Connecting Aerial Gamma Ray Surveys and Geochemical Data

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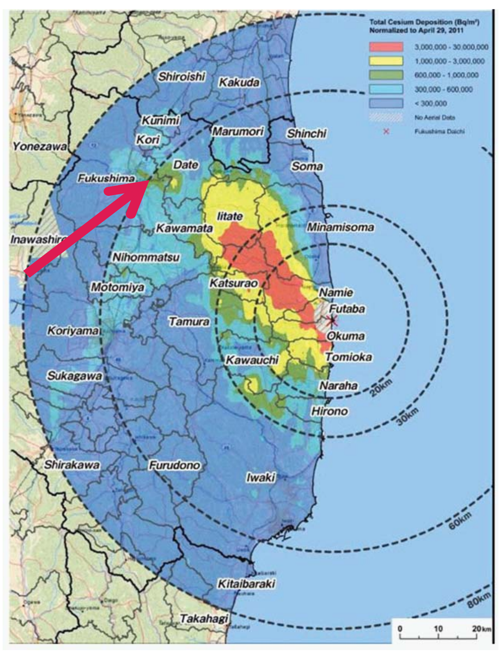
Radiation in the Environment



-Is the arrow pointing to an extension of the radiation plume or an effect of geology?
-When it's your home this distinction becomes important
-Currently to differentiate there must be an aerial gamma ray survey of the area before the disaster occured

Figure 1a: NNSA aerial gamma ray survey of Fukushima Daiichi[8]

- Radiation occurs naturally in bedrock and soil
- Gamma rays are released from the decay of the radioactive isotopes K, U, and Th
- Gamma rays interact with the soil and rock, and can only make it through about 30 cm of material
- Energy of gamma rays is specific to each isotope, allowing identification

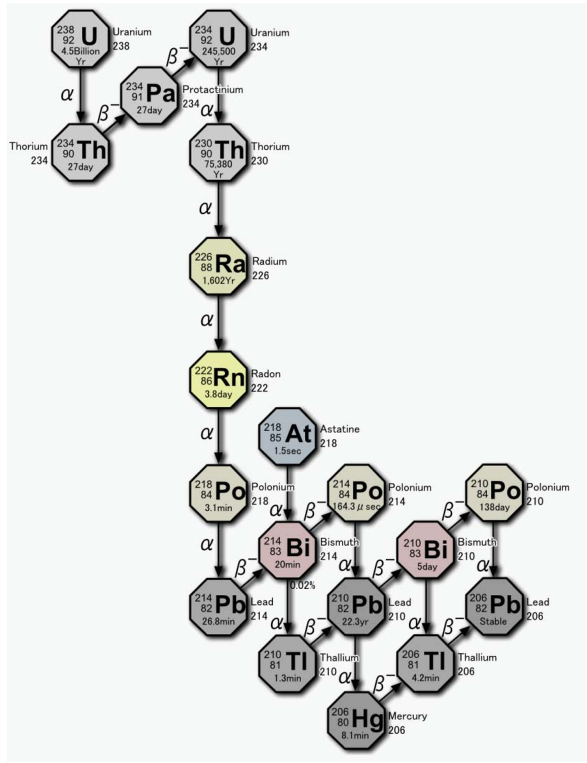


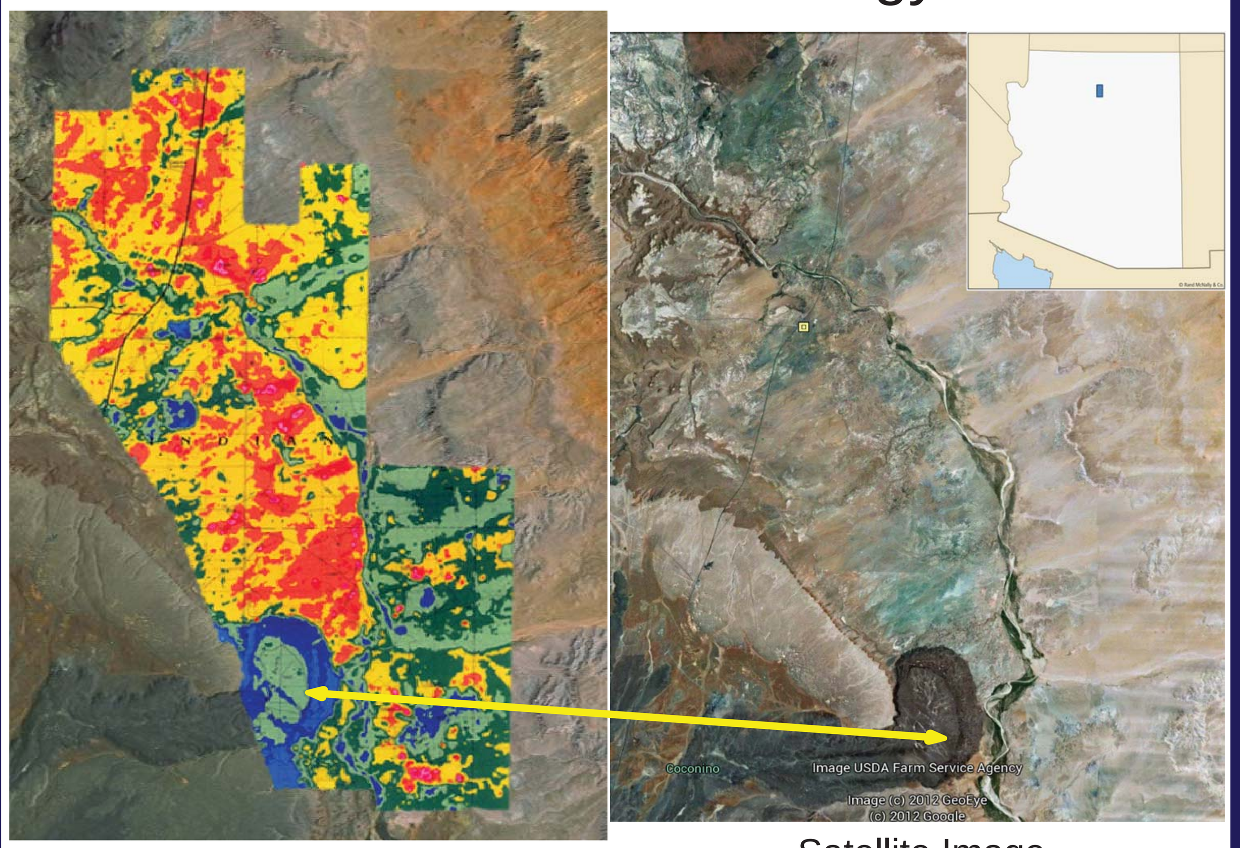
Figure 1b: Decay chain from unstable Uranium-238 to stable Lead-206

Aerial Gamma Ray Surveys

- Measures K, U, Th concentration in rock and soil
- Fly areas with 200-400 m spacing
- Low flying
- Scintillation detectors
- Collect: ground radiation as well as background
  - Cosmic
  - Equipment
  - Atmospheric

Figure 2: NSTec Helicopter with gamma ray detectors attached

Radiation and Geology



NSTec Aerial Gamma Ray Survey[5]   Satellite Image

Figure 3: On the left is an aerial gamma ray survey of our area in north central Arizona known as the Navajo Mines area, on the right is a satelite image of the same area. The yellow arrow indicates the similarity between the blue shape in the aerial gamma ray survey and the basalt flow, thus a relationship between geology and radiation.

Collecting Existing Geochemical Data

Navajo Mines Geochemical Data

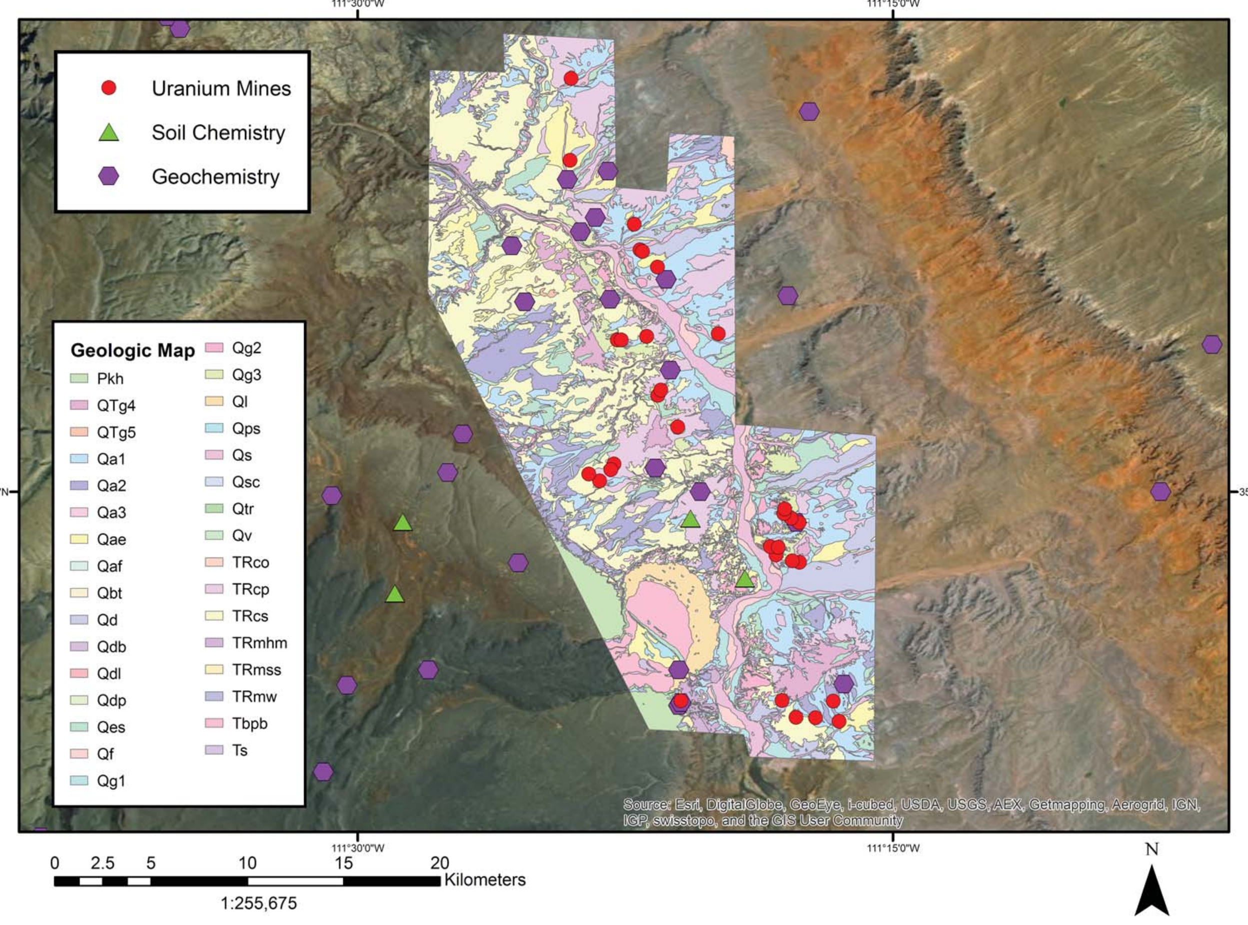
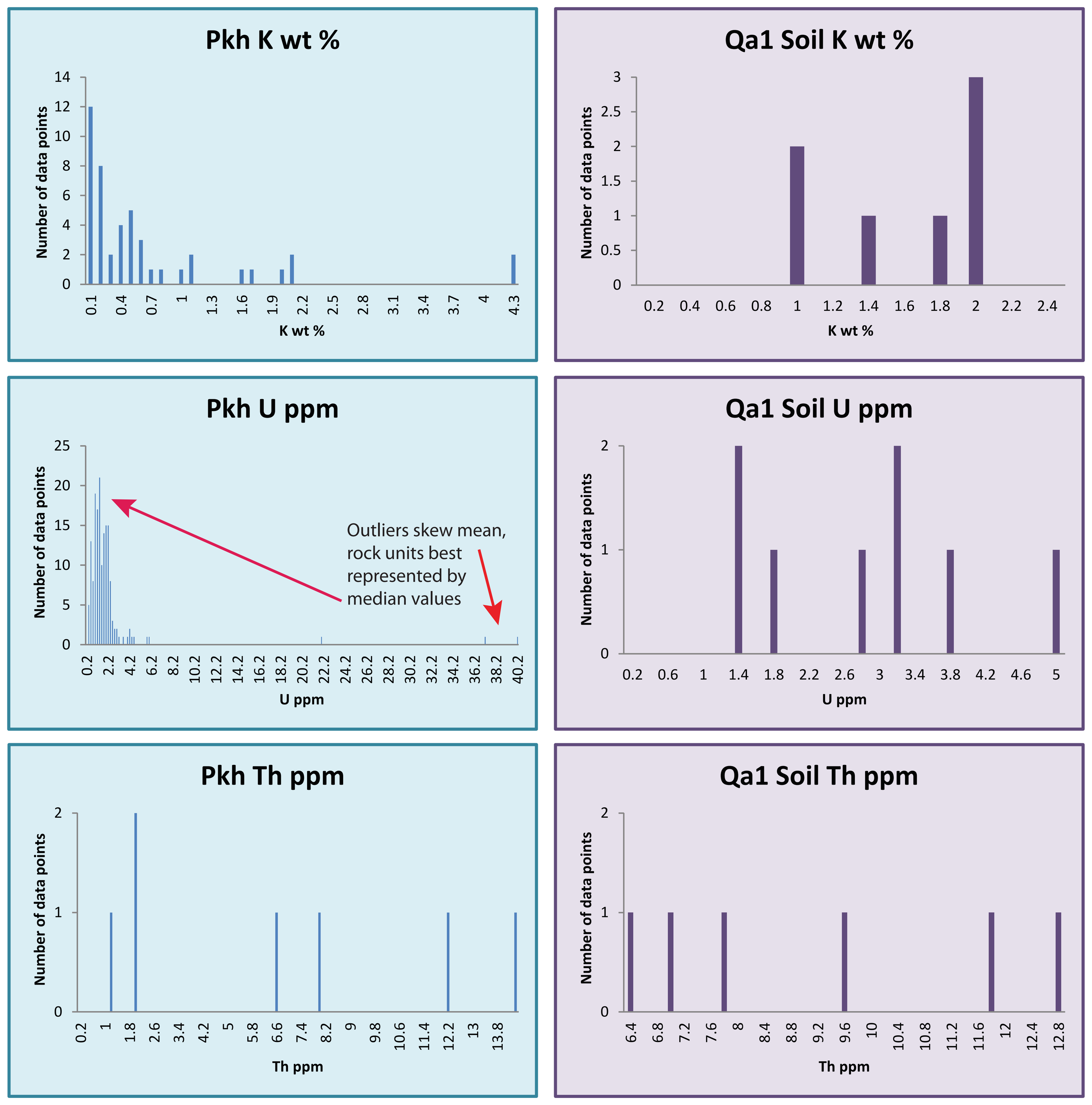


Figure 4: Displays data collected within the Navajo Mines area from national databases such as the USGS, IEDA, and GeoROC; uranium mining companies such as DIR Exploration; and scientific literature. Red points are uranium mines, blue points are soil chemistry, and purple points are geochemical data. Pastel basemap is a USGS geologic map[1].

Rock Unit Geochemistry



Pkh	K (wt %)	U (ppm)	Th (ppm)
mean	0.6525	185.26	6.5386
Standard deviation	0.9459	1670.2507	5.2315
range	4.1938	16599.7	13.1
median	0.37	1.45	6.52
mode	0.04	1.9	N/A

Qa1 Soil	K (wt %)	U (ppm)	Th (ppm)
mean	1.5469	2.7575	8.8633
Standard deviation	0.4727	1.2531	2.9402
range	1.159	3.64	7.7
median	1.799	2.915	8.53
mode	1.9	N/A	N/A

Figure 5: Example rock (blue) and soil (purple) unit reports for Pkh (limestone, Harrisburg Member, Kaibab Fm) and Qa1 (Holocene alluvial fan deposits), includes histograms and statistics of U, K, Th concentration. This is how values were assigned to geologic units with multiple data points.

Model Creation and Comparision

- Data was collected from national databases, private companies, scientific literature and field work
- Rock Unit Reports are used to constrain the U, K, Th content of each unit
- A model is created by converting concentrations of U, K, and Th for each rock and soil unit into a ground exposure rate: D=1.32 K+ 0.548 U+ 0.272 Th
- Compare the original aerial gamma ray survey to the model
- Improve the method and learn the constraints

NSTec Aerial Gamma Ray Survey[5]   **Initial Model from Geochemistry**

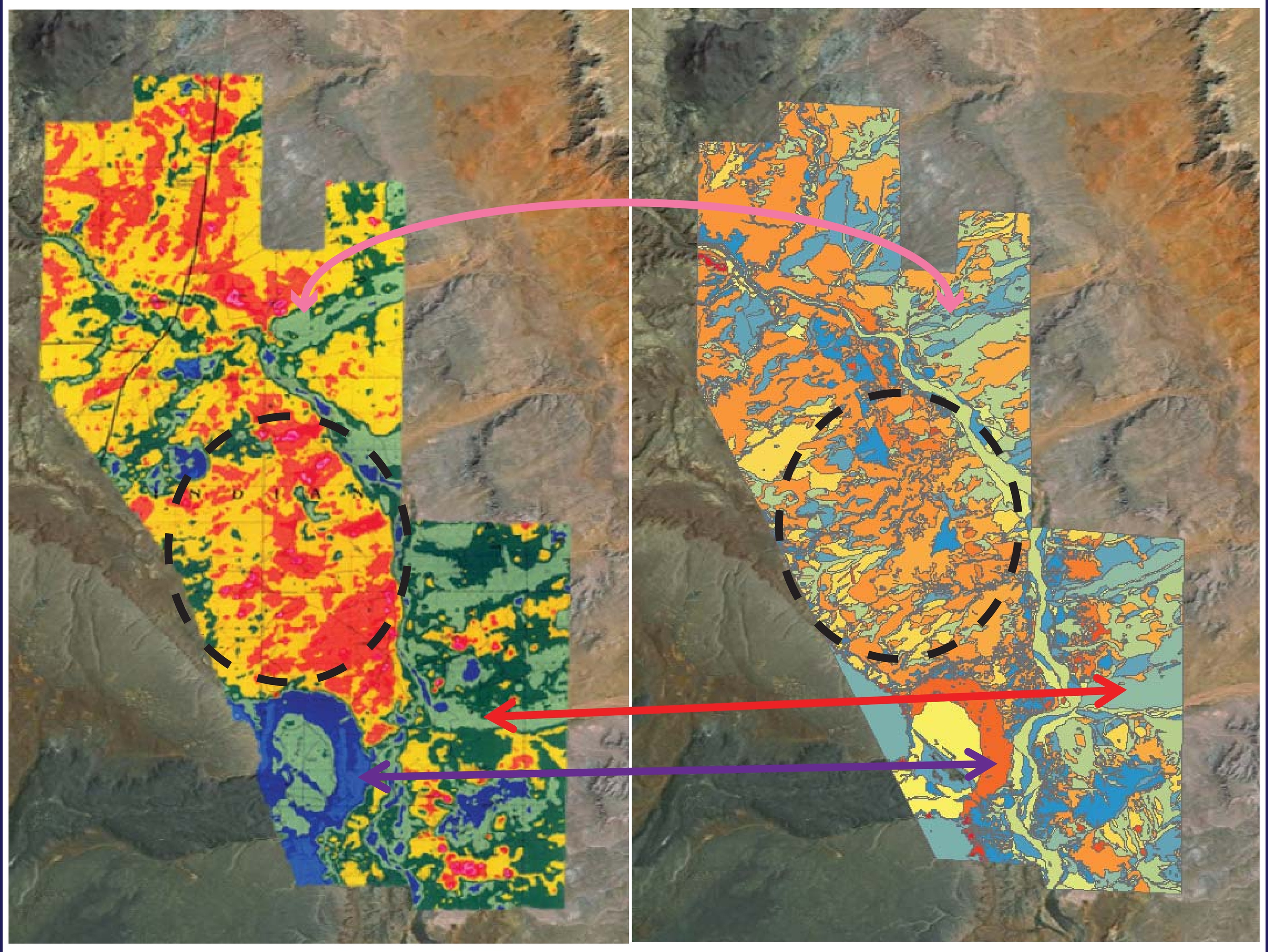


Figure 6: Both have a sliding scale from blue representing low exposure rate to red represent high exposure rate.

Pink Arrow: Shows an alluvial fan that is cooler than the bed rock around it in both the model and survey

Black Circle: Displays that in both map and model the west has overall higher exposure rates than the east

Red Arrow: Shows another set of alluvial fans that are cooler than the bedrock around them in both the model and map

Purple Arrow: Displays discrepancy between the model and the map. In the map, the outside of the Black Point basalt flow is cooler (blue) than the inside (green). In the model the outside (orange) is hotter than the inside (yellow).

Future Work & Acknowledgements

Future work will include creating a two part model containing rock and soil data using Monte Carlo N-Particle Transport Code, examining remote sensing data, creating a contoured model using ioGas, and field work, with a goal to improve the overall model.

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References

(1)Billingsley, G. H., Priest, S. S., & Felger, T. J. (2007). Geologic Map of the Cameron 30' x 60' Quadrangle, Coconino County, Northern Arizona. USGS Geological Survey.
(2)Dickson, B. L. (1995). U-series disequilibrium in Australian soils and its effect on aerial gamma-ray surveys. Journal of Geochemical Exploration, 54(3), 177-186.
(3)Dickson, B. L., Fraser, S. J., & Kinsey-Henderson, A. (1996). Interpreting aerial gamma-ray surveys utilising geomorphological and weathering models. Journal of Geochemical Exploration, 57(1), 75-88.
(4)Dickson, B. L., & Scott, K. M. (1997). Interpretation of aerial gamma-ray surveys-adding the geochemical factors. AGSO Journal of Australian Geology and Geophysics, 17, 187-200.
(5)Hendricks, T. J., (2001). An Aerial Radiological Survey of Abandoned Uranium Mines in the Navajo Nation. Report for Bechtel Nevada Remote Sensing Laboratory.
(6)Mernagh, T. P., & Miezitis, Y. (2008). A review of the geochemical processes controlling the distribution of Th in the Earth's crust and Australia's Th resources. Geoscience Australia.
(7)Minty, B. R. S. (1997). Fundamentals of airborne gamma-ray spectrometry. AGSO Journal of Australian Geology and Geophysics, 17, 39-50.
(8)Reed, A. (2012). U.S. DOE's response to the Fukushima Daiichi reactor accident: Answers and Data Products for Decision Makers, Health Phys. 102(5):557-562.
(9)Ulbrich, H. H. G. J., Ulbrich, M. N. C., Ferreira, F. J. F., Alves, L. S., Guimarães, G. B., & Fruchting, A. (2009). Levantamentos gamaespectrométricos em granitos diferenciados. I: revisão da metodologia e do comporta mento geoquímico dos elementos K, Th e U. Geologia USP. Série Científica, 9(1), 33-53.
(10)van der Meer, F. D., van der Werff, H., van Ruitenbeek, F. J., Hecker, C. A., Bakker, W. H., Noomen, M. F., ... & Woldai, T. (2012). Multi-and hyperspectral geologic remote sensing: A review. International Journal of Applied Earth Observation and Geoinformation, 14(1), 112-128.
(11)Wilford, J. R., Bierwirth, P. N., & M. A. Craig. (1997). Application of airborne gamma-ray spectrometry in soil/regolith mapping and applied geomorphology. AGSO Journal of Australian Geology and Geophysics, 17(2), 201-216.