

Mappable Criteria for Resource Assessment of Orogenic and Metamorphic Graphite Mineral Systems

George Case¹, M. Rebecca Stokes²

¹U.S. Geological Survey Alaska Science Center, Anchorage, United States, ²U.S. Geological Survey Geology, Energy, and Minerals Science Center, Reston, United States

Natural graphite is a critical mineral commodity owing to its use in lithium-ion battery anode material and susceptibility to supply disruption. By utilizing the mineral systems framework, well-defined mappable criteria can support resource assessment and exploration to secure future domestic supply. Economically significant graphite forms in metamorphic and orogenic mineral systems that yield flake and hydrothermal vein (lump and chip) deposits, respectively. Regional amphibolite to granulite facies metamorphism triggered by continent-scale collisional orogenesis drives the formation of graphite in these systems. Flake graphite deposits originate from organic carbon ($\pm$ vanadium-uranium-molybdenum)-rich sedimentary rocks subjected to such conditions. Widespread devolatilization and anatexis of calcareous and carbonaceous rocks at granulite facies can enhance flake graphite quality and grade, whereas mobilizing fluids rich in CO₂ and CH₄ may ascend to higher crustal levels along structural conduits to precipitate graphite vein deposits. Over 90% of global graphite resources formed during Proterozoic pulses of supercontinent assembly, though the most significant deposits in the United States are related to the Paleozoic assembly of Pangea in the Appalachian orogen or Mesozoic orogenesis in the Kigluaik mountains. Lithotectonic maps and geochronologic data aid in the delineation of permissive metamorphic belts as focus areas. Carbon sources can be identified using a combination of geologic maps and geochemical data, specifically redox-sensitive metal (V, U, Mo) concentrations and carbon isotopic data. Drivers and heat energy sources are best delineated by metamorphic grade maps where available, or lithologic descriptions that include indicator minerals such as sillimanite and graphite. Aerial electromagnetic surveys are ideal for mapping graphitic lithologies and, coupled with aeromagnetic data, also reveal regional-scale fluid conduits or high strain zones. Ground electromagnetic surveys are needed to delineate smaller vein deposits. This mineral systems framework optimizes graphite resource assessment and exploration by defining mappable features common to both flake and vein-type deposits.