Star-Reynolds and Carter gold mines, Montgomery County, 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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Abstract

The historic Star-Reynolds and Carter gold mines in Montgomery County, North Carolina, first worked around 1850, are possibly unique occurrences of bonanza-grade gold-telluride mineralization in the Carolina Terrane of central North Carolina. Bonanza grade shoots rich in tellurides at the Star Mine contained as much as 10-20 oz/t Au, with similar grades from selected vein samples at the Carter Mine.

Historic gold production is uncertain, but placer + lode gold totaled around 20,000 ounces at the Star-Reynolds Mine and an estimated 18,000-20,000 ounces was produced from the Carter Mine. At the Carter Mine, up to 9000 ounces of gold were recovered from a lode less than a meter thick along about 50 meters of strike that was worked to a depth of around 20-30 meters. Much of this lode production was from a narrow, sub-horizontal seam that was stoped over a circular area 61 meters in diameter on the 20-meter-level of the mine (**Pratt, 1907**).

The workings of the Reynolds Mine (1851-1896) are located on a 100-meters-long zone of quartz veins and silicic to phyllic alteration, with numerous shallow pits and shafts to depths of 12-24 meters (**Phifer, 2004**). Gold production is estimated at around 17,400 ounces (**Luttrell, 1978**). Bonanza-grade Au-Ag-Te mineralization at the Star Mine (1954-1963) consists of gold-sylvanite-calaverite in steeply-dipping shoots or chimneys along a 10-meters-wide zone of narrow brittle faults and alteration (**Phifer, 2004**). Workings consist of an inclined shaft with a depth of 91 meters and drifts at three levels developed along about 60 meters of strike (**Stuckey and Conrad, 1961**; **Phifer, 2003**).

Plagued by processing and recovery problems, total production for the Star Mine is only around 1,100 ounces Au. However, up to 500 ounces Au was recovered from 20 tons of ore mined from a bonanza-grade chimney measuring 6-meters-long and 1.8-meters-wide that extends from a depth of 91 meters to the surface (**Phifer, 2004**). The Star-Reynolds Mine is part of a mineralized zone 3-11-meters-wide with a strike of at least 120 meters (**Phifer, 2004**).

The Star-Reynolds and Carter gold mines 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 and possibly up to 4,000 meters (**Luttrell, 1978**; **Phifer, 2004**). Gold mine locations maps published by **Pardee and Park (1948**, **Figure 22)** identify five sites of gold workings over a distance of 4,000 meters along this trend, which may explain multiple locations cited for the Carter Mine.

Two different styles of gold mineralization appear to be present at both the Star-Reynolds and Carter mines. The earlier, dominant style of mineralization consists of narrow zones of synkinematic quartz veins and associated silicic, phyllic, and propylitic alteration with auriferous pyrite and accessory carbonate. Pyrite with accessory chalcopyrite, minor bornite and chalcocite, molybdenite, and gold telluride are present in the quartz veins and altered host rocks of the Reynolds Mine (**Emmons, 1856**). Pyrite with minor chalcopyrite, gold telluride, and geochemically anomalous Mo (to 42 ppm), Sb (to 7.6 ppm), As (to 195 ppm), Pb (to 772 ppm), and Zn (to 1705 ppm) are present at the Carter Mine (**Powers, 1989**). 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**). Ore deposits in which Au-Ag tellurides are major ore components are typically either epithermal intrusion-related or epizonal orogenic deposits (**Cook *et al.*, 2009**). The Reynolds-Star and Carter deposits are epizonal orogenic in character, consistent with deposits formed in the upper 6 kilometers of the crust at temperatures of 150°-300°C (**Grooves *et al.*, 1998**). Structural controls of both styles of mineralization are consistent with formation during the Cherokee Orogeny (**Hibbard *et al.*, 2012**).

Evaluation of the Carter Mine by Noranda in 1987-1988 suggests limited potential to define a large-tonnage, bulk minable oxidized gold mineralization target where the central high-grade lode has been mined out (**Powers, 1989**). However, auriferous quartz veins are variably present in a zone up to 30 meters wide centered on the main lodes at the Star-Reynolds and Carter mines. Potential remains for significant tonnages of low-grade oxidized ore along the rest of the fault zone. If the Star-Carter fault zone is an *en echelon* structure, there may be under-evaluated potential within complex step-over zones between fault segments.

More importantly, 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 fault zone hosting the Star-Reynolds and Carter gold mines in Montgomery County, North Carolina. At both the Star-Reynolds and Carter mines, around 20,000 ounces of Au was produced from sections on this fault zone only 100-meters-long, mostly from a depth of less than 30 meters. This totals 40,000 ounces Au 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 central lodes. There appears to be a strong potential to develop additional bonanza-grade targets along strike and at depth.

The combination of low-tonnage bonanza-grade Au-Ag-Te ore bodies, potentially surrounded by a large-tonnage low-grade Au halo, represents a potentially bulk-minable resource to depths of 30-50 meters in oxidized and mixed oxide/sulfide zones along the fault system. The demonstrated value of bonanza-grade Au-Ag-Te ore bodies would justify extending mining underground in primary sulfide mineralization.

Introduction

The historic Star-Reynolds and Carter gold mines in Montgomery County, North Carolina (**Figure 1**, **Figure 2)** occur along a ductile-brittle fault zone with a brittle fault over-print. They are unusual for the occurrence of telluride minerals in both deposits, molybdenite at the Star –Reynolds Mine and geochemically anomalous Mo at the Carter Mine, and local bonanza-grade gold and silver values that appear to range from ounces to tens of ounces per ton. The Star-Reynolds and Carter deposits occur along a possibly *en echelon* fault zone that strikes 030° for at least 2,000 meters, possibly up to 4,000 meters, and dips moderately to the northwest.

Vuggy quartz veins and jasperoid in the mineralized zone of the Carter Mine (**Powers, 1989**) suggest that the Carter Mine gold deposit may be in part the product of an epizonal hydrothermal system. The presence of shoots of bonanza grade Au-Ag-Te mineralization associated with brittle fault breccia at the Star Mine also suggests possible epizonal conditions of mineralization. However, much of the fault-hosted mineralization at the Carter and Star-Reynolds mines is quartz vein and silicic alteration-hosted Au-Ag-Cu-Mo-Te that is more consistent with mesozonal orogenic gold mineralization.

Indications of two periods of deformation at the Star-Reynolds and Carter mines

(**Powers, 1989**) suggest the possible overprinting of a mesozonal phase of orogenic gold mineralization by an epizonal phase. **Powers (1989)** suggests that the earlier, dominant phase of cleavage-parallel mesozonal orogenic gold mineralization at the Carter Mine is cut by post-cleavage brittle fault zones associated with elevated Au values. The brittle fault zones are characterized by silicified clasts in a clay matrix (**Powers, 1989**). Similar fault breccias host bonanza-grade Au-Ag-Te mineralization at the Star Mine (**Phifer, 2004**).

The age of the mineralization and host structures for the Star-Reynolds and Carter mines is uncertain. The Hyco arc volcaniclastic host rocks were deformed by both the Virgilina Deformation between 578 and 554 Ma (**Pollock *et al.*, 2010**) and the Cherokee Orogeny circa 450-430 Ma (**Hibbard *et al.*, 2012**). The association of Mo and Te with gold mineralization suggests a possible connection with felsic magmatism. However, the style of deformation on the mineralized fault zone is more consistent with the circa 450-430 Ma Cherokee Orogeny (**Hibbard *et al.*, 2012**), which lacks any recognized magmatic component. The Star-Carter fault zone and associated Au-Ag-Te mineralization are an isolated occurrence that appears unrelated to intrusive igneous rocks of any age, other fault structures, nearby areas of AES alteration, or other occurrences of precious and base metal sulfide mineralization in this area of the Carolina Terrane.

Both deposits were evaluated in the 1970s-1980s as possible bulk-minable gold deposits, but mineralization appears to be restricted to narrow fault zones. However, both deposits also feature locally spectacular bonanza grades of gold and silver and there is the potential to develop an economically viable narrow-vein underground mining target. Although it is possible that both deposits lie along the same fault structure, it is more likely they may lie along *en echelon* segments of a single fault system.

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 1 ppm Au = 1 g/t Au and 34.28 g/t Au = 1 oz/t Au.

Limitations of the study

This study is based largely on a limited range of available geologic reports on gold mineralization in the Star-Reynolds and Carter mines in Montgomery County, North Carolina. The author worked throughout the region during the 1980s and 1990s, but has limited direct personal knowledge of these occurrences and only a single site visit to the Star Mine. A much larger body of information exists in the proprietary files of individuals and corporations, but is not available to the public sector.

However, a wealth of direct historical observations on the discovery, exploration, geology, and mining of these deposits allows an informed analysis of the character and controls of the mineralization. Comparison with the various styles of gold mineralization recognized in the Carolina Terrane in central North Carolina, their genesis constrained within the context of documented magmatic and tectonic events, makes informed interpretations possible.

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.

Geologic setting

The Star-Reynolds and Carter gold deposits are hosted by andesitic and felsic volcaniclastic units of the Hyco Arc sequence of the Carolina Terrane in central North Carolina (**Figure 1**), and developed along a moderately northwest dipping fault zone that strikes 030° for at least 2,000 meters. This fault cuts across the axis of the Peachland Syncline at an acute angle (**Figure 2**). The Peachland Syncline (**Randazzo, 1972**) is a first order fold paired with the Troy Anticlinorium to the west, both formed during the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**). The Carter and Reynolds-Star mines are located about 5 kilometers southeast of the axis of the Troy Anticlinorium and the apparently coincident Cottonstone Mountain-Ammons Mine alignment of large advanced argillic epithermal alteration systems (**Figure 2**, **Figure 3**), but there appears to be no geologic or metallogenic association.

The Star-Reynolds and Carter gold deposits appear to be an isolated occurrence unrelated to any recognized igneous activity, other geologic structures, or ore deposit occurrences in this area of the Carolina Terrane. Mesozonal orogenic styles of mineralization at both the Reynolds and Carter mines formed along synmetamorphic ductile-brittle fault zones, and are consistent with similar widespread lode gold mineralization formed along reverse fault zones, such as those within the Gold Hill Fault Zone (**LaPoint and Moye, 2013**; **Moye, 2016**), during the Cherokee Orogeny (**Hibbard *et al.*, 2012**). However, possible epizonal bonanza grade Au-Ag-Te mineralization associated with overprinting brittle faults at the Star Mine appears to be unique within the Carolina Terrane in North Carolina.

The Star-Reynolds Mine

The Star-Reynolds Mine is located around 5 kilometers west of the town of Star, and 400 meters west of road SR1340 at a point about 800 meters north of Little River (**Figure 2**, **Figure 3**), at geographic coordinates -79.83645, 35.38982 (WGS84). The Reynolds and Star mines appear to be located on the same lode, or possibly on parallel structures. The head-frame of the Star Mine inclined shaft, the ore storage bin, a pile of mine waste, and a small amount of ore-grade material were present at the site in the mid-1980s, but the present status of the mining infrastructure is unknown. Total gold production from the Star-Reynolds mine area may have totaled around 20,000 ounces.

Mining history

The deposit was discovered by E. Reynolds in 1851. **Emmons (1856)** reports that the mineralized zone was soft, easily mined Fe- and Mn-oxide stained slate traversed by quartz veins, with sulfides encountered at a depth of 18 meters, including copper and silver sulfides and occasional gold tellurides. The value of the ore was around $0.50 per bushel of ore. Around 1896 the original Reynolds Mine workings consisted of numerous pits and shafts, most 12-24-meters-deep, scattered over an area around 90-meters-long and 30-meters-wide **(Phifer, 2004)**. It is estimated that gold production during this period totaled around 17,417 ounces (**Luttrell, 1978**). **Kerr and Hanna (1888)** report the discovery of a second zone of gold mineralization located 550 meters northeast of the original mine workings and prospected to a depth of 12 meters.

In the early 1950s the owner of the mine property, Roy Reynolds, located a subparallel zone of gold mineralization about 10-meters-wide **(Phifer, 2004)**, assumed to be adjacent to the on the Reynolds Mine workings. According to **Phifer (2003)**, while panning along a small stream that crossed the property, Reynolds encountered abundant black, high-specific gravity mineral grains in panned concentrates that also contained grains of gold. The black grains were eventually analyzed by the Colorado Assaying Company in Denver and found to be tellurides, principally sylvanite [$(Au,Ag)Te_2$] and calaverite ($AuTe_2$) , with gold and silver values in excess of $4000 per ton (**Phifer, 2003**), or around 114 oz/t Au (@ ~$35/oz . The stream was diverted and the lode source for the tellurides and gold located.

The Little River Mining Company was formed to exploit the discovery and the cyanide treatment plant at the Candor Mine (formerly the Colossus or Howie Mine) near Waxhaw in Union County, 80 kilometers away, was upgraded to process the ore (**Phifer, 2003**). Unfortunately, the mill was designed to treat the low-sulfide siliceous ore with micron-sized gold of the Howie Mine, and inappropriate for the high-sulfide and telluride-rich ore of the Star Mine (**Phifer, 2003**). The venture stalled due to poor recovery and a new stock company was formed.

The Union Refining and Mining Company of High Point, North Carolina, under the direction of H.A. Knight, Sr., worked the deposit by open cut as the Star Mine in 1954-1955. The excavation was a pit about 6 meters in diameter and 6 meters deep, which then angled downwards at 45° northwest to follow the mineralized zone. A total of about 570 ounces of gold was recovered at the reactivated cyanide plant at the Candor Mine near Waxhaw (**Stuckey and Conrad, 1961**), but operations ended in late 1955.

Around 1958-1959, at the advice of the NC State Geologist, three core holes spaced 60 meters apart along strike were drilled to intersect the new mineralized zone at about 90-meters-depth. All three holes intersected ore grade gold mineralization over widths of 3-11 meters (**Phifer, 2004**). Based on these results, a two compartment -45° inclined shaft was constructed on the fault zone to a depth of 91 meters, with drifts along the ore zone at depths of 15 meters, 38 meters, and 82 meters (**Stuckey and Conrad, 1961**; **Phifer, 2003**). The drift on the 15-meter-level extended about 30 meters to the northwest, the drift on the 38-meter-level extended for 30 meters to the southwest, and at the 82-meter-levels drifts extended for 30 meters both to the northeast and to the southwest (**Phifer, 2003**). The drifts were 2.1-meters-high and 1.8-meters-wide (**Phifer, 2003**).

The work defined a mineralized zone up to 10-meters-wide with unknown strike length, and a new 100 tons per day cyanide treatment plant was constructed at the Candor Mine near Waxhaw in Union County. **Phifer** (**2004**), an employee of the mine at this time, reports that 75 tons of ore was mined and yielded 520 ounces of gold, suggesting a grade of about 6.93 oz/t Au. Due to the presence of abundant tellurides and limitations on the efficiency of the antiquated cyanide leaching facility, the grade may have been higher (**Phifer, 2004**). This mill run included low grade ore blended with 20 tons of ore mined from a high-grade shoot or chimney of Au-Ag-Te ore about 6-meters-long and 1.8-meters-thick that extended from the 91-meters-level of the mine to the surface (**Phifer, 2003**). If most of the gold recovered from the 75 tons processed was from the 20 tons of high-grade ore mined from the ore chimney, then the grade of Au-Ag-Te mineralization in the chimney could be in excess of 20 oz/t Au.

The inclined shaft of the Star Mine intersected the central of the three exploration drill holes, but the drifts did not extend far enough to the northeast and southwest to intersect the other two drill holes before the mine closed (**Phifer, 2004**). Sampling on the 91-meters-level of the Star Mine by the Tennessee Copper Company in the 1960s, prior to final mine closure, indicated scattered high-grade ore zones along the strike of the lode **Phifer (2004)**. The last reported gold production was in 1963.

Mineralization and alteration

The dominant style of mineralization at the Star-Reynolds Mine consists of pyrite with minor chalcopyrite, bornite, chalcocite, molybdenite, gold telluride, and specular hematite disseminated in a series of white vitreous to saccaroidal quartz veins and adjacent altered host rocks (MRDS record #10026497, https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10026497, viewed 01 March 2018. The ore minerals are associated with gangue minerals quartz, sericite, chlorite, and calcite in a zone of silicic to phyllic alteration along a mylonitic fault zone 1.8-2.4-meters-thick that strikes 033° and dips 45°-50° northwest. The 30-meters-width of the zone of historical workings suggest that parallel veins of mineralization may also be present.

The Star mineralized zone is centered on a fault zone 90-180 centimeters thick and comprised of several fault strands 1.3 to 30 centimeters thick (**Phifer, 2004**). These fault strands are filled with brittle fault gouge and silicic altered rock clasts, and contain free gold and abundant tellurides in small shoots or chimneys with very high grades of gold and silver (**Phifer, 2004**). One high-grade shoot or chimney was about 6-meters-long and 1.8-meters-thick and extended from the 91-meters-level to the surface (**Phifer, 2003**). Phyllic alteration with disseminated pyrite around the mineralized zone is gradational outward into unaltered rocks.

Recent exploration activity

There was renewed interest in the Carter and Reynolds mines in the 1970s with the increase in the price of gold. Bear Creek Exploration, part of the Kennecott Mining Company, examined the Reynolds mine and completed trenching, geochemical and surface mapping. Phelps Dodge Exploration East examined both the Carter and the Reynolds mines in the late 1970s. The property was promoted throughout the 1970s and 1980s and visited by numerous exploration companies, but no serious work is reported.

The Carter Mine

The mine is reported as located 4.8 kilometers east of Troy, 4.8 kilometers west of Star, and between 400 and 1,200 meters southeast of the old route of the Norfolk Southern Railroad line (**Figure 2**, **Figure 3**), officially at geographic coordinates -79.847, 35.3726 (WGS84). Uncertainty over the location of the Carter Mine is addressed in a subsequent section. Mineralization at the Carter Mine appears to be on the same fault structure as the Star-Reynolds Mine deposit, located about 1,600-2,000 meters to the north (**Nitze and Hanna, 1896**; **Phifer, 2004**).

Mining history

Residual surface placer gold accumulated along the outcrop of the vein near the Carter mine was worked as the Dry Hollow Mine in the 1850s (**Hafer, 1914**). Small tracts were leased to tribute miners, who received a royalty based on production (**Hafer, 1914**), but lack of water prevented systematic work. Total placer production is reported as around 12,090 ounces of gold. In the 1930s, Mr. G. W. LaPiere of Charleston, West Virginia, attempted to placer mine the gravels in a small stream draining the mine area, but the venture was not successful (**Bryson, 1936**).

The lode deposit was originally worked by the Mauney Brothers in the 1850s, but mining reportedly ceased when the vein pinched out. The ore zone is 30 to 60 centimeters wide with some very rich streaks and was worked for 46 meters along strike to a depth of 20 meters (**Luttrell, 1978**) and possibly as deep as 30 meters (**Pardee and Park, 1948**). **Pratt (1907)** reports that most of the lode gold was mined from a narrow sub-horizontal seam that was stoped over a circular area 61 meters in diameter on the 20-meter-level. Smaller stopes were also present at the 33-meter- and 40-meter-levels (**Pratt, 1907**).

Total historical production is reported as between 4837 and 9676 ounces of gold, with most sources supporting the higher figure (**Luttrell, 1978**; **Hafer, 1914**). Fines from the old mine dumps were assayed in 1912 by **Hafer (1914)** at 0.10-0.19 oz/t Au ($2.00 to $4.00 per ton @ $20.67/oz in 1912).

Two shafts were completed in 1906 by Sam Smitherman of Troy in an attempt to reach the old workings. A drift reached the main stope on the 20-meter-level, but bad ground was encountered at depths of 23-24 meters (**Pratt, 1907**). One shaft encountered a seam of mineralization 10-15 centimeters wide that assayed 19.4 to 24.2 oz/t Au; and a drift cut to the old workings encountered a mineralized seam that pinched and swelled from 0-15 centimeters thick and assayed 82.2 oz/t Au (**Pratt, 1907**). There was no reported production during this period.

Claude Hafer dewatered the mine to a depth of 20 meters circa 1912 and confirmed that the vein had been mined for 46 meters along strike above and below this level (**Hafer, 1914**). He extended the existing drive northeast and southwest on this level and reported that the lode and adjacent rocks contained abundant sulfide and free gold. The ore zone at the northeast end of the drive was 30-60 centimeters thick and assayed 0.30-0.34 oz/t Au (**Hafer, 1914**).

At the southeast end of the drive, the lode was a 60-centimeters-wide zone of quartz stringers in sheared intermediate volcaniclastic rocks and assayed 0.77 to 3.87 oz/t Au (**Hafer, 1914**). This quartz stringer zone was gradational southwest into auriferous pyritic schist (**Hafer, 1914**). **Hafer (1914)** noted that the ore zone and host rock in the Carter Mine dipped about 10°-20° degrees northwest and were crumpled and folded. This shallow dip is only present in the mine area, and may be located on a meso-scale anticline. North of the Carter Mine, cleavage and the ore zone dip 50°-55° northwest (**Hafer, 1914**).

Hafer sank a new inclined shaft about 400 meters north of the original workings, adjacent to the railroad cut, to a depth of 15 meters and intersected stringer quartz veins that may be a continuation of the Carter lode (**Hafer, 1914**). In the railroad cut to the north, cleavage within the fault zone dips 50°-55° northwest (**Hafer, 1914**).

Total lode + placer gold production from the Carter Mine is estimated at around 17,000 to 22,000 ounces. Much of this total represents placer gold, and lode gold production may have benefitted from supergene oxidation of auriferous sulfides and dissolution and precipitation of free gold.

Local geologic setting

The Star-Reynolds and Carter gold mines are located about 5 kilometers southeast of the axis of the Troy Anticlinorium, on or near the axis of the Peachland Syncline (**Randazzo 1974**), along a fault zone that appears to cut the fold axis at an acute angle (**Figure 2**, **Figure 3**). These first-order folds deform the Hyco Arc sequence and the Albemarle Sequence of the Carolina Terrane, and are products of the Cherokee Orogeny in the late Ordovician to early Silurian (**Hibbard *et al.*, 2012**). The Star-Reynolds and Carter Mines are hosted by felsic to intermediate volcaniclastic units of the Hyco Arc sequence (**Powers, 1989**). The rocks are deeply weathered, with saprolite to a depth of 12 meters and local evidence of oxidation to a depth of around 30 meters (**Powers, 1989**).

Many of the Hyco Arc sequence units are lapilli tuffs with clasts typically ranging from 1-2.5 centimeters, occasionally to 7.5-centimeters-long and strongly flattened into the dominant cleavage (**Powers, 1989**). Clasts are dominantly composed of albite in felsic units and strongly chloritic in intermediate units, both in fine-grained matrixes composed of varying proportions of chlorite + quartz + albite + sericite + epidote + calcite. Resorbed quartz phenocrysts are common in felsic volcaniclastic units (**Powers, 1989**). Subordinate feldspar phyric massive units contain plagioclase crystals about 6 millimeters long. A core hole intersected an amygdaloidal basalt flow 60-90 centimeters thick (**Powers, 1989**), although this could be a dike. Local reworking of volcaniclastic material is indicated by well-sorted, rounded clasts and bedded, silt-size sediment over narrow intervals. Massive to well-bedded epiclastic sedimentary units outcrop extensively to the west and south of the Carter Mine.

The dominant cleavage in the area strikes 030° and dips 50° northwest. The zone of gold mineralization appears to dip about 30° northwest (**Powers, 1989**). Observations of bedding-cleavage relationships by **Powers (1989)** suggest that the mine area is located near the axis of a large syncline that plunges gently to the southwest, consistent the location of the mine near the axis of the Peachland Syncline.

Abrupt changes in cleavage orientation were noted in the vicinity of the old mine, including sub-horizontal cleavage and chevron folds with wavelengths of 2.5-5 centimeters (**Powers, 1989**), confirming observations by **Hafer (1914)**. **Pratt (1906)** reports that faulting along the Carter Mine mineralized zone had produced a “large chimney of soft material”. These observations are consistent with meso-scale, post-cleavage, post-mineralization folding and faulting at the Carter Mine (**Hafer, 1914**; **Powers, 1989**). Zones of brittle fault gouge 60-120 centimeters thick were intersected in some Noranda drill holes, and composed of silicified clasts in a crumbly, clay-rich matrix (**Powers, 1989**). These intervals often contained anomalous gold values.

Powers (1989) suggests two deformation events, one associated with formation of a penetrative cleavage, probably axial planar to the Peachland Syncline, and a second, more localized deformation of this cleavage, possibly associated with meso-scale folding and brittle faulting. This second deformation event post-dates the formation of vein-hosted lode gold mineralization, and brittle faulting may locally up-grade existing gold mineralization or accompany a second mineralizing event.

Mineralization and alteration

A small zone of advance argillic alteration is located west of the old mine workings, and composed of quartz and pyrophyllite with locally abundant fine-grained disseminated chloritoid (**Powers, 1989**). The association of this isolated occurrence with advanced argillic epithermal alteration centers (AES) along the Cottonstone Mountain-Ammons Mine alignment to the northeast (**Figure 3**) is uncertain, but suggests possible localized epithermal alteration processes in the Carter Mine area.

Propylitic alteration and weak phyllic alteration are widespread in the Carter Mine area, but silicic and strong phyllic alteration assemblages are closely associated with gold mineralization (**Powers, 1989**). Propylitic alteration is distinguished from regional greenschist metamorphic assemblages by the presence of abundant fine-grained disseminated pyrite and locally up to 20 vol% fine-grained disseminated magnetite (**Powers, 1989**). Pyrite and magnetite are not typically found together.

A hard, black, magnetite-rich unit 30 to 1.5-meters-thick strikes 030°, parallel to the dominant cleavage, for 90 meters along the eastern side of the mine property (**Powers, 1989**). This unit is fine-grained to coarse-grained with apparent lithic clasts to 7.5-centimeters-long and composed of 30 volume percent magnetite as fine disseminated grains and coarser-grained cross-cutting veinlets (**Powers, 1989**).

The propylitic alteration with either disseminated fine-grained pyrite or magnetite in the Carter Mine area suggests highly variable redox conditions and/or sulfur activity that appear inconsistent with mesozonal style of gold mineralization. However, similar disseminated oxide-sulfide alteration is common in propylitic alteration zones peripheral to advanced argillic epithermal alteration systems (AES) in the Carolina Terrane of North Carolina (**Moye, 2013**), including those along the Cottonstone Mountain-Ammons alignment to the northwest and along the Robbins Fault to the east in Moore County. The propylitic alteration with disseminated magnetite or pyrite in the Carter Mine area may be associated with the nearby advanced argillic epithermal alteration zone, rather than the gold mineralization.

The dominant type of Carter Mine mineralization consists of sheeted foliation-parallel quartz stringers in a chlorite to sericite altered shear zone up to 91-centimeters-wide with disseminated auriferous pyrite (**Pardee and Park, 1948**; **Luttrell, 1978**). **Emmons (1856)** reports the presence of a gold telluride mineral associated with calcite in the quartz veins. Pyrite is the dominant sulfide in the mineralized zone as disseminated grains, in quartz stringers, and locally as cleavage-parallel stringers and veins (**Powers, 1989**). Minor chalcopyrite is associated with gold mineralization, and calcite is a common gangue mineral in the veins.

Ore zones are characterized by moderate to intense silicic alteration as hydrothermal replacement of the host rocks along the foliation and as saccaroidal quartz veinlets, with strong phyllic alteration containing 1-5 vol% fine-grained disseminate pyrite along the lode margins (**Powers, 1989**). Typically, the intensity of phyllic alteration increases with the intensity of cleavage development (**Powers, 1989**). At greater depth, silicic alteration largely occurs as jasperoid in veins and small areas of replacement (**Powers, 1989**). This jasperoid contains fine-grained disseminated hematite, and may represent a different mineralizing event.

Two zones of anomalous soil gold values (>100 ppb Au) are present around the old mine workings, and several trench sample intervals contain over 0.03 oz/t Au (**Powers, 1989**). The highest gold values in drill core are associated with zones of intense, often vuggy silicic alteration with calcite common as a gangue accessory. Intervals of fault breccia 60-120 centimeters wide were intersected in several Noranda core holes, and composed of silicified clasts in an unconsolidated clay-rich matrix (**Powers, 1989**). These faults appear to post-date cleavage formation and are sometimes strongly anomalous in gold (>0.2 gpt Au). **Powers (1989)** suggests that the brittle faulting post-dates the lode gold mineralization but may have locally increased gold concentrations. Alternatively, there may be two gold mineralization events at the Carter Mine deposit, one associated with ductile-brittle shearing and formation of the gold lodes and a second associated with younger brittle faulting.

Five core and rotary holes intersected often multiple intervals of gold mineralization that were 60-centimeters to 3-meters-thick and assayed 0.03 to 0.14 oz/t Au (**Powers, 1989**). Selected multi-element analyses included up to 7.6 ppm antimony, 2.9 ppm tellurium, 195 ppm arsenic, 772 ppm lead, 42 ppm molybdenum, and 1,705 ppm zinc (**Powers, 1989**).

Recent deposit exploration and evaluation

The Carter deposit was explored by Noranda in 1987-1988, with a comprehensive program of geologic mapping, soil and trench sampling, geophysics, and rotary and core drill holes (**Powers, 1989**). The conceptual target was a low-grade, bulk-minable gold deposit with local zones of high-grade ore. Geophysical survey methods included ground magnetic, max-min EM, self-potential, and induced-polarization. Station spacing along grid wing-lines was 15 meters, which is probably too widely spaced for effective soil and geophysical surveys on a target of this character. A total of 1,870 meters of trenching was complete across soil gold anomalies of >100 ppb, and mapped and sampled over 3-meter intervals.

In June and July 1988, five core drill-holes totaling 734 meters were drilled at bearings of 120° and -45° dip to test the soil and trench gold anomalies. Ten rotary air drill holes totaling 290 meters were completed around the old mine site, but encountered serious problems with the underground workings (**Powers, 1989**). In November and December 1988, two additional core drill-holes totaling 152 meters and five air drill-holes totaling 201 meters were completed.

Although multiple narrow zones of low-grade gold mineralization were encountered, Noranda concluded that the Cater Mine deposit did not offer significant potential as a bulk-minable gold mining target and the project was terminated.

Where exactly is the Carter Mine?

There is some confusion regarding the location of the Carter Mine. The USGS geographic location of -79.847, 35.3726 (WGS84) for the site (MRDS record # 10055225, https://mrdata.usgs.gov/mrds/show-mrds.php?dep_id=10055225, viewed 01 March 2018) is based on an update by T.L. Klein in 1991. This places the mine about two kilometers southwest of the Star Mine on a bearing of 210° (**Figure 4**). However, this record also states that the two mines are 4,000 meters (2.5 miles) apart along the fault zone.

Hafer (1914) reports that his new shaft was sunk on the fault zone to a depth of 15 meters adjacent to an existing railroad cut, and places the original mine workings 400 meters southwest (**Figure 4)** of the railway line (**Hafer, 1914**). This is presumed to be the Norfolk Southern Railroad line, built around 1910, that ran east-west between Star and Troy. No other rail lines are known in this area of Montgomery County. **Powers (1998)** discussed exploration activities north and south of the railroad line and placed the Star Mine about 1.6 kilometers to the northeast of the Carter Mine.

Luttrell (1978) states that the Norfolk Southern Railroad line passes through the property, and that the line of lode was prospected for 4 kilometers (2.5 miles) northeast from the Carter to the Reynolds Mine. The location of the Reynolds and Carter mines on Plate 22 of **Pardee and Park (1948)** is shown as an alignment of five mines or prospects over a distance of 4,000 meters along the west side of the Little River.

It appears possible that at least two and possibly three locations have been identified as the Carter Mine. However, available discussions of the mine workings appear to refer to a single deposit. The present study concludes that the Star-Reynolds and Carter gold mines are probably located about 2,000 meters apart on a fault zone that strikes about 030°. The report of a zone of gold mineralization located 550 meters northeast of the Star-Reynolds Mine (**Kerr and Hanna, 1888)** could extend the fault strike length of around 2,500 meters. The repeated references to a strike length of 4,000 meters for the fault zone cannot be evaluated at this time.

Discussion

The host rocks for the Star-Reynolds and Carter gold deposits are circa 633-612 Ma volcaniclastic units of the Hyco Arc, which were deformed during the Virgilina Deformation between 578 and 554 Ma (**Pollock *et al.*, 2010**). However, the 030°-strike and northwest dip of the host fault zone, subparallel to a penetrative cleavage, appears to cross-cut the axis of the Peachland Syncline (**Randazzo, 1972**), formed during the Cherokee Orogeny circa 450-430 Ma (**Hibbard *et al.*, 2012**).

The Cherokee Orogeny (**Hibbard *et al.*, 2012**) is characterized by regional-scale development of a penetrative slaty cleavage axial to mega- to meso-scale folds that strike northeast and dip moderately to steeply northwest, and southeast-vergent reverse faults that post-date and often bisect anticlines along or near the axes. The intensity of Cherokee deformation generally decreases southeast from the Gold Hill Fault Zone to the Troy Anticlinorium (**Hibbard *et al.*, 2012**). However, the intensity of deformation again increases to the east of the Troy Anticlinorium (**Stuckey, 1967**; **Worthington and Kiff, 1970**), although the folds are generally smaller. This may be the result of SE-directed compression during the Cherokee Orogeny tightening and overturning fold formed during the Virgilina Deformation, as observed to the north (**Harris and Glover, 1988**).

The presence of molybdenite at the Reynolds deposit, minor tellurides at the Carter Mine, and bonanza grade Au-Ag-Te mineralization at the Star deposit all suggest a possible association with felsic magmatism. There are multiple episodes of felsic magmatism in this area of the Carolina Terrane; including those associated with Hyco Arc calc-alkaline magmatism circa 633-612 Ma, localized Aaron Formation magmatism circa 578-579 Ma, Uwharrie Formation felsic-dominated bimodal magmatism circa 554-550 Ma, and strongly bimodal felsic-mafic magmatism throughout deposition of the Albemarle Group from about 550-528 Ma (**Hibbard *et al.*, 2013**).

No evidence of magmatism associated with the Cherokee Orogeny is recognized in this area of the Carolina Terrane. However, a number of gold deposits hosted by reverse fault zones in the Albemarle Group are characterized by anomalous Au + Ag + As ± Mo ± Sb ± Te that suggest a possible association with fluids derived in part from a felsic magmatic source. These include the Sawyer, Jones-Keystone, and Lofflin deposits in northwest Randolph County; the Russell and Coggins deposits in the Ophir District of northeast Montgomery County; and zones of gold mineralization along the Robbins Fault Zone in central Moore County.

These gold deposits have similar structural controls, styles of alteration and mineralization, and metallic element signatures that are distinct from the typical narrow vein mesozonal orogenic gold deposits that characterize the Gold Hill Fault Zone (**LaPoint and Moye, 2013**; **Moye, 2016**). However, all appear to have formed during the Cherokee Orogeny and represent a distinct style of mesozonal orogenic gold mineralization, typically associated with zones of strongly appressed asymmetric meso-scale folds, intense axial cleavage development, and axial reverse faults. None of these gold deposits have any recognized association with any form of contemporary magmatism. The abundance of Mo, Sb, and Te in these deposits is typically at trace levels and often only significant in selected very high-Au grade ore samples.

The Star-Carter fault zone is interpreted as a probable reverse fault structure, possibly developed coeval with the Gold Hill Fault Zone during a later phase of the Cherokee Orogeny (**Hibbard *et al.*, 2012**). This reverse faulting post-dates the formation of regional scale first-order folds, including the Troy Anticlinorium and Peachland Syncline. Associated gold mineralization appears to include both mesozonal and epizonal characteristics, and is part of a broad spectrum of orogenic gold deposits present in the Carolina Terrane in North Carolina. The apparent presence of two distinct episodes of deformation and associated gold mineralization along the Star-Carter Fault Zone is unusual, and the presence of epizonal gold mineralization possibly unique in the Carolina Terrane in central North Carolina.

Conclusions

The Star-Reynolds and Carter gold mines in Montgomery County, North Carolina are unusual among narrow-vein gold deposits in the Carolina Terrane, due to the occurrence of locally economic and even bonanza-grade concentrations Au-Ag tellurides. Additionally, there is evidence of gold mineralization associated with both synmetamorphic ductile-brittle vein systems and post-metamorphic, late-kinematic brittle faulting.

At both the Star-Reynolds and Carter mines, the dominant form of mineralization is narrow, cleavage-parallel shear zones hosting sheeted or stock work quartz veinlets 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, possibly surrounded by more widespread propylitic alteration. These features are consistent with those of a typical mesozonal orogenic gold deposit (**Grooves *et al.*, 1998**). This mineralizing event appears to be synkinematic under regional greenschist facies metamorphic conditions. However, the more localized bonanza-grade Au-Ag-Te mineralization at the Star Mine is associated with post-metamorphic brittle faulting and appears to have formed at lower temperatures and shallower crustal levels.

Orogenic gold deposits form over an unusually broad range of P-T conditions (**Grooves *et al.*, 1998**). In the comprehensive classification (**Figure 5**) proposed by **Groves *et al*. (1998)**, hypozonal deposits form at depths >12 kilometers and temperatures >475°C, mesozonal deposits at depths of 6-12 kilometers and temperatures of 300-475°C, and epizonal deposits form in the upper 6 kilometers of the crust at temperatures of 150-300°C. Some epizonal orogenic gold deposits form at temperatures of 200°-250°C and only a few kilometers depth, and may be characterized by textures similar to classic epithermal styles of gold mineralization (**Grooves *et al.*, 1998**). The highest crustal levels of orogenic gold systems may consist of Sb-Hg mineralization without gold or silver (**Grooves *et al.*, 1998**).

The Star-Reynolds and Carter gold deposits are largely typical of mesozonal orogenic gold mineralization as defined by **Grooves *et al*. (1998)**. They are hosted by ductile-brittle fault structures formed in a compressional tectonic regime, have proximal alteration assemblages of sericite ± albite ± chlorite with ≤3-5 vol% sulfide (mostly pyrite) and ≤5-15 vol% carbonate. Like most orogenic gold deposits, they probably formed at syn- to post-peak greenschist facies metamorphic conditions of 300 ± 50°C at pressures of 1-3 kilobars (**Figure 5**).

Orogenic Au ± Ag deposits are typically enriched with varying concentrations of trace elements including As, B, Bi, Hg, Sb, Te, and W; with Cu, Pb and Zn concentrations generally only slightly higher than host-rock background levels (**Grooves *et al.*, 1998**). The presence of molybdenite in the Reynolds Mine ore zone and geochemically anomalous Mo at the Carter Mine is unusual in orogenic gold systems. However, a number of apparently orogenic gold deposits formed during the Cherokee Orogeny in this region of the Carolina Terrane also contain trace to accessory levels of Mo. These include the Russell Mine in the Ophir District of northwest Montgomery County (**Klein *et al.*, 2007**) and the Cagle and Burns gold mines in the Robbins area in Moore County (**Powers, 1993**).

However, the presence of vuggy quartz veins, jasperoid with fine-grained hematite, and overprinting brittle fault zones with silicic clasts in a clay matrix at the Carter Mine (**Powers, 1989**), and similar late-kinematic fault breccias with locally bonanza-grade Au-Ag-Te mineralization at the Star Mine (**Phifer, 2003**) strongly suggest a post-metamorphic epizonal mineralizing event. This overprint could represent a separate and younger metallogenic event that reactivated and overprinted an existing structure. However, both mesozonal and epizonal gold mineralization are more likely to be part of the same widespread metallogenic episode associated with the Cherokee Orogeny.

Au-Ag-Te deposits, those in which gold and silver telluride minerals are major ore components, are typically either epithermal intrusion-related or epizonal orogenic deposits (**Cook *et al.*, 2009**). The absence of associated magmatism of appropriate age at the Star-Reynolds and Carter deposits suggests that brittle deformation and associated Au-Ag-Te mineralization is epizonal orogenic in character (**Figure 5**). Mesozonal orogenic gold mineralization associated with the 450-430 Ma Cherokee Orogeny is widespread in the Carolina Terrane in central North Carolina, especially in association with reverse fault zones (**Moye, 2016**). However, the occurrence of epizonal orogenic mineralization at the Star-Reynolds and Carter gold mines appears to be unique.

In summary, the Star-Reynolds and Carter gold deposits in Montgomery County, North Carolina appear to belong to the broad and diverse family of orogenic gold occurrences as defined by **Grooves *et al.* (1998)**. There appear to be two phases of mineralization present (**Figure 5**): one synkinematic and synmetamorphic that is consistent with the characteristics of mesozonal orogenic gold deposits; and one that is post-metamorphic, late-kinematic, and consistent with the characteristics of epizonal orogenic gold deposits. This is the only recognized occurrence of epizonal orogenic Au-Ag-Te mineralization in the Carolina Terrane in North Carolina.

Both phases of deformation and mineralization are probably associated with the later stages of the Cherokee Orogeny (**Hibbard *et al.*, 2012**). 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.

It is unlikely that the Carter and Reynolds-Star occurrences lie along a single, narrow fault structure 2-4-kilometers-long, and more likely that they occur along *en echelon* fault segments. Exploration in the modern era suggests that a large tonnage, bulk-minable gold mining target along this fault zone is unlikely, although subeconomic concentrations of narrow auriferous veins occur over zones up to 30-meters-wide around the main gold lodes at both the Carter Mine (**Powers, 1989**) and Star-Reynolds Mine (**Phifer, 2004**).

However, the extraordinary bonanza grades of mesothermal Au-Ag and localized epizonal Au-Ag telluride mineralization over short strike intervals at the Carter and Star mines suggest a strong potential to develop additional near-surface and deep underground targets that are potentially highly economic. Evaluation of the potential for this kind of target cannot rely on broadly spaced geochemical sampling, geophysical surveys, and a few scattered drill holes. Detailed geologic mapping with intensive structural analysis, closely spaced geochemical sampling, and focused trenching along the strike of the fault zone are required.

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Figure 1. Location of the Star-Reynolds and Carter gold mines in the Carolina Terrane, central North Carolina.

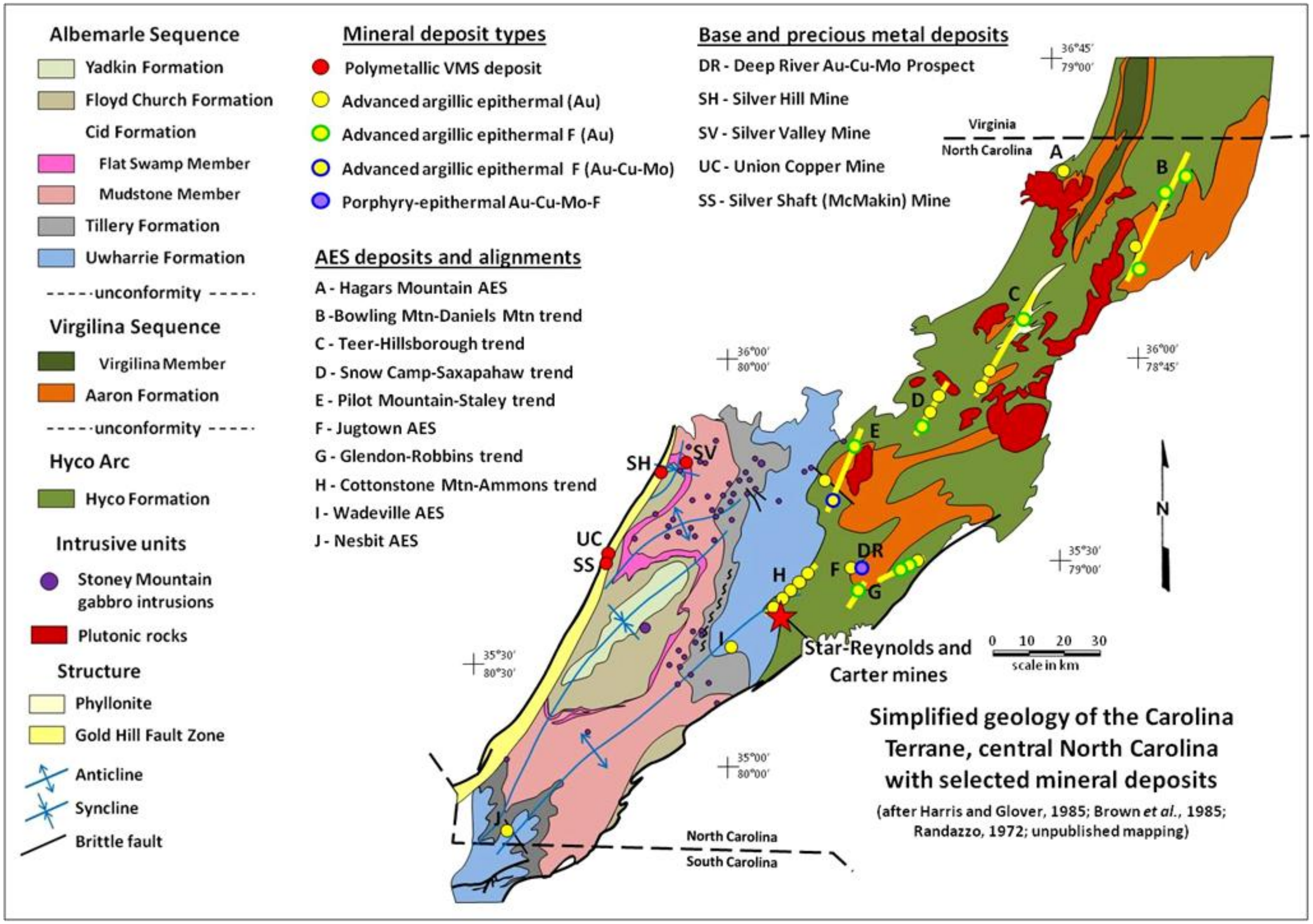

Figure 2. Location and regional geologic setting of the Star-Reynolds and Carter gold mines, Montgomery County, North Carolina.

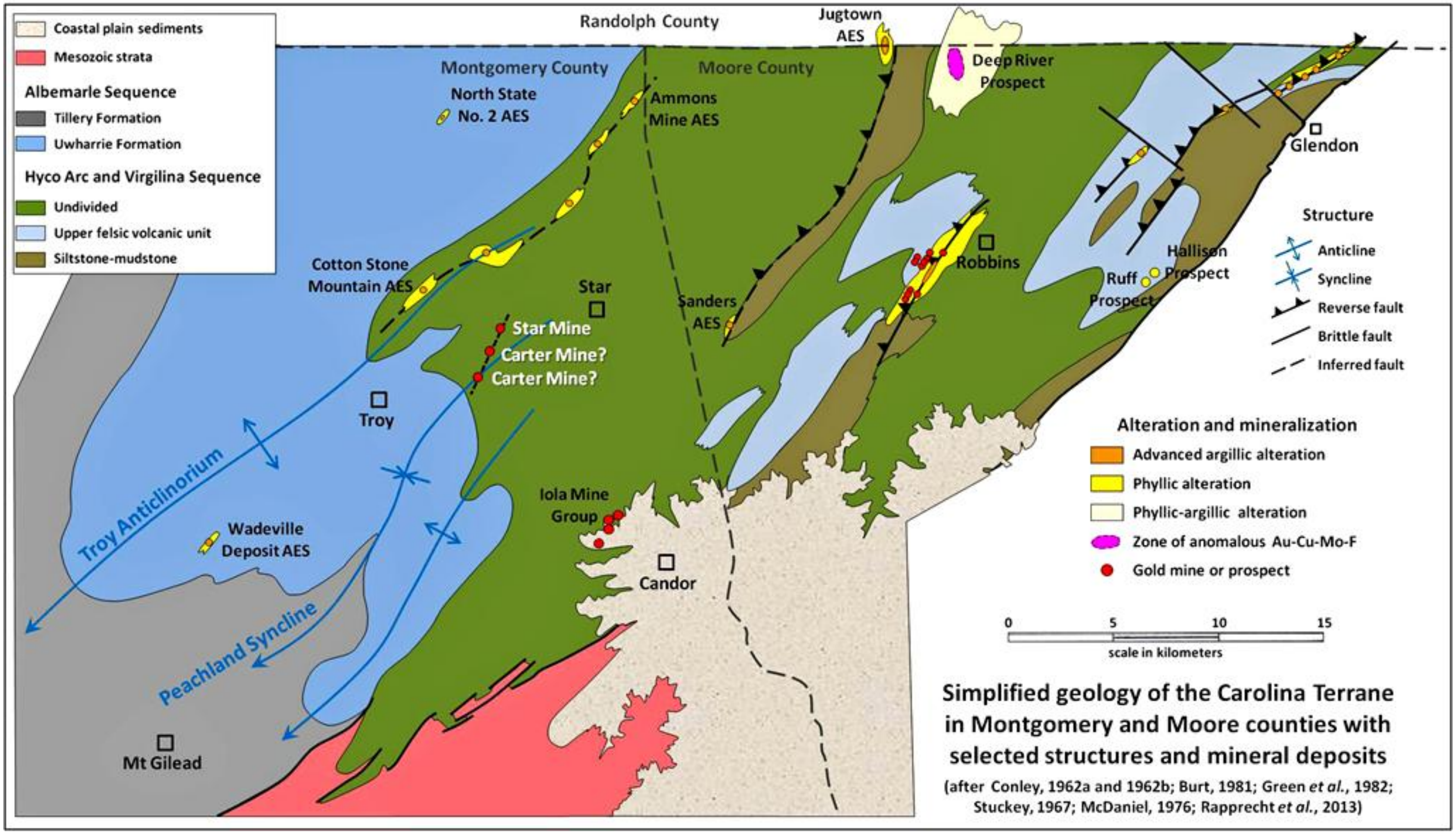

Figure 3. Local geologic setting of the Star and Carter gold mines.

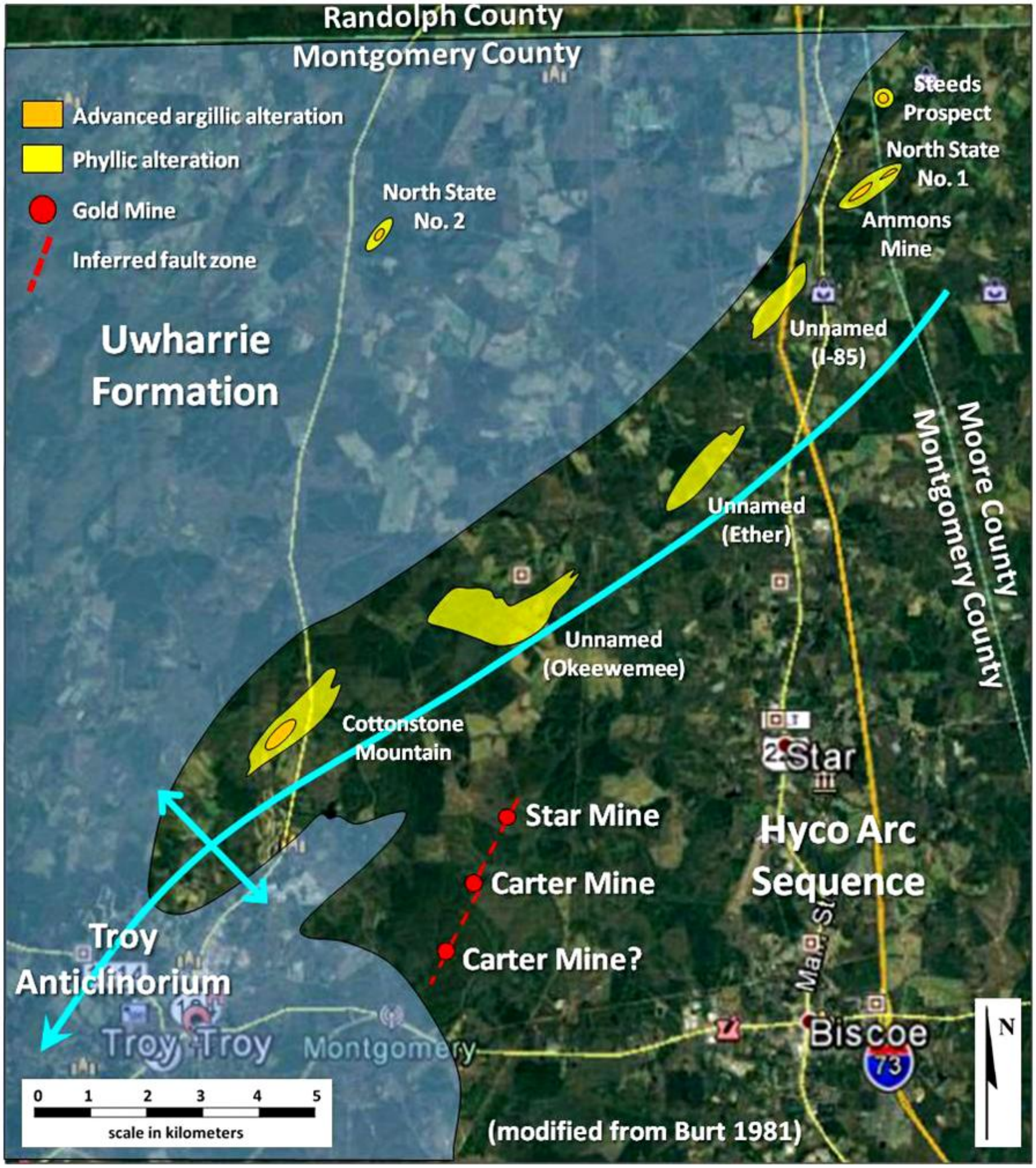

Figure 4. Location of the Reynolds-Star Mine and possible locations for the Carter Mine.

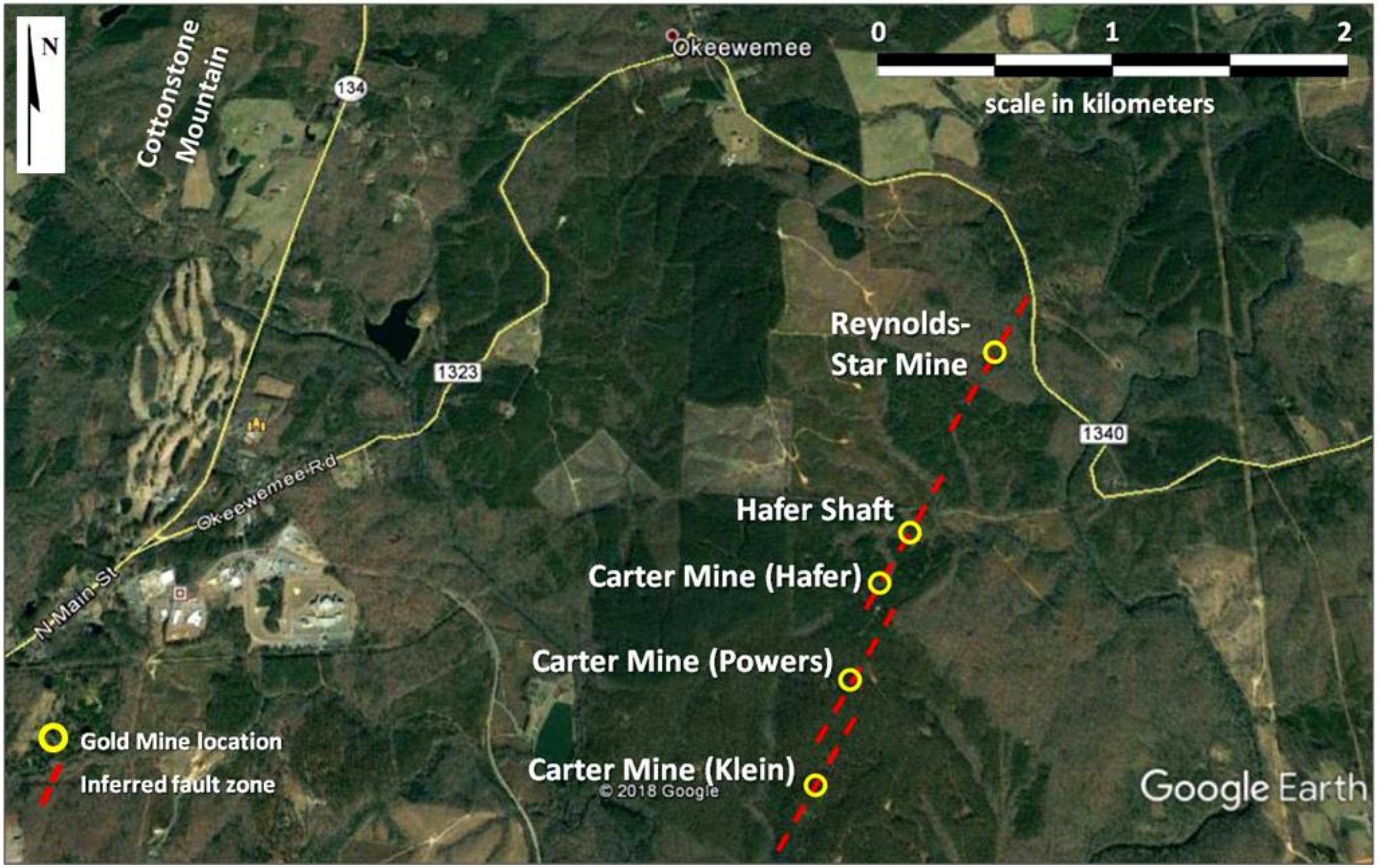

Figure 5. Ore deposit model for Star-Reynolds and Carter mines within the classification scheme of **Groves *et al.* (1998)**.