Task 1.3.1. Sample and Core Curation Plan

The Recipient shall develop a Sample and Core Curation Plan for any physical samples collected during the FORGE project, including, but not limited to, core and cuttings. This strategy must outline plans for preservation of samples and a methodology for handling and fair distribution of samples to interested entities. The plan shall also address long-term housing of physical samples throughout the project lifetime and beyond.

Rock and fluid samples will be collected during Phases 2B and 3 of the FORGE project. This plan covers the collection, preservation and distribution of these samples. This information will enable cost-effective stimulation and assessments of water-rock interaction effects resulting from fluid injection and production. The plan has three major purposes. First, it provides an overview of the type of samples that will be required to characterize the reservoir and the impacts of the project on the surrounding groundwater system. An understanding of the type and quantity of the samples that will be collected, as well as the testing that will be conducted, is a necessary requirement for developing a strategy for preserving and disbursing the samples. We demonstrate in this plan that the Milford FORGE team has the experience and physical capacity required to preserve and disburse the samples. Second, the plan outlines the minimum sampling effort that will be necessary to characterize the reservoir and satisfy DOE objectives. It cannot be assumed *a priori* that researchers will request collection of samples, particularly at the early stages in the project before the production and injection wells have been drilled. The FORGE team recognizes the importance of providing baseline analyses for comparison with data collected later in the project and will make every effort to provide this information. Finally, the plan outlines the mechanism that will be utilized to provide samples to independent researchers. Additional information regarding the submittal of research proposals is presented in the Research and Development Implementation Plan. Throughout the project, the FORGE team will manage and accommodate sample requests by the research community.

Drill Cuttings and Core Samples

Drill cuttings will be routinely sampled at 3 m (10 ft) intervals, unless additional sample intervals are requested by the researchers. Mudlogs of the deep wells will be prepared on site by the mudloggers at the time the wells are drilled to determine the rock types, stratigraphy, and mineralogy of the Milford FORGE reservoir and its overburden. In addition, oriented drill cores will be obtained from the granitic reservoir rocks. Intervals selected for coring will be based on the results of the drilling. It is anticipated one core will be collected from the top of the granitic rocks and the second from near the bottom of the well. Additional core samples may be collected based on scientific need (e.g. better lithology or stress characterization of specific intervals). The cores will allow determination of the physical properties of the rock (e.g., rock strength, porosity, and permeability), the occurrences, orientations, and attributes of fractures and veins, and the hydrothermal minerals that fill them. Mud and drillers logs will be prepared daily and posted on the FORGE website.

Unwashed wet cuttings will be collected, dried during drilling, and stored in sample bags and each bag will be labeled with well name and footage. At a minimum, two splits of the cuttings samples will be taken from each of these samples. Each split will be washed, re-dried, and stored in envelopes suitable for archival preservation. Each envelope will be labeled with the well name

and footage. One set of the cuttings will be stored at the Utah Core Research Center (UCRC) at the UGS and the second at the EGI Sample Library. The remaining bagged samples will be stored at the UCRC and serve as a backup if additional sample material is needed.

We will work closely with the researchers to ensure they obtain sufficient cuttings samples for their investigations. For routine studies (e.g., X-ray diffraction/fluorescence analysis and thin section preparation), a nominal amount of 10 g of cuttings will be provided. We recognize that larger amounts will be required for specialty analyses. As discussed below, release of the cuttings samples will be prioritized based on recommendations by the review panel. However, a minimum of 10 g will be retained in each cuttings packet for long-term preservation.

A few grams of each cuttings samples will be utilized to prepare a chipboard of each well drilled. The chipboards will provide researchers with the ability to quickly locate changes in rock type and hydrothermal alteration and compare the samples with the downhole logs. The chipboards and core will be photographed and made available on the Milford FORGE website.

Coring operations will be based on the need to characterize specific physical, mineralogical, and textural parameters. All core will be oriented so that the geometries (dip and strike) of fractures and veins can be accurately determined. Core will be collected from the reservoir rocks during the drilling of thermal gradient wells in Phase 2C and during the drilling of the injection and production wells in Phase 3. We anticipate that at least several tens of feet of core will be collected beginning at the top of the reservoir in each of the thermal gradient holes. The upper portion of the well will be rotary drilled. Spot cores will be collected during the drilling of the production and injection wells. The precise locations for coring will be finalized in concert with the drilling plan.

In so far as possible, the core will be maintained in an undisturbed state until initial measurements can be made. To maintain the integrity of the core and determine the orientations and distribution of fractures in the least disturbed state, it will be left in the core barrel until CT scans can be obtained. This will preclude damage to the core during removal from the core barrel. In addition, we will attempt to obtain samples of the in-situ fluid by freezing other samples of the core using dry ice. The frozen core will be thawed in the laboratory to collect the fluid. Because freezing could result in fracturing of the hot core, different cores will be used for CT scanning and determining the fluid content. Because mud will be used during the drilling, the approach described below will be utilized to evaluate the composition of the native fluid.

Once the core is removed from the core barrel, high resolution photographs will be taken and made available through the FORGE website and NGDS.

There are several methods that can be utilized to orient the core so that the fracture directions and stress field can be determined. These methods include computation of the core barrel rotation using special down-hole tools, (roll position of the core), and reconciliation of fractures measured in the core with logs based obtained from televiewer or acoustic images.

Table 1 describes the type of testing to be undertaken. To accommodate these tests, the following procedures will be followed:

1. Determine vein and fracture orientations on the full, uncut core, using CT scanning techniques and logging of the core after removal from the core barrel.
2. Cut plugs for mechanical testing from selected sections of the full core. Slab the sections after they are plugged for preservation. Normal plug diameters are 10-20 times the average grain diameter. Plug lengths are nominally twice the diameter. Assuming a grain size similar to that encountered in cored samples of the reservoir rocks (e.g., well 52-21, core plugs will be 3.8 cm (1.5 in) in diameter and 7.6 cm (3 in) long.
3. Conduct routine petrologic investigations of the core and cuttings as described below.
4. The remaining core will be left uncut until samples are requested for research. At that point, a one-third slab will be cut from the core for long-term preservation and study. The remaining two-thirds butt core will made available for testing and research. At least a 1/3 slab of all core will be preserved.

A description of the repository facilities is given below. Space is available for storage of the core and cuttings and to lay out the samples for inspection and study. Microscopes and computers (or data ports for visitors with laptops) will be available for displaying geophysical or image logs. The newly acquired core will be stored and prepared at the UCRC for preservation and disbursement. The repository managers can assist in preparing samples for shipping to analytical laboratories as requested.

We anticipate that some researchers will propose to conduct tests on the core and cuttings that will destroy their integrity (e.g., fracture and strength testing, fluid inclusion and isotope analyses). In order to provide all researchers with fair access to the core and to conduct the testing in a logical manner, researchers will be given an opportunity to submit proposals to the Project Management Team before any of the core samples are disbursed. The strategy for obtaining samples for study is described below under the section Sample Distribution and in the accompanying Research and Development Implementation Plan. Reports, including the data obtained on the core and cuttings samples, must be submitted to the Project Management Team at the conclusion of the research. In some cases, interim reports may be required. All unused sample must be returned to the sample repository with a description of the testing that was conducted.

Some researchers may require significantly more sample than can be readily accommodated by the repository managers. In these cases, efforts will be made to collect additional sample during drilling, if these requests are made in advance. The schedule activities conducted at the FORGE site will be posted on the website, so that researchers can be request information or samples in a timely manner.

Reconnaissance investigations of the core and cuttings samples collected during the drilling of the FORGE wells will be conducted by the FORGE team. These investigations will include X-ray diffraction analyses of the samples, including identification of the clay minerals and semi-quantitative analysis of the bulk mineralogy, petrographic studies of the rocks in thin section, fluid inclusion and isotope analyses. The petrographic investigations will provide information on rock type, primary and hydrothermal mineral assemblages, vein minerals, and mineral paragenesis. Photomicrographs of the thin sections, the results of the X-ray analyses and of petrologic studies (e.g., chemical, isotopic and fluid inclusion analyses) will be made available

on the FORGE website. Regions of strong veining and the depths of minerals suitable for petrologic investigations will be recorded.

Table 1. *Anticipated sample requirements for cuttings and core samples for common tests.*

Sample Type	Test	Sample Requirements	Destructive /Non Destructive
cuttings	lithology; XRF, thermal conductivity	10-40 gr	non destructive
cuttings	petrologic (XRD, thin section, SEM, isotope, fluid inclusions)	10-40 gr	destructive
core	vein/fabric orientation	full core	non destructive
core	Physical property testing (density, seismic velocity, thermal conductivity, thermal diffusivity, porosity and permeability, mechanical testing	full core; core plugs	destructive
core	petrologic (XRD, XRF, thin section, SEM, isotope, fluid inclusions)	core slabs containing veins	destructive

A significant collection of cuttings and core samples from the area immediately surrounding the Milford FORGE site is available for study at the Utah Core Research Center at the UGS and the EGI Sample Library. Cuttings from the Acord-1 well are currently housed at the UCRC. Cuttings and core from more than 2 dozen shallow to deep gradient and exploration wells from the area are housed at the EGI Sample Library. These wells, drilled in the late 1970s, include 24-36 (1706.9 m [5600 ft); 9-1 (2097.9 m [6883 ft), 14-2 (1859.3 m [6100 ft]); and 52-21 (2286 m [7500 ft]). A complete listing of the samples available at the EGI Sample Library is presented in Table 2.

Fluid Samples

In addition to rock sampling, fluid sampling will be undertaken in order to determine the composition of the reservoir pore waters and the compositions of waters filling shallow aquifers. The methods used to obtain these samples will depend on several factors including the temperature of the water and the drilling and testing plan for the wells. Water samples will be analyzed for a range of aqueous species and isotopes, which require different types of pretreatment (e.g., filtering, acidification) and bottle types (e.g., polyethylene, glass) for storage and shipping to the analytical laboratories. Aliquots of samples will be preserved for the life of the project in refrigerators at the EGI Sample Library. Standard preservation and analytical protocols are outlined in Table 2.

Table 2. *Geothermal samples preserved at the EGI Sample Library from the area surrounding the FORGE site.*

Drill Hole	**Location**	**Section**	**Township**	**Range**	**Depth Interval (ft)**	**Sample Type**
UT ST 24-36	Beaver Co.	n/a	n/a	n/a	0-5600	Cuttings
1A	Beaver Co.	3	27 S	9	20-217	Core
1B	Beaver Co.	4	27 S	9W	133-231	Core
1976 ALTN.1	Beaver Co.	34	26 S	9W	10.8-201.8	Core
GTPC 11	Beaver Co.	17	26 S	8W	0-110	Cuttings
GTPC 3	Beaver Co.	4	27 S	9W	0-300	Cuttings
GTPC 4	Beaver Co.	33	27 S	9W	0-300	Cuttings
GTPC 6	Beaver Co.	25	27 S	10W	0-300	Cuttings
GTPC 9	Beaver Co.	12	26 S	8W	0-290	Cuttings
GTPC 7	Beaver Co.	13	27 S	9W	0-300	Cuttings
GTPC 8	Beaver Co.	25	26 S	9W	0-360	Cuttings
GTPC Misc. Comp.	Beaver Co.	n/a	n/a	n/a	n/a	Cuttings
Miscellaneous Cuttings	Beaver Co.	n/a	n/a	n/a	n/a	Cuttings
KGRA 9-1	Beaver Co.	9	27 S	9W	0-6883	Cuttings
Roosevelt TG Wells	Beaver Co.	n/a	n/a	n/a	n/a	Cuttings
14-2	Beaver Co.	2	26 S	9W	0-6100	Cuttings
Roosevelt Miscellaneous	Beaver Co.	n/a	n/a	n/a	n/a	Cuttings
72-16	Beaver Co.	16	27 S	9W	0-1244	Cuttings

GTPC 1	Beaver Co.	6	27 S	9W	0-400	Cuttings
GTPC 2	Beaver Co.	6	27 S	9W	0-300	Cuttings
GTPC 14	Beaver Co.	18	27 S	9W	0-540	Cuttings
GTPC 18	Beaver Co.	18	27 S	9W	0-90	Cuttings
GTPC 13	Beaver Co.	22	27 S	9W	0-240	Cuttings
GTPC 12	Beaver Co.	n/a	n/a	n/a	n/a	Cuttings
GTPC 15	Beaver Co.	18	27 S	9W	0-1870	Cuttings
GOC 52-21	Beaver Co.	21	27 S	9W	0-7500	Cuttings/Core

Samples from the shallow groundwater wells will be collected using a simple cooling coil. In contrast to the groundwater wells, the collection of pristine reservoir water from the deep wells will be challenging and compromised by interactions with the drilling fluids. The extent of contamination will depend on the reservoir pressure, but this parameter will remain unknown until drilling intersects the reservoir. Our plan for characterizing the reservoir pore fluid composition involves regular sampling of drilling fluids and fluids collected either during pump tests or with a downhole sampler. Chemical analyses of ionized and unionized species will allow us to reconstruct the compositions of the subsurface pore waters, assuming they are measurably distinct from the drilling fluid. We propose to collect a total volume of water that will be on the order of 50 liters.

Once the production fluids can be sampled from a pipeline near the wellhead, we will obtain liquid and, if possible, gas samples using conventional collection methods (e.g., mini-separator and condensing coils). Evacuated bottles made of glass and filled with NaOH and $CdCl_2$ are required for collection of the gas samples. These bottles require care in handling and shipping. All sampling and storage methods and procedures will comply with best practices in health and safety.

The compositions of water and gas samples from the production and water supply wells will be monitored quarterly. The liquid samples will be routinely analyzed for pH, Na, K, Ca, Mg, Li, Fe, B, SiO_2, Al, As, Cl, F, SO_4, HCO_3, and NH_3 and for their deuterium and oxygen isotopic compositions. Tritium may be analyzed in some samples. In the event a separate steam sample can be collected, potential analyses could include the noble gases, CH_4, H_2, Ar, N_2, He, H_2S, and O_2 contents. Because gas samples have a very limited shelf life, they will be analyzed shortly after collection. The gas and liquid analyses will be combined using standard geochemical techniques to establish the reservoir composition of the fluids. The sampling and analytical protocols will be finalized once the characteristics of the fluids are determined.

Chemical tracers will be added to the injected fluids to monitor fluid movement. It is anticipated that tracer samples will be collected daily for the first two weeks, then twice a week for the following two weeks and then weekly.

Facilities for Curation of FORGE Samples

Both the UCRC and the EGI Sample Library will be accessible to researchers investigating samples from the FORGE site. The UCRC will be under the control and supervision of the curator, Mr. Peter Nielsen whereas those at the EGI Sample Library will be under the supervision of Mr. David Langton. All work at the repositories will need to be reserved ahead of time to ensure the proposed work does not conflict with other commitments. All activities will be subject to the safety and core handling policies of the repositories. Retrieval of material from the shelves will be carried out by staff members. Core and cuttings that arrive at the repositories will be logged in upon arrival and entered into the respective databases. A listing of the samples and other supporting data including photographs and logs will be accessible to the public through the National Geothermal Data System (NGDS).

Utah Core Research Center

The UCRC is dedicated to the preservation of cores and cuttings of geothermal, oil and gas, and mine exploration and development wells drilled in Utah. The Center contains 1858 m^2 (20,000 ft^2) of floor space and holds about 5 million meters (16 million ft) of cuttings and core from 4000 Utah wells (Figure 1).

The UCRC has excellent facilities for displaying rock samples and for hosting large groups of visitors (up to about 60) in a well-lit classroom environment (Figure 2). The classroom is equipped with projectors and internet access and is frequently used for on-site and online meetings. Analytical equipment housed at the facility includes an EDXRF core scanner (Figure 3), petrographic and binocular microscopes, and photographic equipment for high resolution whole-box and close-up digital core photography (Figure 4). Core collected as part of the FORGE project will be slabbed and depth-indexed in the UCRC slab and preparation room (Figure 5). The UCRC also has a drill press for plugging cores and rock saws for slabbing and obtain blanks for thin section and SEM work. Over 914 m (3000 ft) of core can be displayed in the layout area at one time. The area has internet access, high light levels and is heated (Figure 6).

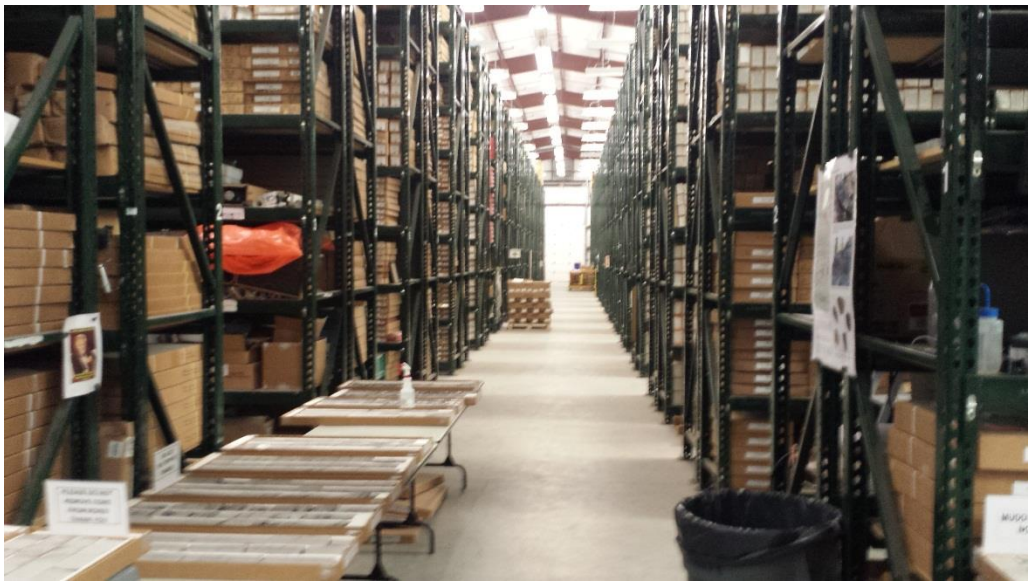

Figure 1. *The Utah Core Research Center (UCRC) repository. Core and cuttings collected as part of the FORGE project will be received, indexed, prepared, and housed at the facility. The UCRC has sufficient storage and handling for the FORGE project.*

Figure 2. *Classroom and meeting room at the UCRC. Facility can hold 60 people, has internet access, and has a PowerPoint projection system. The UCRC typically hosts geologists and students receiving instruction about Utah cores and geology.*

Figure 3. *Laboratory at the UCRC. The laboratory houses UCRC's analytical and digital photographic equipment, and binocular and petrographic microscopes equipped with digital cameras. The facility is well lighted, heated, and has direct access to the core layout area.*

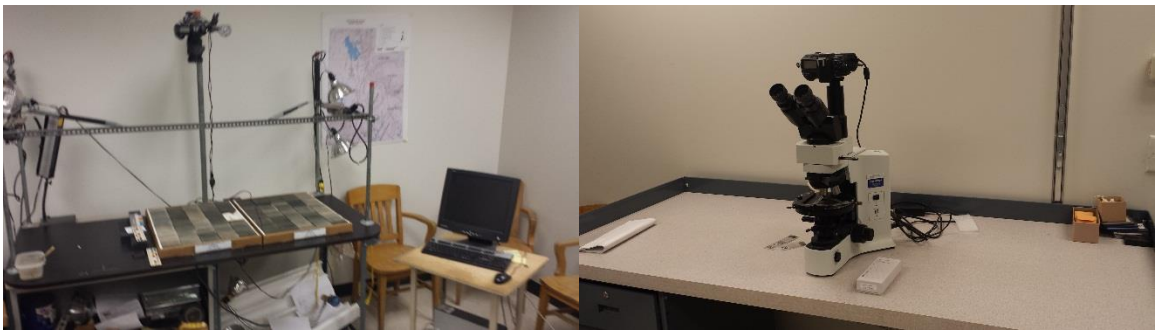

Figure 4. *Digital core photographic and petrographic equipment at the UCRC.*

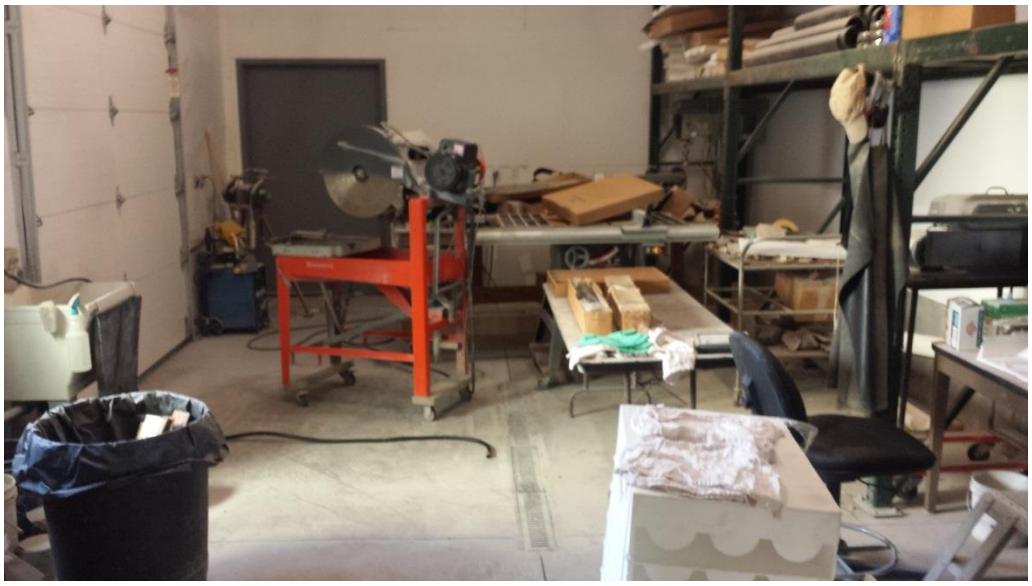

Figure 5. *Core slabbing and sampling preparation room at the UCRC.*

Figure 6. *Core layout area at the UCRC. One thousand feet of core can be displayed. The layout area is well-lighted and heated and has direct access to the laboratory.*

Energy and Geoscience Institute Sample Library

The EGI Sample Library, located near the UCRC, houses one of the largest collections of geothermal core and cuttings in the world. This library has more than 1587 m^2 (17,100 ft^2) of floor space for sample storage, and currently houses more than 177,000 m of cuttings, and more than 110,000 m of core from geothermal systems throughout the world. Space is available to lay out cores and cuttings samples (Figure 7). Office space and binocular microscopes are available for researchers who wish to conduct studies at the Sample Library. Research grade petrographic microscopes with high-resolution cameras are housed at EGI and will be made available to researchers who wish to examine thin sections of the rock samples. Scanning electron microscopes, an X-ray diffractometer and Linkham heating and freezing fluid inclusion stages are also available at EGI for work on FORGE samples.

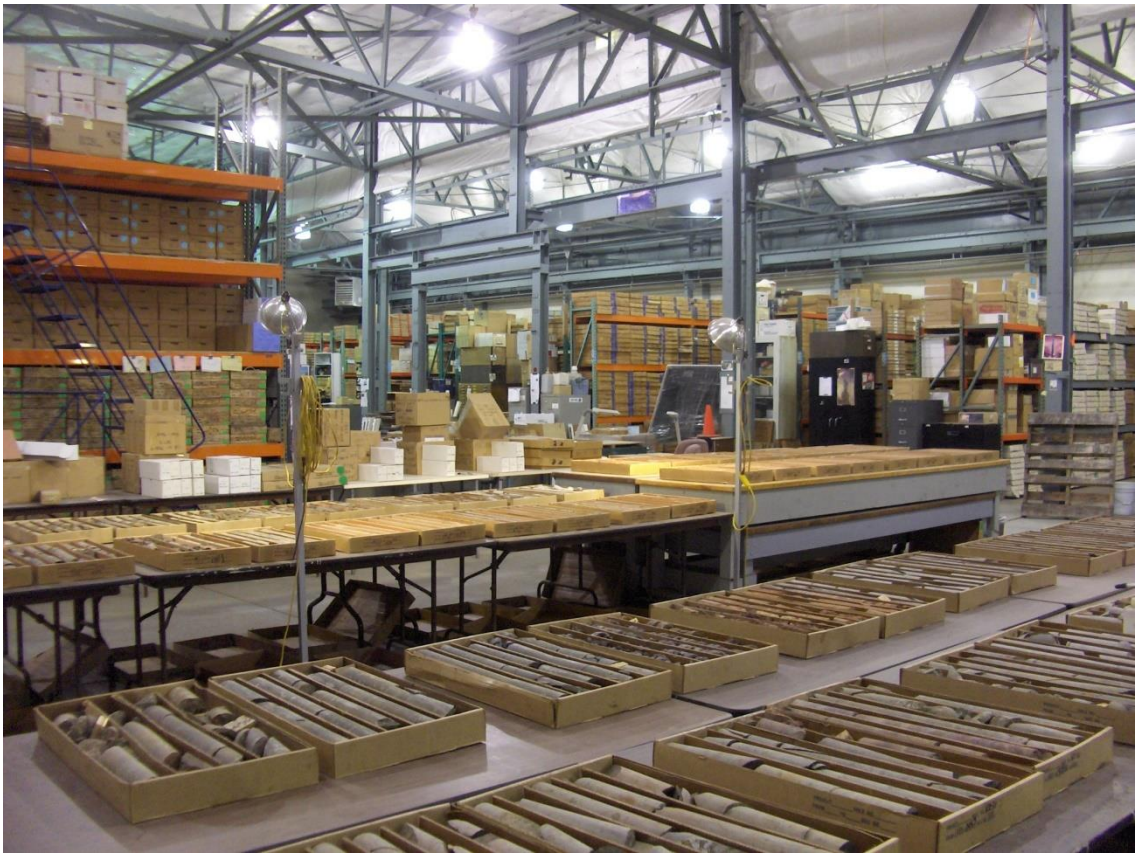

Figure 7. *Core layout area and storage at the EGI Sample Library. The core in the foreground is part of an extensive collection from the Medicine Lake geothermal field, California.*

Fee Schedule

An established schedule of fees will be charged for use of the facilities, including access to the internet, use of visitor's office with laptop computer, staff time setting up for workshops or display material, pulling and returning sample boxes to shelves, and use of in-house equipment such as microscopes (petrographic, binocular), cameras that interface with the microscopes for high-resolution images (14 megapixel images). It is proposed that the maximum access costs be capped at $6000 per year, and that these be billed directly to the project by the UGS and EGI to minimize costs to individual researchers. The $6000 is equivalent to 30 days of use per year at the standard rate of $200 per day. Additional, more intense work on core or cuttings, such as core slabbing and plugging will be separately charged to the project. Once the project has ended, the UCRC will commit to long-term storage of the core and cuttings at no additional cost to DOE.

Sample Distribution

We anticipate significant interest in the analysis of new and existing samples by geothermal researchers in support of the FORGE project. This section describes the methodology that will be utilized to ensure fair and equitable access to the samples. In contrast to cuttings samples, core is preferable for study as it provides unequivocal information on veins, vein and fracture orientations, lithologies, and the rock's mechanical properties. However, the cost of obtaining

core can easily exceed $50,000 for a single core run of 3 to 6 m (10-20 ft). Thus, the amount of core that can be collected will be weighed against the available funds and the importance of the core at each of the targeted intervals. Based on estimates of the current funding levels, it is anticipated that coring activities may be limited. Therefore, both the purpose of the testing and whether the testing will be destructive or not must be understood prior to sample distribution. Table 3 summarizes the kinds of tests that are anticipated and the material requirements. To ensure an equitable distribution, we propose the following strategy:

1. Prior to drilling, researchers will be given an opportunity to request core and cuttings samples through submission of a concept paper that describes the amount and type of sample required and the work that will be conducted.
2. The proposals will be ranked by a team of independent reviewers consisting of DOE and outside experts. The review team will be chaired by a member of the Science and Technology Analysis Team (STAT) unless the Managing PI determines that there is a conflict of interest. In that case, an alternate will be selected to chair the committee.
3. The committee will rank the submittals and estimate the quantity of core and cuttings required by the researchers. These recommendations will be submitted to the Milford FORGE Managing PI. These recommendations will be reviewed by the Managing Committee.
4. Applicants considered to have proposals that merit consideration will be requested to prepare a full, formal proposal as described in the Research and Development Implementation Plan.
5. A report, including the data obtained on the core and cuttings samples, must be submitted to the Project Management Team at the conclusion of the research. In some cases, interim reports may be required. All unused sample must be returned to the sample repository with a description of the testing that was conducted.

In general, testing of the samples will be conducted in a manner that prioritizes non-destructive activities first. Samples will be provided to applicants who propose destructive testing after non-destructive testing is conducted.

In most cases, it is anticipated that samples of the fluids can be obtained when requested by the researchers. Strict protocols will be followed to maintain a safe environment and only authorized personnel will be permitted to collect the samples. Researchers will be required to provide their own correctly prepared sample vessels. ASTM E 1675 provides commonly utilized protocols for fluid sampling (Table 3). Researchers who wish to participate in rock or fluid sampling will be required to complete on site safety training.

Table 3. *Summary of the protocols (ASTM E 1675) for the collection and preservation of liquid and gas samples (compiled by von Hirtz, 2008).*

Sample Type	**Parameter**
Gas bottle, evacuated glass containing $NaOH/CdCl_2$	Ar, 0_2,N_2,CH_4,H_2, He, $C0_2$,H_2S, NH_3 saturated hydrocarbons, radon-222, SF6 tracers
Gas bottle, evacuated glass containing deionized water/$CdCl_2$	Unsaturated hydrocarbons, aromatic hydrocarbons, CO
lmpinger, gas scrubbing bottle containing $NaOH/CdCl_2$; 0.1N H_2S0_4	H_2S, NH_3
Raw, unacidified (RU) condensate in polyethylene bottle, 250-500 ml	Cl-, F-, B, $Si0_2$, Na, As, Se
Raw, acidified $HN0_3$(RA) or filtered acidified $HN0_3$(FA) in polyethylene or TFE-fluorocarbon bottle, 250 ml + 5 ml $HN0_3$	Fe, Mn, other heavy metals
Raw, $HN0_3$/K2Cr207 preserved in glass bottle, 125 to 250 ml + 25 to 50 ml preservative solution	Hg
Raw, unacidified (RU) condensate in glass vial containing copper wire,	Stable isotopes