and reasonably definitive, and should express the distinctive characteristics and principal variations in the map units. Map units (including surficial units) should be described in terms of lithologic character, physical properties, thickness (where possible), economic significance, geologic and/or absolute age and contact relations. Definition of map units and stratigraphic nomenclature should be consistent with current USGS standards.

4.7 <u>Limitations</u>: None

4.8 <u>Other (Hold Points and Interfaces)</u>: Hold points consist of the documented review of the final report by independent peer reviewers, quality assurance reviewers, and management reviewers. Hold points during field activities do not generally apply but will be designated by the PI if applicable. Personnel performing geologic mapping activities interact with personnel who perform tests or analyses in a laboratory or office on samples obtained from subsurface investigations, other field studies, structural geology, stratigraphy and volcano-tectonics. Responsibility for such interfaces rests with the PI.

5.0 CALIBRATION REQUIREMENTS. Calibration is not required as a part of this technical procedure.

6.0 IDENTIFICATION AND CONTROL OF SAMPLES. Samples will be collected as part of this procedure.

6.1 Sample Identification: As part of the data records and documentation, and in compliance with QMP-8.01, all samples will be identified as follows: All samples will be labeled with a unique identifier, using indelible ink whenever possible. Samples with surfaces too rough to mark, or samples which are too porous to mark will be placed in bags and the bags will be marked with the unique sample identifier. Sample identifiers will be recorded on field sheets, base maps, or photos as deemed appropriate by the PI. PIs shall assure that the original sample identifier is traceable to all documentation associated with the samples, and is maintained when the samples are handled by different organizations.

6.2 Control and Storage: In compliance with QMP-8.01, the collected and identified samples shall reside in the custody of the PIs who shall establish a system to track sample from collection through final disposition. This may be achieved by maintaining a logbook, individual sample forms, or by other methods. The system must indicate action taken such as submission for analysis or transfer to another organization. The final disposition of all samples, be it disposal, total consumption during analysis, storage, or transfer of custody to another organization shall be recorded.

PIs shall assure that samples are stored under conditions appropriate to their intended use and lifetime. Physical segregation of NNWSI samples from non-NNWSI samples during storage shall be used whenever possible to preclude intermixing of like samples.

6.3 Special Treatment: Samples are prepared for examination or analyses according to the purpose for which they were collected. Samples are routinely prepared for petrographic or geochemical analyses.

7.0 QUALITY ASSURANCE RECORDS. All information collected and recorded under this procedure that is to be used in support of the NNWSI Project licensing process is required to be a part of the official 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 will constitute a record are field notebooks, field sheets, base maps, annotated aerial photographs, samples, photographs of specific features using hand-held cameras, and logbooks.

7.1 Field Notebooks or other organized documentation will 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. Each page of the field notebook will be numbered consecutively and chronologically. Information superceded as a result of any revisions will be lined out, initialed, and dated.