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Mineralogy and Geochemistry of Heavy-Mineral Beach Placer Sandstones in New Mexico

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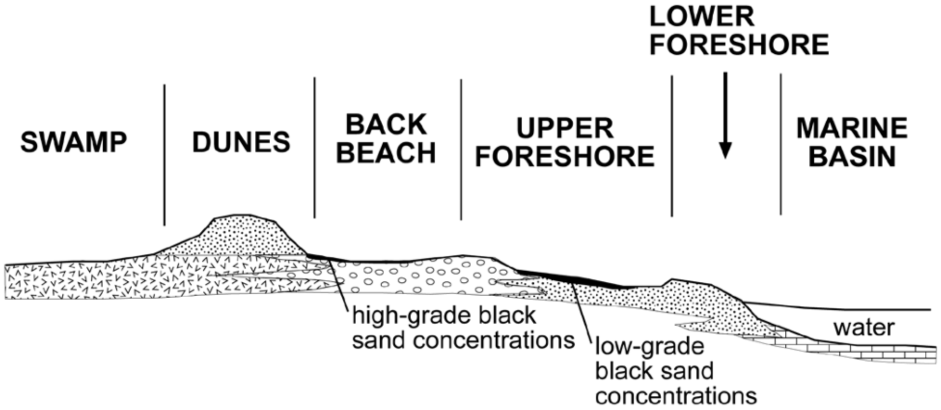
- Any persons wishing to conduct geologic investigations on the Navajo Nation must first apply for and receive a permit from the Minerals Department, P.O. Box 1910, Window Rock, Arizona 86515, phone (928) 871-6588

What are heavy-mineral sandstones?

- Natural accumulations of dense, resistant minerals
  - Zircon ($ZrSiO_4$), rutile (TiO_2), ilmenite ($FeTiO_3$), monazite ($[Ce,La]PO_4$)
- Concentrated by waves, currents, winds
  - Marginal marine environments



From McLemore (2017). Modified from Houston and Murphy (1970, 1977).

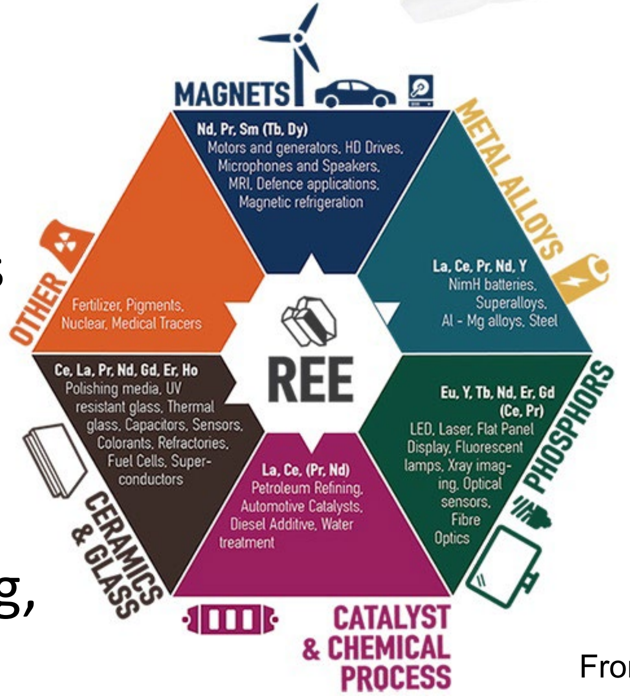
Why are they important?

- Enriched in critical minerals
  - Titanium (rutile and ilmenite)
  - Zirconium (zircon)
  - REE (monazite)
- Relatively easy to mine and process
  - Nature’s done the hard work

From usgs.gov (public domain)

Why are they important?

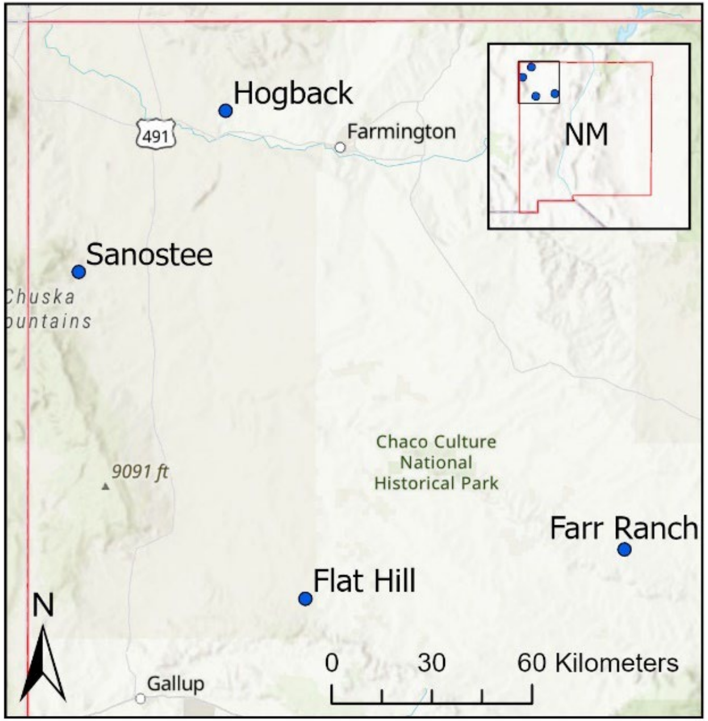
- Primary source of TiO_2 and $ZrSiO_4$
  - Ti: white pigment, alloys, carbides/nitrides, chemicals
  - Zr: abrasives, refractory, alloys, chemicals
- REE co/byproducts
  - Magnets, catalysts, polishing, batteries, phosphors



From eurare.org, eia.gov

Where do we find them?

- Worldwide as sands and sandstones
  - East coast U.S. has current and historic production
- In northwest NM, in the San Juan Basin of the Colorado Plateau



Heavy-mineral sandstones in NM

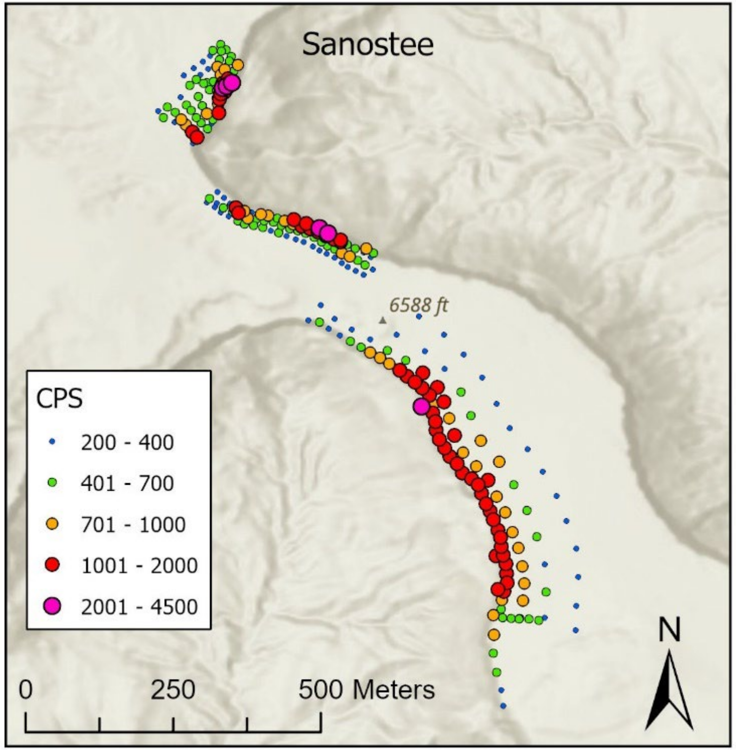
- Numerous, small heavy-mineral sandstones in the San Juan Basin
- Detailed examination of 4 areas, more in the future
  - Whole rock and trace element geochemistry
  - Radiometric maps

Ground radiometric surveys

- Many deposits originally discovered with airborne radiometrics
- Handheld scintillation counter
- “On the fly” surveys
  - Define the extent of mineralized sandstones
  - Assist in sample selection
- Variable station spacing (~15 – 50m)

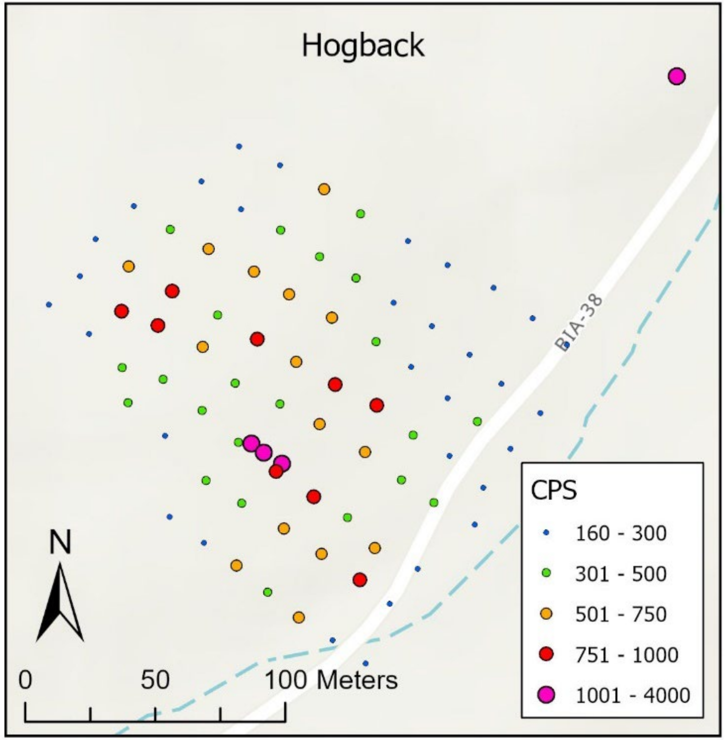
Sanostee ground radiometric map

- Sanostee deposit
  - Navajo Nation in San Juan Co.
- 234 stations
- Ledges of the mesa exposed mineralized sandstone
- 1200 m long, NW trending zone
- Likely continuous between the central and southern portion
  - Possible extension to the NW



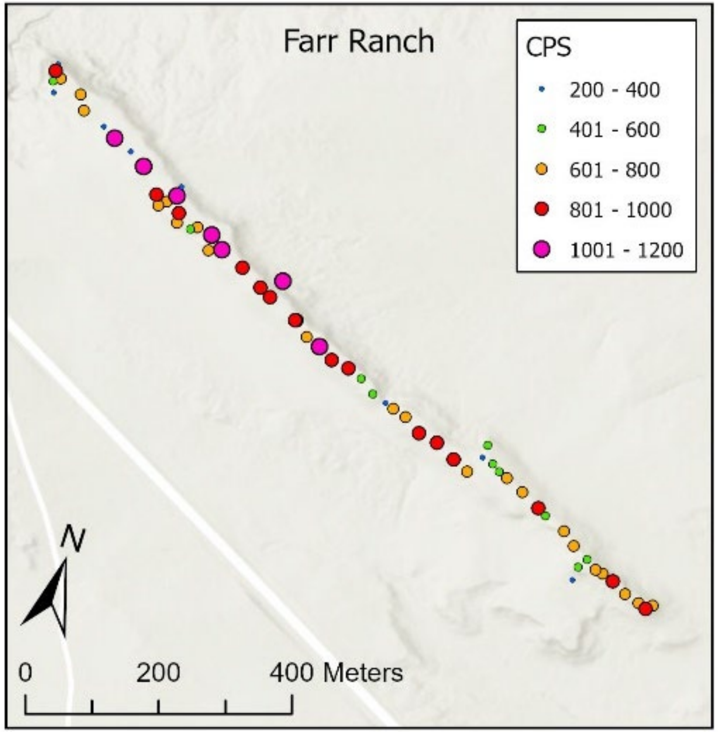
Hogback ground radiometric map

- Hogback deposit
  - San Juan Co. between Shiprock and Farmington (along the Hogback)
- 82 stations
- 200 m long, N-NW trending zone
- Less well-defined anomaly
- Stockpile of higher-grade material to the NE (historic prospecting)



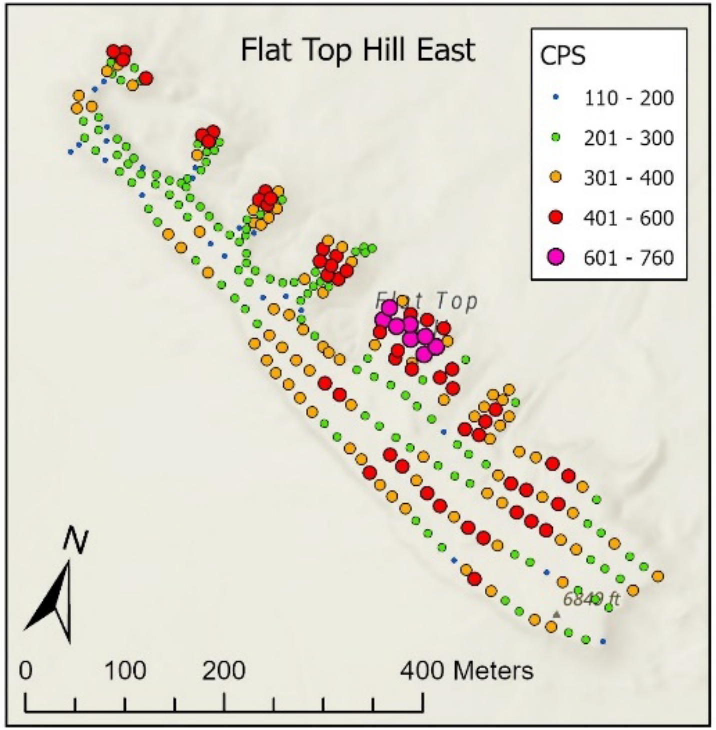
Farr Ranch ground radiometric map

- Farr Ranch (Star Lake) deposit
  - Navajo Nation in McKinley Co.
- 71 stations
- 1200 m long, NW trending zone
  - Very narrow, <50 m
- Erosion has cut away many portions of the mineralized sandstone



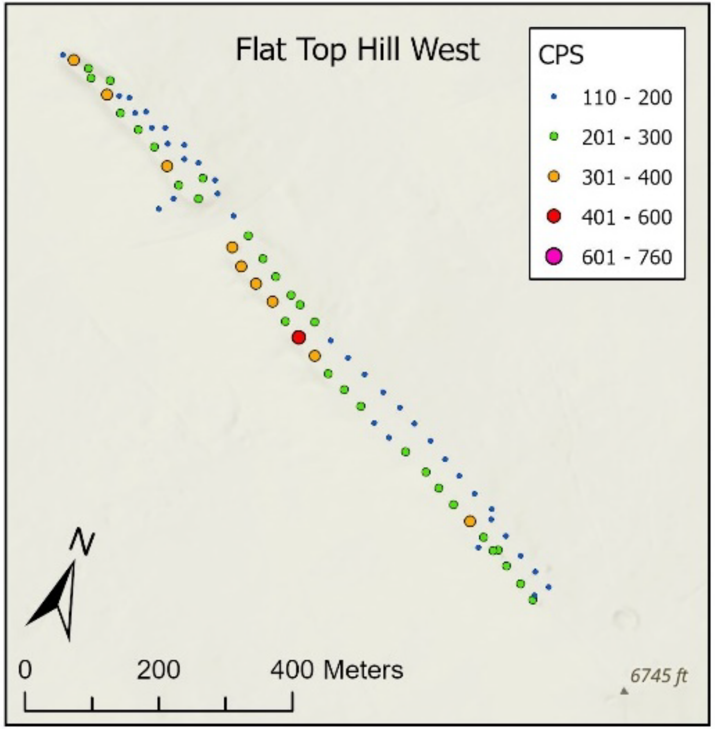
Flat Top Hill ground radiometric maps

- Flat Top Hill (Standing Rock) deposit
  - Navajo Nation in McKinley Co.
- Flat Top Hill East and West
  - Two separate but aligned mesas
- 273 stations (East)
- 800 m long, NW trending zone
- Again, erosion has cut away many portions of the mineralized sandstone
  - “Fingers” expose highest-grade material



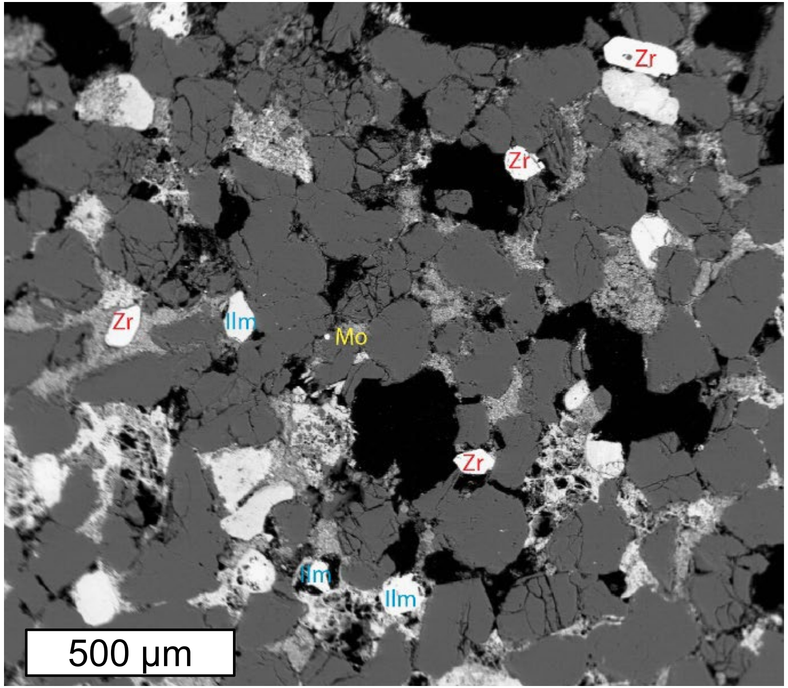
Flat Top Hill ground radiometric maps

- 1.6 km northwest of East
- Long, narrow ridge
- 75 stations
- 1000 m long, NW trending zone
- Less mineralized or more eroded (or both) than East
- No other apparent NW trending hills/mesas in the vicinity



Mineralogy of NM HM sandstones

- Variable amounts of ilmenite, rutile, zircon, monazite, quartz
  - Cemented by iron oxides
- Generally fine-grained, well sorted with subrounded to rounded clasts
- Zircon may still show terminations
  - High hardness

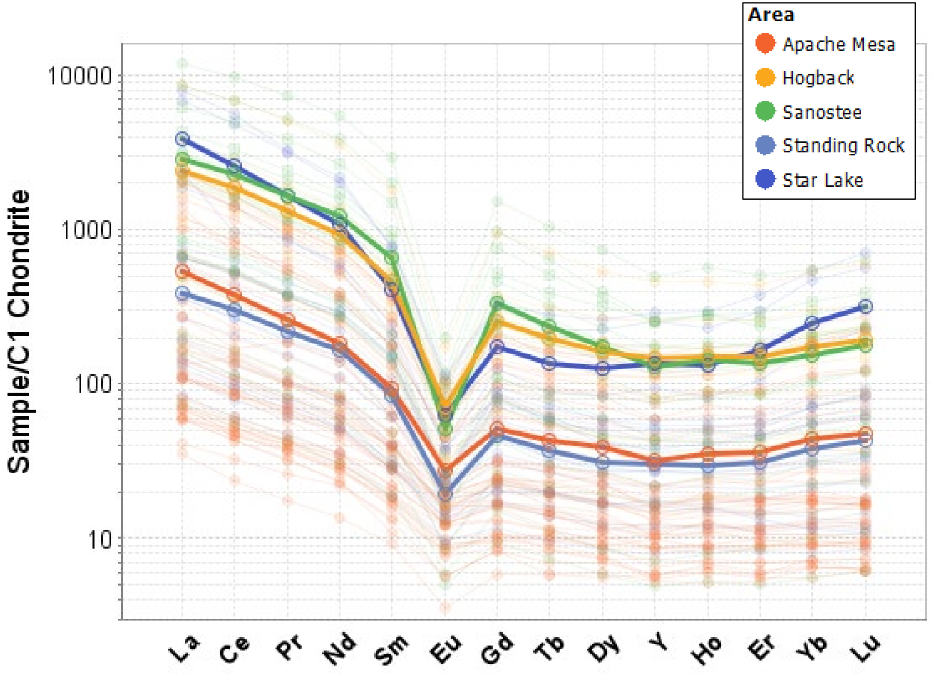


Zr: zircon; Ilm: ilmenite; Mo: monazite
From McLemore & Robison (2016)

Whole-rock and trace element data

- 49 new geochemical samples from the four sites
- Up to 29.4% TiO_2, 1.4% total REE, >1% Zr
- Distinct light REE enrichment, slight heavy REE enrichment
  - Prominent negative Eu anomaly
  - Likely explained by monazite and zircon proportions

Tab
n=9
Min
Ma
Me
Me



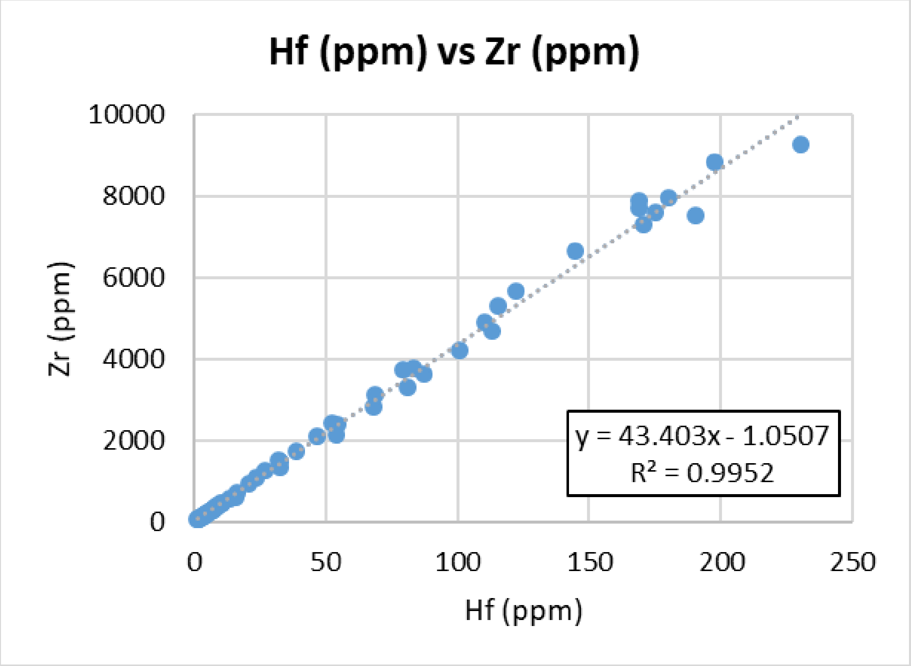
Estimating Zr content of HM sandstones

- Upper limit of detection from ALS Global in standard multielement package is 10,000 ppm
- Many of the highly mineralized samples exceed this
- Can we estimate Zr without ordering a new package?

From sandatlas.org

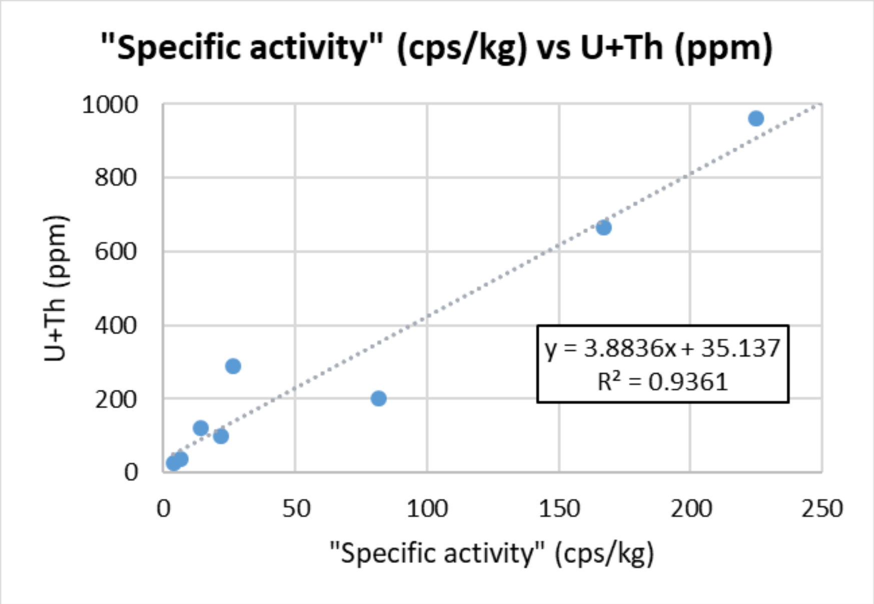
Estimating Zr content using Hf

- Yes we can!
- Hf substitutes within zircon
- Strong correlation between Hf and Zr for Zr < 10,000 ppm
- Extrapolate to estimate Zr > 10,000 ppm
- Results show our samples can contain up to 5% Zr



Estimating U+Th content using a scintillation counter

- Upper detection limit for Th is 1000 ppm
- Weigh sample over 500 g
- Measure background radioactivity and that of sample
- “specific activity” = activity per sample mass



Results from extrapolations

Sample	Laboratory data				Extrapolations			"Specific activity" (cps/kg)
	TiO_2 (%)	Zr (ppm)	TREE+Y (ppm)	U+Th (ppm)	Zr (ppm) from Hf	TREE (ppm) from Sp.act.	U+Th (ppm) from Sp.act.	
Flat12	8.74	7280	810	120.5	7399	1623	89	13.8
Flat13	2.34	1060	321	27.3	1041	1430	50	3.8
Flat18	0.58	204	150	7.9	193			nd
Hog10	6.89	3780	1446	99.0	3627	1773	119	21.6
Hog16	6.08	8830	1951	202.9	8571	2932	352	81.6
Hog17	23.60	>10000	9908	>1000	**49044**	5360	**840**	207.3
SAN 6	16.90	>10000	9628	>1000	**17230**	11872	**2149**	544.4
SAN54	0.23	264	86	8.3	295			nd
SAN56	1.10	1340	255	35.5	1431	1476	59	6.2
SAN57	18.55	>10000	4981	664.6	**32334**	4581	684	167.0
SAN58	8.21	9280	2222	289.8	9982	1868	138	26.5
SAN60	16.55	>10000	7093	959.9	**28167**	5700	909	224.9

Preliminary Conclusions

- NM heavy-mineral sandstones are worth reinvestigating for critical mineral potential as economics may change
- Locally, highly enriched in important critical minerals
- Scintillation counter is very useful in characterizing these deposits
  - Extent of deposit, sample selection, estimating U+Th content
- Future work will examine the REE distribution in monazite and zircon, more detailed petrography

Questions?