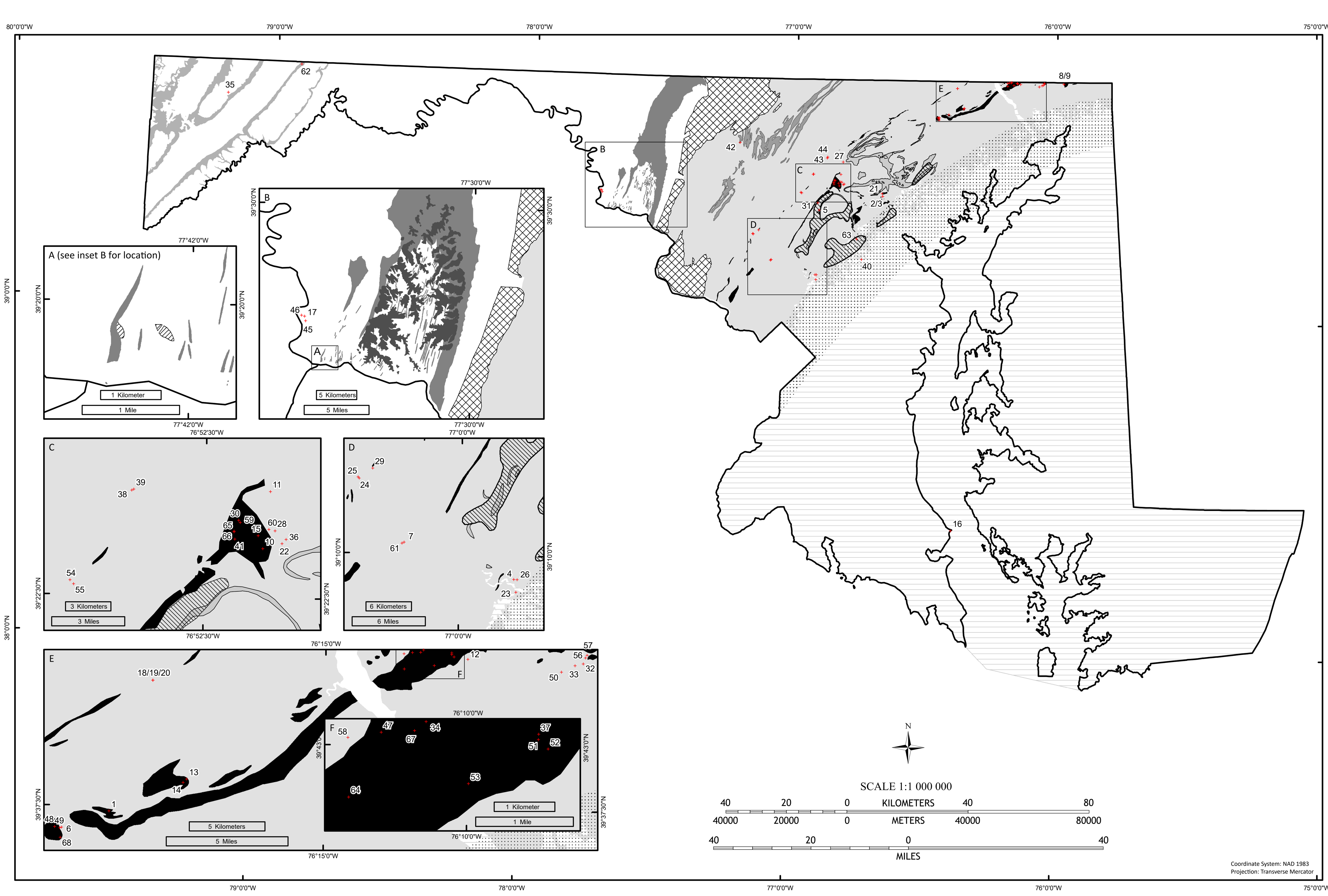

Mineral Resource Data System (MRDS) deposit (see Table 2)

AREAS OF POTENTIAL OCCURRENCE, FROM NW TO SE

- -Allegheny+Pottsville Formation high-alumina clays (westernmost Maryland)
- -Catoctin Formation
- -Middletown Valley Late Proterozoic paleosol
- -Garnet graphite gneiss (inset A only)
- -Myersville Burkettsville complex (inset B only)
- -Mesozoic Basin intrusions
- -Piedmont orogenic Au
- -Piedmont placers
- -Sams Creek Metabasalt
- -Eastern and Central Piedmont mafic-ultramafic/mafic-siliciclastic rocks
- -Eastern Piedmont pegmatitic granite
- -Cockeysville Marble
- -Fall Line placers
- -Coastal Plain placers

Critical Mineral Potential Occurrence Map of Maryland

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2020

The Critical Mineral Occurrence Potential Map of Maryland shows areas within the State of Maryland that may have the potential to contain one or more of the 35 mineral resources identified by the U.S. Department of Interior as critical to the economic and national security of the United States (Fortier et al., 2018). Production of the map was funded jointly by the Maryland Geological Survey (MGS) and the United States Geological Survey (USGS) Earth Mineral Resources Initiative (Earth MRI) and National Geological and Geophysical Data Preservation Program (NGGDPP).

To produce the map, a variety of publicly available geologic data were analyzed to identify areas within the state of Maryland where geologic conditions favor the occurrence of deposits formed by one or more of the mineral systems included in Open-File Report 2020-1042, "Systems-Deposits-Commodities-Critical Minerals Table for the Earth Mapping Resources Initiative" (Hofstra and Kreiner, 2020). Within the boundaries of the State of Maryland we have identified 14 areas that each correspond to one or more geologic units or physiographic regions or features within which one or more of the 35 critical minerals has the potential to occur. For areas that correspond to formal geologic units, area outlines correspond to geologic map unit contacts extracted from various map sources, including recently completed geologic quadrangle maps published by the MGS. For areas that correspond to physiographic regions or features, area outlines either were drawn by hand based on descriptions in references, or correspond to geologic map unit contacts extracted from map sources.

TABLE 1. AREAS OF CRITICAL MINERAL POTENTIAL OCCURRENCE

Map symbol	Area of potential occurrence	Description	Mineral system(s)--deposit type(s) (if known)[1]	Potential critical mineral commodities[2]	Historically prospected or mined critical mineral commodities	Areal extent reference
	Allegheny + Pottsville Formation high-alumina clays	Include high-alumina Mt. Savage Clay and Bolivar Clay layers. Clay layers from the Georges Creek Basin, Upper Potomac Basin, and Castleman Basin have yielded Al contents of up to 37% and contents commonly greater than 25% (Waagé, 1950). Similar clay deposits in West Virginia yielded Al contents of up to 40% in layers up to 9 m-thick, as well as contents commonly greater than 20% (Tallon and Hunter, 1959). Samples from clays of the Pottsville and Allegheny Formations in West Virginia and Maryland yielded REE contents greater than 300 ppm (TetraTech, 2018), and similar high-alumina clay deposits in Pennsylvania yielded Li contents as high as 2100 ppm (Tortelot and Brenner-Tourtelot, 1977).	Chemical Weathering--Bauxite, Clay	Al, Li, REE, *Ga*	none known	Brezinski and Conkwright, 2013
	Catoctin Formation	Includes rhyolitic dike and metabasalt member units. Pillow structures reported within portions of the metabasalt member in Central Virginia (Espenshade, 1986; Spencer et al., 1989; Klein et al., 1990) suggest the potential for volcanogenic seafloor deposits, although no evidence of subaqueous deposition has been found in Maryland deposits. Elevated REE abundances from a sample of the rhyolitic dike member indicate a potential source of REEs and associated critical mineral commodities (Burton et al., 1995).	Volcanogenic Seafloor Magmatic REE--Peralkaline pegmatites	*As, barite, Bi, Co, Ga, Ge, In, Mn, Sb, Sn, Te* REE, *Be, Hf, Nb, Ta, U, Zr*	none known	Fauth, 1977; Brezinski, 2004a, 2004b, 2004d, 2009; Brezinski and Fauth, 2005, 2009
	Coastal Plain placers	Mesozoic and Cenozoic Coastal Plain sands that include heavy mineral sands potentially enriched in Zr-, Ti-, and REE-bearing minerals. Magnetic surveys have revealed shallow heavy mineral sediment concentrations in Chesapeake Bay (Shah et al., 2012). Zircon has been reported as a typical component of heavy mineral assemblages in fluvial facies of the Coastal Plain (Glaser, 1971). Anomalously high mean Ti concentrations have been demonstrated for correlative sediments in an area corresponding to the majority of the Coastal Plain in Virginia (Van Gosen and Ellefsen, 2018). Coastal Plain sand deposits of the Lakehurst district in nearby southern New Jersey have historically produced ilmenite (Van Gosen and Ellefsen, 2018). The Cove Point deposit in Calvert County has yielded samples with elevated monazite (Bern et al., 2016) and over 20% rutile (Shah et al., 2017), and as recently as 1962 produced ilmenite, rutile, and zircon (Engineering and Mining Journal, 1955; Berquist et al., 2015).	Placer--Monazite/xenotime, Ilmenite/rutile/leucoxene, Zircon)	REE, Ti, Zr, *Hf*	Ti, Zr	none
	Cockeysville Marble	Includes Phlogopitic Metalimestone Member reported to include some bedding surfaces rich in graphite (Crowley, 1976).	Metamorphic--Graphite	graphite	none known	Horton et al., 2017
	Eastern and Central Piedmont mafic-ultramafic/mafic-siliciclastic rocks	Mafic-ultramafic bodies (and adjacent mineralized rocks) of debated origin and of diverse composition and geologic context. Bodies range in size from a few centimeters to several kilometers in length (Candela et al., 1989), and with minor exceptions occur as intercalated slices or blocks within the predominantly metaclastic Morgan Run Formation (Muller et al., 1989) and as intercalated slices, blocks, and layers within the metamorphosed plutonic-volcanic-volcaniclastic Baltimore Mafic Complex (Crowley, 1976). Interpretations put forth for the origins of the various intercalated mafic-ultramafic bodies and their associated mineral deposits are diverse and complex and vary between bodies. Interpretations include epigenetic hydrothermal vein mineralization (Heyl and Pearre, 1965), deposition of exhalative detrital ultramafite layers interbedded with other metasediments (Burke, 1987; Candela et al., 1989), emplacement onto metasedimentary rocks of mineralized ophiolite fragments either by gravitational slumping (Crowley, 1976) or tectonic interleaving (Morgan, 1977), tectonic emplacement of mineralized island-arc basement material onto metasedimentary rocks (Sinha et al., 1980), and premetamorphic mafic-ultramafic layering within a layered mafic body intrusive into metasedimentary rocks (Knopf and Jonas, 1929; Herz, 1951; Pearre and Heyl, 1960; Hopson, 1964; Southwick, 1970; Higgins, 1972; Gates et al., 1991 ; Sinha et al., 2012). Mineral deposits associated with mafic-ultramafic bodies have not been mined since WWII, but historically yielded more than 300,000 tons of chromite, over 10,000 tons of metallic Cu, several hundred tons of Fe ore, along with minor amounts of Ag, Al, As, Au, Co, Mg, Mn, Ni, and Ti (Pearre and Heyl, 1959, 1960; Heyl and Pearre, 1965; Kuff, 1981; Kuff and Sushko, 1983; McFaul et al., 2000).	Volcanogenic Seafloor Mafic Magmatic	As, Mg, Mn, *Co, barite, Bi, Ga, Ge, In, Sb, Sn, Te* Co, Cr, Ti, *PGE, REE, Te, V*	Al, As, Co, Cr, Mg, Mn, Ti	Horton et al., 2017
	Eastern Piedmont pegmatitic granite	Occur as swarms of tabular intrusions commonly concordant to the foliation and/or layering of host rocks (Hopson, 1964). Rb-Sr ages around 425 m.y. were determined for minerals separated from five pegmatite dikes intruding the Baltimore Gneiss Domes (Tilton et al., 1959; Wetherill et al., 1966), although the extent to which these ages reflect intrusion versus subsequent thermal events remains unclear (e.g. Higgins, 1972). Due to age uncertainty and ambiguous field relations, much uncertainty remains concerning the origins of the pegmatitic intrusions and their relationship to adjacent units. Intrusions vary in outcrop size from less than a foot in thickness and a few feet in length, to sheets several hundred feet thick and over a mile long (Knopf and Jonas, 1929). Intrusions are of alkali-granite composition and consist predominantly of quartz, albite, microcline-perthite, and muscovite (Hopson, 1964). Accessory amounts of the REE-bearing mineral allanite has been reported as occurring sporadically within the intrusions, in some cases associated with metasomatism of dolomitic marble wall rock (Ostrander, 1940). Potash has been produced commercially from microcline in pegmatitic granites (Cleaves, 1964; Mathews and Watson, 1929). Small quantities of beryl have also been produced historically (Cleaves, 1964).	Magmatic REE--pegmatites	REE, Be, *Hf, Nb, Ta, U, Zr*	Be	Hopson, 1964
	Fall Line placers	Mesozoic and Cenozoic sands derived from Piedmont and Blue Ridge crystalline rocks and deposited along paleoshorelines located near the "Fall Line," i.e. the boundary separating the Piedmont and Coastal Plain physiographic provinces. The majority of mined heavy mineral sand deposits in the southeastern United States are located along the fall line (Shah et al., 2017), including past producers of ilmenite and zircon in Virginia and North Carolina (Carpenter and Carpenter, 1991), and monazite in South Carolina (Mertie, 1975). Heavy mineral sands deposited in a similar geologic setting along the fall line from Alabama to North Carolina have yielded elevated monazite and xenotime concentrations (Bern et al., 2016; Shah et al., 2017).	Placer--Monazite/xenotime, Ilmenite/rutile/leucoxene, Zircon)	REE, Ti, Zr, *Hf*	none known	none
	Garnet graphite gneiss	Garnet graphite paragneiss with reported 10 to 20% of volume composed of flecks and books of graphite (Burton and Southworth, 1993; Burton et al., 1995; Southworth and Brezinski, 1996). Gneiss weathers to soil that contains abundant graphite (Southworth and Brezinski, 1996).	Metamorphic--Graphite	graphite	none known	Southworth and Brezinski, 1996
	Mesozoic Basin intrusions	Includes diabase sheets that potentially host hydrothermal vein mineralization. A ferrogabbro zone in an equivalent diabase sheet in Pennsylvania and similar zones in a ferrodiorite deposit in New Jersey yielded elevated concentrations of Pd and Pt (Robinson, 1988). Co- and As-bearing sulfide minerals have been found in similar zones in Pennsylvania (Gordon, 1922). Findings in other states suggest similar diabase sheets in Maryland may include mineralized zones enriched in critical mineral commodities.	Mafic Magmatic	As, Co, Cr, *PGE, REE, Te, Ti, V*	Maryland: none known; Pennsylvania: As, Co	Horton et al., 2017
	Middletown Valley Late Proterozoic paleosol (underlies Catoctin Formation)	Paleosol of poorly constrained extent, thickness, and composition. Overlies Grenville basement crystalline rocks including anorogenic (A-type) granitic rocks compositionally similar to the Catoctin Formation rhyolitic dike member, a sample of which yielded elevated REE abundances (Burton et al., 1995). Underlies Swift Run Formation (too small to map at this scale) and may be found beneath areas mapped as either Catoctin Formation or Swift Run Formation (D.K. Brezinski, personal communication, April 3, 2020). May represent concentrated mineral accumulations derived from underlying granitic material as a consequence of prolonged pedogenesis (Foley and Ayuso, 2015).	Chemical Weathering--Regolith (ion adsorption) REE	REE	none known	Fauth, 1977; Brezinski, 2004a, 2004b, 2004d, 2009; Brezinski and Fauth, 2005, 2009
	Myersville-Burkettsville complex	Regolith interval typically greater than 6 ft thick, of unknown age (Kraft, 2002). Overlies both Grenville basement crystalline rocks and Catoctin Formation (Brezinski, 2004b, 2004d, 2009; Brezinski and Fauth, 2005, 2009). Consists of a gravelly weathered residuum derived from metabasalt and granitic gneiss (Kraft, 2002). May represent concentrated mineral accumulations derived from granitic source material as a consequence of prolonged pedogenesis (Foley and Ayuso, 2015).	Chemical Weathering--Regolith (ion adsorption) REE	*REE*	none known	Brezinski, 2004d, 2009; Brezinski and Fauth, 2005, 2009
	Piedmont orogenic Au	Metamorphic rocks host quartz veins associated with gold mineralization. Quartz veins and mineralization occur over the entire Piedmont but are most concentrated in Montgomery County. Both quartz veins and placer deposits have been mined (Kuff, 1987). Gold deposits have not been mined since the 1940's, but historically produced approximately 6000 troy ounces (Cleaves, 1964). The bismuth-bearing mineral tetradymite is reported as occuring along a quartz vein at one locality (Emmons, 1890).	Orogenic--Gold	Bi, *As, Sb, Te, W*	Bi	Horton et al., 2017
	Piedmont placers	Quaternary sands and gravels derived from Piedmont and Blue Ridge crystalline rocks and deposited in stream valleys. Numerous minor fluvial placer deposits have been prospected and mined for heavy minerals, including monazite and zircon, within the western Piedmont of other southeastern states (Mertie, 1953; McFaul et al., 2000), and larger deposits may remain undiscovered (Mertie, 1975). In an area located in a similar geologic setting in southeastern Pennsylvania, anomalously elevated radiometric Th has been reported (Smith, 1997), as have the locations of Th and REE processing plants (McFaul et al., 2000). Geochemical and geophysical data have been used to infer elevated REE concentrations in placer deposits in similar geologic settings elsewhere in the southeastern United States (Shah et al., 2017).	Placer--Monazite/xenotime, Zircon	REE, Zr, *Hf*	none known	Horton et al., 2017
	Sams Creek Metabasalt	Abundant metabasalt deposits of debated age and origin. Pillow structures reported within portions of the metabasalt in the Walkersville quadrangle, Frederick County, Maryland (Brezinski et al., 2004) are consistent with volcanogenic seafloor deposits. Metabasalt deposits are spatially associated with massive marble and metaclastic deposits although stratigraphic relationships between lithologic units remain unclear (Reger and Edwards Jr., 2006). Cu deposits, and historically less productive Pb-Ag-Zn-Cu, Zn-Cu and barite deposits have been mined or prospected at numerous locations, with mineralization typically concentrated at or near the boundary between metabasalt and marble deposits (Heyl and Pearre, 1965). Mineral deposits associated with the metabasalt have not been mined since WWII, but historically yielded over 4000 tons of metallic copper, approximately 70 tons of metallic Zn, unreported quantities of Fe, and minor amounts of barite, Pb, Ag, and Au (Heyl and Pearre, 1965; McFaul et al., 2000).	Volcanogenic Seafloor	Barite, *As, Bi, Co, Ga, Ge, In, Mn, Sb, Sn, Te*	Barite	Horton et al., 2017

1. Mineral systems and deposit types after Hofstra and Kreiner, 2020
2. On the basis of in-text references; italics: on the basis of Hofstra and Kreiner, 2020

TABLE 2. SUMMARY OF MINERAL RESOURCE DATA SYSTEM (MRDS) RECORDS RELEVANT TO CRITICAL MINERAL OCCURRENCE POTENTIAL IN MARYLAND[1]

# (on map)	Deposit ID	Site name	Commodities summary[2]	Development status[3]	Grade[4]
1	10121809	Ayres Mine	Cr	PP	D
2	10067845	Bare Hills Copper Mine	Cu, Co, Ni	PP	D
3	10194383	Bare Hills Copper Mine	Cu, Co, Ni	PP	D
4	10145462	Ben Murphy Mica-Beryl Mine	Be, Mica	PP	D
5	10145904	Biddison Pegmatite Deposit	Be, Mica, Feldspar	Pr	D
6	10218603	Birdseye Mine	Cr	PP	D
7	10243598	Brookville Mine	Mn	PP	D
8	10084023	Brown Farm Placer	Cr	PP	D
9	10242699	Browns Farm Placer	Cr	PP	D
10	10084506	Calhoun	Cr	PP	D
11	10145365	Calhoun Mine	Cr	PP	D
12	10291785	Cedar Run	Cr	Pr	D
13	10243235	Cherry Hill Chrome Sand Placer	Cr	PP	B
14	10145731	Cherry Hill Mine	Cr	PP	D
15	10169501	Choate Mine	Cr, Fe, Si	PP	B
16	10067935	Cove Point Placer	Ti-rutile, Ti-illmenite, Zr	PP	B
17	10194353	Dargan Mine	Mn	PP	D
18	10068347	Dinning Mine	Ti, metal, Fe, P-phosphates	O	B
19	10083904	Dinning Mine	Ti, metal, Fe	PP	C
20	10266778	Dinning Mine	Ti, Fe, P-phosphates	Pr	D
21	10083861	Discovery Workings/Main Workings At Bare Hills District	Cr	PP	D
22	10218536	Dolfield Placer	Cr, Si, Mg, Fe, Al, Ti	PP	D
23	10267523	Earth Products Company Mines	Feldspar, Be, mica	PP	D
24	10243171	Etchison Mine	Al, Ca, Cr, Fe, Mg, Si	PP	B
25	10100513	Etchison Mine & Lyde Griffith Property	Cr	PP	D
26	10291499	George Iager Beryl-Mica Prospects	Be, mica	PP	D
27	10038138	Glyndon	Fe, Cr, Pt	O	D
28	10242528	Gore Placer	Cr, Al, Ca, Fe, Mg, Si, Ti	Pr	B
29	10291511	Griffith Mine	Al, Fe, Si, Cr	PP	D
30	10121099	Harris Mine	Cr	PP	D
31	10291531	Henryton Pegmatite	Be, feldspar, mica	Pr	D
32	10170289	John R. Harris Prospect	Cr	Pr	D
33	10121826	Lincoln Farm Placer	Cr	PP	C
34	10083863	Line Pit Lowe's Mine	Cr	PP	B
35	10121267	Louis A Morgart Clay Deposit	Al, Fe, Si, Ti	Pr	D
36	10145896	Lutz Chromite Placer	Cr	Pr	D
37	10170269	Marshall Sand Chrome Property	Cr	PP	D
38	10067844	Mineral Hill	Cu, Co, Ni	PP	D
39	10242703	Mineral Hill Mine	Fe, Cu, Co	PP	D
40	10218269	Mineral Ridge Property	Al, fire clay (refractory, sand and gravel, construction)	PP	D
41	10267246	Old Triplett Placer	Cr	PP	D
42	10243519	P.G.Saubles Quarry	Ba-barite	PP	D
43	10105495	Patapsco	Cu, Co, Ni	PP	C
44	10145484	Patapsco Mines	Ni, Fe, Cu, Co	PP	B
45	10084500	Potomac Refining Co. Mine	Mn	PP	C
46	10243173	Potomac Refining Company Deposit	Fe, Mn	PP	C
47	10243697	Preston Farm Pits	Cr	PP	B
48	10267083	Reed Mine	Al, Ca, Cr, Fe, Mg, Si, Ti	PP	D
49	10106473	Reed Mine Et Al., Jarretsville-Dublin District	Cr	PP	C
50	10169536	Reynolds Farm Placer	Cr	PP	D
51	10169882	Riley Sand Chrome Property	Cr, feldspar, talc-soapstone	Pr	D
52	10267383	Schofield Sand Chrome Deposit	Cr, feldspar, talc-soapstone	O	C
53	10267165	Southwest Rock Springs Pits	Cr	PP	C
54	10067843	Springfield	Co, Cu, Ni	PP	B
55	10267263	Springfield Mine	Cu, Fe, Co	PP	D
56	10083866	Stevenson Farm Placer	Cr	PP	D
57	10218418	Stevenson Farm Placer	Cr	PP	D
58	10194239	Stubbs Sand-Chrome Property	Cr	Pr	D
59	10194410	Triplett Placer	Cr, Ti, Si, Mg, Fe, Al, Ca	PP	C
60	10169984	Unnamed Mine	Ti, Si, Mg, Fe, Cr, Al, water, free Ca	PP	D
61	10100512	Unnamed, Near Brookville	Mn	PP	D
62	10121598	Upper Tunnel Deposit	Fire clay (refractory)	PP	D
63	10291821	Waranch Prospect	U	Pr	B
64	10266794	Weiant Property	Cr, feldspar, stone	PP	B
65	10267377	Weir Mine	Cr	PP	D
66	10084019	Weir Mine Et Al.	Cr	PP	D
67	10243287	West Placer Area	Cr, Al, Ca, Fe, Mg, Si, Ti	Pr	D
68	10267087	Wilkins Mine	Cr	PP	C

1. Includes select fields and entries extracted from the Mineral Resources Data System (MRDS), a USGS collection of reports describing metallic and nonmetallic mineral resources throughout the world (McFaul, 2000). Entries displayed on this map include occurrences, past producers, and prospects from the state of Maryland that list as commodities one or more of the 35 critical mineral resources. Note that some entries are likely duplicated and that deposits vary widely by grade.

2. Al, aluminum; Ba, barium; Be, beryllium; Ca, calcium; Co, cobalt; Cr, chromium; Cu, copper; Fe, iron; Mg, magnesium; Mn, manganese; Ni, nickel; P, phosphorus; Pt, platinum; Si, silicon; Ti, titanium; U, uranium; Zr, zirconium

3. PP, past producer; Pr, prospect; O, occurrence

4. MRDS evaluation of overall quality and completeness of deposit record

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