Report to the National Park Service for Permit Number: LAKE-2014-SCI-0002

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Purpose of study:

The overall purpose of the study is to determine how to use existing geologic data to predict gamma-ray background levels as measured during aerial radiological surveys. Aerial radiological surveys have typically been for resource exploration purposes but are now also used for homeland security purposes and nuclear disaster assessment as well as determining the depth of snowpack. Foreknowledge of the background measured during aerial radiological survey will be valuable for all the above applications. The gamma-ray background comes from the rocks and soil within the first 30 cm of the earth's surface in the area where the survey is being made. The background should therefore be predictable based on an understanding of the distribution and geochemistry of the rocks on the surface. We are using a combination of geologic maps, remote sensing imagery and geochemical data from existing databases and the scientific literature to develop a method for predicting gamma-ray backgrounds. As part of this project we have an opportunity to ground truth our technique along a survey calibration line near Lake Mojave that is used by the Remote Sensing Lab (RSL) of National Security Technologies, LLC (NSTec). RSL makes aerial measurements along this line on a regular basis, so the aerial background in the area is well known. By making ground-based measurements of the gamma-ray background and detailed observations of the geology of the ground surface as well as local topography we will have the data we need to make corrections to the models we build based on the remote sensing and geologic data. Our project involves collaborators from the Airborne Geophysics Section of the Geological Survey of Canada as well as from NSTec's RSL.

Findings

The study area relevant to this permit lies on the western shore of Lake Mohave, which is located on the Nevada- Arizona state line south of Lake Mead. As described in the permit application, the purpose of the study is to determine how best to predict the background radiation derived from rocks and soil for the purpose of better understanding aerial radiological surveys.

We obtained background radiation data for the permit area using an array of thallium activated sodium iodide (NaI:Tl) detectors mounted on a helicopter. Aircraft position was recorded using differential GPS. The data were analyzed by NSTec's Remote Sensing Lab AMS to produce exposure rates at 1 m (3.3 ft) above ground level. Contributions from cosmic rays and atmospheric radon were removed from the data. The area was flown on the same day that the field work was conducted, ensuring that soil moisture conditions were the same for all data. Field work was conducted in January 2014. We collected 9 soil samples and made ground level radiation measurements with a high-purity germanium detector and pressurized ionization chamber.

Geochemical data for quaternary alluvial units and soil was acquired from databases (USGS 2008), culled for internal consistency, and associated with geologic units. To calculate background radiation levels from geochemical data we used the equation of Grasty (1984):

$$D = 1.32K + 0.548eU + 0.272eTh.$$

With the concentrations of $K$ in percent potassium and of $eU$ and $eTh$ in ppm of equivalent uranium and equivalent thorium, respectively, $D$ will be in μR/h. Here, "equivalent" means that U and Th are assumed to be in equilibrium with their progeny. We found that the geochemical data significantly over-predicted the background radiation as observed in the survey data. We also used NURE national airborne gamma ray spectrometry survey data measurements of K and equivalent U and Th values to calculate exposure rates for given geologic units. The NURE measurements combined with radiation background units (RBU) based on mapped alluvium (House 2008) compared similarly with RBUs built from ASTER remote sensing images (using a 1-6-10 band combination for classification). In both cases results were significantly closer to the measured background than the geochemistry based prediction.

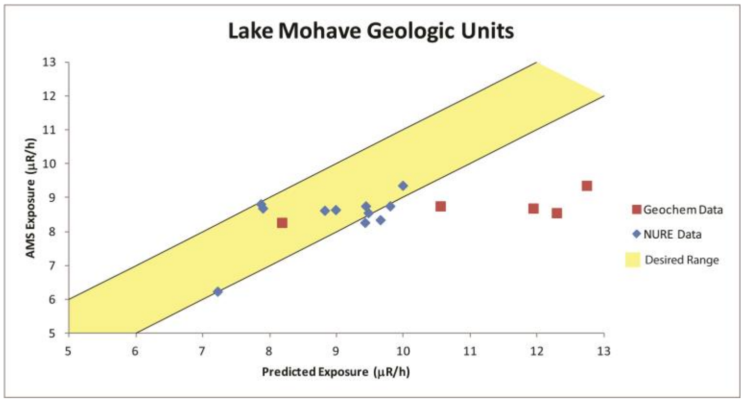


**Figure 1: Comparison of exposure rates as measured by AMS with predicted exposure rates calculated from NURE data and from geochemical data from the USGS database.**

We are using the soil samples to further investigate the discrepancies between geochemistry based data and measured background radiation. The soil samples were sent to an independent laboratory (TestAmerica Laboratories, Inc., 13715 Rider Trail North, Earth City, Missouri 63045) for gamma ray counting.

We have also used polarized light microscopy and X-ray diffraction to characterize the mineralogy of the soils. We are using this data to develop a suite of RBUs based on ASTRER remote sensing imagery and band math which can then be combined with NURE survey data or geochemical data to predict the distribution of background radiation. We are currently preparing to use ICPMS to analyze the soil samples that we collected.

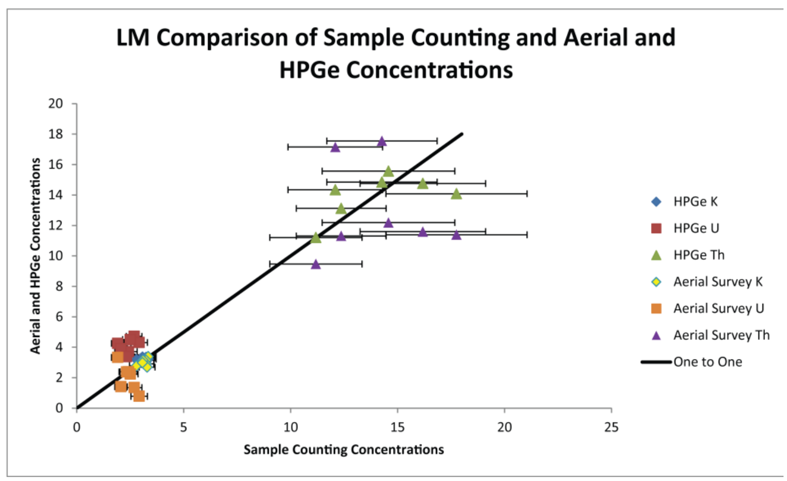


**Figure 2: Comparison of K, U and Th content as measured by gamma ray spectroscopy, and in-situ aerial and ground based gamma ray spectroscopy.**

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References

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House, P. K., J. E. Faulds. Preliminary Geologic Map of the North Half of the Spirit Mtn. NW Quadrangle, Clark County, Nevada and Mohave County, Arizona, Nevada Bureau of Mines and Geology, Reno, Nevada, 2008, http://www.nbmg. unr.edu/dox/of085.pdf, accessed October 7, 2014.