

The U.S. Geological Survey's TRIGA® Reactor

The U.S. Geological Survey (USGS) operates a low-enriched uranium-fueled, pool-type reactor located at the Federal Center in Denver, Colorado (fig. 1). The mission of the Geological Survey TRIGA® Reactor (GSTR) is to support USGS science by providing information on geologic, plant, and animal specimens to advance methods and techniques unique to nuclear reactors. The reactor facility is supported by programs across the USGS and is organizationally under the Associate Director for Energy and Minerals, and Environmental Health. The GSTR is the only facility in the United States capable of performing automated delayed neutron analyses for detecting fissile and fissionable isotopes. Samples from around the world are submitted to the USGS for analysis using the reactor facility. Qualitative and quantitative elemental analyses, spatial elemental analyses, and geochronology are performed. Few research reactor facilities in the United States are equipped to handle the large number of samples processed at the GSTR. Historically, more than 450,000 sample irradiations have been performed at the USGS facility. Providing impartial scientific information to resource managers, planners, and other interested parties throughout the world is an integral part of the research effort of the USGS.



Figure 1. Cerenkov radiation or "blue glow" from operation of the TRIGA® reactor.



Figure 2. TRIGA® reactor control console.

The USGS TRIGA® reactor has been in operation since the late 1960s in support of nuclear-based research for the USGS and a number of universities across the Nation. It is the only research reactor of its type in the Department of the Interior and the only research reactor within a 350-mile radius of Denver, Colo. The reactor design is similar to research and training reactors at universities throughout the United States (see control console in figure 2). The reactor provides an intense neutron source for experiments and is capable of continuous steady-state operation at 1,000 kilowatts (thermal). Also, it may be pulsed to a peak power of approximately 1,600 megawatts. Services include, but are not limited to, neutron irradiations for argon isotopic dating, neutron activation analysis, uranium and thorium analysis by delayed neutron counting, radioisotope production, gamma spectrometry, and fission track experiments.

What the GSTR Can Do

Routine operations at the GSTR involve the irradiation of samples to produce changes in the sample specimens (see sample package in figure 3). This change or "transmutation" of the original elements in the sample is accomplished when neutrons from the reactor strike the sample and change its nuclear composition. This technique, where the specimen is "activated" and then analyzed to determine its elemental composition, is called neutron activation analysis (NAA). Most elements can be detected at a level of a few nanograms or less. An advantage of NAA is that the samples can be analyzed without any

chemical processing before or after the activation. This composition information is useful in determining geological sources and origins of mineral deposits. The reactor is also used to produce nuclear changes in rock and mineral samples to determine their ages. Elemental analyses using other methods often result in data of less precision and (or) less accuracy. The GSTR provides high-quality data on rock and mineral elemental composition using state-of-the-art techniques while providing the research tools needed to develop new and improved analytical techniques (see figure 4 for a sample container setup at the GSTR).



Figure 3. Sample package before assembly.



Figure 4. Sample transport containers.

Safety

The TRIGA® reactor has many safety features, primarily through the inherent design of the reactor, that prevent overheating or a “core meltdown.” Numerous radiation monitors with automatic alarms are located throughout the facility. The control system provides warnings against unsafe operations by monitoring power levels, temperatures, and other important properties of the reactor. An automatic reactor shutdown will occur in a fraction of a second if any operational limit is exceeded. A reactor bay air-monitoring system detects airborne contamination and immediately isolates the reactor space if necessary. This isolation system will then provide absolute filtering of all reactor space air to prevent the release of contaminants to the environment. The safety of operations is checked annually by the U.S. Nuclear Regulatory Commission.

Collaboration

The reactor staff provides guidance to researchers from across the country on the feasibility and design of proposed experiments, including preliminary irradiations and assistance with counting equipment. The staff also provides radiation safety management and nationwide assistance to USGS projects that involve radioisotopes. A Memorandum of Understanding (MOU) exists between the USGS and the Colorado School of Mines, and the collaborative research benefits both organizations in academic and basic research efforts.

Examples of Research Projects That Use the Reactor Facility

Coral Reefs and Dust (Neutron Activation Analyses)

Off the coast of Jamaica, USGS scientists studied an array of coral reefs to determine the source of reddish-brown soil that is affecting reef ecology. The soil is believed to be endangering the continued growth and development of the reefs. Reefs are important sources of food and protect tropical shorelines from storms. Through neutron activation analysis at the reactor facility, the soil was “fingerprinted” as a combination of volcanic ash originating from the Lesser Antilles island arc and airborne dust from Africa (Muhs and Budahn, 2009). Dust from Africa is also a dominant parent material for soils in the Florida Keys, the Bahamas, and Barbados (Muhs and others, 2007). For the first time, climatic teleconnections could be established using neutron activation analyses.

2011 Japanese Earthquake and Radioactive Fallout (Gamma Spectrometry)

The Fukushima reactor accident in March 2011 dispersed radioactive materials into the atmosphere. Smoke from the reactor traveled around the world, depositing radioactive material as it spread (fig. 5). The GSTR analyzed hundreds of water and filter samples to help determine the type and amount of fission products deposited across the United States (Wetherbee, DeBey, and others, 2012; Wetherbee, Gay, and others, 2012).

Understanding Volcanic Eruptions (Argon Geochronology)

Geologists at the USGS Cascades Volcano Observatory (Vancouver, Washington) have used the reactor to understand volcanic systems and to develop detailed eruptive histories of active volcanoes in the Western United States, Alaska, and Hawaii. One of these research projects is in the Three Sisters volcanic field west of Bend, Oregon. This area includes three stratovolcanoes surrounded by lava flows (fig. 6), several of which have erupted in the last 4,000 years. Using argon geochronology, scientists concluded that two of the Three Sisters volcanoes formed simultaneously in a narrow time interval between 48,000 and 15,000 years ago, while the third was determined to be substantially older. This research suggests that the stratovolcanoes are less likely to erupt in the near term, but the surrounding lava flows have been more active recently and, therefore, pose the greater hazard to people and property (Fierstein and others, 2011).

Future Science at GSTR

Continuing improvements in the neutron profile characterization of the GSTR provide greater precision in geochronology measurements for numerous laboratories. The Colorado School of Mines, in cooperation with the GSTR, plans to install a neutron radiography instrument in 2012. The instrument will be the only neutron radiography system within a 450-mile radius of Denver, Colo., and will be able to facilitate new types of analytical research.



Figure 5. Smoke coming from the Fukushima nuclear plant following the accident in March 2011 (from DigitalGlobal®).



Figure 6. Aerial view of Three Sisters volcanoes in Oregon.

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