Glendon and Robbins AES alignments in the Carolina Terrane of central North Carolina: Review of geology and metallogeny

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Foreword

Introduction and statement of purpose

This report is one of a series of four North Carolina Geological Survey open-file reports and North Carolina Geological Survey, Special Publication 11, prepared in cooperation with the North Carolina Geological Survey, that provide a geologic and metallogenic review and analysis of several groups and associations of historic gold mines in the Carolina Terrane in central North Carolina. Although representing diverse styles of mineralization, the gold deposits reviewed in these reports all appear to represent a broad spectrum of orogenic gold deposits within the classification of **Grooves *et al*. (1998)**. This includes classic low-sulfidation mesozonal orogenic narrow-vein lode gold deposits, represent by mines of the Gold Hill District (Gold Hill-type) and similar deposits along the Gold Hill Fault Zone (**Moye, 2016**); a newly recognized style of large-tonnage, low-grade mesozonal orogenic deposits with disseminated and stockwork vein mineralization (Sawyer Type); and a possibly unique occurrence of epizonal orogenic mineralization with bonanza-grade Au-Ag-Te mineralization. Deposit analysis indicates that, although geographically widespread and hosted by rocks with a wide range of ages, these various styles of orogenic gold deposits all formed during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**).

Sawyer-type high-tonnage mesozonal orogenic deposits

The newly defined Sawyer-type mesozonal orogenic gold deposits include mineralization at the historic New Sawyer, Sawyer, Jones-Keystone, and Lofflin mines in northwest Randolph County; the Russell and Coggins mines in the Ophir District in Montgomery County; and possibly the Burns-Allen-Red Hill deposit near Robbins in Moore County, North Carolina.

These deposits are characterized by often multiple parallel or *en echelon* lenses of silicic ore-grade mineralization, meters to tens of meters wide and tens to hundreds of meters long, enclosed by zones of pyritic phyllic alteration tens to hundreds of meters wide and often hundreds to thousands of meters long. Alteration and mineralization intensity are heterogeneous and gradational with indefinite boundaries, and ore grade is typically determined by assay. The large volume of rock that has experienced pervasive sulfidation in these deposits could arguably be compared to high-sulfidation alteration.

Gold occurs with disseminated pyrite and narrow, millimeter-scale, cleavage-parallel quartz ± pyrite vein swarms and stockworks. Sulfide minerals average about 2-5 vol%, locally up to 10 vol%, dominated by pyrite ± accessory arsenopyrite ± minor pyrrhotite with trace base metal sulfides. The characteristic trace element association for Sawyer-type gold mineralization is Au ± Ag ± As ± Mo ± Pb ± Sb and trace to geochemically anomalous Cu and Zn.

These deposits appear to have formed within discontinuous deformation zones characterized by reverse faults that are often axial to appressed, northeast-trending meso-scale anticlines with axial planes that dip steeply to the northwest. Although commonly classified as structurally modified syngenetic exhalative gold-rich massive sulfide deposits, alteration and mineralization are confined to the host structures and synkinematic with ductile-brittle deformation under regional lower greenschist facies metamorphic conditions.

Within the oxidized zone, pyrite dissolution results in acid leaching with deep (~30 meters) weathering and the formation of free gold, often with increased fineness and coarser grain size compared to gold in primary sulfide ore, and surface and supergene enrichment to form large-tonnage, low-grade, easily mined and processed ore deposits. These deposits were historically mined by open-pit methods to the water table, with more localized underground mining of narrow, high-grade zones of secondary oxide, mixed, and primary sulfide mineralization.

Considerations of economic potential

Sawyer-type deposits are among the more attractive targets for modern precious metals exploration programs in the Carolina Terrane in central North Carolina. This is based on the indicated potential for large-tonnage, bulk-minable, low-grade deposits with relatively high gold recovery at low unit cost over a significant mine life. Evaluation of these deposits has historically involved extensive surface sampling and a broad variety of geophysical surveys, but minimal subsurface evaluation through drill-hole testing, mostly to relatively shallow depths. Due to the heterogeneity of gold distribution in this style of mineralization, even a few dozen drill-holes are unlikely to provide an adequate estimate of the grade and tonnage of the gold resource.

Additionally, the structural and lithologic controls of mineralization are often poorly understood, and the misapplication of incorrect ore deposit models may result in wasted drill-holes and discouraging results. An early investment in detailed geologic mapping and structural analysis, coupled with comprehensive petrographic and mineralogical analyses to fully constrain ore controls, is strongly recommended for the predictive constraints of this approach.

Historic open cut mining of Sawyer-type deposits typically focused on recovery of oxidized ore with free-milling gold at grades of generally 0.10 to 0.30 oz/t Au, leaving lower-grade (0.01-0.09 oz/t Au) oxide ore on the periphery and as “horses” within the open cuts. Additionally, zones of highly siliceous unoxidized sulfide ore that was difficult to mine and mill was also left as “horses”. Although much of the easily mined and milled oxide ore above the water table (~20-30 meters depth) in many deposits was historically depleted, much of the lower-grade oxide ore remains, along with mixed oxide/sulfide and primary sulfide mineralization present at greater depth.

Intercepts of primary sulfide ore in those deposits that have been drill-hole tested commonly contain tens of meters of low-grade mineralization (0.01-0.10 oz/t Au) with narrow (meters) intervals of higher-grade values (0.10-0.25 oz/t Au). However, few deposits have been adequately drilled to establish a reliable estimate of grade and tonnage, given the notoriously heterogeneous gold distribution in primary sulfide ores. This same problem was inherent in the evaluation of the Kennecott Ridgeway and Oceanagold Haile deposits in South Carolina, where hundreds of drill-holes were required to define the minable resources.

One of the only Sawyer-type deposits to be adequately drill-hole tested is the Russell Mine in the Ophir District in northwest Montgomery County, North Carolina. The deposit has an estimated historical production of around 37,500 ounces Au, plus drilling-based estimates of proven, probable, and possible reserves of over 300,000 ounces of gold (**Maddry *et al.*, 1992**) with a total resource around 350,000 ounces in oxide, sulfide, and mixed ore. This resource represents only the upper 150 meters of two of the five known mineralized zones on the property.

The vertical extent of Sawyer-type mesozonal orogenic gold deposits has not been tested, although historic mining, topographic exposures, and modern drill-hole testing suggest a vertical extent of at least 500 meters. The character of the structural controls of ore fluids and their likely source in the middle crust suggests possible vertical extents of over a kilometer. The presence of narrow zones of bonanza-grade Au mineralization in some deposits suggest a distinct potential for underground mining targets, possibly within ore fluid feeder zones similar to those discovered at the Haile Mine and associated with Carlin-type disseminated gold deposits in Nevada.

Star-Carter bonanza-grade epizonal orogenic deposits

The Star-Reynolds and Carter gold mines in Montgomery County, North Carolina are located about 2,000 meters apart along narrow faults that strike 030° and dip ~50° northwest, possibly as part of an *en echelon* fault zone with a strike length of at least 2,000 meters. Both mines produced around 20,000 ounces of gold from surface placer deposits and narrow zones of high-grade lode mineralization along strike-lengths of less than 100 meters to a depth of 20-30 meters. Bonanza grade shoots rich in Au-Ag tellurides at the Star Mine contained as much as 10-20 oz/t Au (**Phifer, 2004)**, with similar grades from selected vein samples at the Carter Mine.

There appear to be two stages of mineralization present. The dominant form is narrow (<2 meters), cleavage-parallel shear zone hosted sheeted or stockwork quartz veins and silicic alteration with disseminated sulfides and carbonates. These zones carry locally high-grade Au-Ag mineralization and are enclosed by narrow haloes of phyllic alteration with disseminated auriferous pyrite. Sulfides are dominantly pyrite with minor accessory chalcopyrite ± molybdenite ± gold telluride ± minor bornite and chalcocite with geochemically anomalous Sb, As, Pb, and Zn. This style of mineralization is consistent with mesozonal orogenic gold deposits formed at depths of 6-12 kilometers and temperatures of 300°-475°C (**Grooves *et al.*, 1998**).

This mesozonal orogenic vein mineralization is overprinted by brittle faulting at the Star and Carter mines, with locally bonanza-grade Au-Ag-Te mineralization (**Powers, 1989**, **Phifer, 2004**). At the Star Mine, high-grade gold + sylvanite [$(Au,Ag)Te_2$] + calaverite ($AuTe_2$) occur in chimneys within the plane of the brittle fault zone, characterized by silicified clasts in a clay-rich gouge matrix. In the absence of associated felsic igneous intrusive rocks, this mineralization is consistent with epizonal orogenic deposits formed in the upper 6 kilometers of the crust at temperatures of around 150°-300°C (**Grooves *et al.*, 1998**; **Cook *et al.*, 2009**).

Trace element associations suggest that both styles of mineralization are associated with a single hydrothermal event. The transition from ductile-brittle to brittle deformation is possibly due to orogenic crustal thickening and uplift, followed by rapid denudation through gravitational collapse or rapid weathering within the duration of the mineralizing event.

Evaluation of the Carter Mine by Noranda in 1987-1988 suggests that the presence of a large-tonnage, bulk minable gold mineralization target is unlikely (**Powers, 1989**). However, a total of 40,000 ounces Au was produced from only 200 meters of strike along a fault zone at least 2,000 meters long, and mostly from surface accumulations and the upper 20-30 meters of the lodes. There is a distinct possibility that a series of bonanza-grade Au-Ag-Te ore bodies may be present along the 2,000-meter strike of the Star-Carter fault zone in Montgomery County, North Carolina, both near the surface and at depth, that could be mined profitably with a small footprint.

Acknowledgements

This series of reports is the result of a productive relationship with the North Carolina Geological Survey, dedicated to providing mining industry-based information and insights into the character and economic potential of base and precious metal mineralization in the Carolina Terrane in central North Carolina.

The success of this partnership is directly attributed to the indefatigable energy and commitment of Dr. Jeffrey C. Reid PhD, PG, CPG, Senior Geologist, Energy and Minerals of the North Carolina Geological Survey, Division of Energy, Mineral and Land Resources, North Carolina Department of Environmental Quality. His encouragement and organizational and editing skills have been instrumental in bringing this project forward.

Additionally, these studies have benefitted enormously from the published resources of the North Carolina Geological Survey, the United States Geological Survey, and the remarkable academic achievements in constraining the stratigraphy, structure, and geochronology of the Carolina Terrane in North Carolina over the past 20 years. These contributions are reflected in the list of References Cited in these papers.

Many accomplished geologists have contributed to understanding the character and evolution of the geology of the Carolina Terrane and the hydrothermal ore deposits that it hosts. It is important to remember that well-trained geologist make accurate and useful observations. It does not dismiss or diminish their contributions to modify or disagree with their interpretations.

Finally, I strongly encourage the mineral deposit exploration geologists who were active in the Southeastern USA piedmont in the 1970s-1990s to contribute their reports, maps, and data to public institutions, such as state geological surveys and universities, to preserve and pass on hard won and valuable natural resource knowledge for the benefit of society. Don't allow information to languish and disappear. You had a fair go; now give someone else a chance.

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Glendon and Robbins AES alignments in the Carolina Terrane of central North Carolina: review of geology and metallogeny

By Robert J. Moye

Abstract

Advanced argillic epithermal alteration systems (AES) are large (1-20 km^2) metamorphosed late Proterozoic hydrothermal alteration centers characteristic of the Carolina Terrane in central North Carolina (**Moye, 2013**). These are concentrically zoned high sulfidation hydrothermal systems with pyrite as the dominant sulfide, typically strongly anomalous in fluorine, and often associated with subeconomic Au ± Ag ± Cu ± Mo mineralization, usually concentrated in areas of silicic to strong phyllic alteration (**Schmidt, 1985**; **Moye, 2013**). They are similar to epithermal expressions of porphyry-related Cu-Mo-Au deposits (**Schmidt, 1985**),

Hydrothermal alteration is variably present for about 12 kilometers along the Glendon Fault in northeast Moore and for at least 6 kilometers along the Robbins Fault in central Moore County. The alteration is characterized by extensive phyllic (quartz-sericite-pyrite ± chlorite ± ottrelite) alteration and more localized advanced argillic (pyrophyllite-quartz ± sericite ± pyrite ± ottrelite) and silicic (quartz ± pyrophyllite ± sericite ± pyrite) alteration (**Conley, 1962a**; **Stuckey, 1967**; **McDaniel, 1976**; **Klein, 1985**; **Powers, 1993**). Unlike most AES in the Carolina Terrane (**Moye, 2013**), those along the Glendon and Robbins faults do not show well-defined concentric zonation and are strongly deformed and elongated within the host fault zones, locally in reverse fault duplex structures, formed axial to large-scale appressed anticlines.

Geochemically anomalous Au, Mo, Cu, and F are commonly associated with AES along both the Glendon and Robbins faults (**Lesure, 1981**; **Powers, 1993**), and gold was historically mined from a number of deposits in zones of silicic to phyllic alteration along and hanging wall to the Robbins Fault (**Conley, 1962a**; **Powers, 1993**). The trace element signature for both the Glendon and Robbins AES is Au-Ag-As-Mo-F ± Cu, similar to that of the Pilot Mountain AES (**Schmidt, 1985**) and the Deep River Au-Cu-Mo prospect (**Rapprecht, 2013**) in Randolph County, North Carolina, and the Kennecott Ridgeway and Haile gold deposits in South Carolina (**Moye, 2012**). Robbins area gold deposits lack advanced argillic alteration assemblages and anomalous F, and have the trace element signature Au ± Ag ± As ± Mo ± Pb ± Sb.

The age and origin of AES and associated mineralization along the Glendon and Robbins faults is poorly constrained, and their relationship to other AES in the Carolina Terrane in central North Carolina uncertain. The economic potential of these large hydrothermal systems for minable deposits of precious metal mineralization and their potential linkage to large-tonnage porphyry Au-Cu-Mo mineralization at depth remains poorly constrained.

Introduction

Advanced argillic epithermal alteration systems (AES) are large (1-20 km^2) metamorphosed Late Proterozoic hydrothermal alteration centers characteristic of the Carolina Terrane in central North Carolina (**Figure 1**). Many are concentrically zoned, with core areas of advanced argillic (andalusite-pyrophyllite) and intense silicic alteration enclosed by a broad envelope of phyllic (quartz-sericite-pyrite) alteration, often with a transition to peripheral propylitic alteration halo with iron oxide enrichment (**Stuckey, 1928**; **Schmidt, 1985**; **Moye, 2013**).

These are high sulfidation hydrothermal systems with pyrite as the dominant sulfide, and similar to epithermal expressions of porphyry-related Cu-Mo-Au deposits (**Schmidt, 1985**). Additionally, AES are typically anomalous in fluorine and often associated with subeconomic Au ± Ag ± Cu ± Mo mineralization, usually concentrated in areas of silicic to strong phyllic alteration (**Schmidt, 1985**; **Moye, 2013**). Most AES in North Carolina occur along a series of 20-40 kilometer long *en echelon* alignments striking 025°-030° that may represent fault control (**Moye, 2013**). Typically, AES appear to post-date the Virgilina Deformation between 578 Ma and 544 Ma (**Samson *et al.*, 2001**; **Ingle *et al.*, 2003**), pre-date the circa 450-430 Ma Cherokee Orogeny (**Hibbard *et al.*, 2012**), and may be associated with intrusive phases of Uwharrie-age felsic magmatism circa 554-550 Ma (**Hibbard *et al.*, 2002**; **Moye, 2013**).

The Glendon and Robbins AES alignments extend for about 30 kilometers northeast through Moore County, and include advanced argillic epithermal alteration centers along the Glendon Fault and the Robbins Fault (**Figure 2**). Hydrothermal alteration is variably present for about 12 kilometers along the Glendon Fault in northeast Moore County (**Figure 2**). This complex reverse fault zone strikes 055°-060° and dips moderately to steeply northwest, axial to a large-amplitude anticline that strikes northeast and is overturned to the southeast (**Stuckey, 1928**; **Conley, 1962a**; **Green, 1977**; **Green *et al.*, 1982**; **Klein, 1985**). Hydrothermal alteration is developed for at least 6 kilometers along the Robbins Fault in central Moore County (**Figure 2**), a complex reverse fault zone that strikes about 030° and dips moderately to steeply northwest (**Conley, 1962a**; **Powers, 1993**).

Although AES alignments in the northern half of the Carolina Terrane of central North Carolina strike 025°-030° (**Figure 2**), the Cottonstone Mountain-Ammons alignment in eastern Montgomery County strikes 045°-050°, subparallel to the axis of the Troy Anticlinorium (**Figure 2**). The Robbins and Glendon alignments in Moore County also subparallel the axes of NE-striking first order folds. Although generally interpreted as products of Virgilina Deformation (**Green *et al.*, 1982**; **Harris and Glover, 1988**), the first order folds that dominate the Carolina Terrane in Moore County are subparallel to the orientation of first order regional folding of the Albemarle Sequence to the west during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**). It is uncertain whether the Glendon and Robbins anticlines are products of the Virgilina Deformation, the Cherokee Orogeny, or a combination of the two.

Hydrothermal alteration along both the Glendon and Robbins faults is characterized by extensive phyllic (quartz-sericite-pyrite ± chlorite ± ottrelite) alteration and more localized advanced argillic (pyrophyllite-quartz ± sericite ± pyrite ± ottrelite) and silicic (quartz ± pyrophyllite ± sericite ± pyrite) alteration (**Conley, 1962a**; **Stuckey, 1967**; **McDaniel, 1976**; **Klein, 1985**; **Powers, 1993**). Unlike most AES in the Carolina Terrane (**Moye, 2013**), those along the Glendon and Robbins faults do not show well-defined concentric zonation and are strongly deformed and elongated within the host fault zones, locally in reverse fault duplex structures.

Geochemically anomalous gold is commonly associated with intense phyllic and localized silicic alteration along both the Glendon and Robbins faults (**Lesure, 1981**; **Powers, 1993**), and gold was historically mined from a number of deposits in zones of silicic to phyllic alteration along and hanging wall to the Robbins Fault (**Conley, 1962a; Powers, 1993**). Anomalous Cu and Mo are present in AES along the Glendon Fault, and a sample of quartz-sericite-pyrite schist from the Womble Pit contained 500 ppm Mo (**Lesure, 1981**). Accessory arsenopyrite and molybdenite are locally present in alteration along the Robbins Fault Zone (**Powers, 1993**).

Accessory apatite (probably F-bearing), topaz, and fluorite are present in AES along the Glendon Fault (**Conley, 1962a**; **McDaniel, 1976**). **Powers (1993)** reports trace disseminated topaz and fluorapatite as disseminated grains in the advanced argillic alteration zone at the Standard Minerals Mine on the Robbins Fault, and fluorite is present in synkinematic quartz veins. Additionally, aggregates of fluorapatite intergrown with an opaque mineral occur in angular clasts from a zone of intense silicic alteration in the footwall of the deposit (**Powers, 1993**).

The trace element signature for both the Glendon and Robbins AES is Au-Ag-As-Mo-F ± Cu, similar to that of the Pilot Mountain AES (**Schmidt, 1985**) and the Deep River Au-Cu-Mo prospect (**Rapprecht, 2013**) in Randolph County, North Carolina, and the Kennecott Ridgeway and Haile gold deposits in South Carolina (**Moye, 2012**). As with many other AES throughout the Carolina Terrane in North Carolina, strongly anomalous Mo and F in the Glendon and Robbins AES suggest a possible felsic magmatic contribution to the causal hydrothermal fluids.

The structural relationship between the Glendon and Robbins faults and associated AES is uncertain. They do not appear to form a continuous fault zone, but show similar structural architecture and may be part of an *en echelon* fault array. It is uncertain whether these faults are related to the Virgilina Deformation (**Harris and Glover, 1985**), the Cherokee Orogeny (**Hibbard *et al.*, 2012**), or an unrecognized deformation event. The age of AES formation along the Glendon and Robbins faults is unknown, but alteration pre-dates or is synchronous with deformation on the faults (**Klein, 1985**).

Available geologic mapping in the area includes **Conley (1962a)**, **Green (1977)**, **Burt (1981)**, **Green *et al.* (1982)**, and **Powers (1993)**. Host lithologies include metamorphosed felsic, intermediate, and mafic volcanic and volcaniclastic units and interbedded epiclastic sediments; all interpreted as part of the Hyco Formation and Virgilina Sequence, folded during the Virgilina Deformation (**Harris and Glover, 1988**; **Hibbard *et al.*, 2002**; **Hibbard *et al.*, 2008**). However, **Bradley (2011)** notes that there is generally little detailed mapping in the area of the Glendon and Robbins deposits and no published geochronological data. Additionally, the impact of the Late Ordovician Cherokee Orogeny (**Hibbard *et al.*, 2012**) on the area and possible modification of Virgilina-age structures has not been examined.

The advanced argillic epithermal alteration systems along the Glendon and Robbins faults are atypical of most AES developed throughout the Carolina Terrane in central North Carolina (**Moye, 2013**). Andalusite, characteristic of the advanced argillic alteration assemblage in most AES, is absent at Glendon and Robbins and the only significant Al-silicate phase is pyrophyllite. Core areas of intense, pervasive silicic alteration, present in other AES, are also absent. Additionally, the Glendon and Robbins deposits lack well-defined concentric zonation and are strongly overprinted by ductile-brittle shear along large-displacement reverse faults that appear axial planar to overturned and appressed anticlines.

Geochemically anomalous gold is common in Carolina Terrane AES, typically associated with pyritic silicic and phyllic alteration (**Schmidt, 1985**, **Moye, 2013**), but seldom reaches economic grade and tonnage. Several historic gold mines and prospects occur in association with the Pilot Mountain AES in Randolph County, possibly the most strongly mineralized AES of the Carolina Terrane in North Carolina. The largest of the small historic gold producers at Pilot Mountain was the Pine Hill Mine, located at the contact between dacite porphyry and Hyco Arc volcanic rocks. Mineralization occurs in a zone of intense epithermal silicic and phyllic alteration with anomalous Au-Cu surface values over an area of 150 x 500 meters (**Klein and Schmidt, 1985**).

The occurrence of several linear, probably fault-controlled zones of historically mined, locally high-grade gold mineralization peripheral to the Robbins AES alignment is atypical, and the deposits more closely resembles orogenic styles of gold mineralization associated with the Cherokee Orogeny in the late Ordovician (**Hibbard *et al.*, 2012**).

The Robbins area was a highly sought-after gold exploration target in the 1980s, and numerous mining companies sampled and evaluated hydrothermal alteration zones and gold deposits in the area. The Cagle Mine was drilled by Newmont Exploration in 1981, and the Burns Mine was drilled by Tenneco in 1983 (**Powers, 1993**). **Powers (1993)** reports that the Adena Mineral Company applied for permits to mine a mineralized zone 200 meters long and about 10 meters thick with an average grade of 0.07 oz/t Au at the site of the old Burns Mine. The gold deposits in the area of the Robbins Fault remain targets of exploration interest but their character and genesis are poorly constrained.

Purpose of the study

This review and analysis is intended to more fully document the geologic character and metallogeny of advanced argillic epithermal alteration centers along the Robbins and Glendon faults and to better constrain their origin and associations. Additionally, the character and significance of historically mined lode gold deposits in the Robbins area is reviewed and analyzed to better constrain their genesis and timing relative to their apparent association with AES along the Robbins Fault.

Finally, there is an attempt to better constrain the genesis of the Glendon and Robbins AES and Robbins area gold deposits in the context of known tectonic and magmatic events, including the Virgilina Deformation sometime between 578 and 554 Ma (**Pollock *et al.*, 2012**), Uwharrie magmatism in the Carolina Terrane from circa 554 Ma to 550 Ma (**Pollock *et al.*, 2012**), and the Cherokee Orogeny circa 450-430 Ma (**Hibbard *et al.*, 2012**).

Geologic descriptions are also provided for individual AES centers and spatially associated precious and base metal sulfide occurrences along both trends, largely summarized from available published resources. Available information is also provided on other advanced argillic alteration occurrences in Moore County.

In this report, historic gold values reported as dollar amounts have been converted to ounces per ton (oz/t) using historical USA gold prices for the year of publication. Except in discussions of geochemistry, mineral chemistry, and trace element concentrations, gold values reported as part per million (ppm) or parts per billion (ppb) are reported in grams per tonne (g/t) and ounces per ton (oz/t); where 1ppm Au = 1 g/t Au, 34.28 g/t Au = 1 oz/t Au.

Limitations of the study

This study is based largely on available published geologic studies and documentation of advanced argillic alteration along the Glendon and Robbins fault zones in Moore County, North Carolina, and those of precious and base metal mines and prospects that occur in apparent association with these occurrences. Additionally, the study includes the direct personal experience of the author as an exploration geologist working throughout the region during the 1980s and 1990s. A much larger body of information on some of these deposits is held in the proprietary files of individuals and corporations, but is not available to the public sector.

This work is part of an ongoing metallogenic analysis of the Carolina Terrane, which seeks to correlate specific types of precious and base metal mineralization with specific lithotectonic environments and metallogenic events in the geologic history of the Carolina Terrane. The analysis is intended to better focus and constrain future exploration and analysis of metallic ore deposits in the Southeastern piedmont of the United States of America.

Geology of the Glendon AES alignment, Moore and Chatham counties

Zones of advanced argillic alteration are developed locally for 5-6 kilometers along the main segment of the Glendon Fault Zone in northern Moore County, located between a large bend in the Deep River and the Moore-Chatham county line to the northeast (**Figure 3**). It is a major reverse fault zone generally 10-50 meters thick, and attenuates the axial zone of a large-amplitude anticline that strikes northeast and is overturned to the southeast (**Stuckey, 1928**, **Conley, 1962a**; **Green *et al.*, 1982**; **Klein, 1985**; **Bradley, 2011**). This faulted anticline is one of a series of large-scale folds that characterize this area of the Carolina Terrane (**Green *et al.*, 1982**). **Conley (1962a)** estimates the offset on the fault at up to a kilometer. The Glendon Fault variably juxtaposes mafic to intermediate volcaniclastic and epiclastic units, felsic volcanic rocks, and mudstones and siltstones assigned to the Hyco Formation and Virgilina Sequence

(**McDaniel, 1976**; **Green, 1977**; **Green *et al.*, 1982**; **Harris and Glover, 1988**; **Hibbard *et al.*, 2002**).

Phyllic to silicic alteration are developed almost continually along the Glendon Fault, reaching a width of around 150 meters in the area of the Phillips, Womble, and White mines and narrowing to as little as 10 meters to the northeast and the southwest (**Conley, 1962a**; **Stuckey, 1967**). There are four major AES centers along the Glendon Fault, all historically or currently mined for pyrophyllite. These include, from southwest to northeast, the Bates, Phillips, Womble, and White deposits (**Figure 4**).

The largest deposits, the Phillips, Womble, and White, form a single AES zone about 1.5 kilometers long and up to 150 meters wide (**Figure 5**). This zone is located where the Glendon Fault juxtaposes hanging wall intermediate to mafic volcaniclastic rocks against footwall mudstone and siltstone with local andesitic to basaltic volcanic units (**McDaniel, 1976**; **Green *et al.*, 1982**; **Klein, 1985**). This section of the fault zone appears to be a complex reverse fault duplex about 45 meters wide.

The footwall of the Glendon Fault through the Bates-Phillips-Womble-White mine area is a polylithic breccia unit with clasts 2.5-5.0 centimeters, locally up to 20 centimeters, in diameter; with the matrix often strongly impregnated by Fe-oxides, chiefly hematite ± magnetite (**Stuckey, 1925**; **Stuckey, 1967**; **Conley, 1962a**; **McDaniel, 1976**). **McDaniel (1976)** noted that clasts in the breccia range from angular to round with the appearance of conglomerate. Chloritoid is abundant in the transition zone from pyrophyllite-rich advanced argillic alteration assemblages to Fe-rich footwall breccia at the Womble Mine (**Stuckey, 1925**). **Stuckey (1925)** extends this footwall breccia unit from the Bates Mine northeast into Chatham County (**Figure 4**), although this continuity is not confirmed. A similar breccia is reported in the hanging wall of other pyrophyllite deposits on this trend (**Stuckey, 1925**).

The footwall breccia at the Womble Mine appears to be overprinted by younger pyrophyllite mineralization (**Stuckey, 1925**), possibly during formation of the high-grade pyrophyllite ore bodies along the Glendon Fault Zone. The breccia unit may represent an early phase of dominantly brittle deformation along the fault zone.

Northeast of the White Mine (**Figure 4**), the Glendon Fault Zone hosts several areas of less strongly developed advanced argillic alteration including the Jones and Currie Prospects. The Glendon Fault Zone continues to the southeast of the Bates Mine for another 6-7 kilometers, and may include two separate reverse faults developed axial to a pair of anticlines overturned to the southeast (**Figure 3**). Based on the work of **Green *et al.* (1982)**, the southern fault appears to be the continuation of the Glendon Fault. The more northerly fault, axial to a second anticline, continues for about 7 kilometers to the southeast and hosts the small McConnell and Jackson pyrophyllite prospects (**Figure 3**).

The age of formation of the Glendon Fault and associated AES is unknown, but alteration pre-dates or is synchronous with deformation on the fault (**Conley, 1962a**; **Klein, 1985**). The strongly foliated, high-purity pyrophyllite ore bodies of the Phillips, Womble, and White mines appear to occupy several fault strands within a reverse fault duplex zone.

Alteration and mineralization along the Glendon AES Trend

Hydrothermal alteration along the Glendon Fault is characterized by extensive phyllic (quartz + sericite + pyrite ± chlorite ± ottrelite) alteration variably developed along the entire length of the fault zone, with more localized advanced argillic (pyrophyllite + quartz ± pyrite ± sericite ± ottrelite ± diaspore) and silicic (quartz ± sericite ± pyrophyllite ± pyrite) alteration (**McDaniel, 1976**; **Klein, 1985**). Silicic alteration does not form large, well-defined core areas of intense hydrothermal leaching, as in most Carolina Terrane AES (**Moye, 2013**), but is largely present as small, irregularly distributed zones of cherty to fine-grained silica, coarse, vitreous silicification, and areas of abundant, multi-generation quartz veins that may represent major structural fluid pathways.

Geochemically anomalous Au, Cu, and Mo are present locally in association with hydrothermal alteration along the Glendon Fault (**Lesure, 1981**). Fractures in silicic alteration in the hanging wall of the Womble Mine are stained by azurite and malachite (**Conley, 1962a**), and a sample of pyritic quartz-sericite schist from the Womble Mine contained 500 ppm Mo (**Lesure, 1981**). Accessory apatite (probably F-bearing) is common in the pyrophyllite-rich zones (**McDaniel, 1976**) and fluorite is present locally (**Conley, 1962a**; **McDaniel, 1976**). **Conley (1962a)** noted small augen-like masses at the Phillips, Womble, and White mines composed almost entirely of pyrophyllite, diaspore, and topaz. A sample of this material contained 27% pyrophyllite, 36% diaspore, 37% topaz, and 1% fluorite (**Conley, 1962a**).

The advanced argillic, silicic, and intense phyllic alteration zones along the Glendon Fault are domains of pervasive high sulfidation, with essentially all available Fe fixed as pyrite by S-rich fluids that were geochemically reduced and low pH. Peripheral to this domain of pervasive sulfidation, there is a distinct enrichment in chlorite, chloritoid, and magnetite ± hematite across the transition from phyllic to propylitic alteration and into the enclosing unaltered host rocks (**Stuckey, 1925**; **Conley, 1962a**; **Stuckey, 1967**). **Stuckey (1967)** describes a close association between the occurrence of chloritoid and Fe-oxides (magnetite + hematite) on the periphery of most North Carolina pyrophyllite deposits.

Conley (1962a) suggests a bulk geochemical zonation from Al-enrichment (advanced argillic) to potassic enrichment (phyllic) to iron enrichment (propylitic) in the major Glendon Fault AES centers, which would also include a peripheral redox transition (pyrite-Fe oxide). **McDaniel (1976)** found occurrences of coexisting pyrite and hematite in the transition zone from the pyrophyllite-rich ore body to Fe-oxide impregnated breccia in the footwall of the Womble Mine, suggesting such a transition.

Pyrophyllite mines and prospects of the Glendon AES Trend

Eight pyrophyllite mines and prospects are located along the Glendon fault in northeast Moore County (**Figure 3 and Figure 4**). Historically, the most important deposits are the Phillips, Womble, and White mines, all adjoining and part of the same broad zone of intense hydrothermal alteration (**Figure 4 and Figure 5**). The width and intensity of alteration along this section of the fault may be coincident with an area of complex reverse duplex faulting.

McConnell Prospect

This prospect lies about 800 meters northeast of the village of McConnell, located at the intersection of SR 1487 and NC 22, at geographic coordinates -79.50421, 35.4701 (WGS84). It is not located on the Glendon Fault, but on a reverse fault located north and parallel to the southern extension of the Glendon Fault (**Figure 3**). An open cut 3-4.5 meters wide and up to 4.5 meters deep extends for 120 meters across the strike of the fault zone, with sheared and silicic to phyllic altered felsic volcanic rocks in the hanging wall to the north and mudstone in the footwall to the south (**Stuckey, 1967**). The fault zone is about 12 meters wide at this location and the pyrophyllite-bearing advanced argillic alteration zone about 3 meters thick (**Conley, 1962a**).

Jackson Prospect

This prospect lies on the Glendon Fault on the south side of the Deep River, inside the tight curve of a large meander, and about 5 kilometers northeast of the McConnell prospect (**Figure 3**) at geographic coordinates -79.46365, 35.49038 (WGS84). The Glendon Fault Zone is about 61 meters wide at this site, with andesite volcaniclastic rocks in the hanging wall to the north and mudstone in the footwall to the south (**Conley, 1962a**; **Stuckey, 1967**). Two prospect pits extend to a depth of 3-5 meters in phyllic alteration, but no significant pyrophyllite appears to be present.

Bates Mine

The mine lies along the Glendon Fault on the northeast side of Deep River about 3.2 kilometers northeast of the Jackson prospect and 2.4 kilometers northwest of Glendon (**Figure 4**), at geographic coordinates -79.44143, 35.49899 (WGS84). Prospecting is reported by 1903 and a mill was built in 1904; however, mining ceased in 1919 and attempts to reopen the mine in the late 1920s and the 1930s failed (**Stuckey, 1967**). The alteration zone is 45 to 90 meters wide, with sheared phyllic-altered andesite volcaniclastic rocks in the hanging wall to the north. **Stuckey (1967)** states that brecciated and altered felsic volcanic rocks with clasts 2.5-5.0 centimeters in diameter form the footwall; however, **Conley (1962a)** suggests that a mudstone sequence forms the footwall. The footwall breccia described by **Stuckey (1976)** may be a continuation of the altered footwall breccia zone in the Phillips and Womble mines to the northeast.

An open cut 6 meters wide and up to 12 meters deep extends for 76 meters across the strike of the fault zone and into the hanging wall, with cross-cut extensions to the northeast and southwest at the north end and a short adit driven into the slope (**Stuckey, 1967**). Open cuts 6-9 meters wide, about 6 meters deep, and 9 meters long parallel the footwall breccia zone on either side of a small stream in the footwall zone. West along strike from the footwall open cuts, a shaft was opened to a depth of about 18 meters and drifts extended northeast and southwest (**Stuckey,**

1967). The zone of pyrophyllite-rich advance argillic alteration is about a meter thick on the fault surface, grading into phyllic alteration in the hanging wall and footwall (**Conley, 1962a**). It strikes 070° and dips 80° northwest (**Conley, 1962a**).

Phillips Mine

One of the major pyrophyllite producers on the Glendon trend, this mine is located about 650 meters northeast of the Bates mine and immediately southwest of SR 1006, at geographic coordinates -79.42556, 35.5032 (WGS84). The hydrothermal alteration zone is about 460 meters long and 90 to 150 meters wide (**Figure 4, Figure 5**), with the most pyrophyllite-rich assemblages developed along the Glendon Fault in a zone 30-60 meters wide (**Stuckey, 1967**). The hanging wall of the deposit is composed of dacitic volcaniclastic units, and the footwall is characterized by locally highly ferruginous (hematite) breccia separating the fault zone from a mudstone-siltstone sequence. Production was from an open cut 365 meters long, up to 60 meters wide, and 18-24 meters deep. A small mill built on the mine site in 1902 burned in 1927, and a new mill built at the railway station in Glendon in 1928.

The pyrophyllite is strongly foliated, with a penetrative cleavage that strikes 055°-060° and dips from 45° to 70° northwest. Zones of pyrophyllite-rich ore are interspersed with broad zones of impure pyrophyllite with abundant silicic alteration and quartz veins (**Stuckey, 1967**). Disseminated chloritoid is present along the footwall of the deposit, but not as abundant as in the Womble Mine to the northeast. Other hydrothermal minerals include pyrite, diaspore, apatite, zircon, ilmenite, rutile, epidote and fluorite (**McDaniel, 1976**). As previously noted, small augen-like masses within the Glendon Fault at the Phillips, Womble, and White mines are composed largely of pyrophyllite, diaspore, and topaz with minor fluorite. Fluorite crystals are locally present in late-kinematic quartz veins within the fault zone at the Phillips Mine (**Conley, 1962a**).

Pyrite is especially abundant at the Phillips Mine, and strongly developed in silicic to phyllic alteration in the hanging wall and footwall of the pyrophyllite-rich central zone. Pyrite commonly occurs as disseminated irregular grains and as euhedral cubic crystals ranging in size from a millimeter to 10 centimeters across. They are often slightly deformed by late-kinematic strain into rhombohedrons with quartz ± chlorite pressure shadows. Pyritohedrons are also observed locally.

Based on the mapping of **Conley (1962a)**, the zone of intense, pyrophyllite-dominated advanced argillic alteration at the Phillips Mine appears to be coincident with a reverse fault duplex zone developed along the Glendon Fault in this area (**Figure 6**). This duplex zone appears to continue northeast through the Womble and White mine areas and may include several anastomosing fault splays between the main roof and floor faults.

Womble Mine

This major pyrophyllite producer lies adjacent to the Phillips Mine on the opposite (northeast) side of SR 1006 (**Figure 4**, **Figure 5**) at geographic coordinates -79.42309, 35.50343 (WGS84). The advanced argillic alteration zone is lenticular along strike and down-dip, and approximately 550 meters long and up to 150 meters wide (**Stuckey, 1967**). Like the Phillips Mine, the hanging wall is composed of rhyolite to dacite volcaniclastic units, and the footwall is characterized by locally highly ferruginous (hematite) breccia.

Most production was from an open cut 120 meters long, 23-38 meters wide, and generally 12-18 meters deep at the northeast end of the deposit. A second pit was opened at the southwest end of the property adjacent to SR 1006. The rest of the zone has been extensively prospected by shallow shafts, pit, and open cuts to depths of up to 15-23 meters (**Stuckey, 1967**).

A strong penetrative cleavage strikes 055° and dips 70° northwest. Synkinematic to post-kinematic quartz veins and irregular areas of cherty silicic alteration are common throughout the advanced argillic alteration zone, with ore-grade areas composed largely to strongly foliated pyrophyllite. Quartz veins include cleavage-parallel veins and stringers, cross-cutting tension vein arrays, and irregular veins. Chloritoid as disseminated dark-green grains 1-2 millimeters in diameter is widespread in the footwall ferruginous breccia immediately adjacent to the pyrophyllite-rich advanced argillic alteration zone, and diminishes in abundance into the pyrophyllite zone. Silicic alteration in the hanging wall of the Womble deposit is locally stained along fractures by azurite and malachite (**Conley, 1962a**).

White Mine

Previously known variously as the Rogers Creek Mining Company property, the Snow Mine, and the Reaves Mine, this deposit is located on the Glendon Fault about 610 meters northeast of the Womble Mine (**Figure 4**, **Figure 5**) at geographic coordinates -79.41754, 35.50593 (WGS84). Prospect pits extend along strike for about a kilometer, mostly southwest of Rogers Creek. Just southwest of Rogers Creek, a zone of pyrophyllite has been exposed for 150 meters along strike in an open cut up to 45 meters wide, deepening to around 18 meters at the northeast end.

The advanced argillic alteration zone is lenticular along strike and down-dip, strikes about 065° for over 100 meters, and dips 60°-70° northwest (**Conley, 1962a**; **Stuckey, 1967**). This zone ends abruptly at the northeast end of the pit, but appears to continue to the southeast (**Conley, 1962a**). **Stuckey (1967)** reports the presence of strongly silicic-phyllic altered breccia with clasts to 10 centimeters across, and preservation of a fragmental texture in some of the pyrophyllite-rich alteration.

Conley (1962a) suggests that the alteration zone is developed within a reverse fault duplex, with the main Glendon Fault as the footwall (floor) and a sympathetic secondary fault as the hanging wall (roof). Within the duplex zone, hanging wall andesite volcaniclastic rocks are strongly imbricated with footwall mudstone. The transition between altered and unaltered rocks is unusually narrow at this location, commonly only a few centimeters to a meter thick (**Conley, 1962a**), and may represent post-alteration fault contacts. Minor chloritoid and chlorite are present on the periphery of the advanced argillic pyrophyllite zone (**Stuckey, 1967**).

Jones Prospect

The prospect lies is located on the Glendon Fault about 1.6 kilometers northeast of the White mine (**Figure 4**) at geographic coordinates -79.39976, 35.51566 (WGS84). Prospect pits and an open cut 30 meters long and up to two meters deep are opened in strongly foliated pyrophyllite and sericite schist with accessory chloritoid (**Conley, 1962a**; **Stuckey, 1967**). The pyrophyllite is strongly stained by Fe-oxides and does not appear to be economic.

Currie Prospect

The site is about 800 meters northeast of the Jones Prospect (**Figure 4**), very close to where SR 1620 crosses the Moore-Chatham county line, at geographic coordinates -79.39254, 35.51704 (WGS84). Small prospect pits expose strongly sheared mudstone altered to sericite schist, and **Stuckey (1928)** reported the presence of pyrophyllite. The deposit appears to occupy a splay to the southeast and footwall to the main Glendon Fault.

Gold and base metal mines and prospects of the Glendon Trend

Although the Glendon Fault AES are commonly geochemically anomalous in Au, Cu, Mo, and F, no known precious or base metal sulfide mines or prospects are known in direct association with the advanced argillic alteration centers along the Glendon Fault. Two gold ± copper prospects, the Ritter and Cotton, may be located on the southwest extension of the parallel reverse fault that hosts the McConnell pyrophyllite prospect. However, there is no demonstrable genetic linkage.

Ritter prospect (Au)

Also known as the McDonald and the Teisson, this mine is located about 1.9 kilometers southeast of the town of High Falls at geographic coordinates -79.51394, 35.46816 (WGS84), and possibly on the southwest extension of the reverse fault zone that hosts the McConnell pyrophyllite prospect. The mine opened sometime prior to 1890 and continued until around 1900, with two shafts about 160 meters apart (**Figure 7**); with the northeastern shaft up to 30 meters deep (**Conley, 1962a**). Gold mineralization is associated with pyrite and occurs with chlorite, calcite, and sericite in a meter thick zone of silicic and phyllic altered rocks that strike 010° and dip 30° northwest (**Conley, 1962a**; **Carpenter, 1976**). The relationship of this mineralization to the Glendon Fault and other reverse faults in the area is unknown.

Cotton prospect (Au-Cu)

Also known as the Donaldson, the mine is located about 2.2 kilometers southeast of the town of High Falls and about 640 meters southeast of the Ritter Mine at geographic coordinates -79.51171, 35.46593 (WGS84). The site was worked as a placer mine in the 1850s and early 1860s, with a later shaft to a depth of about 18 meters (**Conley, 1962a**). **Carpenter (1976)** describes a large group of deep shafts with extensive spoil piles (**Figure 8**). The mineralization is associated with a 20 centimeter thick massive, vuggy quartz veins that contains pyrite, malachite, and azurite (**Conley, 1962a**; **Carpenter, 1976**). The vein occurs in sheared and phyllic-altered (?) felsic volcanic rocks (**Conley, 1962a**). Foliation in the rocks strikes 080° and dips 30° northwest (**Carpenter, 1976**).

The mine lies somewhere near the probable southwest extension of the reverse fault zone that hosts the McConnell pyrophyllite prospect. However, the relationship of this mineralization to the Glendon Fault and other reverse faults in the area is unknown.

Tennessee Copper prospect (Cu-Ag-Au)

This prospect is located 2.4 kilometers northeast of Glendon on the north side of the Haw Branch Road and well south of the Glendon Fault, at geographic coordinates -79.40506, 35.5015 (WGS84). The relationship of this copper mineralization to alteration along the fault zone is uncertain. A two meter square shaft at least 46 meters deep and a small trench and pit 60 meters to the southwest were excavated along a zone of copper mineralization that strikes 030° and dips 60° northwest (**Conley, 1962a**; **Carpenter, 1976**). **Conley (1962a)** estimates the thickness of the mineralized zone at around 76 centimeters.

A zone of silicified grey, cherty breccia is cemented by saccaroidal quartz, orthoclase, chlorite, calcite, epidote, sericite, biotite, and kaolin, with stringers of cuprite, bornite chalcocite, malachite, azurite, and fine-grained disseminated pyrite (**Conley, 1962a**; **Carpenter, 1976**). This zone also contains quartz veins with chlorite and calcite. Samples assayed from this site by the Tennessee Copper Company carried 0.85% Cu, 0.18 oz/t Ag, and 0.02 oz/t Au (**Carpenter, 1976**). The host rock is a silicified lithic tuff or tuff breccia with minor epidote, chlorite, sericite, and milky quartz veins with accessory carbonate (**Carpenter, 1976**). These rocks are brecciated and bleached with silicic, phyllic, and chloritic alteration.

Geology of the Robbins AES alignment, central Moore County

Advanced argillic alteration, characterized by pyrophyllite-rich mineral assemblages, occurs intermittently for around 8 kilometers along the Robbins Fault Zone through the Cabin Creek area, located southwest of the town of Robbins in central Moore County, North Carolina (**Figure 2**). The Robbins Fault Zone is a complex reverse structure that locally forms a duplex with multiple fault strands. The fault zone strikes about 030° to 040° and dips 50° to 70° northwest (**Conley, 1962a**; **Powers, 1993)**. **Conley (1962a)** suggests that the Robbins Fault is part of a shear zone up to 1.5 kilometers wide. **Powers (1993)** notes that all of the pyrophyllite and gold mineralization in the district occur with a northeast-trending zone up to 1.7 kilometers wide with a strike length of around 5.2 kilometers (**Figure 9**).

The host rocks for the Robbins District (**Figure 9**) are dominantly quartz and feldspar phyric, coarse to fine-grained felsic volcaniclastic units with interbedded epiclastic sedimentary facies and subordinate laminated and locally spherulitic felsic flows, domes, or cryptodomes (**Powers, 1993**). A sequence of intermediate to mafic volcaniclastic units is present to the east, and a sequence of mudstones with interbedded greywacke sandstone may occupy a faulted syncline to the south (**Figure 9**).

Evaluation of stratigraphic and structural data from the work of **Powers (1993)** and **Conley (1962a)**, and comparison with work in the Glendon area by **Green et al. (1982)**, suggest that the Robbins Fault Zone is probably developed axial planar to a complex antiform overturned to the southeast and cored by a dominantly felsic volcaniclastic sequence. Rock fabrics along and peripheral to the fault zone are dominated by a strong, penetrative cleavage that strikes about 030° and dips about 65° northwest (**Conley, 1962a**; **Powers, 1993**). **Powers (1993)** interprets this as S_1 cleavage axial planar to an F_1 fold. However, the dominant fold architecture of the area may be related to the Virgilina Deformation (D_1), which did not produce a penetrative axial planar cleavage (**Harris and Glover, 1988**; **Hibbard *et al.*, 2002**). Virgilina F_1 folds may have been compressed, over-turned, and possibly reoriented with development of a strong axial planar cleavage during the Cherokee Orogeny (D_2) of **Hibbard *et al*. (2012)**. Assuming the influence of both orogenic events, folds in the Robbins area could be interpreted as F_{1-2} and the penetrative axial parallel cleavage as S_2. Alternatively, folding in the Robbins area is solely a product of the Cherokee Orogeny (D_2) and the folds are, regionally speaking, F_2 folds with an axial planar S_2 cleavage.

The S_1 cleavage of **Powers (1993)**, formed during D_1 axial to F_1 folds, is present over a broad zone footwall and hanging wall to the Robbins Fault Zone. This cleavage is heterogeneously overprinted by an S_2 cleavage (**Figure 10**) formed during D_2, but only within or immediately adjacent to the fault zone (**Powers, 1993**). The S_2 cleavage deforms and transposes porphyroblasts of pyrite and ottrelite that grew across the S_1 fabric, although pressure shadows on some pyrite crystals suggest that their growth was late kinematic (**Powers, 1993**).

Additionally, large veins that cross-cut the S_1 cleavage in the footwall and hanging wall of the Robbins Fault (**Figure 10**) are folded, dismembered, and transposed during D_2 within the fault zone (**Figure 10**). Complex D_2 deformation within the Robbins Fault Zone is characterized by multiple, anastomosing reverse fault strands and meso-scale intrafolial F_2 drag and kink folds (**Figure 10**). The pyrophyllite ore bodies of the Standard Minerals Mine formed along these reverse fault strands (**Figure 11**, **Figure 12**), synkinematic with D_2 deformation.

The Robbins Fault Zone in the Standard Minerals Mine is a reverse fault duplex, with possibly large offset along the floor and roof faults (**Figure 10**, **Figure 12**) that detaches the lithologies within the fault zone from those in the footwall and hanging wall and disrupts patterns of zonation in hydrothermal alteration assemblages. Advanced argillic alteration assemblages within the Robbins Fault reach a width of up to 45 meters in the Standard Mineral Company Mine open-cut (**Figure 11**, **Figure 12**), with phyllic alteration (sericite-quartz-pyrite ± chlorite) extending up to 100 meters into the hanging wall and footwall (**Conley, 1962a**).

Many of the smaller vitreous quartz veins discordant to cleavage in the hanging wall and footwall of the Robbins Fault (**Figure 10**) may be tension veins associated with D_2 reverse or oblique reverse strain. Additionally, many of the vitreous quartz veins within the Robbins Fault Zone may be reverse strain tension veins formed at various stages during the D_2 development of the reverse fault duplex and variably deformed, disarticulated, and transposed into successive S_2 cleavage fabrics.

Powers (1993) also documents localized D_3 deformation along the Robbins Fault as subvertical cross-faults that strike northeast and northwest and truncate D_1 and D_2 structures and fabrics, as well as large quartz veins and pyrophyllite ore bodies (**Figure 11**). Subhorizontal slickensides along the faults suggest largely strike-slip displacements, with kinematic indications of sinistral movement (**Powers, 1993**).

Although deformation within and peripheral to the Robbins Fault Zone is interpreted as the product of three separate deformation events (**Powers, 1993**), all three events may represent different phases of a single tectonic event. Early heterogeneous axial planar S_1 cleavage development and reverse shearing (D_{1a}) occurred along a 030°-striking zone up to 1500 meters wide, with subsequent more localized oblique-reverse strain (D_{1b}) to form the Robbins Fault Zone duplex and high-grade pyrophyllite ore bodies, and a late kinematic phase (D_{1c}) of minor sinistral strike-slip faulting. It is significant that both D_1 and D_2 deformations occurred under regional lower greenschist facies metamorphism.

This pattern of structural development is not consistent with deformation associated with the Virgilina Deformation, characterized by upright folding without significant axial planar cleavage development (**Harris and Glover, 1988**; **Hibbard *et al.*, 2002)**. However, this style of deformation is consistent with that characterizing the Cherokee Orogeny (**Hibbard *et al.*, 2012**). Mega-scale to meso-scale northeast-striking, asymmetric F_1 folds appressed and overturned to the southeast formed during the early phases of the Cherokee Orogeny (**Hibbard *et al.*, 2012**).

Initial formation of broad zones of axial planar S_1 cleavage is locally overprinted by narrower zones of reverse faulting and associated S_2 cleavage, often forming a reverse fault zone duplex. The Gold Hill Fault Zone along the western margin of the Carolina Terrane in North Carolina is a large-scale, large-displacement reverse fault duplex structure that overprints earlier-formed F_1 folding (**Hibbard *et al.*, 2012**). Additionally, late kinematic sinistral displacement is present along the Gold Hill Fault (**Hibbard *et al.*, 2012**).

Alteration and mineralization along the Robbins AES Trend

Advanced argillic alteration, characterized by pyrophyllite-rich mineral assemblages, occurs intermittently for around 8 kilometers on the Robbins Fault Zone in the Cabin Creek area, located southwest of the town of Robbins in central Moore County (**Figure 2**). The Robbins Fault Zone is a complex reverse structure that locally forms a duplex with multiple internal fault strands. The fault zone strikes about 030° to 040° and dips 50° to 70° northwest. **Conley (1962a)** suggests that the Robbins Fault is part of a shear zone up to 1.5 kilometers wide. **Powers (1993)** notes that all of the pyrophyllite deposits and gold mineralization in the area occur with a northeast-trending zone of widespread phyllic alteration up to 1.7 kilometers wide with a strike of around 5.2 kilometers (**Figure 9**).

Advanced argillic alteration is continually present for a distance of over 1500 meters along the Robbins Fault (**Figure 9**), from just southeast of the historic Cagle Au Mine to just northeast of the California Au Mine (**Stuckey, 1967**). The Standard Minerals Mine exploits a 600 meters long portion of this zone rich in ore-grade pyrophyllite. Additional advanced argillic alteration is also present at the Dry Creek Mine near the southeast end of the Robbins Fault, as 6-7.5 meter wide bodies in two parallel shear zones.

Advanced argillic assemblages consist largely of pyrophyllite + quartz ± sericite with minor to trace ottrelite, pyrite, fluorapatite, and rutile (**Powers, 1993**). Lenses composed largely of quartz and pyrophyllite are present in the Standard Mineral Mine. Associated silicic alteration includes irregular zones of pervasive silicification that varies from coarse- to fine-grained and variably deformed veins, lenses, and pods of locally vuggy white vitreous quartz (**Powers, 1993**). Ottrelite commonly occurs as randomly oriented prismatic crystals up to a millimeter long and as radiating clusters, locally transposed into the S_2 foliation in the highly sheared pyrophyllite ore bodies (**Powers, 1993**).

Phyllic alteration is composed of quartz + sericite + pyrite ± chlorite ± carbonate with varying proportions of relict protolith minerals, especially partly altered potassium and plagioclase feldspars (**Powers, 1993**). Zones of fine-grained pervasive silicification are locally present, along with stringer and stockworks quartz veinlets conformable with cleavage that may be gray due to the presence of very fine-grained disseminate pyrite, especially where associated with gold mineralization (**Powers, 1993**). Vitreous quartz veins ranging from a centimeter to five meters thick are common and often cross-cut cleavage (**Powers, 1993**). Many of these veins may represent reverse strain tension veins.

Powers (1993) also describes an association of fine-grained reddish-brown silicic alteration (jasperoid) with gold mineralization in the Robbins area, probably colored by fine-grained hematite. This distinctive alteration occurs southwest along strike from the Burns Mine and also to the north. **Powers (1993)** also noted the presence of disseminated magnetite and hematite in propylitic alteration assemblages in the hanging wall of the Robbins Fault. **Conley (1962a)** also noted extensive hematite-enrichment of the hanging wall phyllic alteration zone at the Standard Mineral Mine. These occurrences are similar to the Fe-enrichment noted by **Conley (1962a)** peripheral to advanced argillic and intense phyllic alteration along the Glendon Fault.

Pyrite, the dominant sulfide in all alteration assemblages, is almost ubiquitous in the advanced argillic, phyllic, and silicic alteration assemblages, possibly as a product of pervasive sulfidation of Fe-bearing mineral phases in the protolith. Pyrite occurs as generally < 2 millimeter euhedral to anhedral grains disseminated grains, in pyrite and quartz + pyrite veinlets and veins, and locally as massive to semi-massive lenses in the advanced argillic zone (**Powers, 1993**). Pyrite also occurs as bedding-parallel pyrite-rich laminae in epiclastic sediments near the Burns Mine (**Powers, 1993**).

A similar occurrence of pyrite-rich laminae parallel to bedding is noted in phyllic altered fine-grained epiclastic sedimentary rocks proximal to gold mineralization at the Russell deposit in the Ophir District of Montgomery County, North Carolina and in the Ridgeway and Haile deposits in South Carolina. Although commonly interpreted as evidence of syngenesis of gold mineralization and host rocks, the occurrences at the Ridgeway Mine result from the sulfidation of detrital Fe-Ti oxides along the coarser basal layer of turbidite beds (**Moye, 2012**). At Ridgeway this paragenetically earliest phase of pyrite does not carry Au mineralization. Typically, these laminae are only preserved peripheral to zones of high strain at the Ridgeway, Haile, and Russell mines; but are typically dismembered, transposed, and remobilized in zones of higher strain that host economic-grade gold mineralization (**Moye, 2012**).

As previously noted, pyrite occurs in quartz veinlets within the Robbins Fault Zone, especially in zones of gold mineralization, that are typically conformable with the dominant cleavage but form randomly oriented stockworks in zones of more massive silicification (**Powers, 1993**). These quartz veinlets are locally gray or black due to the presence of extremely fine-grained (<<1 millimeter) pyrite, especially in gold-bearing zones (**Powers, 1993**).

Lenses of semi-massive to massive pyrite (>30% by volume) are present in the advanced argillic zone in Pit 3 of the Standard Minerals Mine (**Powers, 1993**). The largest is 7 meters long, 3 meters wide, and conformable to foliation (**Powers, 1993**). These pyrite lenses do not carry significant Au mineralization (**Powers, 1993**), and are similar to barren to low Au-grade pyrite lenses at the Russell Mine in Randolph County, North Carolina (**Klein *et al.*, 2007**), and at the Haile Mine (**Schrader, 1921**) in South Carolina.

Pyrite also occurs within or peripheral to the advanced argillic alteration zone at the Standard Minerals Mine as late-kinematic euhedral crystals up to 5 centimeters in diameter that cut across the S_2 foliation (**Powers, 1993**). These crystals are commonly poikiloblastic with inclusions of quartz + pyrophyllite ± sericite. Although they cut the earlier cleavage, the pyrite crystals are often slightly deformed with pressure shadows, suggesting that they are late kinematic. Similar large, euhedral, late-kinematic pyrite crystals are present in the periphery of many gold deposits of the Carolina Terrane characterized by large zones of pervasive phyllic to advanced argillic alteration and sulfidation. These include AES along the Glendon Fault to the east, the Pilot Mountain AES and Sawyer-type gold deposits in Randolph County, North Carolina, and the Ridgeway and Haile gold deposits in South Carolina.

Powers (1993) also reports the presence of minor to trace amounts of arsenopyrite, pyrrhotite, and molybdenite associated with advanced argillic alteration in Pit 3 of the Standard Mineral Mine, and pyrrhotite and molybdenite in drill core from the Cagle and Burns gold prospects. Poikiloblastic inclusions of pyrite in arsenopyrite suggest that the latter is younger (**Powers, 1993**) and growing at the expense of pyrite from As-rich fluids. Powers reports the presence of highly anomalous Hg in some samples from the Burns and Cagle gold mines and Standard Mineral pyrophyllite mine (**Powers, 1993**); however, these results are regarded with suspicion.

Samples from the Burns Mine contain up to 220 ppm Mo, those from the Cagle Mine up to 240 ppm Mo, and samples from the Standard Mineral Mine contain up to 110 ppm Mo (**Powers, 1993**). **Powers (1993)** reports the presence of widespread F-bearing mineral phases in the advanced argillic alteration zone in the Standard Minerals Mines open pit. These include fluorite in synkinematic quartz veins, trace topaz, and possibly widespread fluorapatite as disseminated grains. **Powers (1993)** noted aggregates of fluorapatite intergrown with an opaque mineral in angular clasts present in a zone of intense silicic alteration footwall to the advanced argillic alteration zone at the Standard Minerals Mine.

Trace element analyses and mineralogical studies by **Powers (1993)** suggest that the characteristic geochemical association for advanced argillic alteration and associated gold mineralization in the Robbins area is Au-Ag-As-Mo-Pb-Sb-F ± Bi. This is very similar to the trace element associations of the Pilot Mountain AES in North Carolina (**Schmidt, 1985**; **Moye, 2013**) and the Ridgeway and Haile gold deposits in South Carolina (**Moye, 2012**). Although there is a general association, there is no consistent correlation of higher Au values with any other elements (**Powers, 1993**). This aggregate characterization is not consistent, however, as F-bearing minerals are only associated with advanced argillic alteration zone on the Robbins Fault and neither advance argillic alteration nor F are present in association with the gold mineralization.

Gold mineralization is present in the silicified footwall to the advanced argillic alteration zone in Standard Mineral Pit 3 (**Powers, 1993**). This footwall silicification is characterized by cleavage-parallel domains of white quartz separated by spaced planes of quartz + pyrophyllite and does not contain gold mineralization (**Powers, 1993**). Stockworks of gold-bearing dark-gray to black quartz + pyrite veinlets, darkened by the abundance of very fine-grained pyrite, cross-cut this earlier stage of barren white quartz (**Powers, 1993**). The presence of clasts of barren silicic footwall alteration enclosed by dark gray Au- mineralized quartz was interpreted by **Powers (1993)** as the possible result of hydraulic fracturing and brecciation. Similar sulfide-rich gray quartz veins are present within the advance argillic alteration zone in Pit 3, but occur as foliation-parallel stringers and lenses that suggest late kinematic formation.

The timing of gold mineralization in the Robbins area is poorly constrained, but generally appears to be associated with pyritic-silicic alteration and quartz veins, locally characterized by gray or blue-gray to dark gray silica, that post-dates both advanced argillic and phyllic epithermal alteration with earlier phases of barren silicic alteration along the Robbins Fault.

Pyrophyllite mines and prospects on the Robbins AES Trend

Two pyrophyllite mines (**Figure 1**, **Figure 2**, **Figure 9**) are present along the Robbins AES alignment (**Conley, 1962a**; **Stuckey, 1967**). The most important is the Standard Mineral Company Mine, previously mined underground and still active as an open-cut operation. Additional advanced argillic alteration is present at the Dry Creek Mine near the southeast end of the Robbins Fault, as 6-7.5-meter-wide bodies in a zone of complex shearing and faulting.

Standard Mineral Company Mine

The mine, previously known as the Hemp Mine, is located about 2.6 kilometers southwest of the town of Robbins (formerly Hemp), and centered at geographic coordinates -79.6131, 35.41649 (WGS84). Pyrophyllite was discovered at the site in 1888, when a zone about 3 meters thick was exposed in an adit driven in search of gold (**Stuckey, 1967**). Production began soon after the nearby discovery of a pyrophyllite-rich zone about 46 meters wide in 1918.

Initially mined from open cuts at the surface, a shaft was excavated to a depth of 27 meters and a 4.3-meter-thick lens of pyrophyllite was mined underground. Exploration identified a 9-metet-thick lens of pyrophyllite to the northwest and around 1925 a production shaft was constructed to a depth of 61 meters (**Stuckey, 1967**). A two-compartment shaft was later sunk into the footwall of the deposit to a depth of 200 meters. This is the only pyrophyllite mine in North Carolina historically worked underground.

Open-pit mining started at Robbins in 1940, and the mine combined underground and open cut production. By the mid-1960s, the open cut extended for about 400 meters and pyrophyllite was also being mined from the eighth level (~ 122 meters) underground (**Conley, 1962a**; **Stuckey, 1967**). Underground mining ceased in 1966 and open pit production continues to the present. The Standard Mineral open pit mine occupies a 600-meter-long portion of a zone of advanced argillic alteration that begins immediately south of the historic Cagle Au Mine and extends southwest for around 1,500 meters to just north of the California Au Mine.

The advanced argillic alteration zone lies within the Robbins Fault (**Figure 11**, **Figure 12**), with a strong penetrative cleavage that strikes 020°-030° and dips 50°-70° northwest (**Conley, 1962a**; **Stuckey, 1967**). Silicic and phyllic alteration extend for 23-30 meters into the fault hanging wall and about 34 meters into the footwall (**Stuckey, 1967**). The main pyrophyllite-bearing zone is about 610 meters long and averages 70-100 meters wide (**Powers, 1993**). Economic concentrations of pyrophyllite occur in laterally and vertically anastomosing zones from less than 10 meters thick to 70 meters thick throughout the area of advanced argillic alteration (**Powers, 1993**). Although **Conley (1962a)** suggested imbricated repetition of a single pyrophyllite ore zone by reverse faulting, pyrophyllite ore bodies appear to be developed along anastomosing reverse fault strands (**Powers, 1993**).

Synkinematic white quartz veins are common within the advance argillic alteration zone, as deformed, discontinuous veins, lenses, and elongated pods conformable with the foliation (**Powers, 1993**). This quartz is locally vuggy and contains accessory pyrite and fluorite.

Gold mineralization is locally present in the silicified footwall to the advanced argillic alteration zone in Standard Mineral Pit 3. Stockwork dark-gray to black quartz + pyrite veinlets, darkened by the abundance of very fine-grained pyrite, cut across an earlier stage of barren milky white quartz (**Powers, 1993**). The earlier quartz veining is characterized by cleavage-parallel domains of quartz separated by spaced planes of quartz + pyrophyllite (**Powers, 1993**). The presence of clasts of barren silicic alteration enclosed by dark gray mineralized quartz was interpreted by **Powers (1993)** as the possible result of hydraulic fracturing, brecciation, and mineralization. Similar sulfide-rich quartz veins are present within the advance argillic alteration zone in Pit 3, but occur as foliation-parallel stringers and lenses.

Dry Creek Mine

The mine is located on the Robbins Fault about 3.2 kilometers southwest of the Standard Mineral Company Mine (**Figure 9**) at geographic coordinates -79.63197, 35.3973 (WGS84) The mine consists of two pits 150 meters apart (**Figure 13**), the Tucker Pit and the Williams Pit. Each is opened along two thin parallel shear zones hosting pyrophyllite bodies that pinch and swell along strike and are typically less than 6 meters thick (**Conley, 1962a**).

Based on an apparent offset of the pyrophyllite zones between the two pits, **Conley (1962a)** suggests either most-mineral faulting or *en echelon* structures. However, this could represent heterogeneity of structure and alteration in a complex reverse fault duplex. The host rocks are advanced argillic to phyllic (sericite-quartz) altered mudstones (**Conley, 1962a**).

Gold mines and prospects on the Robbins trend

At least a dozen historic gold mines are present along or near the trend of the Robbins Fault Zone, most to the west of the Robbins Fault (**Figure 14**). Gold is associated with linear zones of silicic to strong phyllic alteration with disseminated pyrite and quartz veins, stockworks, and stringer zones. Most of these zones strike about 025°-030° and dip 45-55° northwest, parallel to the locally dominant cleavage (**Powers, 1993**). They may be developed along second-order reverse faults and other structures in the hanging wall of the Robbins Fault.

These deposits are typically of small tonnage, but with grades of 0.25-0.5 ounces Au per ton that justified underground mining at historic scales. Initial mining was probably largely by open-cut, and may have benefitted greatly from supergene oxidation of sulfide ores and significant secondary enrichment. **Powers (1993)** noted evidence of gold liberation by oxidation of pyrite and supergene gold enrichment in Robbins area gold deposits. Mine workings seldom extend below the zone of supergene oxidation above the water table.

Most gold-mineralized zones are a few meters wide with strike lengths of less than 250 meters (**Powers, 1993**). Gold mineralization is hosted by 1-5% disseminated pyrite, stockwork quartz veinlets, and some larger quartz veins in lodes typically 1-3 meters thick that are contained within zones of silicic to phyllic alteration meters to tens of meters thick. The largest known zone of gold mineralization is up to 60 meters wide and extends for around 760 meters along strike between the Red Hill and Burns gold mines on Laurel Hill (**Powers, 1993**).

Although gold mineralization is typically pyritic, there is no correlation between pyrite abundance and gold grade (**Powers, 1993**). Gold is variably associated with anomalous As, Mo, Sb, Pb, and Bi, but there is no consistent correlation between gold concentration and trace element abundance (**Powers, 1993**). Ore-grade gold mineralization appears to be most closely associated with silicification, as pervasive silicic alteration or quartz veins, stringers, and veinlet stockworks. Where paragenetic constraints are available (**Powers, 1993**), auriferous pyritic silicic alteration and gold-bearing quartz veins appear to post-date phyllic, advanced argillic, and earlier barren silicic alteration along the Robbins Fault Zone. However, it may pre-date or is synchronous with the latest phase of ductile-brittle reverse faulting on the Robbins Fault.

Powers (1993) defined three main trends of gold mineralization associated with the Robbins Fault Zone (**Figure 9, Figure 14**). One includes the Standard Mineral Company open pit mine on the advanced argillic alteration zone, the Cagle Gold Mine to the northeast, and the old California gold mine to the southwest, all on or proximal to the main Robbins Fault (**Figure 14**). The Jenkins-Kendale-Richardson trend of gold mineralization is located about 300 meters into the hanging wall of the Robins Fault to the southwest of the Standard Minerals Mine (**Figure 14**). The Wright-Clegg-Red Hill-Allen-Burns trend is located about 350 meters into the hanging wall of the Robbins Fault to the northwest of the Standard Minerals Mine open pit (**Figure 14**). **Powers (1993)** suggests that the Wright-Clegg-Red Hill-Allen-Burns alignment is conformable within a lapilli-rich volcaniclastic unit. However, it is probable that these textures are structural, consisting of foliation-bounded lithons along a shear zone rather than lapilli. Similar tectonic textures characterize the Ridgway and Haile gold deposits in South Carolina (**Moye, 2012**).

The Robbins area was a highly sought-after gold exploration target in the 1980s, and numerous mining companies sampled and evaluated hydrothermal alteration zones in the area. The Cagle Mine was drilled by Newmont Exploration in 1981, and the Burns Mine was drilled by Tenneco in 1983 (**Powers, 1993**). **Powers (1993)** reports that the Adena Mineral Company applied for permits to mine a mineralized zone 200 meters long and about 10 meters thick with an average grade of 0.07 oz/t Au at the site of the old Burns Mine (**Figure 14**).

Cagle Mine

The mine is located about 300 meters on a bearing of 350° from the intersection of S.R. 1434 and S.R. 1002 on the east side of Cabin Creek (**Figure 14**, **Figure 15**), at geographic coordinates -79.6081, 35.4251 (WGS84). The deposit was mined from sometime before 1865 until around 1900. The ore was mined along an almost continuous series of open cuts and underground through three inclined shafts (**Nitze and Hanna, 1896**; **Conley, 1962a**). The northernmost shaft followed the lode to a depth of over 50 meters, and a second shaft about 15 meters to the southwest reached a depth of about 80 meters (**Conley, 1962a**). A third shaft farther southwest extended to a depth of 55 meters, with drifts opened for at least 60 meters to the southwest. An open cut extends northeast from the first shaft for around 90 meters, and six additional open cuts along the lode were opened to a depth of around 10 meters (**Conley, 1962a**). Up to 30 stamp mills were active along the line of lode during the peak period of mining.

Mapping by **Lesure (1981)** traced workings associated with historic mapping along the Cagle Mine deposit for 200 meters at a strike of 021° to the north of SR1002 (**Figure 15**). South of the road, after a gap of about 70 meters, workings continue for another 100 meters at a strike of 038° (**Figure 15**). The lode was mined almost continually along the surface through open cuts and inclined shafts. A series of at least six shafts and collapsed shafts spaced every 20-50 meters along the northwest side of the line of lode probably provided access to the base of the stopes.

The presence of two mineralized trends at different strikes suggests either *en echelon* structural segments, mineralization adjacent to a bend or deflection in a single structure, or a post-mineralization offset. The position of the Cagle Mine mineralized zone is very close to the projected position of the Robbins Fault, and may be located along a secondary structure in the immediate hanging wall. Pyrophyllite-bearing assemblages extend along the Robbins Fault to immediately south of the mine (**Stuckey, 1967**), and **Powers and Klein (1992)** suggest the presence of pyrophyllite in the phyllic alteration assemblages flanking the vein.

The ore body is described as a blue-gray quartz vein or siliceous zone about 76 centimeters thick with 3-4% disseminated pyrite and trace chalcopyrite, enclosed by sheared sericite schist that was also auriferous over a width of about 38 centimeters on either side of the vein (**Kerr and Hanna, 1888**; **Conley, 1962a**). The lode strikes 027° and dips 50° northwest, with a strike length of at least 200 meters. It was mined over a total width of about 152 centimeters, locally increasing to over 2.5 meters, with grades of 0.2-0.4 oz/t Au and around 0.1-1.1 oz/t Ag (**Nitze and Hanna, 1896**; **Conley, 1962a**). The higher gold grades were restricted to localized shoots within the vein, with assays as high as 2.3 oz/t Au (**Nitze and Hanna, 1896**).

Powers (1993) analyzed five samples of mineralization from the Cagle Mine. All were strongly anomalous in Au, ranging from 0.25-3.40 ppm. Two samples contain Au in excess of 2.0 ppm (2.40 and 3.40 ppm Au). Silver values were generally low (0.2-0.8 ppm), but one sample contained 2.4 ppm Ag, along with 0.645 ppm Au and 180 ppm As. No As was present in the other four samples. All five samples contain anomalous Mo; three with Mo in excess of 100 ppm (130, 170, and 240 ppm). None of the high Mo values were associated with the two samples with the highest Au values. Base metal values were at background levels.

California Mine

Also known as the California Shaft, this mine is located in the extreme southwestern end of the Standard Mineral Company pyrophyllite pit (**Figure 14**) at geographic coordinates -79.61505, 35.41121 (WGS84). The shaft was extended to a depth of 23 meters in 1896, but the ore grade was low and the mine soon closed (**Conley, 1962a**). In 1991 the workings are described as about 20 meters long, 15 meters wide, and 5 meters deep, with accessory minerals pyrophyllite, sericite, and quartz (MRDS record # 10095907, https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10095907, viewed 01 January 2018).

Dry Hollow Placer Mine

This placer working (**Figure 14**) is located at geographic coordinates -79.61977, 35.4057 (WGS84). It was mined intermittently until 1907 along a small stream south of the Standard Mineral Company pyrophyllite mine. It is reported that a 3 ounce gold nugget was found in this stream sometime before 1896. The site is now covered by the pyrophyllite mine dumps.

Jenkins Mine

This mine is located about 400 meters southwest of the Standard Mineral Company pyrophyllite mine (**Figure 14**) at geographic coordinates -79.61977, 35.41149 (WGS84). It opened prior to 1865 and there was intermittent production until 1890, with an attempted re-opening in 1912 (**Conley, 1962a**). Two shafts have been sunk along strike on the lode, the southwestern extending to a depth of about 26 meters. Drifts extended from the shaft along the strike of the lode at three levels; the first level was the longest at around 90 meters (**Conley, 1962a**). The depth of the northeast shaft is unknown. The 90 to 120 centimeter thick ore zone is a highly silicified cream colored felsic volcaniclastic rock, locally called “crushed flint” (**Conley, 1962a**). This mine is now covered by the dumps of the Standard Minerals pyrophyllite mine.

Kendale Mine

This mine is located at geographic coordinates -79.62255, 35.40788 (WGS84), 0.9 kilometers southwest of the intersection of State Roads S.R. 1434 and S.R. 1276 (**Figure 14**). Little information is available on the history of mining at this site, but it is probably similar to that of the Jenkins and Richardson mines. Three pits 3-7 meters deep with moderate amounts of dump material, which may be collapsed shafts, two wide trenches, and several small pits are present over a distance of about 55 meters (**Klein and Powers, 1987**). Lenses of strong silicic alteration with disseminated pyrite occur in a zone of phyllic alteration up to 15 meters wide that extends for about 55 meters. Alteration and mineralization are parallel to a strong 040° cleavage that dips 60° NW in fine-grained felsic volcaniclastic rocks (**Klein and Powers, 1987**).

Richardson Mine

This property is located at geographic coordinates -79.62366, 35.40677 (WGS84), around 457 meters southwest of the Jenkins Mine (**Figure 14**), and described as a possible extension of the same lode (**Conley, 1962a**). However, this correlation has not been confirmed. The mine was first worked around 1860 and in operation as late as 1906. The ore body appears to be similar to the Jenkins lode. The two meter thick zone strikes 015° degrees, and consists of strongly silicified felsic volcaniclastic rock with cross cutting quartz veins (**Conley, 1962a**). Nine shafts of unknown depth are regularly spaced along the lode over a distance of about 400 meters, with drifts developed along the ore zone at several levels (**Conley, 1962a**).

Wright Mine

This mine (**Figure 14**) is located at geographic coordinates -79.61421, 35.4301 (WGS84), about 46 meters northeast of the Clegg Mine, and appears to be a continuation of the same zone. A vertical shaft was sunk on the lode before 1862, and a second shaft completed to a depth of 18 meters before the mine closed in 1912. After grinding the ore on Chilean mills, the gold was recovered in riffle boxes.

Mineralization is disseminated through a 28-50 centimeter zone of fault gouge strongly stained by Mn oxides (**Conley, 1962a**). The host rocks for the Wright-Clegg-Red Hill-Allen-Burns mines trend are rhyolite crystal tuffs, with the width and intensity of the alteration zone increasing to the southwest (**Powers, 1993**).

Clegg Mine

The Clegg or Clegg-Wright Mine is located 2.4 kilometers west of Robbins and 400 meters west of the Cagle Mine (**Figure 14**) on the opposite side of Cabin Creek at geographic coordinates -79.61421, 35.4301 (WGS84). It appears to be a continuation of the lode at the Wright Mine, located 46 meters to the northeast.

The mine was initially an open cut operation but two shafts were excavated after 1900, one to a depth of about 34 meters and the Gerhardt Shaft to a depth of 39 meters (**Conley, 1962a**). The open cut is 65 meters long, up to 20 meters wide, and 10 meters deep (**Klein and Powers, 1987**). Disseminated gold is present in a zone of quartz-sericite schist with a stockwork of small quartz veinlets (**Conley, 1962a**). This zone is about 3.7 meters thick, strikes 025° and dips 75° northwest. The host rock is a sheared felsic volcaniclastic unit.

Red Hill Mine

The mine is located at geographic coordinates -79.61421, 35.42677 (WGS84), 600 meters at 302° from the intersection of SR 1434 and SR 1002 (**Figure 14**). It is part of the discontinuous, possibly *en echelon* line of lode between the Clegg Mine to the northeast and the Allen Mine to the southwest. The starting date for mining is unknown, but the mine closed in the early 1900s.

A large, irregular open cut at the site is about 25 meters across and up to 8 meters deep (**Klein and Powers, 1987**). A vertical shaft reached a depth of 30 meters, with a drift that extended 015° for 76 meters to intersect the hillside (**Figure 16**). Gold is reported disseminated through sericite schist in a zone about 18 meters wide (**Conley, 1962a**), probably sheared and phyllic altered felsic volcaniclastic units. The mineralized zone is at an acute angle to the dominant foliation, which strikes 025°-040° and dips 60°-75° northwest (**Klein and Powers, 1987**).

Powers (1993) analyzed 5 samples of mineralization from the Red Hill Mine. Only three samples contained detectable Au, with values of 0.18, 1.20, and 3.70 ppm. No anomalous Ag was present in the samples; and As, Cu, Mo, and Zn values were at background levels. Two samples contain anomalous Pb (55 ppm and 100 ppm Pb), but there is no consistent association with high values of Au.

Allen Mine

This mine is located at geographic coordinates -79.61505, 35.42427 (WGS84), on a hill 150 meters southwest of the Red Hill mine (**Figure 14**), and is probably an extension of the same mineralized zone. A shaft over 12 meters deep is present (**Figure 17**), with drifts extending from the bottom to the northeast and southwest along strike (**Conley, 1962a**). An adit driven into the west side of the hill failed to intersect the shaft.

The ore body is a silicified zone about 11 meters wide that strikes 025° and dips steeply northwest (**Conley, 1962a**). The relative positions of the historical mine workings at the Allen Mine and the Burns Mine to the southwest (**Lesure, 1981**) suggest that these areas of gold mineralization are not part of a continuous zone, but appear to be discontinuous north and east-stepping *en echelon* segments.

Samples (7) of mineralization analyzed by **Powers (1993)** varied widely in Au content, from <0.02 ppm to 1.4 ppm Au, averaging 0.32 ppm. Silver values ranged from <0.1 to 2.0 ppm, averaging 0.97 ppm. All samples contained >4.0 ppm Mo with a high value of 35 ppm; and three samples contained detectable As, ranging from 20-70 ppm. Base metals were negligible.

Burns Mine

Also known as the Burns and Alred (**Nitze and Hanna, 1896**), the mine is located on Moody Hill above Cabin Creek (**Figure 14**) at geographic coordinates -79.6181, 35.42204 (WGS84), about 320 meters southwest of the Allen mine. **Nitze and Hanna (1896)** reported that the mine had been in production for 40 years at the time of their survey. The main production period was 1830-1880, with additional production in 1894-1895. The mine reopened briefly in 1906, and again in 1915 for about 18 months before closing for the last time. The workings (**Figure 18**) are a series of open pits from 6 to 30 meters wide and up to 15 meters deep that extend for around 320 meters along strike (**Nitze and Hanna, 1896**).

The lode strikes 020° and dips 55° northwest, with mineralization disseminated through variably silicified sericite and chlorite schists with disseminated pyrite and a swarm or stockwork of quartz stringers and lenses (**Nitze and Hanna, 1896**; **Conley, 1962a**). The grade averaged 0.16 to 0.24 ounces Au per ton, but higher-grade shoots were encountered (**Nitze and Hanna, 1896**). According to **Nitze and Hanna (1896)**, the gold is too fine-grained to be visible, and ore grade had to be determined by panning or by analysis of mill runs. Ore near the surface disaggregated easily and was milled by Chilean wheel, but harder ore at depth was difficult to grind and required a 10 stamp mill with bumping tables, installed in 1895 (**Nitze and Wilkens, 1897**). Mining typically did not extend below the water table.

The Burns Mine is located on a mineralized zone of variably silicified phyllic alteration that strikes about 020°-025° that has been traced discontinuously for about 700 meters northeast through the Allen and Red Hill mines, and may continue to the Clegg-Wright Mine (**Powers, 1993**). This zone is generally 10 to 30 meters thick, over 50 meters thick near the Allen Mine, and narrows to less than 4 meters at the Clegg Mine.

Ore grade mineralization appears to occur as irregular lenses, composed of pyritic silicic alteration and cleavage-parallel quartz vein swarms, which narrow along strike and down dip. The dip of the ore lenses varies from about 55° northwest at the Burns Mine to 75° northwest at the Clegg Mine. Ore lenses are enclosed by a zone of less intense phyllic alteration from meters up to 100-150 meters wide that grades outward into unaltered rocks.

At the Burns Mine, drilling by Tenneco in 1983 identified up to three lenses of silicic alteration within the phyllic alteration zone (**Figure 19**), and defined a mineralized zone 200 meters long and about 10 meters wide in the upper lens, with an average grade of 0.07 oz/t Au (**Powers, 1993**).

The Burns Mine mineralized zone is hosted by felsic volcaniclastic units. **Powers (1993)** suggests that alteration and mineralization are stratigraphically confined to a unit of lapilli-rich tuff above the contact with a mudstone sequence. However, this degree of stratigraphic control is unlikely, and the lapilli in the phyllic to silicic alteration zones are probably lithons formed by a combination of shearing, textural destruction, and enhanced hydrothermal alteration along the anastomosing foliation.

Powers (1993) collected and analyzed 19 samples from the mineralized zone of the Burns Mine. The gold content of one sample was below detection (<20 ppb), but in the others ranged from 0.046 to 4.110 ppm. Eight samples contained over 1.0 ppm Au, and averaged 2.105 ppm Au. Silver content ranged from below detection (2) to 46.0 ppm, with over 1.0 ppm Ag present in 8 samples. Geochemically significant As was present in only two samples, one with 110.0 ppm and the other at 440.0 ppm As. Both samples contained >1.0 ppm Au. Copper and Zn are present at background values, but five samples contain Pb ranging from 38-66 ppm, significantly higher than average background values for felsic volcanic rocks (~20 ppm). All are associated with Au values in excess of 1.0 ppm.

Fourteen samples contain Mo significantly in excess of the average background value for felsic volcanic rocks (~1.5 ppm), eight ranging from 3-6 ppm and four ranging from 20-70 ppm Mo. Two samples contain Mo in excess of 100 ppm. Theses samples appear to be high-grade gold ore. Sample BU-7a' contains 2.82 ppm Au, 46.0 ppm Ag, 440 ppm As, and 130 ppm Mo. Sample BU-l1' contains 1.35 ppm Au, 11.5 ppm Ag, 220 ppm Mo, and 52 ppm Pb, but there is no value for arsenic.

Brown Mine

This mine is located in a sharp meander of Cabin Creek about 238 meters southwest of the Burns mine (**Figure 14**) at geographic coordinates -79.6231, 35.42204 (WGS84). It was last operated about 1905. The mineralized zone is about 375 meters long, with production largely from an open cut about 320 meters long with depths of 12-15 meters (**Figure 20**), along with a few shallow shafts or prospect pits less than 12 meters deep (**Nitze and Hanna, 1896**; **Conley, 1962a**).

The mineralization was about a meter thick and subhorizontal, with a narrow pay seam rich in quartz that finally became too thin to work profitably (**Nitze and Hanna, 1896**). **Conley (1962a)** reports that the host rock is brecciated and silicic to phyllic altered felsic volcaniclastic rocks, with minor disseminated gold. **Powers (1993)** interprets mineralization as conformable and stratabound, in a varied sequence of felsic lapilli and crystal tuffs, felsic flows, and mudstone, with alteration and mineralization present in all lithologies.

Samples (12) collected from the mineralized zone by **Powers (1993)** included 7 barren samples and 5 mineralized samples. The mineralized samples contained 0.06 to 1.885 ppm Au with an average value of 0.485 ppm. Values for Ag, As, Mo, Cu, Pb, and Zn were below detection or at background levels.

Shields Mine

This mine is located about 200 meters northwest of the Brown mine (**Figure 14**) at geographic coordinates -79.62307, 35.4195 (WGS84). The mine was active around 1895. Production was from an open cut and one shaft of unknown depth. **Conley (1962a)** reports an ore shoot about 76 centimeters wide in schistose phyllic alteration with numerous quartz veins.

Discussion and analysis of the Glendon and Robbins AES alignments

AES in the Glendon and Robbins alignments of Moore County, North Carolina occur along complex, northeast-striking, steeply or moderately northwest-dipping reverse fault zones. The Glendon Fault apparently developed along the axial plane of an anticline compressed and overturned to the southeast (**Green, 1977**; **Green *et al.*, 1982**). The fault has been traced for about 12 kilometers, but may include a companion *en echelon* fault developed along the axis of a parallel anticline to the northwest. The Robbins Fault Zone has been traced for at around 6 kilometers, and may be part of a larger zone of heterogeneous shearing, faulting, and hydrothermal alteration (**Conley, 1962a**; **Powers, 1993**). The Glendon and Robbins fault zones appear to be separate, but possibly *en echelon* structures. There are no known occurrences of advanced argillic alteration in the gap between these two fault zones.

The Glendon Fault varies from about 10 meters up to 45-50 meters thick, with possibly a kilometer of offset (**Conley, 1962a**). Thicker sections of the fault appear to be complex reverse or oblique duplexes, often with multiple anastomosing fault strands present between the roof and floor faults. A similar width and architecture is characteristic of the Robbins Fault (**Conley, 1962a**; **Powers, 1993**). Many of the larger AES along both the Glendon and Robbins faults appear to be centered within these duplex zones, with pyrophyllite-dominated advanced argillic alteration assemblages generally confined between the floor and roof faults. However, phyllic alteration may extend up to 100 meters into the hanging wall and footwall (**Conley, 1962a**; **Powers, 1993**).

The character and origin of AES on the Glendon and Robbins faults

Stuckey (1928) and **Broadhurst and Council (1953)** related AES development on the Glendon and Robbins faults to hydrothermal replacement. **Conley (1962a)** suggests that AES formation by hydrothermal fluids was synchronous with reverse shear along the faults. **Spence (1975)**, **McDaniel (1976)**, **Klein (1985)**, and **Powers (1993)** interpret the Glendon AES as products of surface or near-surface geothermal alteration formed synchronously with felsic volcanism and subsequently metamorphosed and structurally modified.

The absence of andalusite as a major aluminum silicate phase in Glendon and Robbins advanced argillic alteration assemblages is atypical of the AES in the Carolina Terrane in central North Carolina. Additionally, strong concentric zonation and core areas of intense, fine-grained silicic alteration, characteristic of other AES, are not present. **Schmidt (1985)** suggested that the absence of these features at Glendon was the result of lower temperatures of formation relative to other AES occurrences, at possibly a more distal location relative to felsic magmatic reservoirs and heat sources. This is supported by the apparent absence of closely associated felsic intrusive units, including dikes, plugs, and stocks.

The present study supports the interpretations of **Spence (1975)**, **McDaniel (1976)**, **Klein (1985)**, and **Powers (1993)** regarding the primary formation of the AES on the Glendon and Robbins fault; however, with the caveat that the associated felsic magmatism is Uwharrie-age rather than Hyco-age. This study also supports the interpretations of **Stuckey (1928)**, **Broadhurst and Council (1953)**, **Conley (1962a)**, and **Schmidt (1985)** regarding the importance of reverse faulting and hydrothermal overprinting to the present form of these deposits; but with the caveat that this synkinematic hydrothermal overprint occurred at higher pressure but lower temperature than the primary hydrothermal assemblage.

The AES along the Glendon and Robbins faults are advanced argillic epithermal alteration systems that may be linked to felsic magmatic reservoirs at depth. They most likely formed during the late Proterozoic, possibly in association with Uwharrie felsic magmatism, at paleodepths of less than a kilometer. Like the Pilot Mountain AES in Randolph County, they may represent higher crustal level expressions of porphyry-style Au ± Cu ± Mo deposits (**Schmidt, 1985**). However, the Glendon and Robbins area AES have been structurally modified, mineralogically altered, and metamorphosed under southeast-directed compressive strain during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**), obscuring their character and origin.

The structural evolution of the Glendon and Robbins faults and AES

Conley (1962a) suggests that hanging wall and footwall lithologies are repeated by imbrication within a reverse duplex on the Glendon Fault at the White Mine, and that advanced argillic alteration zones are repeated by imbrication on the Robbins Fault in the Standard Mineral Mine. However, **Powers (1993)** concludes that pyrophyllite-bearing assemblages in the Standard Minerals Mine are intensely sheared and enriched to ore-grade along discrete reverse fault strands. The resulting advanced argillic mineral assemblages is pyrophyllite ± quartz ± sericite ± pyrite ± ottrelite, formed synchronous with the S_2 cleavage at greenschist facies metamorphic conditions. Similar observations along the Glendon Fault (**Conley, 1962a**; **Stuckey, 1967**; **McDaniel, 1976**; **Klein, 1985**) suggest a similar genesis for high-grade pyrophyllite ore bodies. However, pyrophyllite ore bodies along both faults may be locally imbricated by late kinematic reverse faulting (**Powers, 1993**).

Along both the Glendon and Robbins faults, this pyrophyllite ore-forming event overprints earlier rock fabrics, quartz veins, and hydrothermal alteration mineral assemblages (**Conley, 1962a**; **Klein, 1985**; **Powers, 1993**). The earlier event is expressed by a strong, penetrative, synmetamorphic cleavage (S_1) and shearing over a zone up to 200-300 meters wide along and peripheral to both the Glendon and Robbins faults. As AES form under shallow crustal conditions in typically tensional tectonic settings, the primary advanced argillic and phyllic alteration mineral assemblages appear to have formed prior to the synmetamorphic cleavage (S_1)

and shearing. The primary advanced argillic alteration assemblages are uncertain, but the synkinematic assemblage is composed of pyrophyllite + quartz + sericite ± pyrite ± ottrelite, which does not represent ore-grade pyrophyllite mineralization.

These observations (**Conley, 1962a**; **Stuckey, 1967**; **Klein, 1985**; **Powers, 1993**) suggest that primary AES formation is overprinted by two phases of ductile-brittle deformation under greenschist facies metamorphic conditions; an earlier phase of more widespread, heterogeneous reverse shear strain and a later phase of high strain localized along anastomosing reverse fault strands. Intense shearing, high volatile flow (indicated by multiple generations of synkinematic quartz veins), and greenschist facies metamorphic conditions contributed to pyrophyllite enrichment along reverse faults strands, possibly by the reaction:

$$2KAl_3Si_3O_{10}(OH)_2 + 6Si0_2 + 2H^+ = 3Al_2Si_4O_{10}(OH)_2 + 2K^+$$

(muscovite + quartz = pyrophyllite)

Euhedral porphyroblasts of ottrelite and pyrite overgrow the S_1 cleavage and are subsequently deformed during formation of S_2, suggesting a hiatus between the two deformation phases but under sustained greenschist facies metamorphic conditions. Additionally, the individual pyrophyllite-rich ore bodies are lenticular in form and pinch and swell along strike and down dip (**Stuckey, 1928**; **Conley, 1962a**), suggesting that their morphology may be the result of continued post-mineralization ductile strain.

The alteration assemblages, rock fabrics, and structures present along the Glendon and Robbins fault zones appear to be the products of a protracted but episodic deformation event synchronous with regional greenschist facies metamorphism at a paleodepth possibly in excess of six kilometers. The compressed folds overturned to the southeast, intense axial planar cleavage development, and formation of large-scale reverse faults is consistent with deformation during the Cherokee Orogeny (**Hibbard *et al.*, 2012**). The original fold architecture of the area may have formed during the Virgilina Deformation (**Harris and Glover, 1985**), with subsequent tightening, overturn to the southeast, and cleavage development during the Cherokee Orogeny, as described farther north in the Carolina Terrane by **Harris and Glover (1985)**.

The AES along the Glendon and Robbins faults are unlikely to have formed during the Virgilina Deformation or the Cherokee Orogeny. There are no known occurrences of AES developed in association with the Cherokee Orogeny. Many AES in central North Carolina appear to have formed after the Virgilina Deformation, possibly along *en echelon* transtensional fault zones in association with Uwharrie-related felsic magmatism (**Moye, 2013**). All appear to have been deformed and metamorphosed during the Cherokee Orogeny. Additionally, despite a similarity of structural controls, the metallogeny of the Glendon and Robbins AES is not consistent with mineralization associated with the Cherokee Orogeny.

Contrasting Uwharrie and Cherokee metallogeny

Two styles of gold mineralization, formed during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**), are recognized in the Carolina Terrane in Central North Carolina (**LaPoint and Moye, 2013**). Both are synkinematic, synmetamorphic, and associated with high-angle reverse or oblique ductile-brittle fault zones. Low-sulfidation, mesozonal orogenic gold deposits hosted by generally narrow, well defined quartz veins and silicic alteration zones include the historic high-grade lode gold mines of the Gold Hill Fault Zone, including those of the Gold Hill District (**Moye, 2017**).

A second style of orogenic gold mineralization is interpreted as shallow mesozonal, low-sulfide, low average Au-grade, large-tonnage gold deposits. They are characterized by often multiple parallel or *en echelon* lenses of silicic ore-grade mineralization meters to tens of meters wide enclosed by zones of pyritic phyllic alteration tens to hundreds of meters wide. Gold in silicic alteration lenses is associated with disseminated pyrite and narrow, millimeter-scale, cleavage-parallel quartz-pyrite vein swarms and stockworks. Alteration and mineralization intensity are heterogeneous and gradational with indefinite boundaries, and ore grade is typically determined by assay. The large volume of rock that has experienced pervasive sulfidation in these deposits could arguably be compared to high-sulfidation alteration.

These deposits appear to have formed within lower strain, less continuous deformation zones than typical orogenic gold deposits. Their structural controls are characterized by multiple, parallel reverse faults that are often axial to appressed, northeast-trending meso-scale anticlines with axial planes that dip steeply to the northwest. These atypical orogenic gold deposits include the Lofflin, Jones-Keystone, Sawyer, and New Sawyer mines in northwest Randolph County, and the Russell and Coggins mines in the Ophir District of Montgomery County, North Carolina (**LaPoint and Moye, 2013**).

Associated hydrothermal alteration is silicic and phyllic, but no advanced argillic alteration is reported for any of these occurrences. The characteristic trace element association for this Sawyer-type gold mineralization is Au-Ag-As ± trace to geochemically anomalous base metal sulfides. Locally anomalous Mo, Pb, and Sb are present in some deposits, especially in high-grade Au ores. No occurrence of fluorite, topaz, fluorapatite, or geochemically anomalous fluorine is reported for these hydrothermal systems.

The trace element association of the Glendon and Robbins AES is Au-Ag-As-Mo-F ± Cu, distinct from deposits formed during the Cherokee Orogeny. This association is similar to that of the Pilot Mountain, Snow Camp-Saxapahaw, and Hillsborough AES (**Figure 1**), the Deep River Au-Cu-Mo prospect located north of Robbins (**Figure 2**) at the Moore-Randolph county line (**Rapprecht *et al.*, 2013**), and the Ridgeway and Haile gold deposits in South Carolina (**Moye, 2012**). All of these occurrences appear to be associated with an episode of widespread felsic-dominated magmatism in the Carolina Terrane circa 550 Ma, including Uwharrie magmatism in central North Carolina (**Ingle, 1999**; **Ingle-Jenkins *et al.*, 1998**; **Ingle *et al.*, 2003**), a felsic dike associated with the Deep River Au-Cu-Mo-F porphyry gold prospect (**Rapprecht *et al.*, 2013**), Brewer Mine porphyry intrusions and breccia pipes in South Carolina (**Ayuso *et al.*, 2005**), and stitching plutons along the Carolina-Charlotte terrane suture zone in South Carolina (**Dallmeyer *et al.*, 1986**; **Barker *et al.*, 1998**; **Secor *et al.*, 1998**).

Additionally, the characteristic zone of peripheral Fe-enrichment, including magnetite and hematite, peripheral to the Glendon and Robbins AES is not reported for any of the orogenic Au deposits formed during the Cherokee Orogeny. However, this peripheral Fe-enriched zone is characteristic of the transition from phyllic to propylitic alteration in other AES occurrences in the Carolina Terrane of North Carolina (**Stuckey, 1925**; **Stuckey, 1967**. This suggests the presence of a strong redox boundary, possibly representing the interaction of two distinct fluids, in the genesis of Carolina Terrane AES.

In summary, the structural controls, rock fabrics, and mineralogy of the Glendon and Robbins fault-hosted AES are consistent with formation during the Cherokee Orogeny, which is characterized by large-scale folding overturned to the southeast and by often broad, large-offset reverse fault zones. However, the large-scale development of intense advanced argillic alteration and the trace element signature (Au-Ag-As-Mo-F ± Cu) appear to preclude association with the Cherokee Orogeny. These features are more consistent with the metallogeny of other AES in the Carolina Terrane in central North Carolina, apparently formed synchronous with Uwharrie-age magmatism at shallow crustal levels (**Schmidt, 1985**; **Moye, 2013**). The presence of highly anomalous fluorine in these deposits may be particularly diagnostic.

The problem of the Robbins area gold deposits

The AES deposits in the Carolina Terrane, including those along the Glendon and Robbins faults, appear to be products of epithermal hydrothermal systems that formed at shallow crustal levels (**Schmidt, 1985**; **Moye, 2013**). However, the gold mineralization historically mined in the Robbins area is not texturally consistent with epithermal styles of mineralization (**White and Hedenquist, 1995**). Equally, the suggestion by **Powers (1993)** that epithermal alteration and gold mineralization formed in stratigraphic aquifers within the felsic volcaniclastic sequence, and were then structurally rotated into their present orientation, is not consistent with the demonstrable primary structural control by reverse fault zones.

Most of the gold deposits historically mined in the Robbins area occur either along or adjacent to the Robbins Fault, or as part of two discontinuous, possibly *en echelon* trends parallel to the dominant S_2 cleavage and the strike and dip of the Robbins Fault. Ore bodies along the Robbins Fault (Cagle-California), and the Jenkins-Kendale-Richardson alignment in the hanging wall, are described as generally 0.5-2.5 meters thick zones of silicification and quartz veins enclosed by relatively narrow zones of phyllic alteration. These mineralized zones strike 015°-027° and dip about 50° northwest, with strike lengths typically less than 250 meters. These small, locally high-grade deposits are generally consistent with orogenic style gold mineralization associated with the Cherokee Orogeny (**LaPoint and Moye, 2013**; **Moye, 2017**), similar to those common along the Gold Hill Fault Zone.

Additionally, gold-bearing dark-gray to black silicic veins, similar to lode mineralization at the Cagle Mine on the Robbins Fault to the north (**Kerr and Hanna, 1888**; **Conley, 1962a**) cross-cut silicic alteration in the footwall of the pyrophyllite deposit in the Standard Mineral Mine (**Powers, 1993**), suggesting that gold mineralization along the Robbins Fault post-dates AES formation but may be synchronous with subsequent deformation, metamorphism, and formation of the pyrophyllite ore bodies.

Trace element constraints for Robbins area gold deposits

Powers (1993) concludes that gold in the Robbins area is variably associated with anomalous Mo, As, Sb, Hg, Pb, and Bi, although there is no consistent correlation between gold concentration and trace element abundance. However, Sb values in all samples of lode gold mineralization (**Powers, 1993**) are generally below detection and only locally exceed 2 ppm with a high value of 8 ppm. Samples of dark gray auriferous quartz veinlets cutting the footwall of the pyrophyllite ore body in the Standard Minerals Mine Pit 3 are an exception; with values of up to 29 ppm Sb. Values for Bi in all samples are typically below detection and only locally reach 2-3 ppm. All Hg analyses above detection are considered highly suspect.

Arsenic values for samples from most historic gold mines, including the Allen, Brown, California, and Red Hill mines, are typically low; most below detection and only locally ranging from 10-70 ppm (**Powers, 1993**). The only exceptions are one sample with 180 ppm As at the Cagle Mine and two samples (110 and 440 ppm As) at the Burns Mine (**Powers, 1993**). Lead values are typically in the 5-15 ppm range and seldom exceed 50 ppm, with a single sample of 100 ppm Pb at the Red Hill Mine (**Powers, 1993**). Copper and Zn concentrations in samples of gold mineralization are at background levels (**Powers, 1993**).

High-Au grade ore samples from the Burns Mine locally contain up to 4.11 ppm Au, 46 ppm Ag, 440 ppm As, 220 ppm Mo, and 66 ppm Pb. Samples from the Cagle Mine contain up to 3.4 ppm Au, 180 ppm As, and 240 ppm Mo (**Powers, 1993**). The trace element signature of dark-gray to black quartz + pyrite veinlets that cross-cut AES alteration in Standard Mineral Mine Pit 3 (**Powers, 1993**) is similar to that of the lode gold deposits. Sample SM-8 from these gold-bearing quartz stringers contains 1.5 ppm Au, 2400 ppm As, 110 ppm Mo, 28 ppm Pb, and 29 ppm Sb (**Powers, 1993**).

High-grade samples of gold mineralization from the Robbins area (**Powers, 1993**) suggest that the metallic trace element signature for these deposits is Au ± Ag ± As ± Mo ± Pb ± Sb, which is distinct from that of the AES along both the Glendon and Robbins faults. However, this signature is similar to that for Russell-Sawyer type gold deposits, especially the Russell Mine deposit in the Ophir District in Montgomery County (**LaPoint and Moye, 2013**).

A model for the Clegg-Wright-Red Hill-Allen-Burns gold alignment

Gold mineralization along the Clegg-Wright-Red Hill-Allen-Burns alignment to the west, well into the hanging wall of the Robbins Fault, appears to be strongly developed over a wide zone that strikes 015°-025°, dips 50°-70° northwest, and narrows to the north. The mineralized zone may be locally discontinuous or *en echelon*, but generally increases in width and alteration intensity to the southwest. It is 0.5 meter wide on a fault zone at the Wright Mine, increasing to

3.7 meters of phyllic alteration and stockwork quartz veinlets at the Clegg Mine (**Conley, 1962a**), with up to 18 meters of pyritic silicic and phyllic alteration at the Red Hill Mine, and at least 11 meters wide at the Allen Mine (**Conley, 1962a**). At the Burns Mine, drilling by Tenneco in 1983 identified up to three lenses of ore-grade silicic to intense phyllic alteration from 10 to 30 meters thick within a zone of heterogeneous phyllic alteration 150 meters thick (**Figure 19**). Drilling defined a mineralized zone 200 meters long and about 10 meters thick in the upper mineralized lens, with an average grade of 0.07 oz/t Au (**Powers, 1993**).

The character of this mineralization, with multiple lenses of siliceous ore-grade mineralization within a wide zone of phyllic alteration, is very similar to that of the Russell and Sawyer-type gold deposits in Randolph and Montgomery counties, North Carolina. Similarly, the Robbins area gold deposits appear to have formed along reverse fault or shear zones synkinematic and synmetamorphic with intense cleavage development. This is consistent with the Russell Mine and Sawyer Mine model of synkinematic upper mesozonal orogenic gold mineralization developed in reverse fault-fold zones during the Cherokee Orogeny.

The character and distribution of hydrothermal alteration

Conley (1962a) and **Powers (1985)** suggest that AES along the Robbins Fault and the gold deposit alignments in the hanging wall to the west are enclosed by a single, continuous domain of hydrothermal alteration (**Figure 9**). However, review of field descriptions of outcrops in the area by **Lesure (1981)** suggest that phyllic alteration in the Robbins area is not as pervasively widespread as suggested (**Figure 14**).

The distribution of phyllic alteration in the Robbins area may represent the local merging or overlap of phyllic alteration zones associated with the AES along the Robbins Fault and those formed in association with the gold deposit alignments to the west. Phyllic alteration zones of different ages that were affected by regional greenschist facies metamorphism during the Cherokee Orogeny would be difficult to distinguish on the basis of composition and texture.

However, the trace element signature of associated mineralization would potentially distinguish separate and distinct hydrothermal events. The trace element data for AES and lode gold mineralization in the Robbins area appears to support the presence of two separate and distinct hydrothermal and metallogenic events, possibly separated by around 100 Ma.

Conclusions

It appears that two styles of mineralization representing two separate and distinct metallogenic events may be represented in the Glendon and Robbins area of Moore County, North Carolina; 1) late Proterozoic epithermal formation of AES along the precursor structure for the Robbins and Glendon faults, and 2) early Paleozoic formation of pyrophyllite ore bodies along both AES alignments and formation of mesozonal orogenic lode gold deposits in the hanging wall of the Robbins Fault during reverse faulting associated with the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**).

The advanced argillic epithermal alteration systems (AES) along the Glendon and Robbins faults most likely formed at paleodepths of less than a kilometer during the late Proterozoic, possibly in association with Uwharrie magmatism circa 550 Ma, and may be linked to felsic magmatic reservoirs at depth. The trace element association of the Glendon and Robbins AES is Au-Ag-As-Mo-F ± Cu, similar to other AES occurrences in the Carolina Terrane in North Carolina. Like the Pilot Mountain AES in Randolph County, this metallogenic signature is consistent with the higher crustal level epithermal expressions of porphyry-style Au ± Cu ± Mo deposits (**Schmidt, 1985**).

Several alignments of AES in the Carolina Terrane in central North Carolina appear to have formed along tensional fault zones associated with the early phases of arc-rifting of the older Hyco Arc and Virgilina Sequence circa 554-550 Ma (**Moye, 2013**). This model of AES formation at shallow crustal levels within a tensional tectonic environment (**Figure 21**) is consistent with the ore deposit model classification of **Groves *et al*. (1998)**.

However, the Glendon and Robbins area AES lack many of the features characteristic of most AES in central North Carolina because they have been structurally modified, mineralogically altered, and metamorphosed by southeast-directed compressive strain during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**).

Although geochemically anomalous Au is widespread in the Robbins and Glendon AES (**Lesure, 1981**; **Powers, 1993**), historically mined concentrations of ore-grade Au mineralization only occur in apparent association with the Robbins Fault. Ore-grade Au mineralization along the Robbins Fault post-dates Proterozoic advanced argillic hydrothermal alteration (**Powers, 1993**). It also post-dates AES deformation, metamorphism, intense cleavage development, and silicic alteration in the footwall within the Robbins reverse fault duplex (**Powers, 1993**). However, it may be synchronous with the late-kinematic formation of pyrophyllite-rich ore bodies along anastomosing reverse fault strands (**Powers, 1993**).

Gold mineralization along the Robbins Fault (Cagle Mine) and along reverse fault zones in the hanging wall to the west (Jenkins-Kendale-Richardson and Clegg-Wright-Red Hill-Allen-Burns alignments) occurs in zones of phyllic and silicic alteration that lack advanced argillic alteration assemblages. They have the metallic trace element signature Au ± Ag ± As ± Mo ± Pb ± Sb, but lack anomalous F and any significant base metal association. The character of many of these narrow, discontinuous lodes is broadly consistent with low-sulfidation mesozonal orogenic lode deposits, including those formed within the Gold Hill Fault Zone during the Cherokee Orogeny (**Hibbard *et al.*, 2012**; **Moye, 2017**).

However, the style of alteration and gold mineralization along the Clegg-Wright-Red Hill-Allen-Burns alignment is similar to that of the Sawyer-type gold deposits of northwest Randolph County and the Russell Mine in the Ophir District of Montgomery County, North Carolina (**LaPoint and Moye, 2013**). The Russell and Sawyer-type deposits are characterized by zones of phyllic alteration up to hundreds of meters thick and kilometers long, enclosing multiple parallel or *en echelon* lenses of ore-grade silicic alteration up to tens of meters thick and hundreds of meters long.

Formation of these deposits is synkinematic with the formation of the host structures, characterized by steeply northwest-dipping sets of reverse faults, which host the silicic lodes, within a broad zone of intense synmetamorphic cleavage development. The cleavage and faults are often axial to appressed, asymmetric, meso-scale anticlines that strike northeast and dip moderately to steeply northwest. These structures probably formed during the later phases of the Cherokee Orogeny (**Hibbard *et al.*, 2012**), and the Russell-Sawyer type Au deposits appear to be a poorly described class of shallow mesozonal orogenic gold deposits.

These deposits are not associated directly or indirectly with any known magmatism and the character and source of the causal hydrothermal fluids is poorly constrained. The fluids appear to be relatively enriched in sulfur and hydrothermal alteration results in the complete sulfidation of all available Fe in a large volume of the host lithology, commonly epiclastic sedimentary or volcaniclastic sequences.

In conclusion, gold mineralization along the Robbins Fault and in parallel reverse faults in the hanging wall to the west appears to be part of the diverse family of Russell-Sawyer type shallow mesozonal orogenic gold deposits (**Figure 21**) that formed during the Cherokee Orogeny circa 440 Ma, over 100 Ma later than the Glendon and Robbins AES deposits. The absence of similar orogenic gold mineralization along or proximal to the Glendon Fault may be due to differences in orientation relative to southeast-directed compression during the Cherokee Orogeny. The orientation of the Robbins Fault (~030°) is essentially parallel to that of the Gold Hill Fault Zone; however, the strike of the Glendon Fault is 30° oblique to this orientation.

The Glendon and Robbins AES alignments: unresolved issues

The formation of the Glendon and Robbins area AES relative to the kinematic evolution of the Glendon and Robbins fault zones remains unconstrained by detailed structural analysis and isotopic age determinations. Although some alignments of AES in the Carolina Terrane in North Carolina appear to be associated with post-Virgilina Deformation fault zones and localized Uwharrie magmatism, evidence for these controls are only documented for the Pilot Mountain-Staley and Snow Camp-Saxapahaw alignments (**Moye, 2013**), although similar controls are likely for the Teer-Hillsborough alignment (**Figure 1**). These faults appear to be nearly vertical transtensional features, but the Glendon and Robbins faults are transpressional moderate-dipping reverse faults.

The Glendon and Robbins faults may be post-Virgilina structures that, along with existing D_1 folds, were overturned to the southeast and reactivated during the Cherokee Orogeny. However, there is at present little evidence to support this interpretation. The locally Fe-enriched breccia unit footwall to AES along the Glendon Fault is overprinted by ferruginous and advanced argillic alteration, and potentially represents an earlier phase of brittle faulting. However, similar breccia is not described for the Robbins Fault. No Uwharrie-age felsic intrusive bodies or volcanic rocks, characteristic of some AES alignments, have been identified along the Glendon or Robbins faults. Further, the Glendon Fault is developed axial to an anticline that may have formed during the Virgilina Deformation, although possibly overturned and faulted during the Cherokee Orogeny.

Although highly speculative, it is possible that, rather than a feature of the Virgilina Deformation, the Glendon Anticline is a largely Cherokee Orogeny fold, and that folding initiated along an existing subvertical fault zone. Rotation and reactivation of the fault zone could shear preexisting AES centers and largely obliterate previous textures.

A similar explanation might account for the Cotton Stone Mountain-Ammons AES alignment along the axis of the Troy Anticlinorium to the west **(Figure 1**, **Figure 2**), a large-scale first-order fold formed during the Cherokee Orogeny (**Hibbard *et al.*, 2012**). The Cotton Stone Mountain-Ammons alteration systems are more typical Carolina Terrane AES, with abundant andalusite in the advanced argillic core. Intense cleavage development and shearing of the Ammons AES resulted in the formation of ore-grade pyrophyllite zones, suggesting that incipient reverse faulting was initiated along the axis of the Troy Anticlinorium. Phelps Dodge Exploration East delineated significant intervals of subeconomic gold mineralization associated with silicic and intense phyllic alteration at the Ammons Pyrophyllite Mine in the late 1970s.

The stratigraphic question

Finally, it may be worth reconsidering the litho-stratigraphy of the Carolina Terrane in Moore County. Detailed geologic mapping is limited, and there is a complete absence of geochronological data. Similar dacite to rhyolite unit volcanic units are described in the Glendon (**Conley, 1962a**; **McDaniel, 1976**; **Green, 1977**; **Green *et al.*, 1982**) and Robbins (**Conley, 1962a**; **Powers, 1993**) areas (**Figure 2**). This unit (Unit D of **Green *et al.*, 1982**; Unit 2 of **Powers, 1993**) is composed largely of coarse- to fine-grained feldspar ± quartz-phyric volcaniclastic units, locally interbedded with epiclastic mudstone, greywacke, and conglomerate (**Green *et al.*, 1982**; **Powers, 1993**). Volcanic clasts are aphanitic to feldspar-phyric and some are flow banded, ranging from 0.5-3 centimeters in diameter and locally up to 10-20 centimeters (**Green *et al.*, 1982**; **Powers, 1993**). The matrix has a high vitric component with abundant pumice clasts and fiamme (**Powers, 1993**).

This unit also includes feldspar ± quartz-phyric, flow banded to spherulitic, locally auto-brecciated felsic flows or domes measuring up to 350 meters long and 175 meters wide (**Green *et al.*, 1982**; **Powers, 1993**). **McDaniel (1976)** describes a concentration of rhyolite flows or domes in this sequence to the north of the Phillips, Womble, and White pyrophyllite mines in the Glendon area, possibly representing an eruptive center. **Green *et al.* (1982)** estimate the thickness of this unit at 275 meters in the Glendon area.

The contact between this felsic volcanic unit and the thick (>2000 meters), underlying sequences of felsic to mafic volcanic, volcaniclastic, and epiclastic sedimentary rocks (Units A, B, and C of **Green *et al.*, 1982**) is abrupt (**Green *et al.*, 1982**). In both the Glendon and Robbins areas, the felsic volcanic unit grades upward through an interbedded transition into a fine-grained siltstone and mudstone sequence (minimum thickness 400 meters) that coarsens upwards into sandstone (**Green *et al.*, 1982**; **Powers, 1993**).

Powers (1993) suggested that the felsic volcanic unit in the Robbins and Glendon areas could be correlative with the Uwharrie Formation to the west (**Figure 2**). The conformably overlying sedimentary unit could potentially be correlative with the Tillery Formation. If this proves to be the case, Unit D of **Green *et al.* (1982)** may be in unconformable contact with the older Hyco arc sequence, represented by Units A-C of **Green *et al.* (1982)**, and the Glendon and Robbins AES may be largely hosted by the Uwharrie Formation. Detailed geologic mapping, structural analysis, and targeted geochronological studies of the Robbins and Glendon areas of Moore County would be required to fully examine this possibility.

Other AES and related occurrences in Moore County, North Carolina

In addition to the AES of the Glendon and Robbins faults, several other occurrences of advanced argillic alteration are present in Moore County, North Carolina. The Ruff Mine and Hallison Prospect are small, isolated occurrences located south of the western end of the Glendon Fault with no obvious association (**Figure 2**).

A relatively unknown and poorly documented AES is located just east of the community of Jugtown on the Moore-Randolph county line in northwest Moore County (**Figure 2**). It appears to lie along the same NNE-striking lithologic-structural contact as the Sanders Pyrophyllite Prospect to the southwest, located near the Moore-Montgomery county line east of the town of Star (**Figure 2**). This may represent AES development along a fault similar to the Glendon Fault, but possibly of smaller offset.

The Glendon Fault, Robbins Fault, and possible Jugtown-Sanders Fault in Moore County, along with the Ammons-Cottonstone Mountain alignment along the axis of the Troy Anticlinorium in Montgomery County (**Figure 2**), may represent a series of AES alignments along the axes of faulted anticlines.

The Ruff Mine and Hallison Prospect, Moore County

The Ruff Mine and Hallison Prospect are small pyrophyllite occurrences located relative to the town of Hallison. This small town no longer exists, but was located in the early 1920s at the intersection of the Norfolk Southern railway between Glendon and Hemp (Robbins) and the Randolph and Cumberland railway (1907-1924) between Carthage and McConnell. The old town site is located near the present intersection of the Norfolk Southern railway with highway NC 22. The relationship of these AES to those along the Glendon and Robbins faults is uncertain.

Ruff Mine

This deposit is located 2.4 kilometers southwest of Hallison at geographic coordinates -79.50088, 35.41427 (WGS84). A lens of pyrophyllite-bearing alteration 2-4.5 meters wide is present for 55-60 meters along a fault that strikes 020° and dips 80° northwest. Silica-rich pods and milky quartz veins up to 50 centimeters thick are present in the alteration zone and chloritoid is locally abundant in the pyrophyllite-bearing zone (**Klein, 1992**). The pyrophyllite zone is exposed in an open cut that is 50 meters wide, 10 meters deep, and extends 75 meters along strike (**Klein, 1992**). The host rock is andesitic lithic tuff, but the fault may juxtapose andesite tuff and felsic tuff (**Klein, 1992**).

The zone of advanced argillic alteration narrows and terminates along strike to the northeast and southwest. The pyrophyllite and quartz veins are deformed by mesoscopic folds. The pyrophyllite body is offset by a cross fault that strikes 315° degrees dips 75° northeast (**Conley, 1962a**). **Klein (1992)** suggests that the fault is an extension of the Glendon Fault. However, it is not on strike with the Glendon Fault and more likely to be an *en echelon* companion fault or splay.

Hallison Prospect

Pyrophyllite is present about a kilometer west of Hallison at an old gold mining site (**Stuckey, 1928**), with geographic coordinates -79.49088, 35.41871 (WGS84). A series of shallow pits follows a quartz vein along a ductile-brittle fault that strikes 070° and dips 55° northwest (**Conley, 1962a**). The vein is enclosed by a phyllic alteration zone of quartz-sericite schist that contains minor pyrophyllite (**Conley, 1962a**). The hanging wall of the fault zone is felsic volcaniclastic rocks and the footwall is mudstone.

Jugtown and Sander Prospect AES, Moore County

There is little information on an AES located immediately east of the community of Jugtown in southeastern Randolph County. Pyrophyllite is present along a north-striking ridge enclosed by a broad area of phyllic alteration. This occurrence appears to be located on the same lithologic and possible structural contact as the Sanders Prospect to the southwest.

The Sanders Prospect is a pyrophyllite occurrence located along a reverse fault in west central Moore County, about 8 kilometers southeast of the town of Star and a hundred meters northwest of the intersection of Cotton Creek and Cabin Creek.

Jugtown AES

The Jugtown AES is centered 1.5 kilometers northeast of the community of Jugtown on the Moore-Randolph county line. Pyrophyllite-rich advanced argillic alteration forms a low ridge that trends almost north-south along SR1003 immediately north of the Randolph-Moore county line. It is enclosed by a zone of phyllic alteration that measures about 2000 meters north-south and up to 700 meters east-west. This AES is hosted by andesitic to dacitic crystal tuffs of the Hyco Formation along the north-south contact with thin-bedded metamudstone assigned to the Aaron Formation to the east (**Carpenter, 1999**).

The Sanders pyrophyllite prospect is located along this same contact about 15 kilometers to the south-southwest. The possibility exists that this contact is structural in character, similar to that along the Glendon Fault. The extent of hydrothermal alteration along this contact between the Jugtown AES and Sanders Prospect is unknown.

Sanders Pyrophyllite Prospect

This prospect is located about 8 kilometers southeast of the town of Star and about a hundred meters northwest of the intersection of Cotton Creek and Cabin Creek. A zone of pyrophyllite is traced for 250-300 meters along a prominent ridge (**Stuckey, 1967**). The host rock is a medium- to fine-grained felsic volcaniclastic sequence with a prominent cleavage that strikes 030° and dips 40°-50° northwest (**Stuckey, 1967**). The fault may juxtapose felsic volcaniclastic rocks to the northwest and metamudstone to the southeast.

A number of small pits are present along the deposit. A bulldozer cut exposes the fault zone for about 75 meters along strike, but phyllic alteration continues northeast for another 300 meters (**Conley, 1962a**). The fault zone strikes 035° and dips 70° northwest, characterized by phyllic (sericite) altered mudstone grading into quartz-sericite schist within the zone of highest strain (**Conley, 1962a**).

Pyrophyllite with accessory chloritoid is present in a central zone up to a meter wide that also contains randomly oriented quartz veins (**Conley, 1962a**). Radiating rosettes of pyrophyllite occur along the contacts of the quartz veins, and **Stuckey (1967)** observed veins of diaspore up to 7 centimeters thick.

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Figure 1: AES deposits and alignments in the Carolina Terrane, central North Carolina.

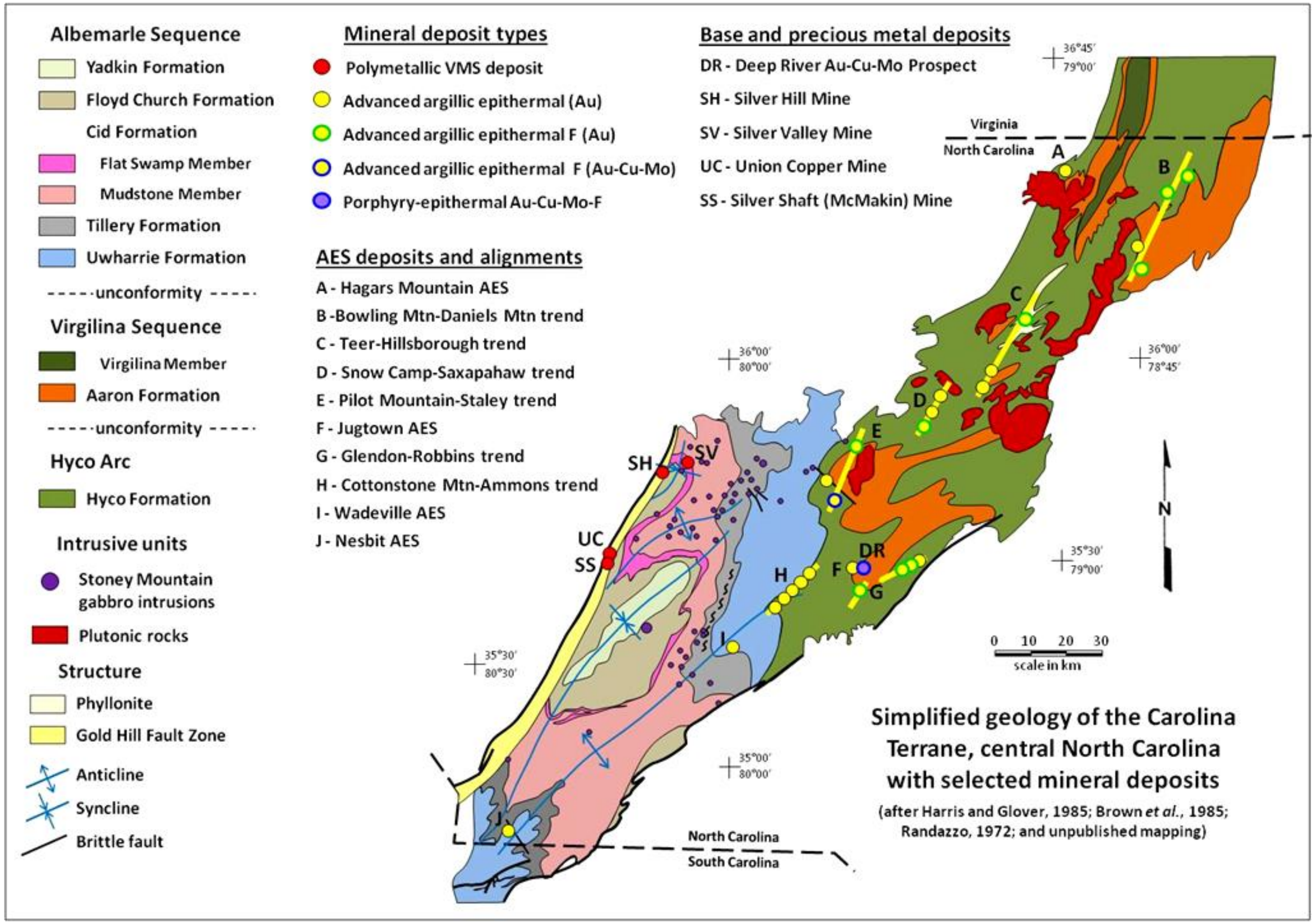

Figure 2. Simplified geology of part of Montgomery and Moore counties, North Carolina, showing areas of hydrothermal alteration and AES occurrences and alignments.

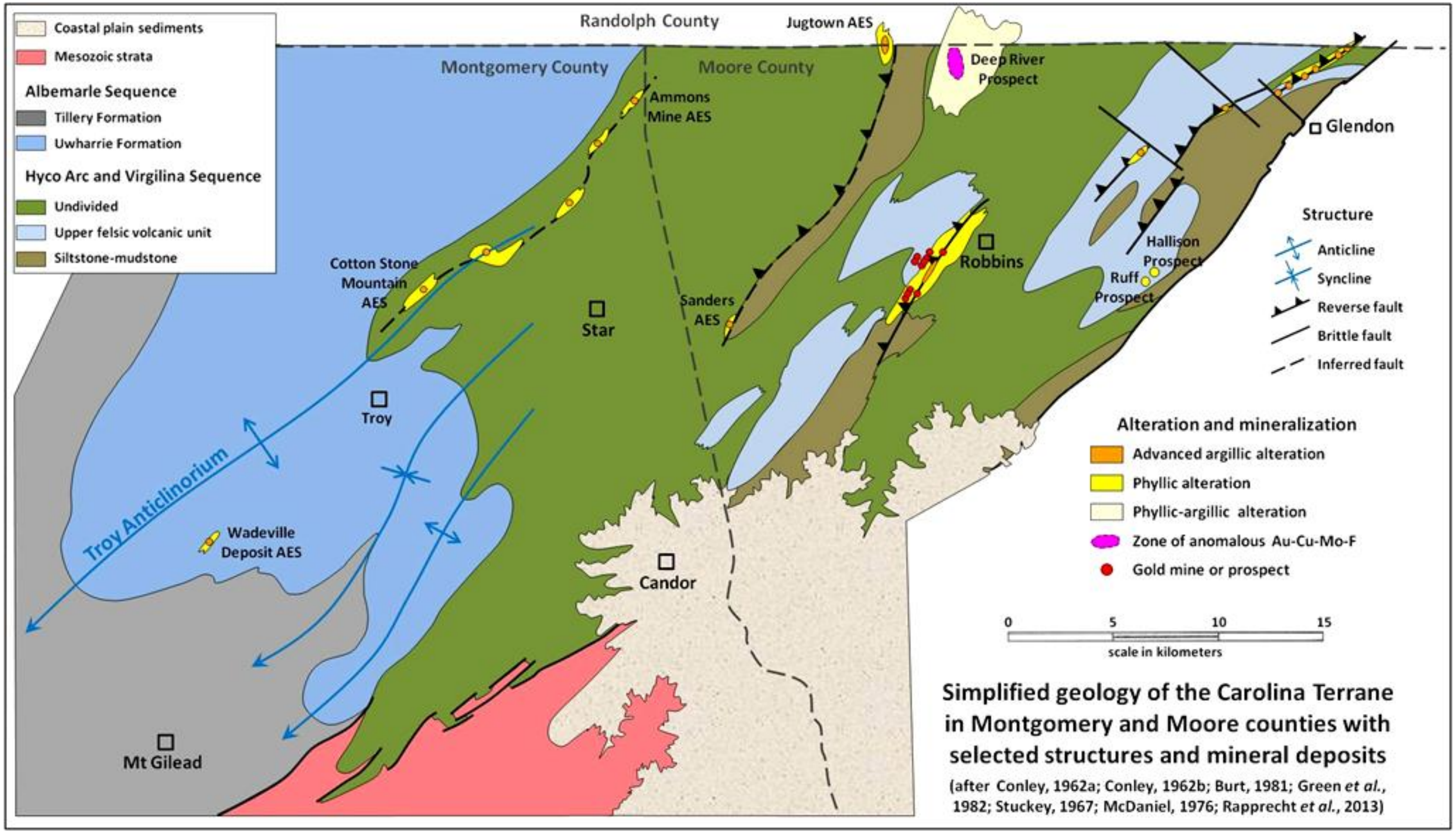

Figure 3. Simplified geology of the Glendon area of Moore and Chatham counties, North Carolina, showing the distribution of occurrences of advanced argillic alteration along the Glendon Fault.

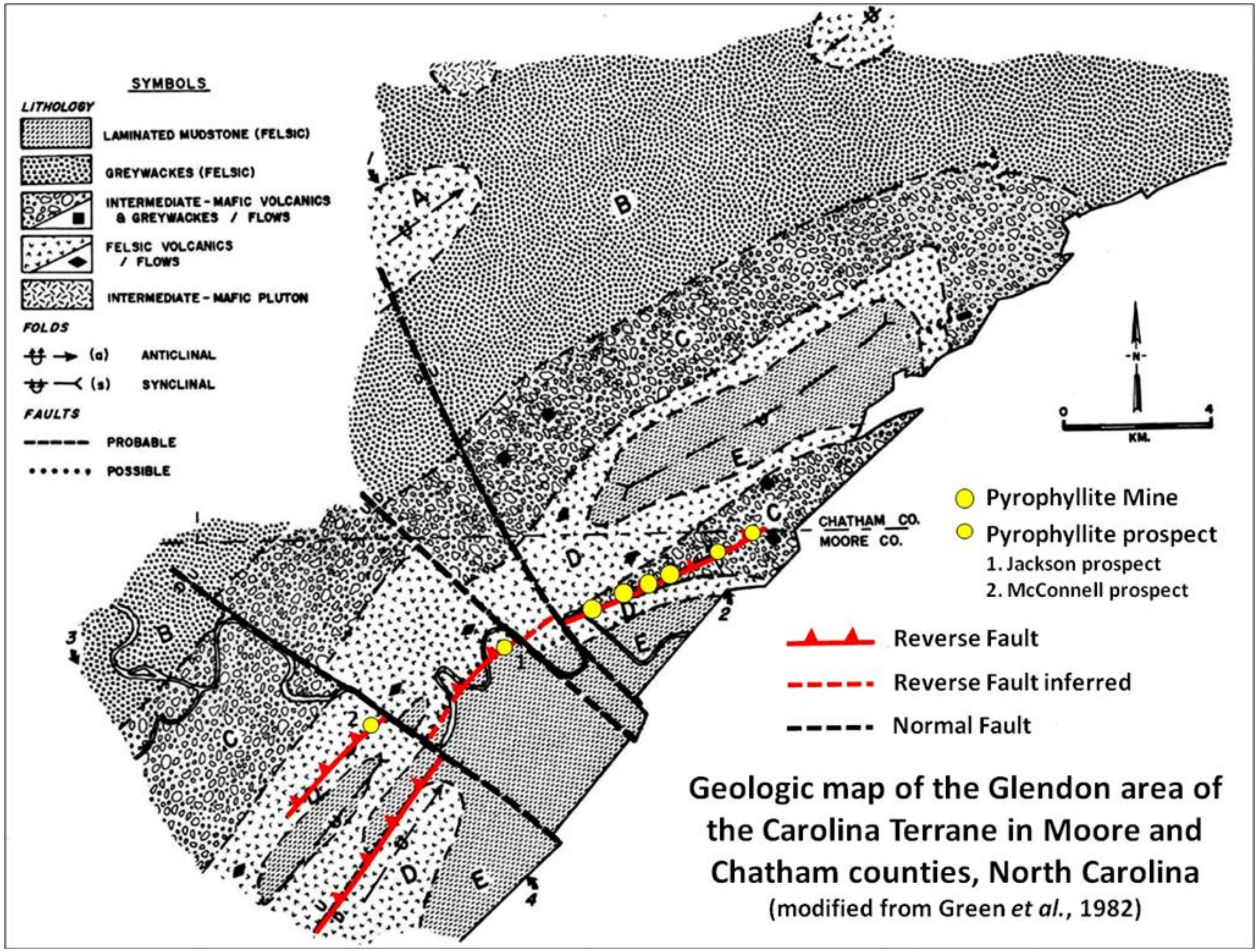

Figure 4. Simplified geology of a portion of the Glendon Fault in portions of Moore and Chatham counties, North Carolina.

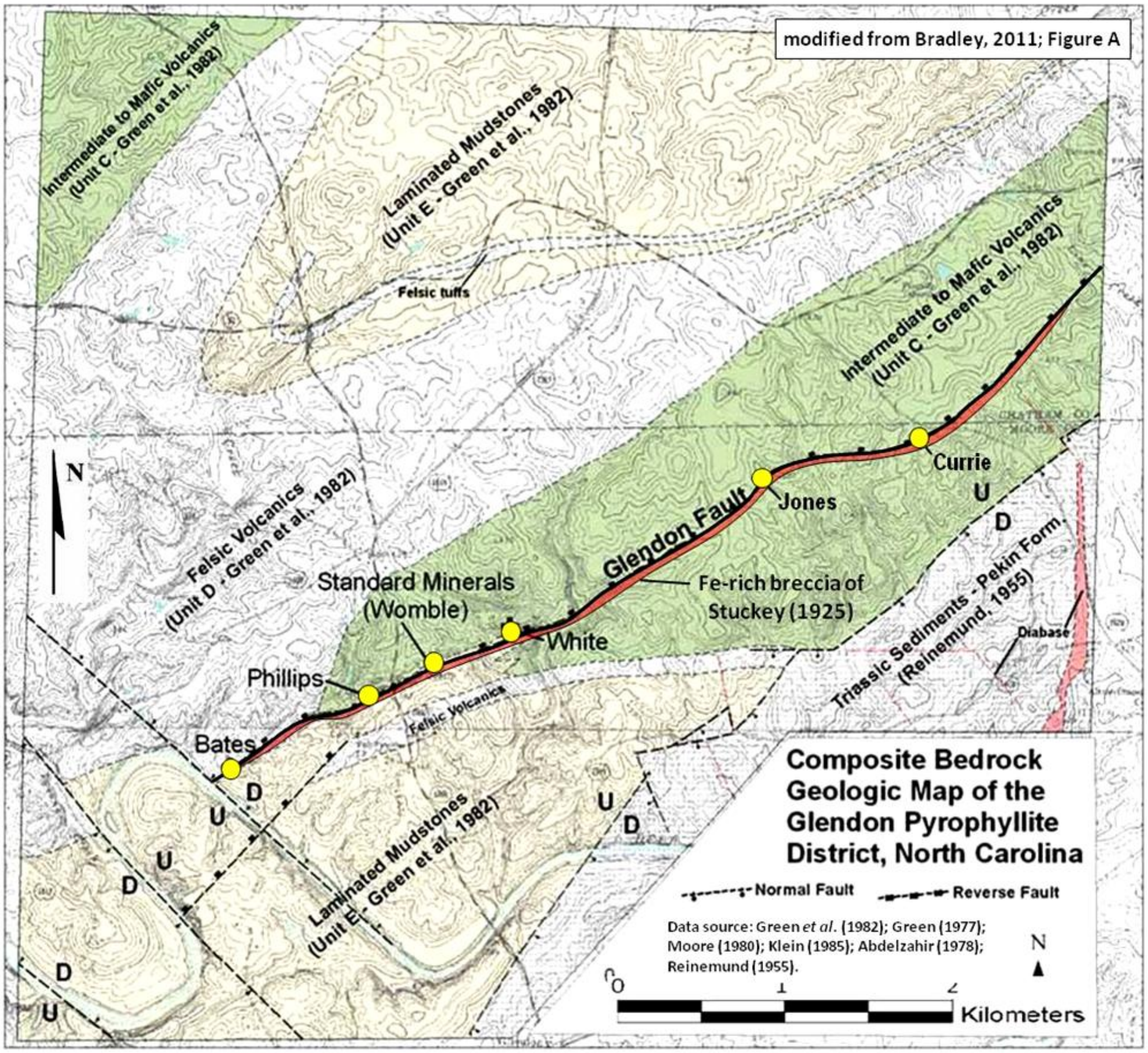

Figure 5. Alteration on the Phillips-Womble-White mines portion of the Glendon Fault in Moore County, North Carolina.

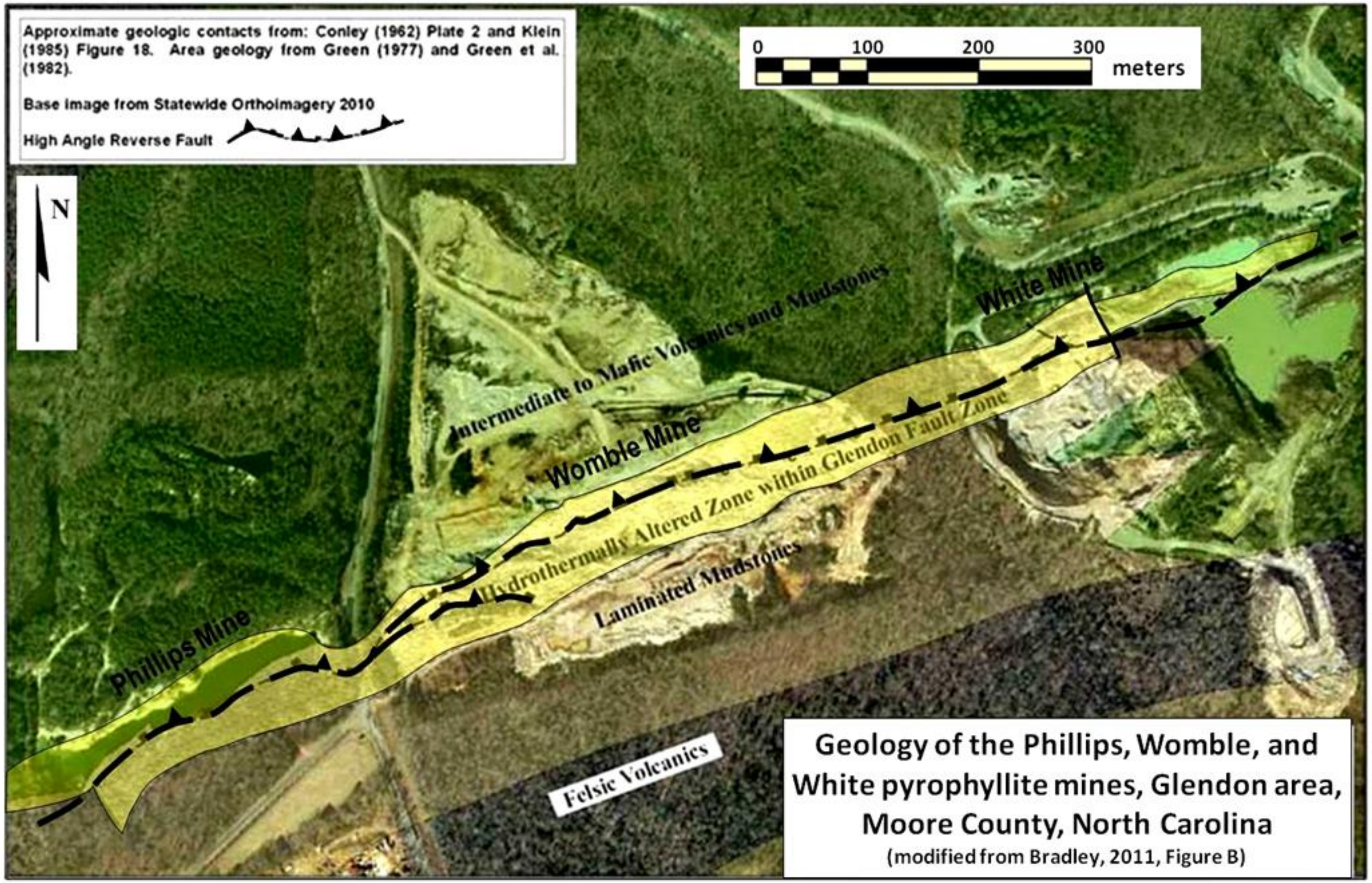

Figure 6. Cross section through the Glendon Fault Zone duplex in the Phillips Mine in Moore County, North Carolina, showing the distribution of hydrothermal alteration.

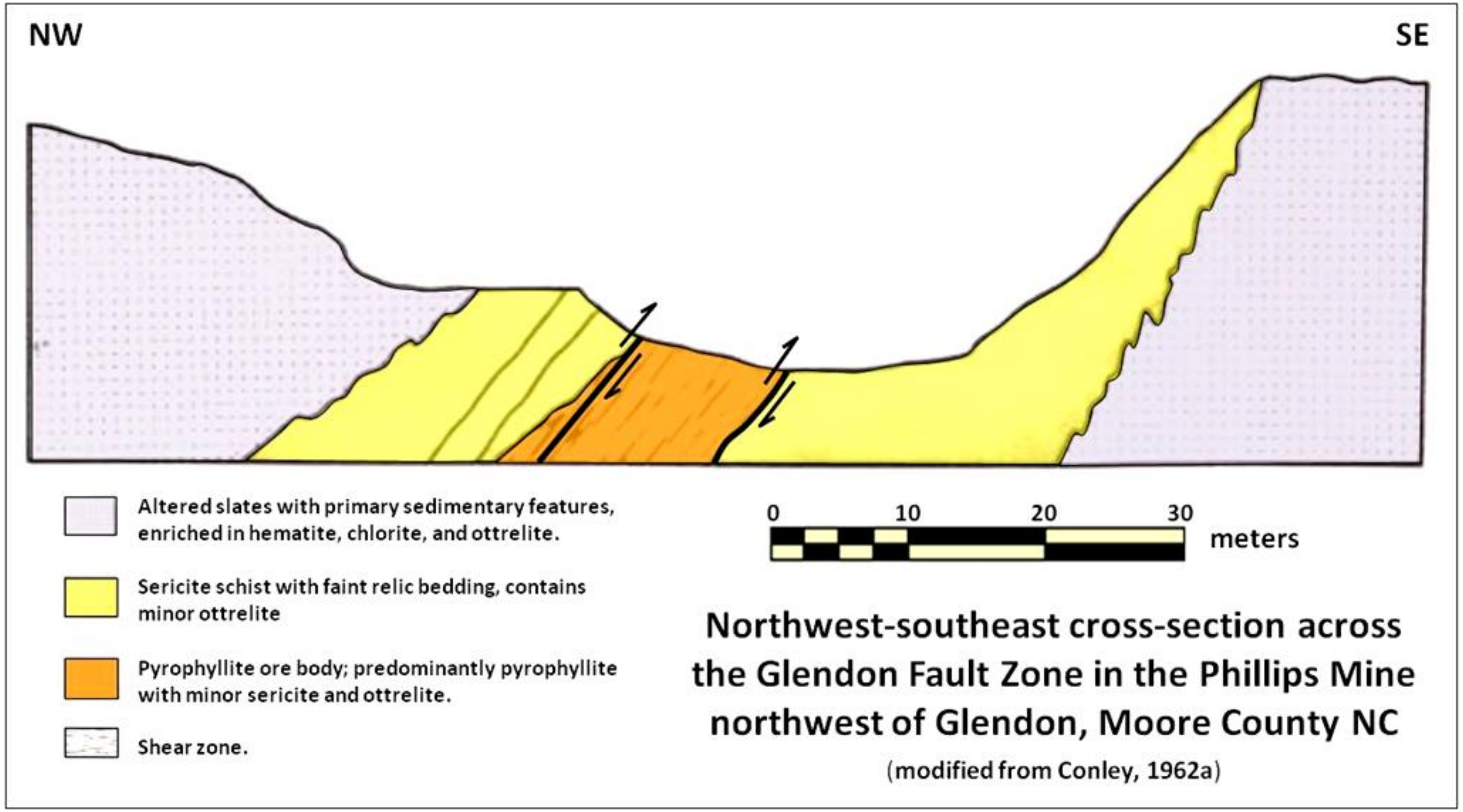

Figure 7. Ritter Au Mine map of historic workings.

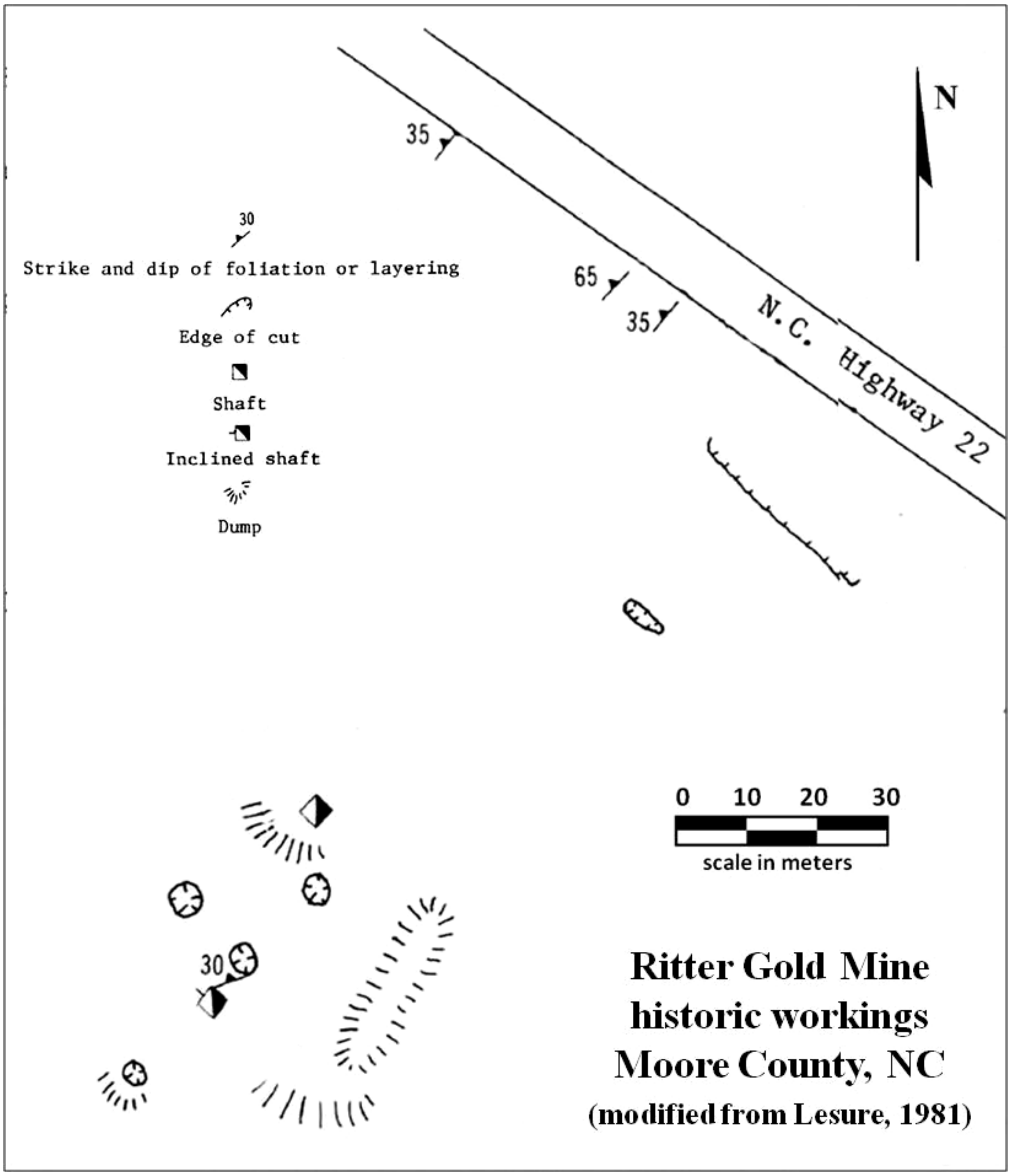

Figure 8. Cotton Au Mine map of historic workings in Moore County, North Carolina.

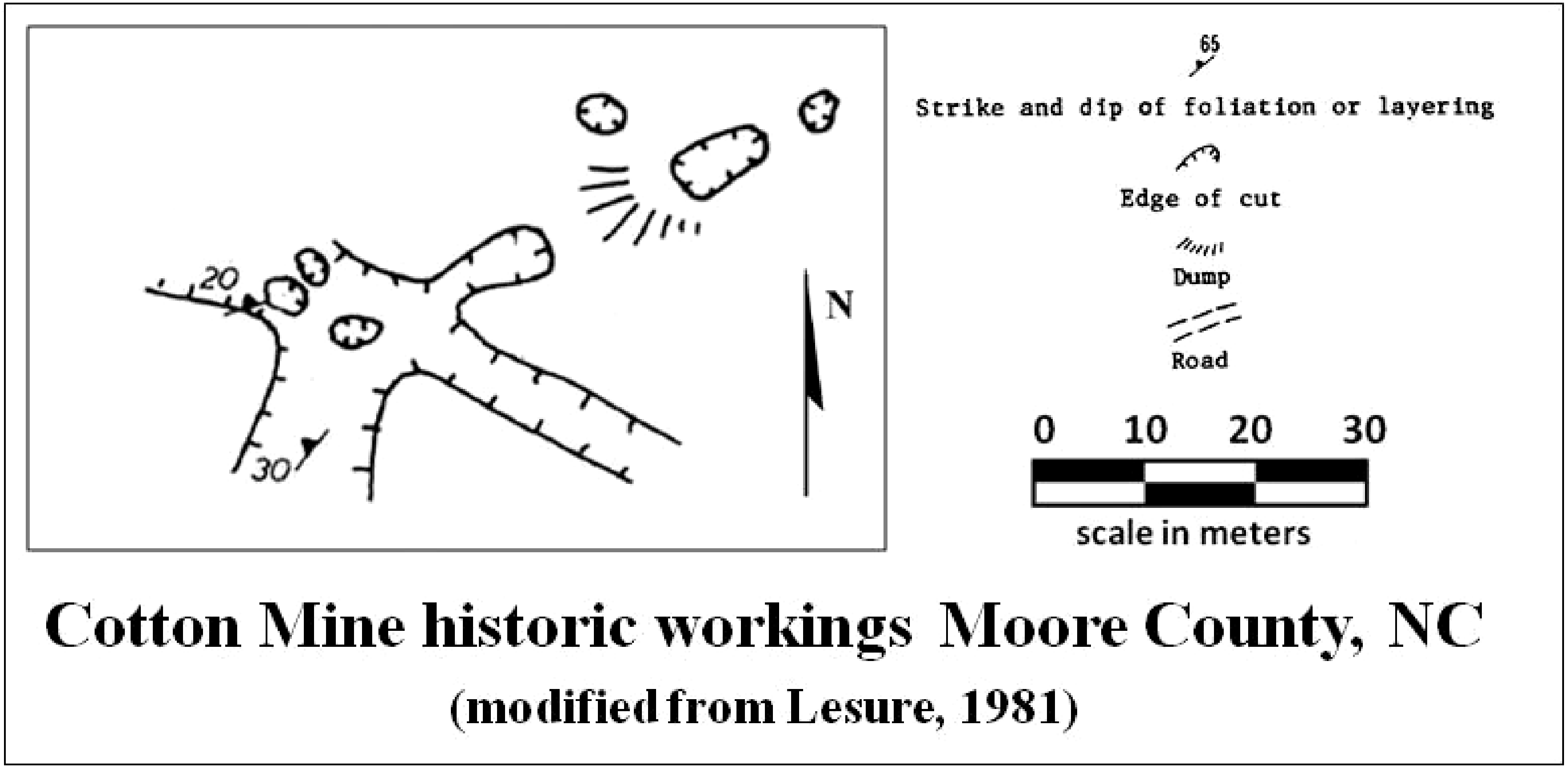

Figure 9. Simplified map of geology, alteration, and mineralization in the Robbins area of Moore County, North Carolina.

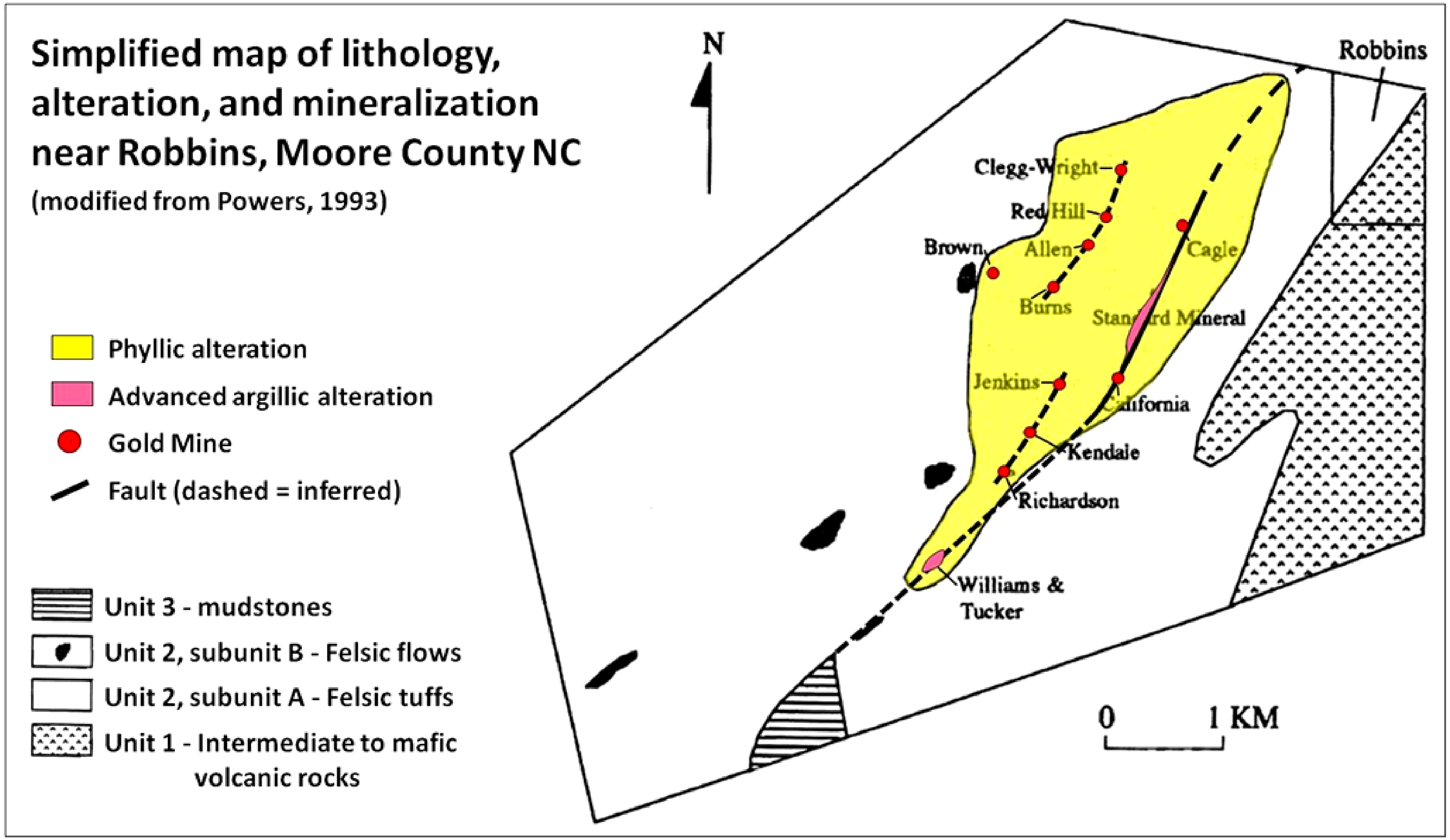

Figure 10. Structural cross-section of the Robbins Fault Zone through the Standard Mineral Mine in Moore County, North Carolina.

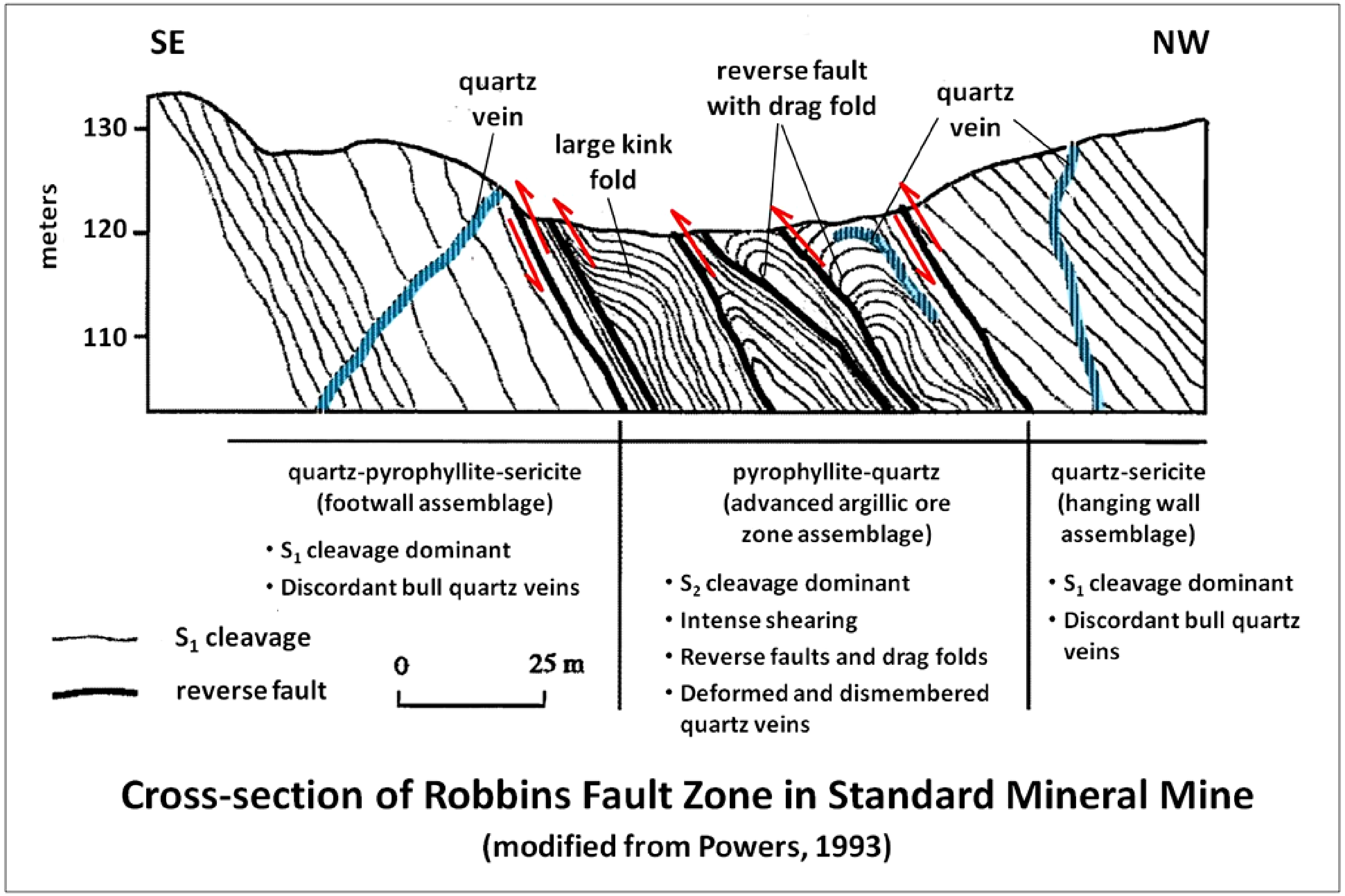

Figure 11. Geologic map of the Robbins Fault Zone in the Standard Minerals Mine in Moore County, North Carolina, showing alteration assemblages.

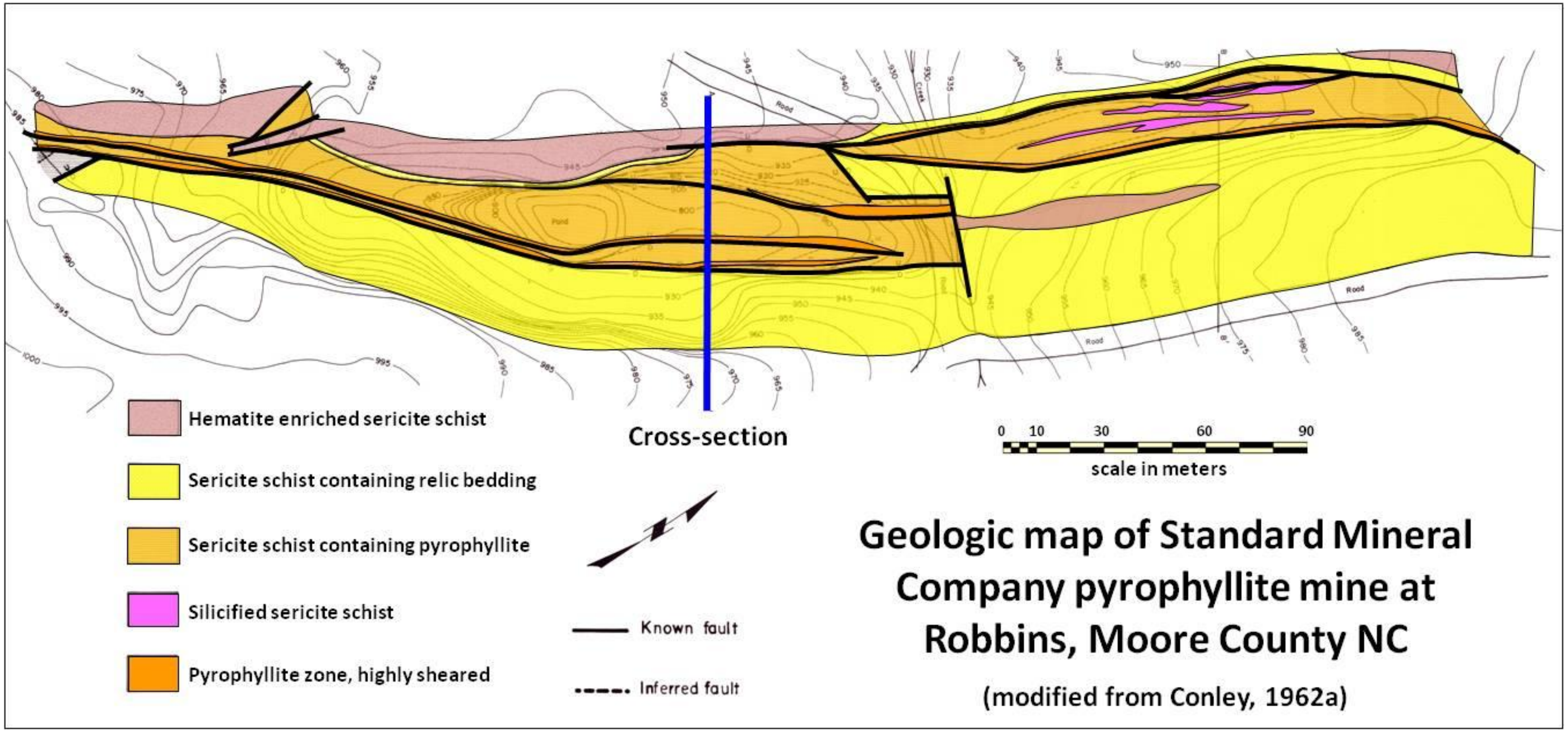

Figure 12. Cross section through the Robbins Fault Zone in the Standard Minerals Mine in Moore County, North Carolina, showing hydrothermal alteration assemblages.

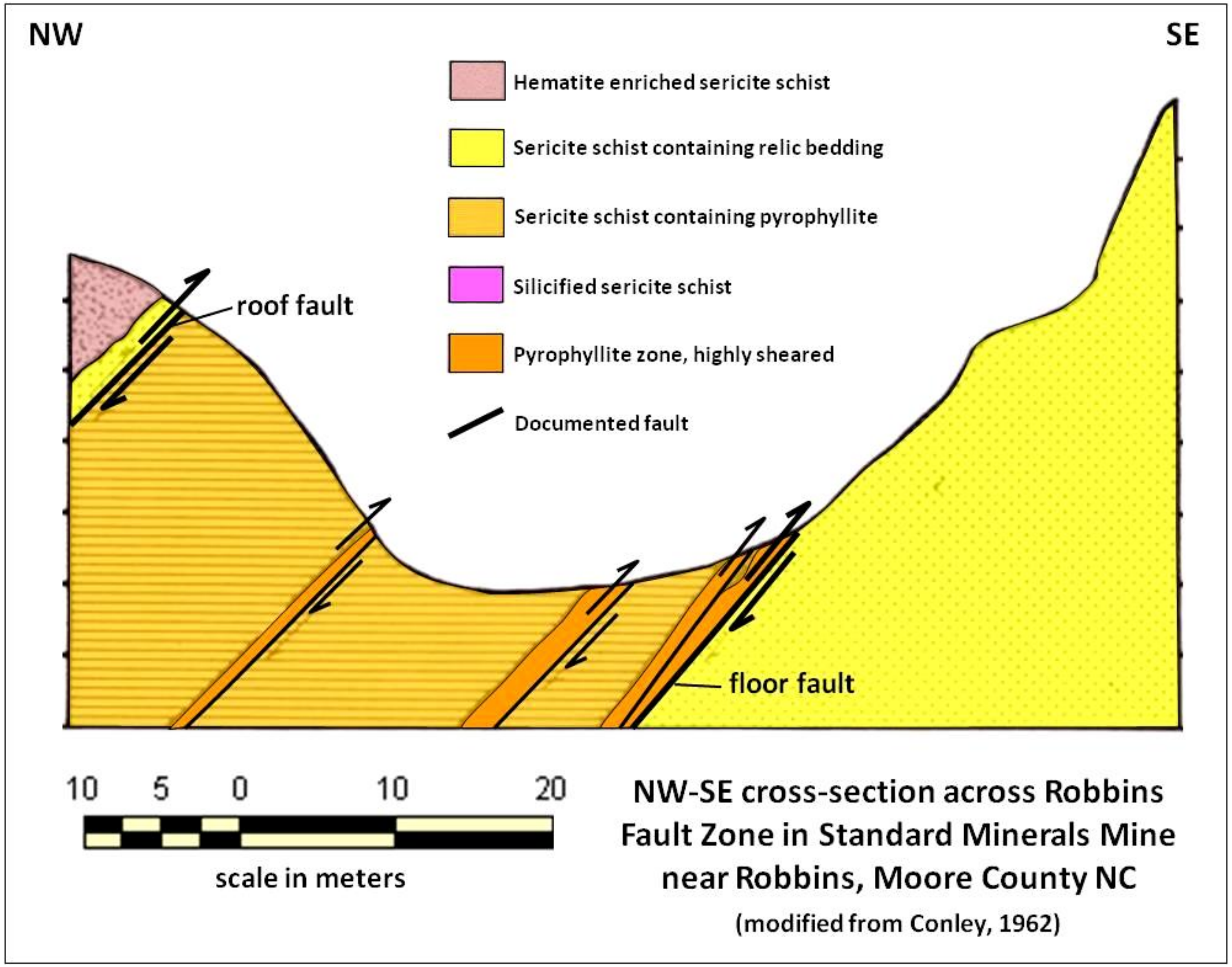

Figure 13. Geologic map of the Dry Creek pyrophyllite mine.

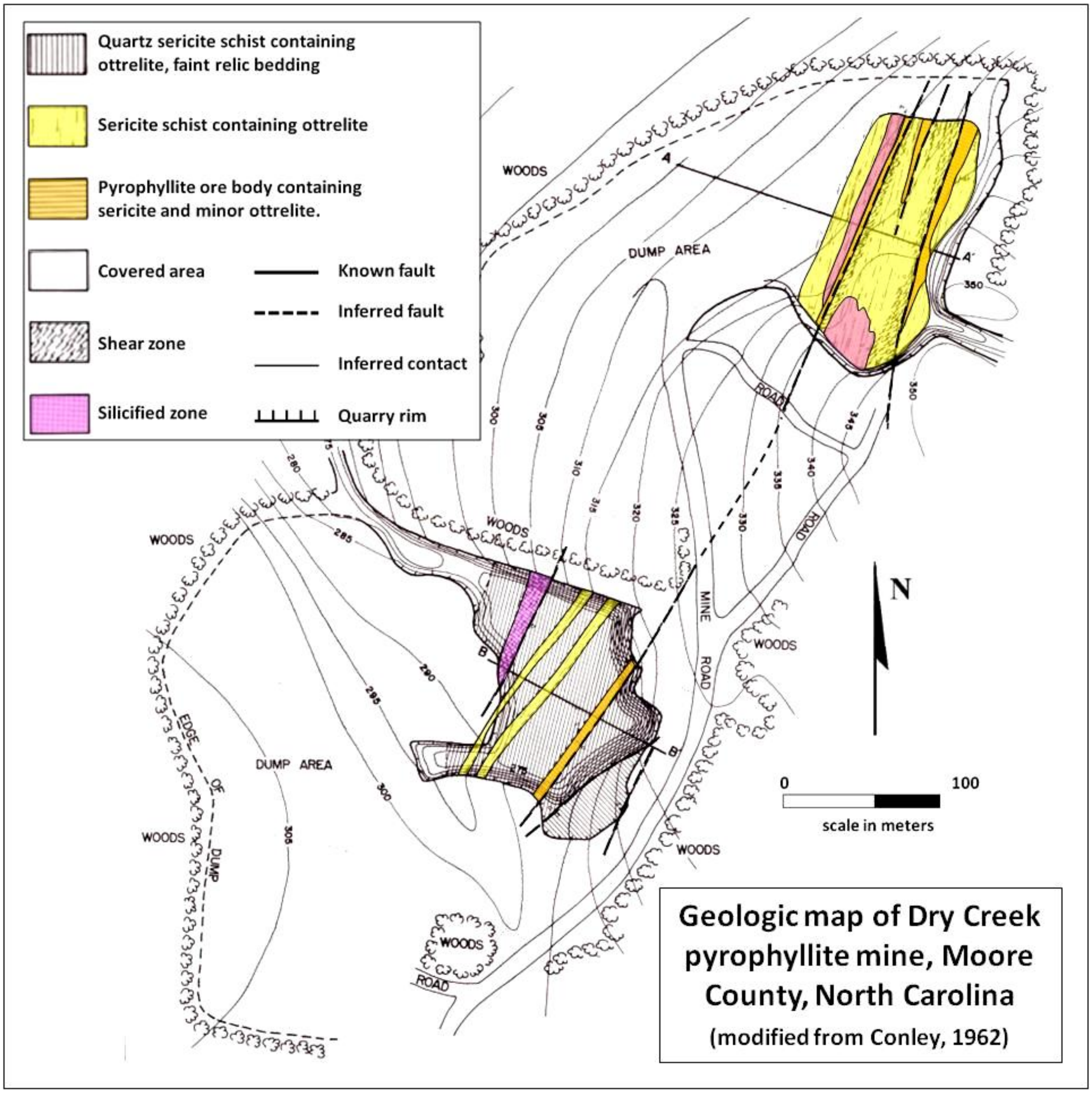

Figure 14. Robbins Fault zone alteration and mineralization in Moore County, North Carolina.

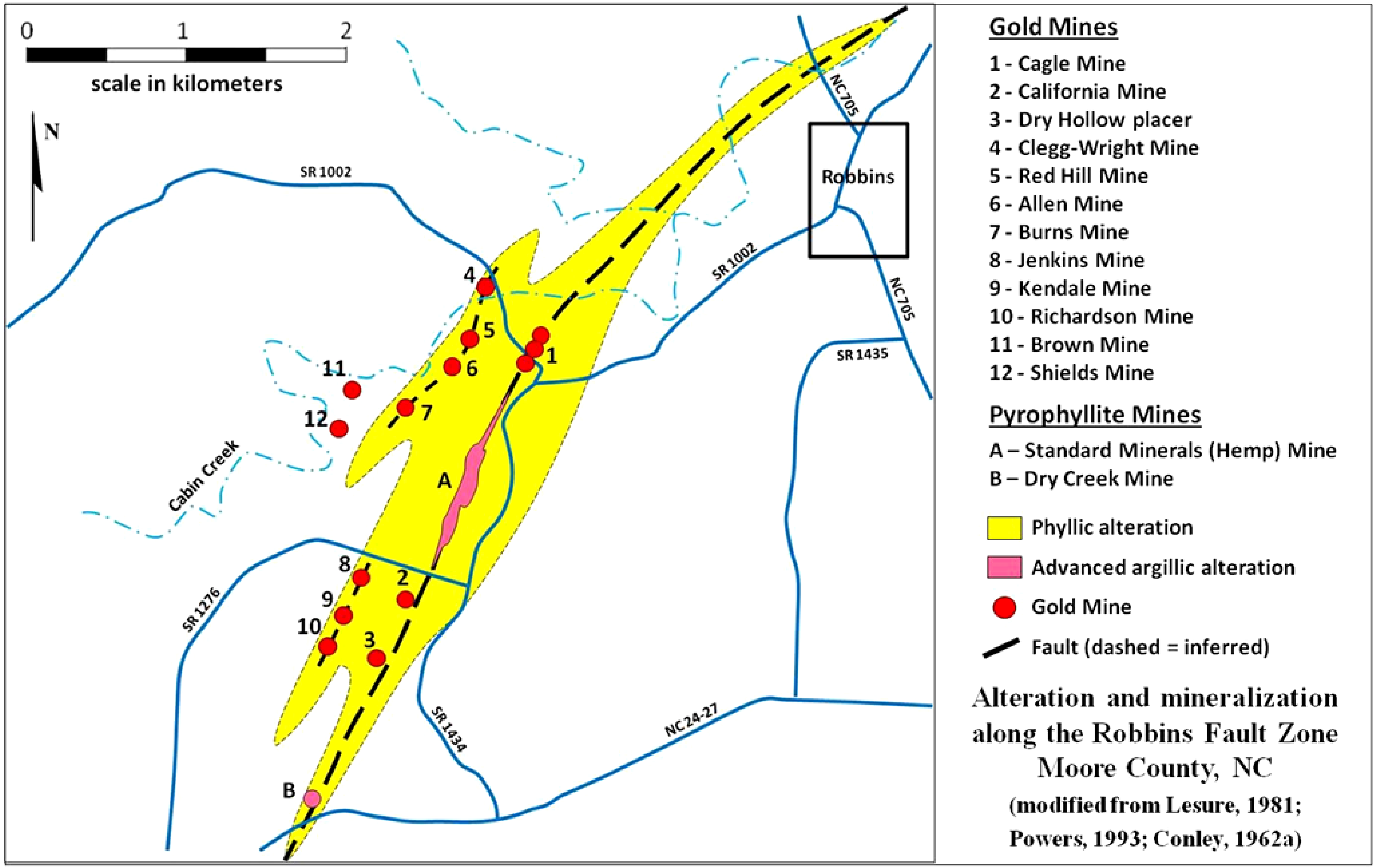

Figure 15. Cagle Au Mine map of historic workings.

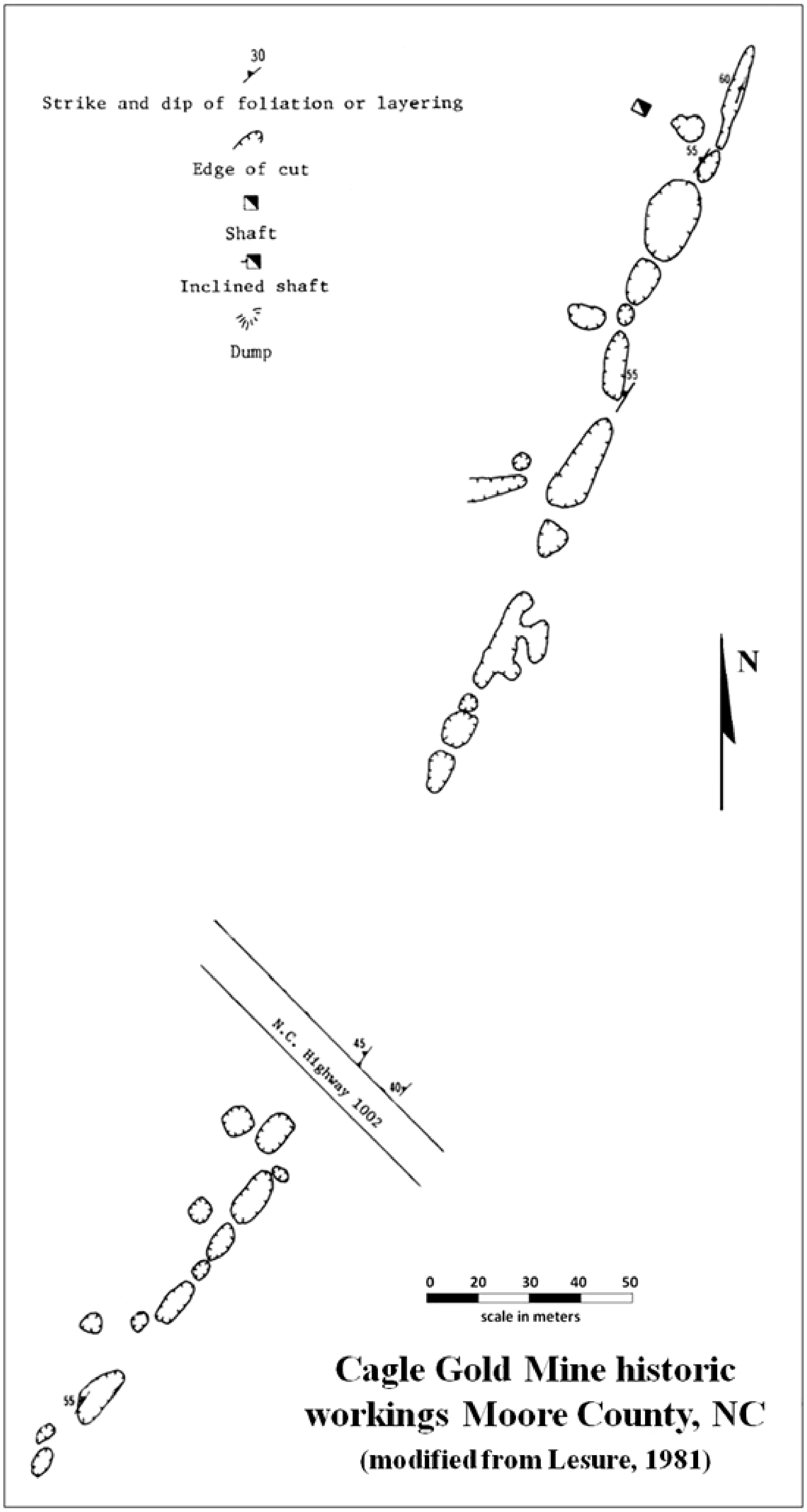

Figure 16. Red Hill Au Mine map of historic workings.

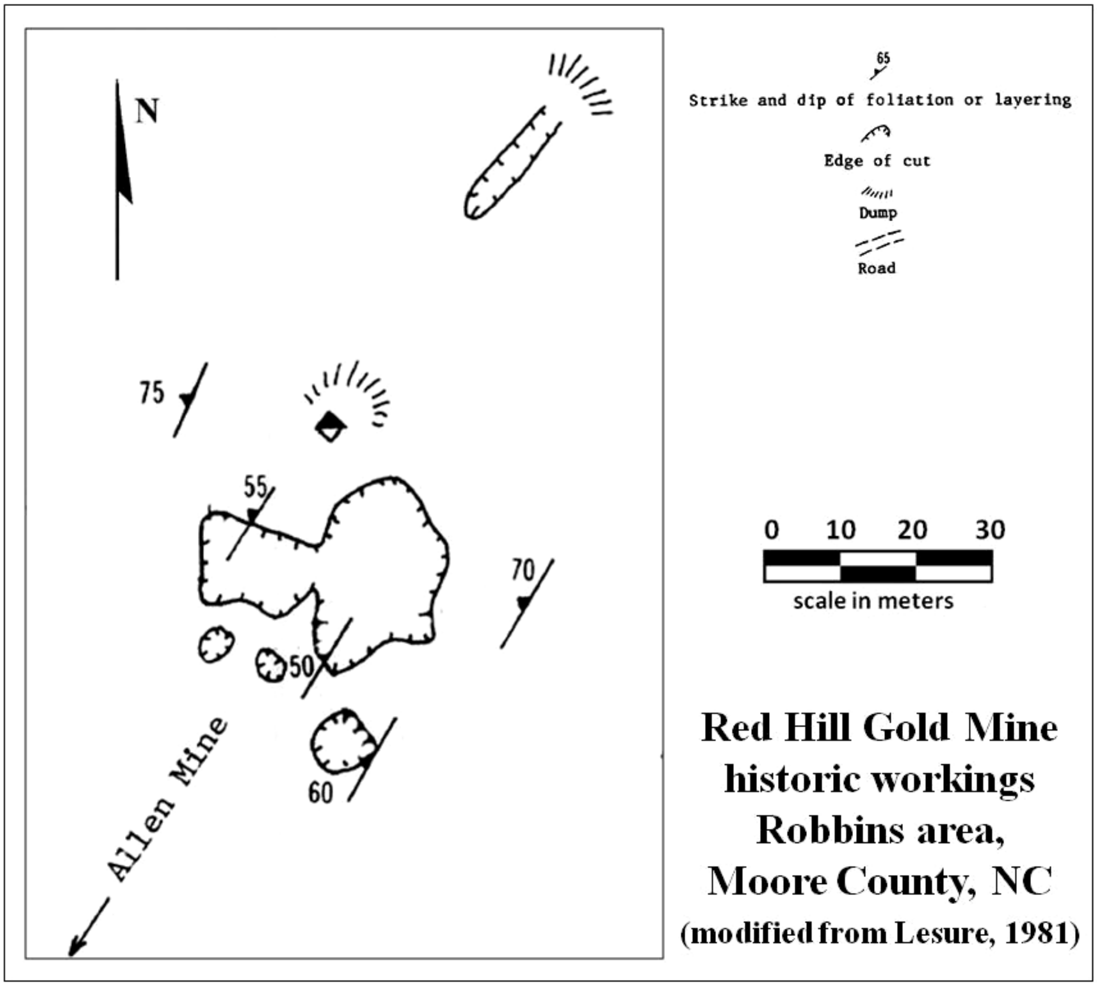

Figure 17. Allen Au Mine map of historic workings.

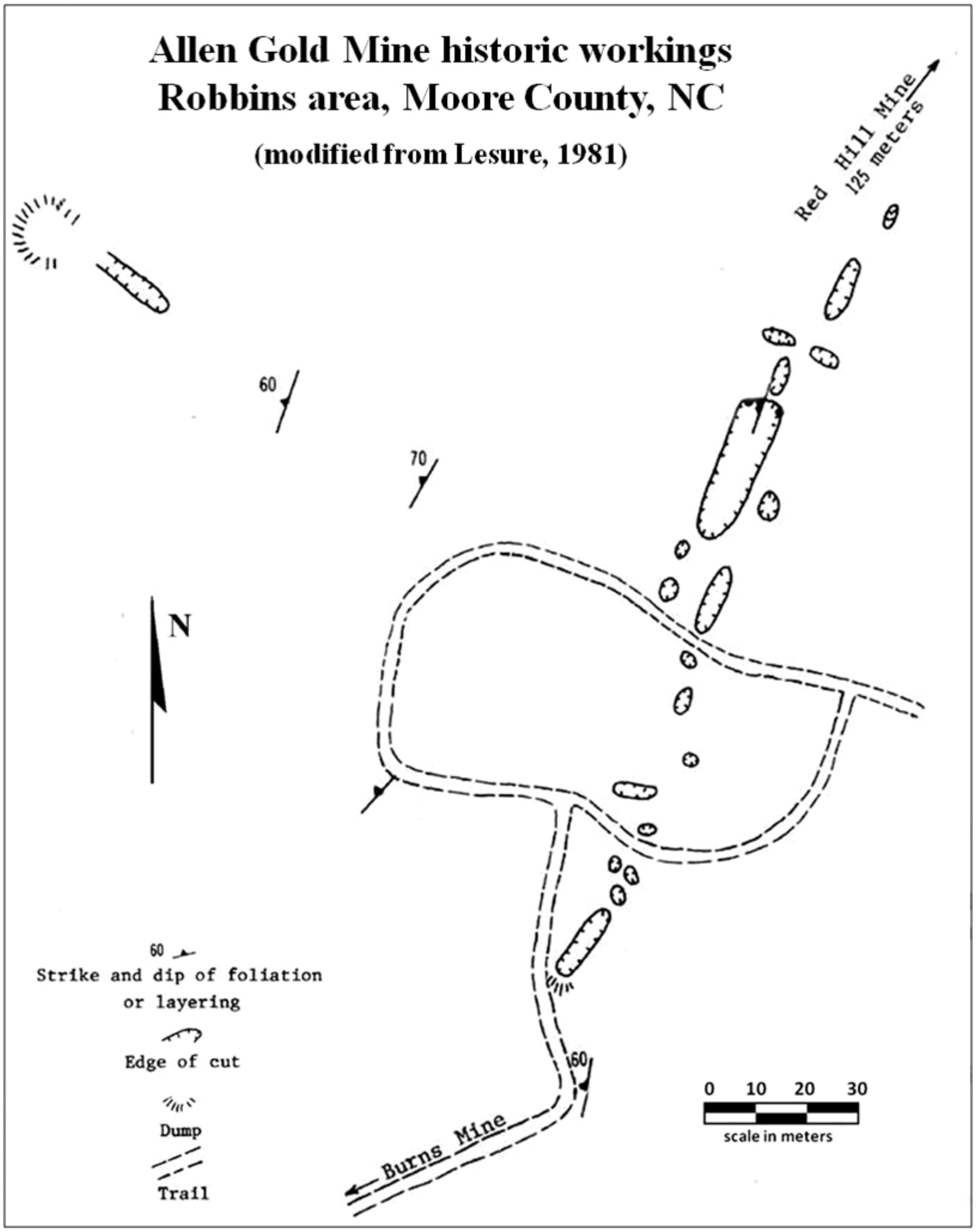

Figure 18. Burns Au Mine map of historic workings.

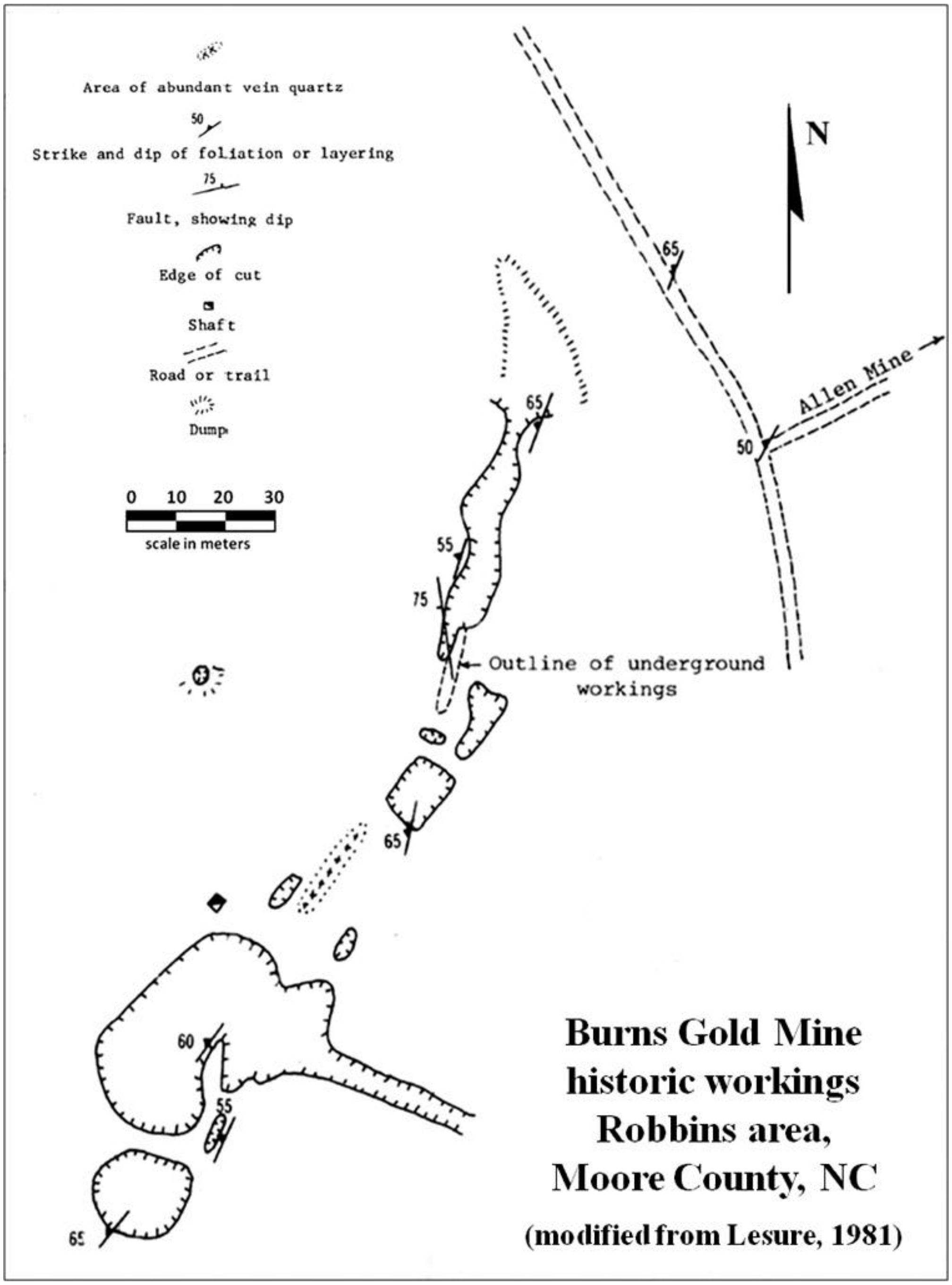

Figure 19. Burns Au Mine map and cross-sections through alteration and mineralization in Moore County, North Carolina.

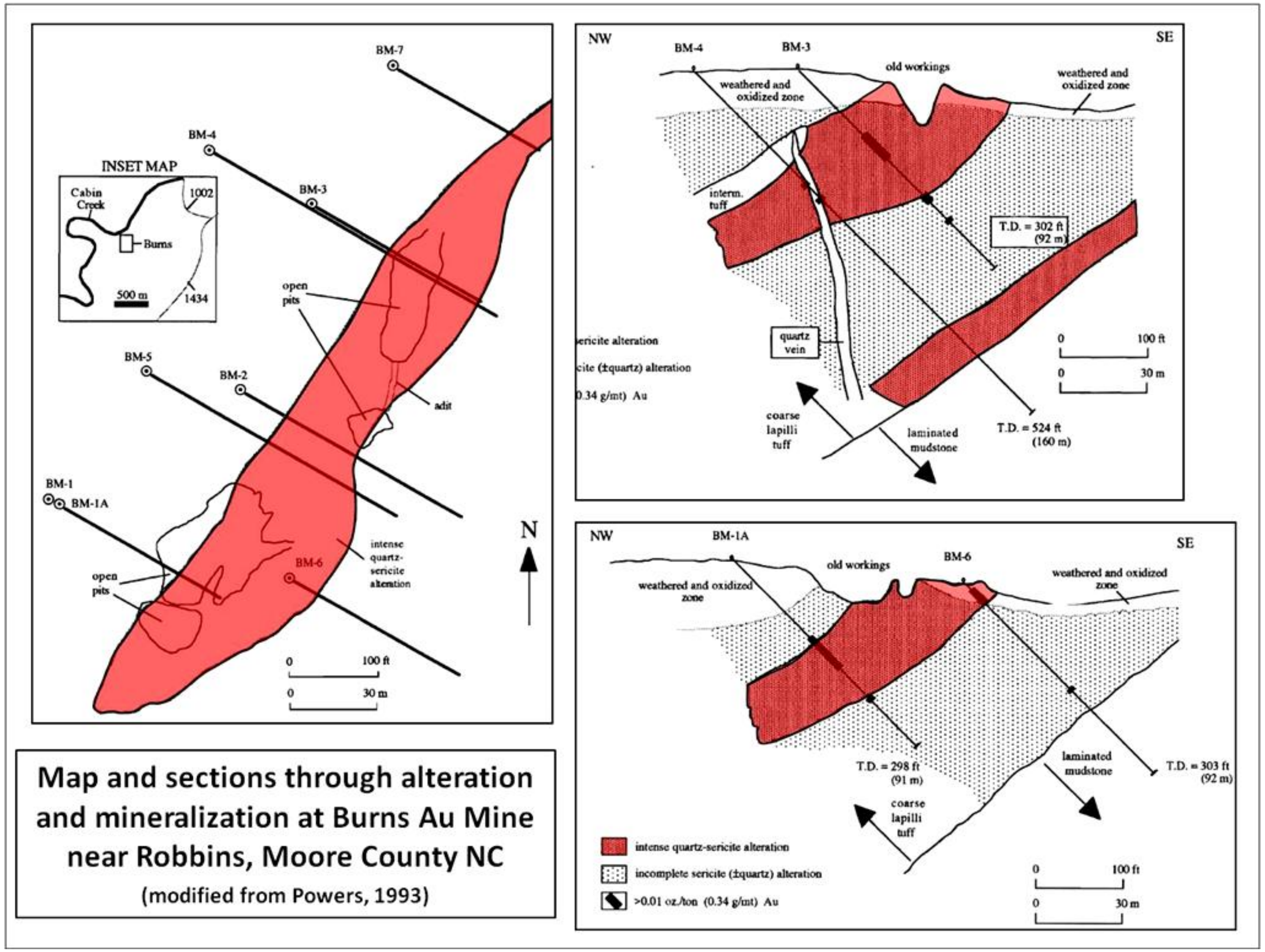

Figure 20. Brown Au Mine map of historic workings in Moore County, North Carolina.

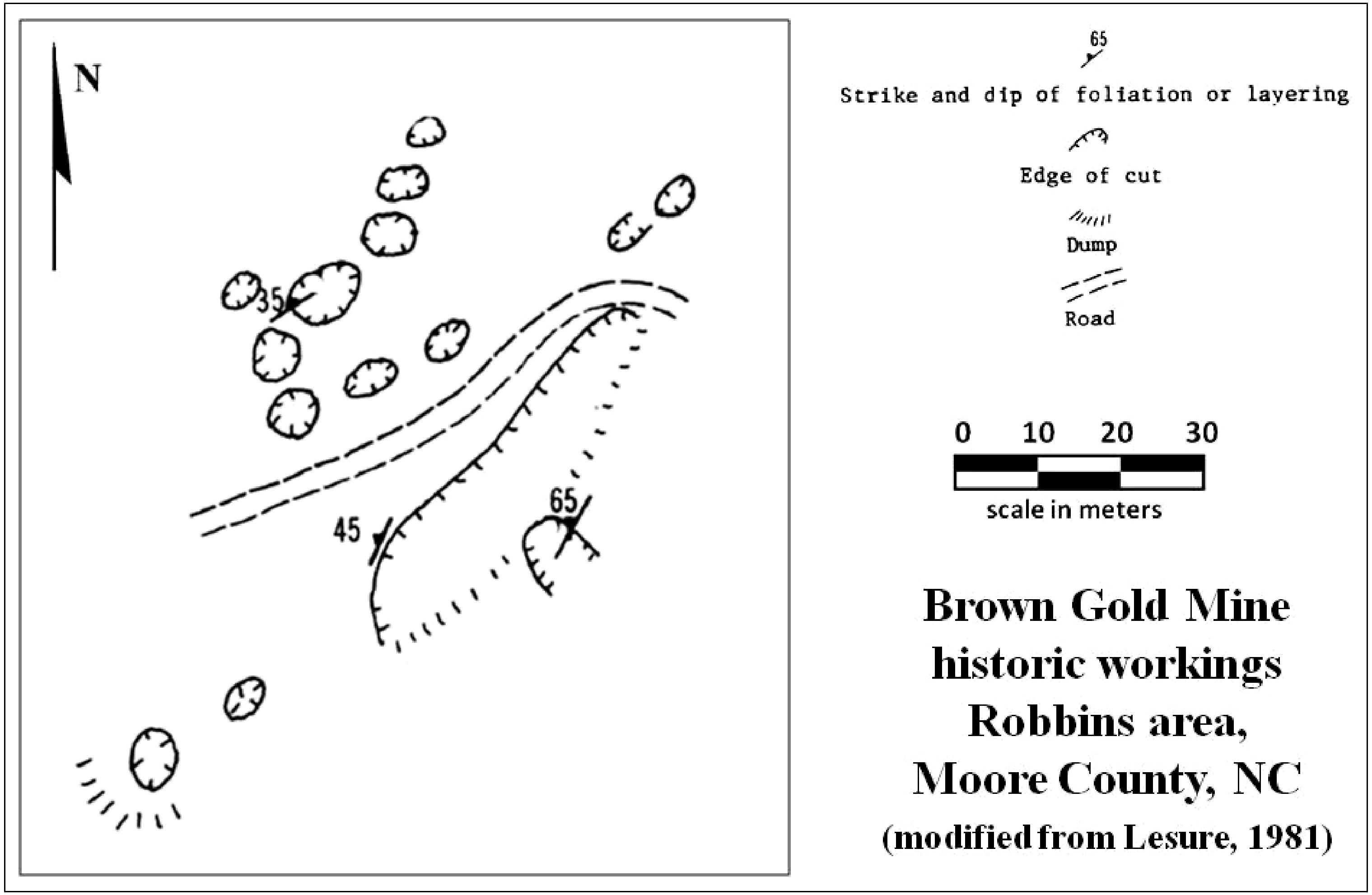

Figure 21. Two-event model for genesis of Robbins Fault AES and lode gold mineralization.