



Needs and Opportunities for R&D within the Critical Minerals

American Midwest Regional Workshop on Critical
Minerals Sustainability

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O'KEEFE INSTITUTE

SUSTAINABLE SUPPLY
OF STRATEGIC MINERALS

MISSOURI
S&T



Thomas J. O'Keefe Institute for Sustainable Supply of Strategic Minerals



- Combining existing excellence across the supply chain at Missouri S&T
- Basic and applied research to develop technology, methodologies and tools that facilitate sustainable supply of strategic minerals for United States
- Science-based policy work on strategic minerals
- Workforce development and international capacity building

mining.mst.edu/research/okeefe-institute/

2017 USGS Critical Minerals List

 Critical Mineral
 Base Metal

1 H 1.00794																	2 He 4.002602				
3 Li 6.941	4 Be 9.012182															5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050															13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80				
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29				
55 Cs 132.90545	56 Ba 137.327	57 La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)				
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 (269)	111 (272)	112 (277)				114 (289)	116 (289)	118 (293)				

Significant Impact and Likelihood of Supply Disruption

Barite Fluorspar Potash	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Significant Impact and Likelihood of Supply Disruption

Barite
Fluorspar
Potash

Energy Minerals

Batteries

Li, Co, Ni, Mn

Electronics

Ga, As, In, REE

Solar

Te, Si

Wind

REE, Co, Sc

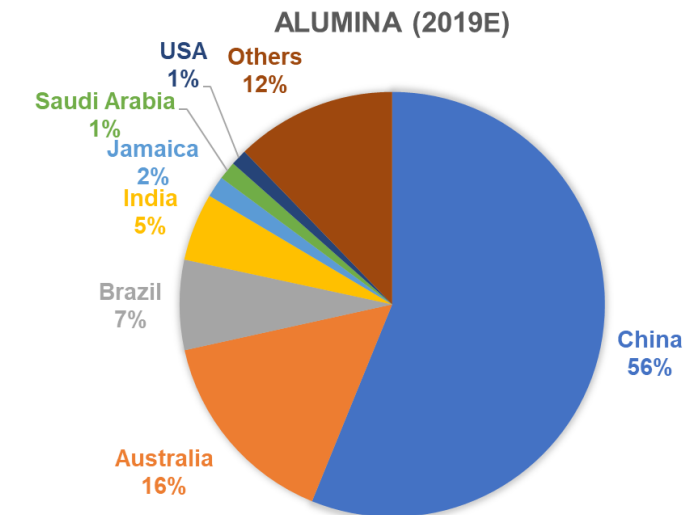
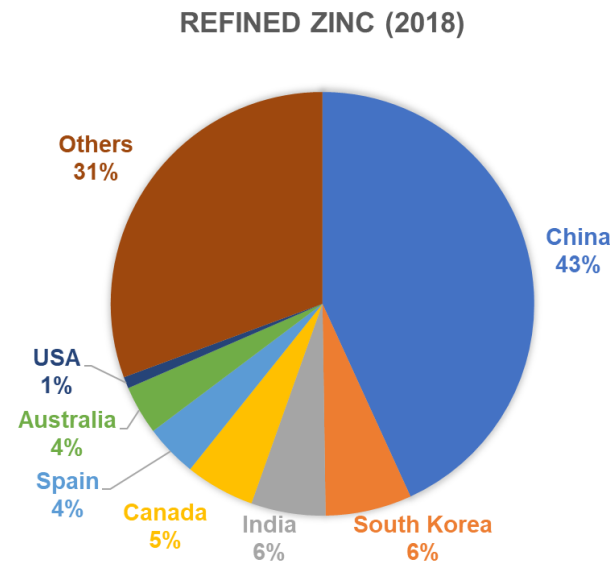
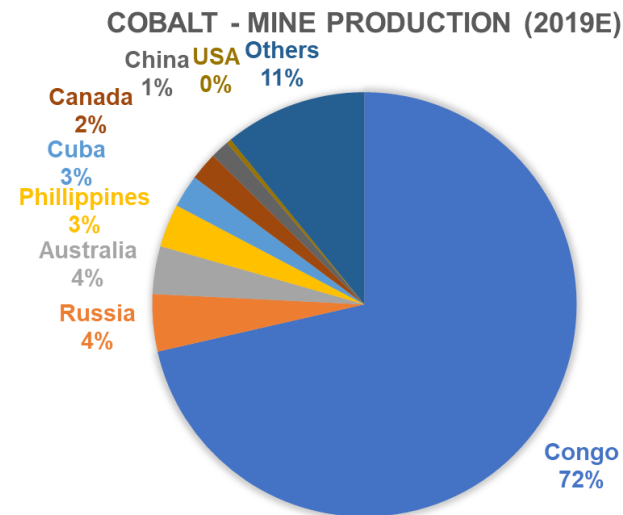
Infrastructure

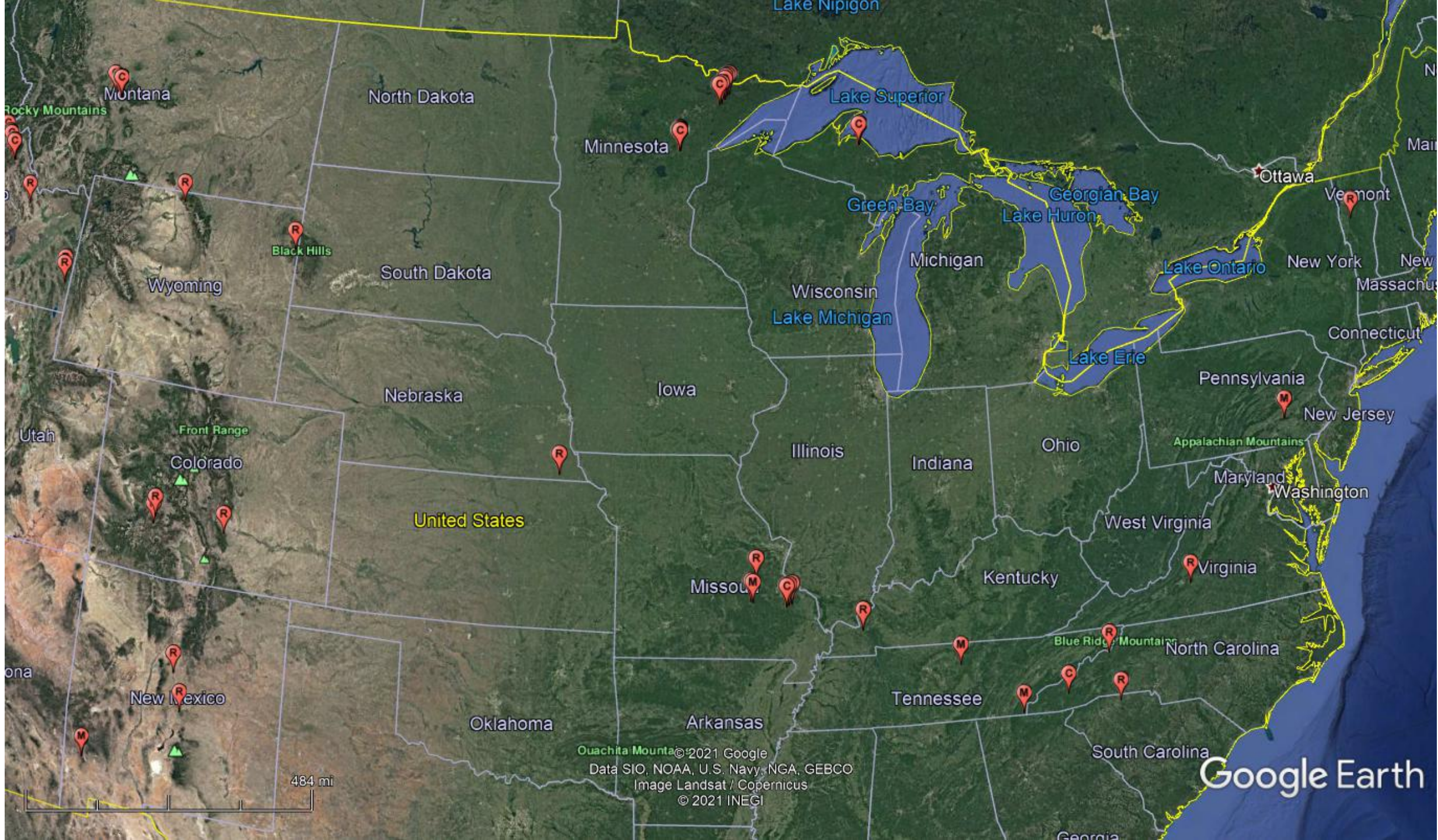
Cu, Fe, Al, Ag, Au

Raw Materials Supply – REEs, Co, In, Ga

- REEs are mined and processed as a primary target
- Co is a by-product from Ni concentrate and Cu ore processing
- In is primarily a by-product from Zn production (not mining)
- Ga is a primarily by-product from alumina production (not mining, not aluminum production)

Data from [USGS Mineral Commodity Summaries](#)

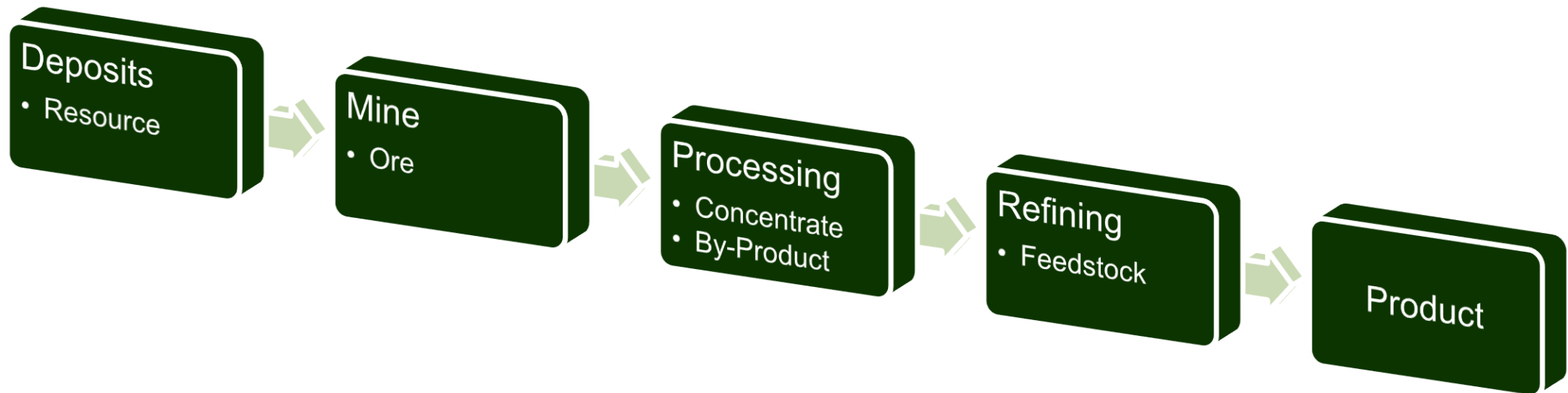




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USA Situation of REEs, Co, In, Ga Supply



Mineral	Deposits	Mines	Processing	Refining	Product
REEs	Yes	One	Limited	None	Limited
Co	Multi-metal deposits	One	Limited	None	Soon
In	Some Zn deposits	None	None	No ITO	Limited
Ga	Some Zn deposits	None	None	High purity Ga, Not GaAs	Limited

Closing Domestic Supply Chain Gaps



Support mineral exploration to uncover new deposits



Streamline mine permitting process



Develop processing and refining infrastructure and innovation



Facilitate off-take agreements between domestic “mining” and “green energy” companies



Educate workforce needed for critical minerals supply and green energy transition



Ensure sustainable extraction and processing

R&D Needs

- Support mineral exploration to uncover new deposits
 - Re-characterize existing core samples for CMs
 - Improve understanding of geologic framework
 - Develop improved ore genesis models
- Innovation in processing and refining
 - Understand deportment of CMs throughout base metal supply chain
 - Develop new flowsheet to treat low grade multi-metal feeds
- Support sustainable extraction and processing
 - Improve understanding of impacts (and risks) of tailings and other waste streams
 - Develop better reclamation techniques to facilitate sustainable post-mining land use
 - Develop technology to improve renewable energy use in mining


National Workshop:

RESILIENT SUPPLY OF CRITICAL MINERALS

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<https://criticalminerals.mst.edu/>