Chapter 4

Petrography

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A petrographic study was taken in order to help determine the sources of lithic artifacts found at archaeological sites on Fort Bragg. In the first phase of the study, known and suspected archaeological quarry sites in the central Piedmont of North Carolina were visited. From each quarry, hand specimens were collected and petrographic thin sections were examined in an attempt to establish a basis for distinguishing among the quarries. If material from each quarry was sufficiently distinctive, then quarry sources could potentially be matched with Fort Bragg lithic artifacts. Seventy-one samples from 12 quarry zones were examined (Table 4.1). Thirty-one of these samples are from five quarry zones in the Uwharrie Mountains region; 20 of these were collected and described previously by Daniel and Butler (1996). Forty specimens were collected from seven additional quarry zones in Chatham, Durham, Person, Orange, and Cumberland Counties.

All quarries are within the Carolina Terrane, except the Cumberland County quarry, which occurs in younger sedimentary material derived primarily from Carolina Terrane outcrops. Rocks include both metavolcanic and metasedimentary types. Compositionally, most metavolcanic rocks are dacitic and include flows, tuffs, breccias, and porphyries. Metasedimentary rocks are metamudstone and fine metasandstone.

The Uwharrie quarries are divided into five zones: Eastern, Western, Southern, Asheboro, and Southeastern. The divisions are based primarily on macroscopic petrography and follow the results of Daniel and Butler (1996); the Uwharries Southeastern zone was added in this study. Each of the Uwharrie quarry zones represents three to six individual quarries in relatively close proximity. Rock specimens are all various felsic metavolcanic rocks, but zones may be distinguished based upon mineralogy and texture. These quarries sample the Tillery, Cid and Uwharrie Formations (Stromquist and Sundelius 1969).

The remaining quarries include three from Chatham County (Chatham Pittsboro, Chatham Silk Hope, and Chatham Siler City) and one each from Orange, Person, Durham, and Cumberland Counties. Rocks from the Chatham Pittsboro, Durham, and Person quarries are dominantly fine-grained metasedimentary rocks. The Chatham Silk Hope and Orange County quarries are metaigneous. The Cumberland County quarry is from a deposit of alluvial cobbles, and the Chatham Siler City quarry is a mixture of metasedimentary and metavolcanic types.

In the second phase of the study, thin sections were prepared from nine Late Archaic Savannah River points collected on Fort Bragg (Table 4.2). These artifact thin sections were examined for the purpose of comparison with the quarry samples. All nine artifacts appear to have been fashioned from rocks belonging to the Carolina Terrane. Two are interpreted as metasedimentary and the remaining seven are metaigneous rocks.

Geological Setting

All quarry sites except Cumberland County occur in outcrop. Geologically, these outcrops belong to the Carolina Slate Belt, which is part of the Carolina Terrane. The Carolina Terrane is the largest of several suprastructural fault-bounded crustal blocks that had a common volcanic-arc origin and may be grouped as the Carolina Zone (Hibbard et al. 2002). In North Carolina, two additional terranes within the Carolina Zone are the Spring Hope Terrane and the Roanoke Rapids Terrane. These lie to the east of the study area and were not sampled, but they contain rocks similar to those in the Carolina Terrane and therefore may also have been a source of lithic material. Traditionally, these eastern terranes have been referred to as the Eastern Slate Belt. Rocks in all terranes of the Carolina Zone are thought to have formed in association with a volcanic arc between 670 and 450 million years ago – during the Late Proterozoic and Early Paleozoic (Butler and Secor 1991; Hibbard et al. 2002).

Within the Carolina Terrane, three stratigraphic sequences are the Albemarle, Virgilina, and Cary sequences. In this study, the five Uwharries quarries lie within the Albemarle sequence, while the Person, Durham, Orange, and Chatham County quarries are within the Virgilina sequence (Hibbard et al. 2002). Uwharrie quarry samples are from the Tillery, Cid, and Uwharrie Formations (Stromquist and Sundelius 1969). Some samples from the Virgilina sequence quarries may be from the Hyco or Aaron Formations (Harris and Glover 1988), but most are from regions that lack detailed mapping and for which a stratigraphic sequence has not been firmly established (Green et al. 1982).

The Cumberland County quarry actually consists of cobbles and boulders that have been transported from their outcrop regions and deposited as alluvial material, perhaps associated with the Cape Fear River. Not surprisingly, this quarry consists of specimens that do not seem to have a common origin. Although the river mainly drains the Carolina Terrane region, and most of the samples clearly come from the Carolina Terrane, one of them is from a much younger (Late Paleozoic) body of granite and has not been metamorphosed (FBL039).

Petrographic Criteria for Characterizing Specimens

With a sole exception, all specimens examined in this study, including the artifacts, are characterized by a combination of primary and secondary minerals and features. Primary minerals and features are those crystallized or acquired during the initial formation of the rock; secondary ones form as a result of subsequent alteration, deformation, or metamorphism. Samples from most of the quarry sites may be distinguished on the basis of their specific combination of primary and secondary minerals and primary and secondary features.

Primary Igneous Minerals and Features

Rocks examined are either metaigneous or metasedimentary. The metaigneous rocks originated as pyroclastic volcanic deposits, or less commonly, lava flows or shallow subvolcanic plutons. Primary igneous minerals are those that crystallized in a magma chamber prior to eruption or complete solidification. These minerals are generally larger than minerals forming later, and are called phenocrysts. The mineral type, shape, size, and relative abundance of phenocrysts are important primary criteria for characterizing these specimens. Common

Table 4.1. Rock Samples Examined, with Selected Normative Values and Classification.

Quarry Zone:	Normative Values				IUGS Field/	IUGS	
Sample	An%	Q/QAP	A/QAP	P/QAP	Petrographic Name	Normative Name	TAS Name
Uwharries Eastern:							
FBL001	0.0	26.5	21.8	51.7	dacite	dacite	rhyolite
FBL002	0.0	27.2	21.1	51.7	dacite	dacite	rhyolite
FBL003	4.5	30.3	24.0	45.7	dacite	dacite/rhyodacite	rhyolite
FBL004	0.0	25.8	15.4	58.8	dacite	dacite	rhyolite
FBL005	0.0	29.3	18.3	52.4	dacite	dacite	rhyolite
FBL006	0.0	28.1	14.3	57.6	dacite	dacite	rhyolite
FBL007	0.0	36.2	25.0	38.8	dacite	rhyodacite	rhyolite
Uwharries Western:							
FBL008	0.0	36.2	16.8	47.1	andesite	dacite	rhyolite
FBL009	0.0	34.8	20.7	44.5	andesite	dacite	rhyolite
FBL010	0.0	36.1	14.0	50.0	andesite	dacite	rhyolite
FBL011	1.5	29.3	18.4	52.2	andesite	dacite	rhyolite
FBL012	0.0	24.5	17.0	58.5	andesite/latite	dacite	rhyolite
FBL013	0.0	31.6	9.9	58.6	andesite	dacite	rhyolite
FBL014	9.5	23.1	20.0	56.9	andesite/latite	dacite	rhyolite
Uwharries Southern:							
FBL015	0.0	29.2	17.2	53.6	felsite	dacite	rhyolite
FBL016	0.0	26.2	24.3	49.5	felsite	dacite	rhyolite
FBL017	0.0	29.7	19.5	50.8	felsite	dacite	rhyolite
FBL018	0.0	29.4	19.9	50.7	felsite	dacite	rhyolite
FBL019	0.0	32.3	15.0	52.6	felsite	dacite	rhyolite
Uwharries Asheboro:							
FBL020	23.4	41.3	15.9	42.7	tuff	dacite	rhyolite
FBL021	2.5	31.2	17.4	51.4	dacite/andesite	dacite	rhyolite
FBL022	15.2	38.0	16.4	45.6	dacite/andesite	dacite	rhyolite
FBL023	12.0	42.7	8.3	48.9	dacite	dacite	rhyolite
FBL024	7.0	36.3	4.6	59.1	tuff	dacite	rhyolite
FBL055	0.0	29.9	11.6	58.5	dacite	dacite	rhyolite
Uwharries Southeastern:							
FBL025	0.4	33.2	26.8	40.0	dacite	rhyodacite	rhyolite
FBL026	0.0	30.0	23.8	46.2	dacite	dacite	rhyolite
FBL051	1.9	40.6	21.0	38.4	dacite	rhyodacite	-
FBL052	0.0	62.5	16.6	20.9	dacite	-	-
FBL053	2.5	37.5	21.5	41.0	dacite	dacite	rhyolite
FBL054	4.1	59.6	23.5	16.9	dacite	rhyodacite	-
Chatham Pittsboro:							
FBL027	11.3	47.1	28.3	24.6	mudstone	rhyodacite	-
FBL028	39.4	35.2	56.4	8.4	mudstone	alkali feldspar rhyolite	rhyolite
FBL029	14.0	43.1	29.4	27.5	siltstone	rhyodacite	rhyolite
FBL030	10.0	31.8	9.2	59.0	fine sandstone	dacite	rhyolite
FBL056	27.2	54.0	40.5	5.4	mudstone	alkali feldspar rhyolite	-
FBL057	0.0	25.2	22.6	52.2	mudstone	dacite	rhyolite
Chatham Silk Hope:							
FBL031	0.0	29.2	27.2	43.5	dacite/rhyodacite	rhyodacite	rhyolite
FBL032	0.0	24.3	21.6	54.1	lithic tuff	dacite	rhyolite
FBL033	0.0	25.9	26.5	47.5	dacite	rhyodacite	rhyolite
FBL034	0.0	27.6	25.0	47.5	lithic tuff	dacite/rhyodacite	rhyolite
FBL058	0.0	28.1	26.3	45.7	lithic tuff	rhyodacite	rhyolite
FBL059	5.1	27.0	34.9	38.1	lithic tuff	rhyodacite	rhyolite

Table 4.1. Rock Samples Examined, with Selected Normative Values and Classification (continued).

Quarry Zone: Sample	Normative Values An%	Q/QAP	A/QAP	P/QAP	IUGS Field/ Petrographic Name	IUGS Normative Name	TAS Name
Orange County:							
FBL060	0.0	28.6	21.5	49.9	dacite	dacite	rhyolite
FBL061	0.0	26.3	21.6	52.1	dacite	dacite	rhyolite
FBL062	0.0	27.3	21.7	50.9	dacite	dacite	rhyolite
FBL063	0.0	30.8	22.4	46.8	dacite	dacite	rhyolite
FBL064	5.7	32.4	24.6	43.0	dacite	rhyodacite	rhyolite
FBL065	0.0	25.4	22.8	51.8	dacite	dacite	rhyolite
Durham County:							
FBL047	0.0	28.3	7.5	64.1	dacite	dacite	rhyolite
FBL048	0.0	9.1	0.3	90.6	sandstone	andesite/basalt	trachyte
FBL049	0.0	18.0	8.0	73.9	sandstone	andesite/basalt	rhyolite
FBL050	0.0	18.2	4.8	77.0	tuff	andesite/basalt	rhyolite
FBL066	2.5	19.0	3.5	77.5	dacite	andesite/basalt	rhyolite
FBL067	14.8	11.2	8.8	80.0	sandstone	andesite/basalt	trachydacite
Person County:							
FBL043	0.4	3.0	6.9	90.1	mudstone?	andesite/basalt	trachyte
FBL044	0.0	30.6	3.6	65.8	tuff	dacite	rhyolite
FBL045	3.2	17.2	7.2	75.5	mudstone	andesite/basalt	rhyolite
FBL046	2.4	42.2	6.9	50.9	sandstone	dacite	rhyolite
FBL068	0.0	34.8	2.0	63.2	siltstone	dacite	rhyolite
FBL069	0.0	23.4	17.6	59.0	siltstone	dacite	rhyolite
Chatham Siler City:							
FBL035	22.7	24.8	23.8	51.4	mud/siltstone	dacite	dacite
FBL036	0.0	12.9	21.7	65.5	dacite	andesite/basalt	rhyolite
FBL037	62.8	29.9	31.7	38.4	mudstone	rhyodacite	dacite
FBL038	13.3	0.0	24.0	76.0	sandstone	andesite/basalt	trachyandesite
Cumberland County:							
FBL039	0.6	31.6	28.5	39.9	aplite	rhyodacite	rhyolite
FBL040	32.8	0.0	5.1	94.9	basalt	andesite/basalt	basaltic trachyandesite
FBL041	13.9	2.3	11.1	86.6	diorite	andesite/basalt	basaltic trachyandesite
FBL042	45.2	0.0	13.0	87.0	tuff?	andesite/basalt	trachybasalt
FBL070	60.3	0.0	3.4	96.6	greenstone	andesite/basalt	basalt
FBL071	59.9	0.0	9.6	90.4	metagabbro	andesite/basalt	basalt

phenocryst mineral types are plagioclase feldspar and quartz; alkali feldspar phenocrysts are extremely rare in this study and throughout the Carolina Zone. In a few specimens, there exists indirect evidence that phenocrysts of amphibole or pyroxene were formerly present; they have been replaced by secondary minerals.

Other primary igneous features include flow banding, spherulites, glass shards, amygdules, and fragmental (pyroclastic) texture (McBirney 1993; Vernon 2004). Flow banding is suggested by parallel alignment of plagioclase grains or other elongate features, or by layer-variable concentrations of tiny mineral grains, devitrification features, or fluid inclusions in extremely fine-grained (aphyric or glassy) rocks. Spherulites are round (spherical) features in some very fine-grained felsic volcanic rocks. They consist of radially oriented needle-shaped microcrystals of feldspar and quartz that nucleated from a common point at the center. They are thought to form soon after solidification of glassy rocks, and therefore represent a mechanism of devitrification. Glass shards are thin V- or Y-shaped fragments of glass, believed to form as a

Table 4.2. Fort Bragg Artifacts Examined, with Selected Normative Values and Classification.

Sample	Site	Normative Values An%	Q/QAP	A/QAP	P/QAP	IUGS Field/ Petrographic Name	IUGS Normative Name	TAS Name
FBL072	31Hk100	0.0	30.6	11.2	58.2	dacite	dacite	rhyolite
FBL073	31Hk148	0.0	25.8	14.9	59.3	dacite	dacite	rhyolite
FBL074	31Hk173	0.0	24.2	22.1	53.7	dacite	dacite	rhyolite
FBL075	31Hk182	23.3	16.9	11.1	72.1	andesite	andesite/basalt	dacite
FBL076	31Hk224	0.0	27.3	13.0	59.8	tuff/siltstone	dacite	rhyolite
FBL077	31Hk737	0.0	31.9	11.2	56.9	siltstone	dacite	rhyolite
FBL078	31Hk999	3.2	30.5	14.3	55.2	dacite	dacite	rhyolite
FBL079	31Hk1408	6.6	22.9	26.0	51.1	dacite	dacite	rhyolite
FBL080	Flat Creek	0.0	28.2	16.9	54.9	dacite	dacite	rhyolite

result of rapid vesiculation of rising magma immediately prior to eruption, followed by fragmentation of the porous rock (pumice). The shards then represent the solidified glass walls that separated adjacent gas bubbles. Amygdules represent vesicles (gas bubbles) in a volcanic rock that are later filled in by secondary minerals. This typically occurs soon after cooling of a volcanic rock, and so is included as a primary feature.

Pyroclastic material (tephra) is categorized according to its size, into ash (< 2 mm), lapilli (2-64 mm) and blocks and bombs (> 64 mm). Many felsic pyroclastic rocks consist largely of pumice lapilli. Where tephra accumulates on the surface following a volcanic eruption, it may be consolidated by compaction and welding due to volcanic heat and pressure from the overlying material, or by cementation. A volcanic rock formed by such processes is called tuff (dominantly ash), lapilli tuff (ash and lapilli), or, if it includes larger fragments, tuff breccia or agglomerate. Loose pyroclastic material may be eroded, transported, and redeposited by sedimentary processes, as in tuffaceous sandstone.

Primary Sedimentary Features

Primary sedimentary features include clastic texture, where clasts and corresponding rock names may be classified according to size and composition, as in feldspathic sandstone or quartz siltstone. Deposition from water is indicated by parallel bedding planes or laminae (essentially very thin and cyclic beds). More specialized sedimentary structures may be indicative of water depth, current velocity and direction, and/or stratigraphic younging direction. Such features include graded bedding, ripple marks, and cross bedding. In a couple of specimens, small ovoid features may be trace fossils, possibly fecal pellets.

Metamorphic Minerals

Rocks originally formed in one environment and later held in a different environment tend to change in an attempt to seek equilibrium with the new conditions. Volcanic rocks initially equilibrate at very high temperatures (magmatic, 800-1100°C) and low pressures (surface or near-surface). Sedimentary rocks form in a low-temperature and low-pressure environment at the surface of the earth. Rocks formed in the volcanic arc(s) of the Carolina Terrane during the late Proterozoic and early Paleozoic were later buried under many kilometers of rock during tectonic plate collisions in the middle and late Paleozoic. Under these new conditions of pressure and temperature some primary minerals became chemically unstable and reacted to produce new stable minerals. To the geologist, the particular minerals produced in this manner indicate the general conditions of the metamorphism, or metamorphic grade. Geologists have grouped metamorphic rocks, based upon the types of metamorphic minerals they contain, into several metamorphic facies, each of which denotes a general range of pressure and temperature conditions. Rocks of the Carolina Terrane contain minerals and other features indicative of the greenschist facies, corresponding roughly to 4-10 kbar and 300-500°C. This is a relatively low to moderate grade of metamorphism, and therefore many (perhaps most) of the primary igneous or sedimentary characteristics are preserved as relict features.

Metamorphic minerals in this study include all of the most common greenschist facies minerals, including white mica (muscovite), chlorite, epidote/clinozoisite, albite (Na-plagioclase), actinolite, titanite (also known as sphene), pyrite, and calcite. Less common greenschist facies metamorphic minerals identified include biotite (both green and brown varieties in different specimens), stilpnomelane, (Mn/Ca-rich) garnet, and piedmontite. Because the growth of metamorphic minerals is also a function of the rock's overall composition, the absence of a particular mineral does not necessarily imply a different facies or conditions. For example, actinolite is typical of metamorphosed basalt in the greenschist facies, but is not found in metamorphosed mudstone. However, the presence of biotite in the Carolina Terrane is limited to the southern and western half of the terrane (approximately the Uwharries), and indicates that metamorphic temperatures (and possibly pressures) there were somewhat higher than in the northern and eastern portions (Butler 1991; North Carolina Geological Survey 1985).

Other Secondary Features

Locally, pervasive alteration has affected phenocryst minerals. This process may be a metamorphic event, or it may have begun during or shortly after the igneous rock cooled (deuteric alteration) and then been accentuated during metamorphism. One feature that may have formed in this manner is the progressive replacement of plagioclase by clinozoisite, a process known as saussuritization. Because clinozoisite is a Ca-Al-silicate mineral, this implies that the original plagioclase contained enough Ca to produce the feature. Trachyte and rhyolite typically have low-Ca plagioclase, whereas dacite, andesite, and basalt have plagioclase with increasingly higher Ca content. Sericitization is an analogous process whereby K- and Na-rich feldspar is replaced by fine-grained mica. These processes imply the presence of warm aqueous fluid. One possible mechanism for chemical alteration is by interaction of newly formed volcanic rocks with magmatically warmed seawater (e.g., Butler and Ragland 1969).

Small clusters or clots of associated metamorphic minerals occur in some of the metavolcanic rocks. Because the specific mineral types tend to occur in roughly constant proportions, it appears that they have replaced a primary mineral or minerals. Some clusters have a rounded or ovoid shape and are interpreted as metamorphosed amygdules, that is, the secondary minerals that filled in a vesicle shortly after cooling of the volcanic rock were later converted to a greenschist-facies assemblage (cf. Fodor et al. 1981). In instances where a primary mineral such as a phenocryst is completely replaced, but its original shape and size are preserved, the new mineral is said to be a pseudomorph of the original mineral.

Veins of epidote, calcite, or quartz occur in a few samples. These features did not form from magma, but precipitated out of an H_2O- and CO_2-rich fluid that accompanied the greenschist facies metamorphism. Features indicative of tectonic stress are locally present but sparse. They include microfaults, where primary layers are offset, and also slaty cleavage, a rock fabric characterized by the parallel growth of tiny metamorphic minerals, usually sheet silicates such as white mica, biotite, or chlorite. The slaty cleavage defines a planar direction that is typically parallel to axial planes of large folds in the region, thus indicating the approximate direction of maximum tectonic stress during deformation.

Rock Names

Choosing a name for most rocks in the Carolina Terrane is no simple matter. If asked whether any particular rock sample from the region is igneous, sedimentary, or metamorphic, perhaps the most correct answer is simply "Yes!" Merely consider that many of these rocks consist of material that was originally erupted from a volcano, then perhaps reworked by sedimentary processes, and then subsequently metamorphosed. It is therefore no wonder that there is some confusion and disagreement surrounding the names of these rocks. In this study, three different classifications are applied and their results may be compared: IUGS based upon phenocrysts (and secondarily rock color), TAS based on bulk chemistry, and IUGS based upon normative minerals.

Igneous rock classification is generally based upon the widely accepted IUGS system (Streckeisen 1976, 1978; LeMaitre 1989). For felsic and intermediate rocks, the name is determined by the normalized percentages of quartz, alkali feldspar, and plagioclase (QAP), referring to a triangular QAP classification diagram (Figure 4.1).

The QAP classification procedure is straightforward for coarse-grained plutonic igneous rocks, in which the three minerals can be identified and their percentages determined. However, problems arise with volcanic and related fine-grained igneous rocks in which many (possibly all) of the minerals are too small for identification. In this case, the name must be based upon the minerals that can be identified, i.e., the phenocrysts. A secondary criterion is rock color: lighter colors are typically associated with felsic compositions, darker with mafic. Criteria for this IUGS "field name" are shown in Table 4.3.

Alternatively, where chemical analyses are available, names may be based on certain chemical characteristics. The most common chemical classification, called TAS, is based on a plot of total alkalis ($Na_2O + K_2O$) versus silica (SiO_2) (Figure 4.2). It is important to note that the TAS system combines the alkalis (Na and K) and thus removes the possibility of distinctions based upon type of feldspar, which is the basis for the IUGS QAP system. Furthermore, in the case of the Carolina Terrane, where metamorphism has affected all rocks and chemical alteration has affected at least some, the oxide values upon which TAS is based may not represent the original rock (and magma) composition.

Another classification option when a chemical analysis is available is to determine normative minerals, which are hypothetical mineral percentages calculated from the analysis. Then the normative Q, A, and P values may be plotted on the IUGS triangular diagram.

Pyroclastic rocks are named according to the grain size of the tephra, as described above. But the root name may be modified by a term describing the nature of the fragmental material (vitric for glassy, lithic for rock fragments, and crystal for phenocrysts). Another modifying term may be based on the rock composition, so, for example, one might have a dacitic crystal-lithic lapilli tuff.

In this study, the rocks have been metamorphosed. If the metamorphic changes in the rock obscure the properties of the parent rock, then the rock should be given a metamorphic rock

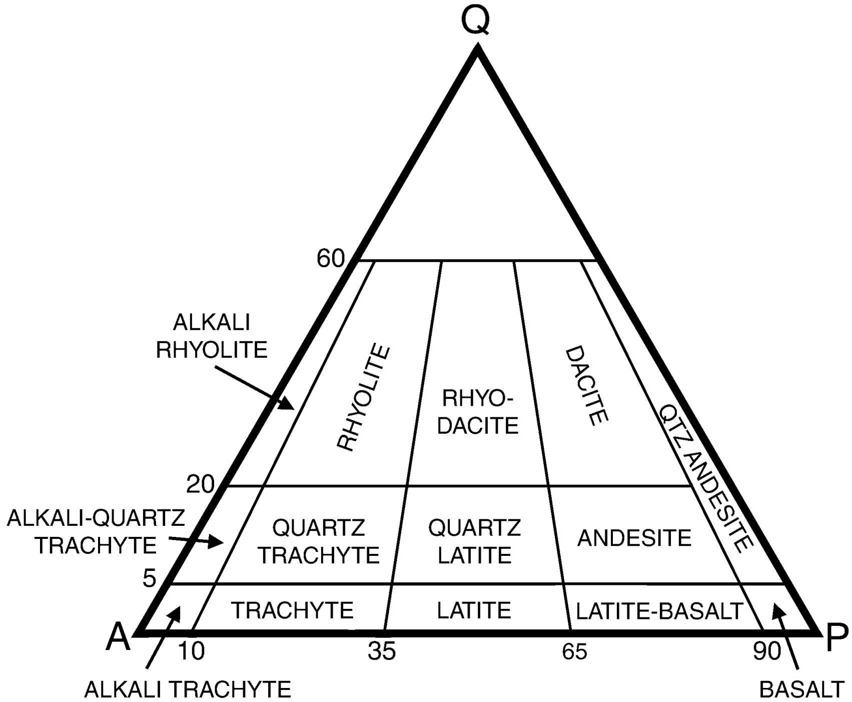

Figure 4.1. IUGS classification for volcanic igneous rocks (from Winter 2001).

name, such as slate or phyllite. However, where the relict primary features of a metamorphic rock dominate over those created during metamorphism, the common practice is to apply a name reflecting the parent rock, preceded by the prefix "meta." This is the case for nearly all rocks in the Carolina Terrane. Thus we have metarhyolite, metamudstone, and metatuff, or even dacitic crystal-lithic lapilli metatuff!

A final caveat in classifying the rocks in this study is that they may have been chemically altered, either shortly following eruption or deposition, or at the time of metamorphism. In this case, the rock name based on phenocrysts would be the most reliable indicator of the original rock type, while those based upon chemistry, either using TAS or norms, reflect the chemical alteration. Rock names determined for the specimens in this study, using these techniques, are given in Table 4.1.

Table 4.3. Practical Field Guide to Volcanic Rock Classification.[a]

Phenocryst Minerals	Typical Color	Possible Rock Types
Quartz only	brown, pink, red	rhyolite
Quartz and alkali feldspar	brown, pink, red	rhyolite, quartz trachyte
Alkali feldspar only	brown, black	trachyte
Quartz and plagioclase feldspar	gray	dacite
Plagioclase feldspar and alkali feldspar	brown	latite
Quartz, plagioclase feldspar, and alkali feldspar	red, brown, pink	rhyodacite or rhyolite
Plagioclase feldspar only	gray, purple, black	andesite or basalt

[a] From Cepeda (1994).

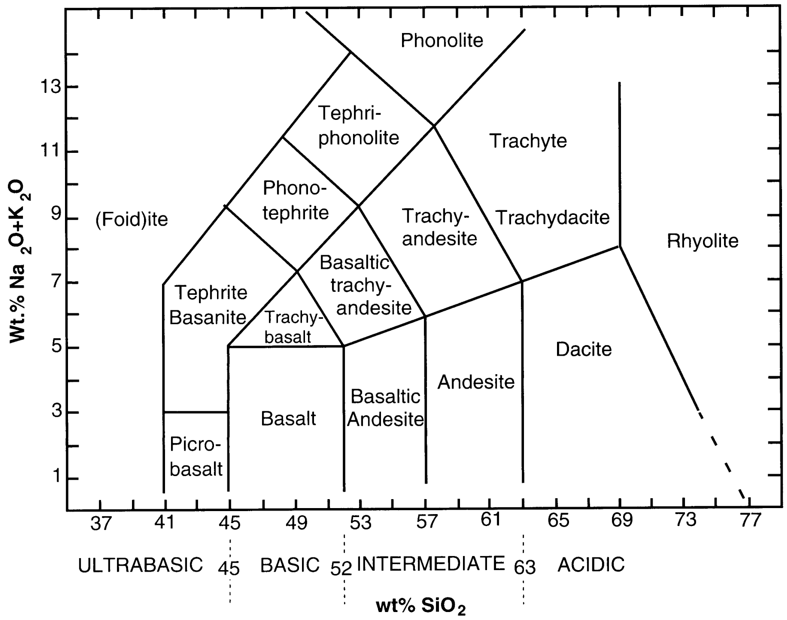

Figure 4.2. Total alkalis versus silica (TAS) classification of volcanic rocks (LeMaitre 1989).

Results

Of the twelve different quarry zones that were studied, ten are sufficiently distinctive that they hold some promise for sourcing. These ten quarry zones include five in the Uwharries region: Uwharries Eastern, Uwharries Western, Uwharries Southern, Uwharries Asheboro, and Uwharries Southeastern. Two quarries are located in Chatham County (Chatham Pittsboro and Chatham Silk Hope), and the remaining are from Person, Durham, and Orange Counties. Samples from Chatham Siler City and Cumberland County are extremely heterogeneous and these zones are therefore unlikely to be of much use in sourcing lithic artifacts. Four of the five Uwharries quarry zones were previously identified by Daniel and Butler (1996). A synopsis of the quarry zones and their distinguishing characteristics follows; descriptions of individual samples may be seen in Appendix C. Colors given refer to fresh rock material; all rocks examined weather to lighter colors, typically tan or light gray.

Table 4.4 summarizes the results. The samples from seven of the ten distinctive quarries are inferred to be primarily of volcanic origin, while those from the remaining three (Chatham Pittsboro, Person County, and Durham County) are thought to be primarily metasedimentary. Each of the seven metavolcanic quarry zones is texturally and mineralogically distinctive. Relict volcanic features include porphyritic texture, flow banding, amygdules, inferred glass shards, spherulites, and pyroclastic material. Metamorphic features include phyllosilicate cleavage. Relict minerals are quartz, plagioclase, and K-feldspar phenocrysts; metamorphic minerals include chlorite, biotite, epidote, calcite, actinolite, titanite, pyrite, garnet, stilpnomelane, and piedmontite. The three metasedimentary quarries preserve relict sedimentary features including laminations, ripples, and graded bedding. Possible cross-bedding and trace fossils are present. Individual samples from each of these metasedimentary sites may not be distinguishable, although the Chatham Pittsboro quarry is overall finer grained and the other two contain more obvious volcaniclastic material.

Table 4.4. Petrographic Features of Quarry Zones.

Quarry Zone	Map Unit (Formation)	Assemblage Type	Rock Types	Textures	Phenocrysts	Metamorphic Minerals
Uwharries Eastern	Tillery	metavolcanic rocks	dacite flows; crystal-lithic tuffs	quartz-epidote-chlorite clusters	plagioclase + quartz	green biotite; stilpnomelane
Uwharries Western	Cid	metavolcanic rocks	dacite; rhyodacite	spherulites; no flow banding	plagioclase; K-feldspar	green biotite; no stilpnomelane
Uwharries Southern	Tillery	metavolcanic rocks	dacite; felsite	spherulites; banding; cleavage	none	stilpnomelane
Uwharries Asheboro	Uwharrie and Tillery	metavolcanic rocks	dacite tuffs and flows	epidote-calcite-pyrite clusters; pumice lapilli	plagioclase; quartz	garnet; brown biotite; stilpnomelane
Uwharries Southeastern	Uwharrie	metavolcanic rocks	dacite flows and porphyries	spherulites; quartz amygdules; banding	quartz + plagioclase	actinolite; epidote; sphene
Chatham Silk Hope		metavolcanic rocks	dacitic lapilli; crystal-lithic tuff; breccia	volcanic rock fragments; glass shards; flow banding	plagioclase; K-feldspar	piedmontite
Orange County		metavolcanic rocks	dacite porphyry; crystal-lithic tuff	no banding; saussuritization	(coarse) quartz + plagioclase	calcite; low-T feldspar clots
Chatham Pittsboro		metasedimentary rocks	mudstone; siltstone; sandstone	bedding; laminae; graded beds; ripples; cross-beds		
Durham County		metasedimentary rocks	dacite tuff; tuffaceous sandstone	rock fragments; epidote veins; layering		
Person County		metasedimentary rocks	mudstone; siltstone; sandstone; tuff	bedding; graded beds; trace fossils(?); pumice(?); microfaults		
Chatham Siler City		heterogeneous	metasedimentary rocks; crystal-lithic tuff			
Cumberland County		heterogeneous	aplite; greenstone; (meta)gabbro; basalt; andesite/diorite; lapilli tuff			

Uwharries Eastern

Rocks of this zone, from Shingle Trap, Hattaway, and Sugarloaf Mountains, are mainly light to dark gray metadacite porphyry or metadacitic crystal-lithic tuff. All seven samples contain plagioclase and quartz phenocrysts (Figure 4.3). Samples from Shingle Trap and Hattaway Mountains are phenocryst-poor, having 2% or less. Samples from Sugarloaf Mountain are more crystal-rich, containing up to 7%. The maximum phenocryst dimension in all Uwharries Eastern samples is between 1.0 and 1.6 mm. This zone includes rocks interpreted as lava flows (e.g., FBL004) and others inferred to be of pyroclastic origin (e.g., FBL005, FBL006). A common textural feature in these rocks is small mineral clusters composed of quartz ± epidote ± chlorite. These may be amygdules, or filled-in vesicles, perhaps modified during metamorphism. Pumice lapilli, flow banding (Figure 4.4), and possible glass shards are locally present. These rocks are interpreted as dacitic crystal-lithic tuffs and dacitic flows within the Tillery Formation. Because they are light-colored rocks with plagioclase and quartz phenocrysts, in the field these rocks would be called dacite. Using normative minerals they are dacite and rhyodacite, and using the TAS chemical classification they are rhyolite. Metamorphic minerals in this group include common green biotite and stilpnomelane (Figure 4.5), and locally calcite. This group corresponds to the plagioclase-quartz phyric rocks of Daniel and Butler (1996).

Uwharries Western

Six samples are from the Wolf Den and Falls Dam area and one sample is from near Eldorado. These gray to black felsic volcanic rocks contain plagioclase phenocrysts and have no obvious flow banding (Figure 4.6). Because of the lack of quartz phenocrysts and their relatively dark color, in the field these rocks might be classified as meta-andesite and metalatite. However, based upon normative mineralogy they are dacite and based upon the TAS chemical classification they are rhyolite. Plagioclase phenocrysts have rounded corners and are locally grouped together as glomerocrysts (FBL008). There are sparse possible K-feldspar phenocrysts in at least one sample. Green biotite and pale green amphibole (actinolite) are present locally (FBL009). Spherulites are present in some samples. They are inferred to be pyroclastic in origin, and are likely ash-fall or ash-flow tuffs within the Cid Formation. These are the plagioclase-phyric rocks of Daniel and Butler (1996).

Uwharries Southern

The five samples in this category were collected from Morrow and Tater Top Mountains. These dark gray metavolcanic rocks are extremely fine grained and contain no obvious phenocrysts. Because of the lack of phenocrysts, the most appropriate field designation is felsite. However, names based on normative mineralogy and the TAS classification are dacite and rhyolite, respectively. Some samples have spherulites (Figure 4.7), and some are banded. In hand specimen, the felsic composition of these rocks may be inferred based upon their high hardness and good conchoidal fracture. These rocks may have originated as ash-flow tuffs, glassy flows, or possibly felsic domes within the Tillery Formation, although it should be noted that there continues to be uncertainty about the stratigraphic sequence within the Albemarle group and specifically the Morrow Mountain felsite (e.g., Hibbard et al. 2002). Most samples contain brown metamorphic biotite and exhibit a local biotite cleavage oblique to banding (FBL019). Metamorphic stilpnomelane, epidote, titanite, chlorite, and actinolite are also present in some samples. These are the aphyric rocks of Daniel and Butler (1996).

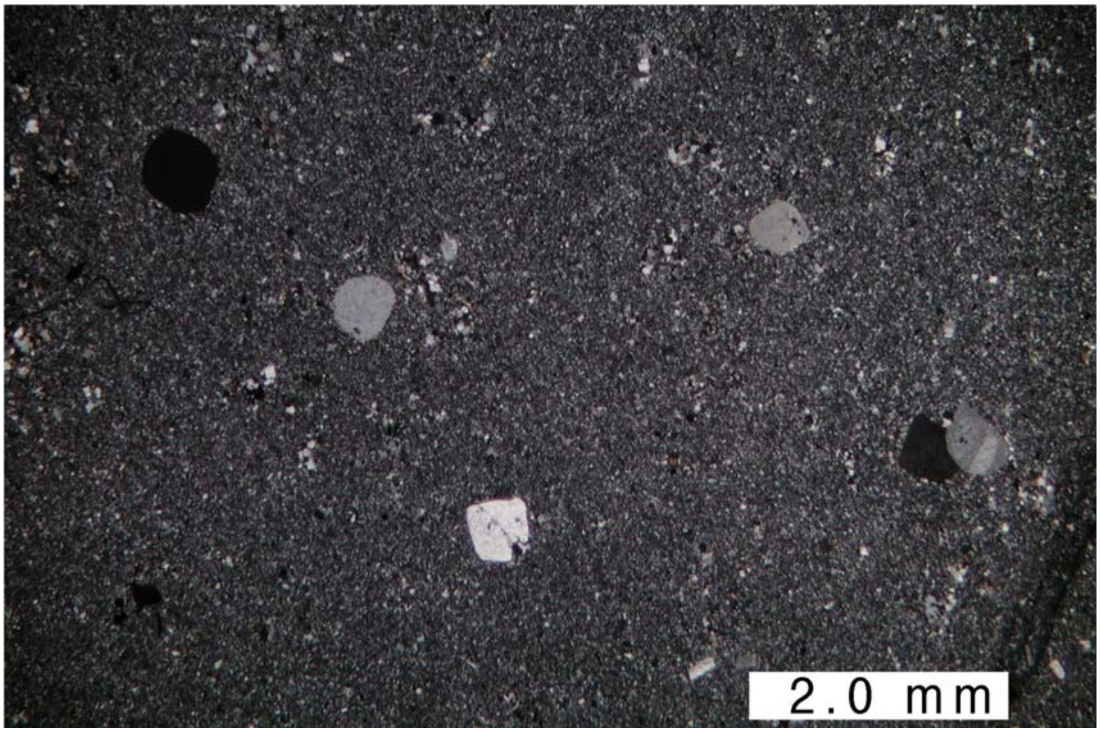

Figure 4.3. Typical Uwharries Eastern sample with quartz and plagioclase phenocrysts (FBL004; crossed polars).

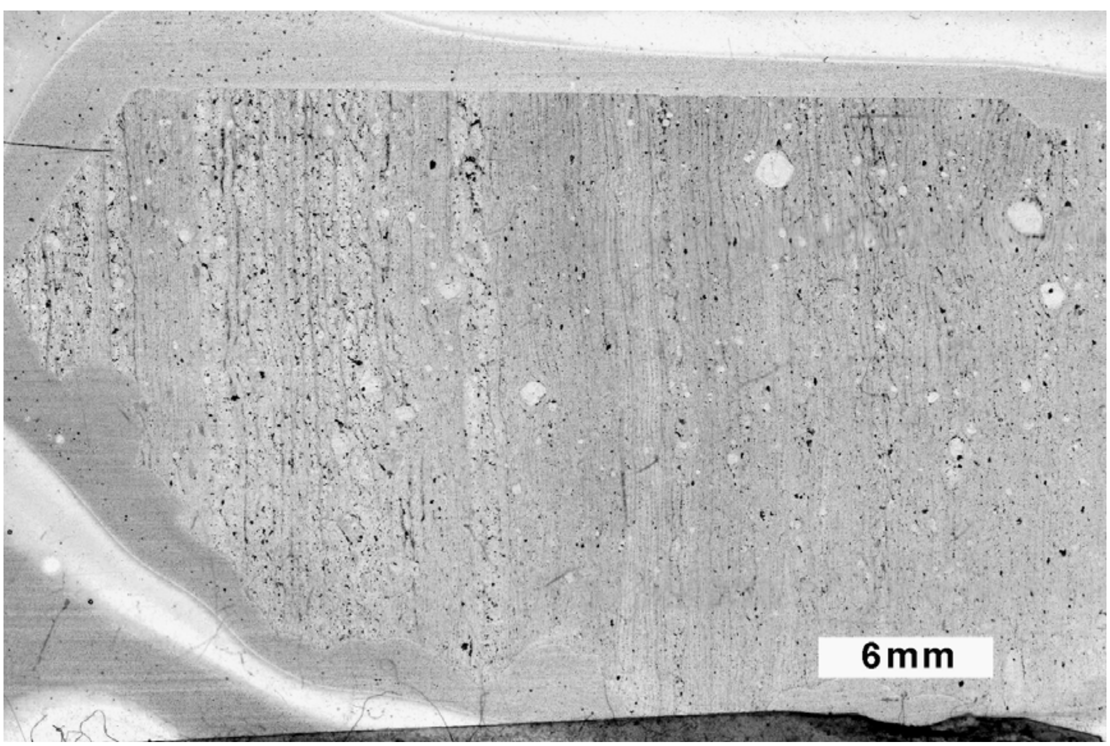

Figure 4.4. Strongly flow-banded dacite with quartz and plagioclase phenocrysts (FBL006; scanned thin section, plane-polarized light).

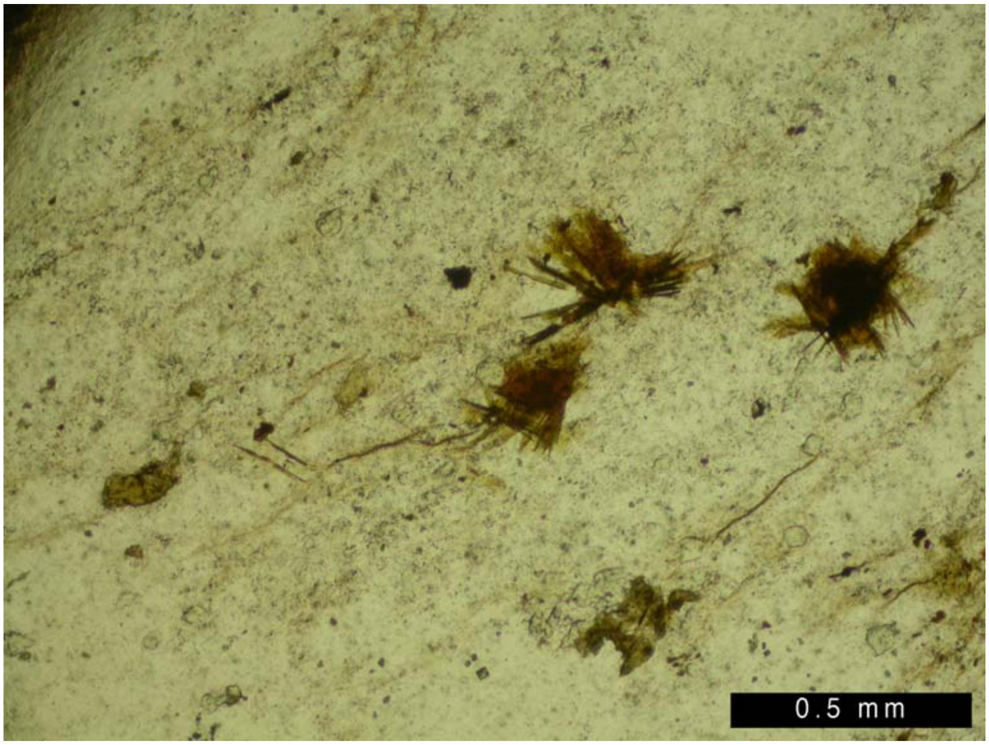

Figure 4.5. Metamorphic stilpnomelane (needle-like aggregates) in Uwharries Eastern sample (FBL005; plane-polarized light).

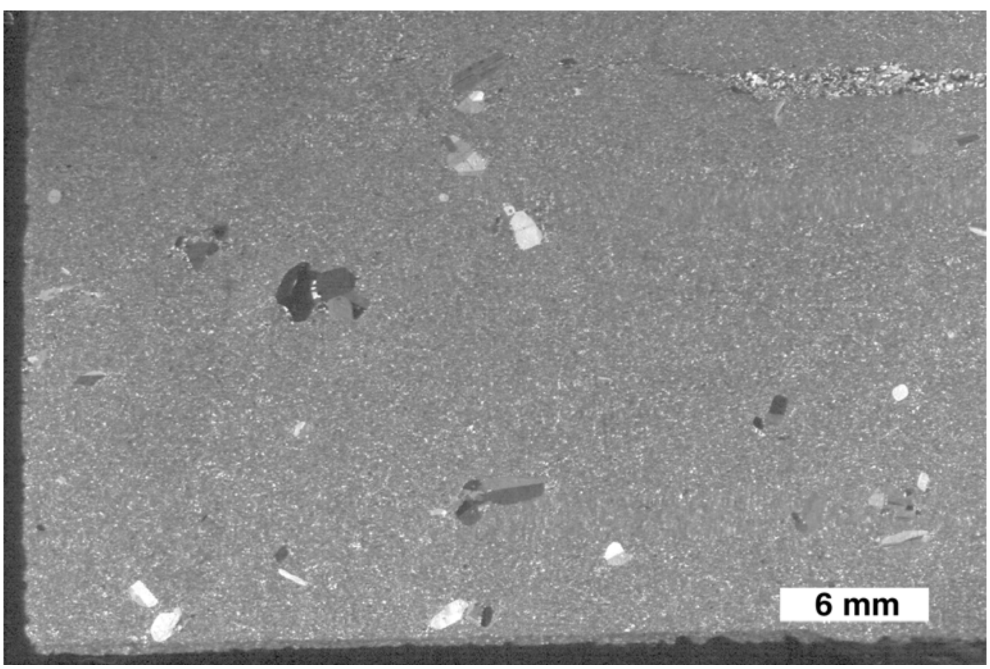

Figure 4.6. Uwharries Western sample with sparse plagioclase phenocrysts and fine groundmass (FBL010; scanned thin section, crossed polars).

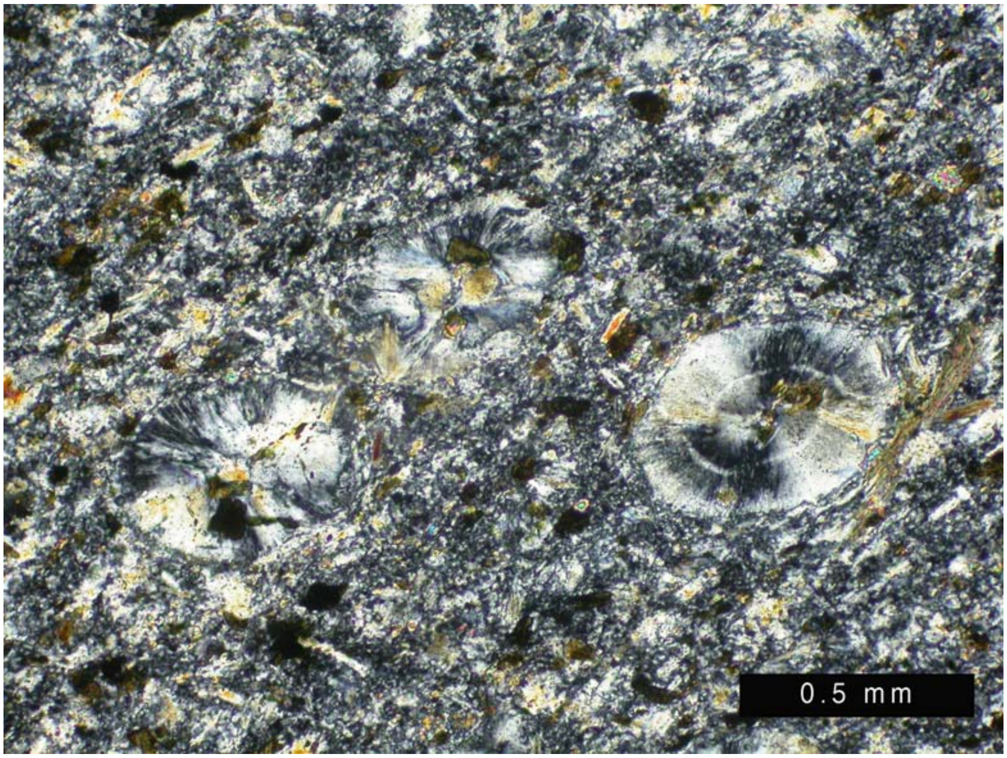

Figure 4.7. Uwharries Southern sample with spherulites (FBL017; crossed polars).

Uwharries Asheboro

This zone consists of five samples collected by Daniel and Butler from Dave's Mountain, Caraway Mountain, and other sites in the northern Uwharries near Asheboro, plus one sample collected for this study in Asheboro (FBL055). The zone is dominated by relatively coarse-grained, dark- to medium-gray pyroclastic rocks. They are mostly classified as metadacite tuffs. There are some fine-grained ash-lapilli tuffs but most are coarse-grained crystal-lithic tuff. Sample FBL023 is extremely crystal-rich (estimated 15% phenocrysts) with crystals ranging to at least 2.5 mm, the largest phenocrysts of any of the Uwharries zones examined. There is at least one possible flow rock (FBL022). Four of the six specimens contain phenocrysts of plagioclase and quartz, while the other two are aphyric. Clusters of epidote with calcite and pyrite occur and may be metamorphosed amygdules (Figure 4.8). Euhedral to subhedral garnet porphyroblasts are common in this zone (Figure 4.9), as is brown biotite. Calcite and stilpnomelane occur locally. These correspond to Daniel and Butler's (1996) northern Uwharries sites and are from the Uwharrie and Tillery Formations. Using normative minerals, these rocks are dacite; using the TAS classification they are rhyolite.

Uwharries Southeastern

This zone of newly collected samples includes two from Horse Trough Mountain and four from Lick Mountain, all from the Uwharrie Formation. Samples contain 1-3% phenocrysts of plagioclase and quartz ranging in size up to 1.6 mm, though the Lick Mountain specimens are

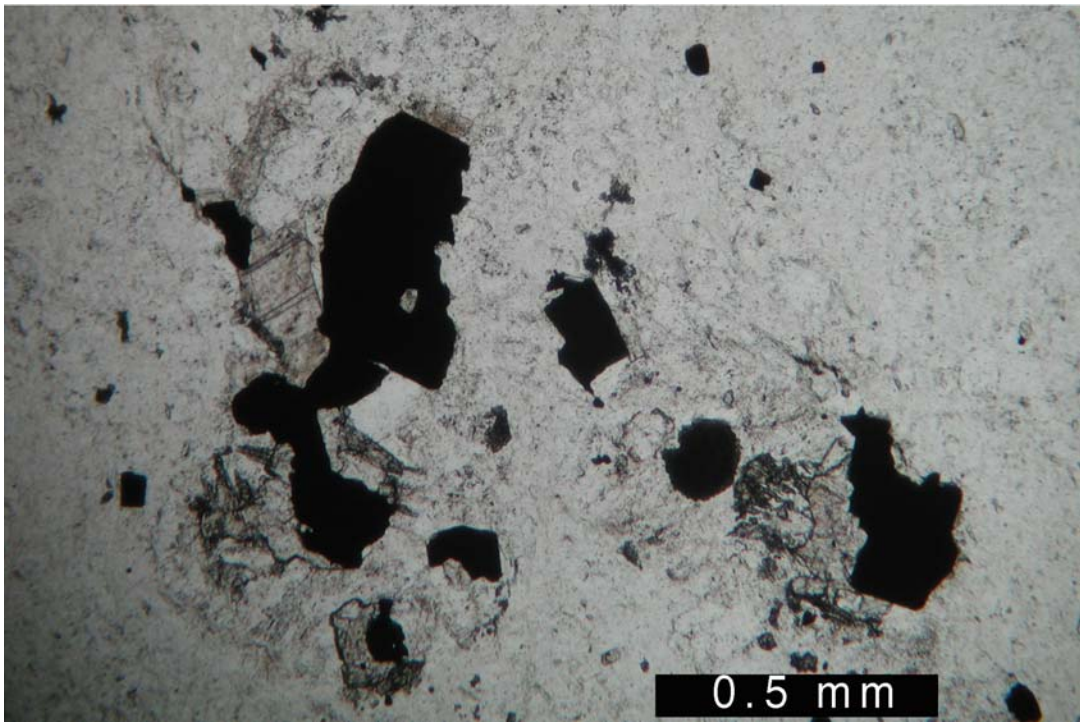

Figure 4.8. Uwharries Asheboro sample with mineral clusters of pyrite + calcite + epidote (FBL021; plane-polarized light).

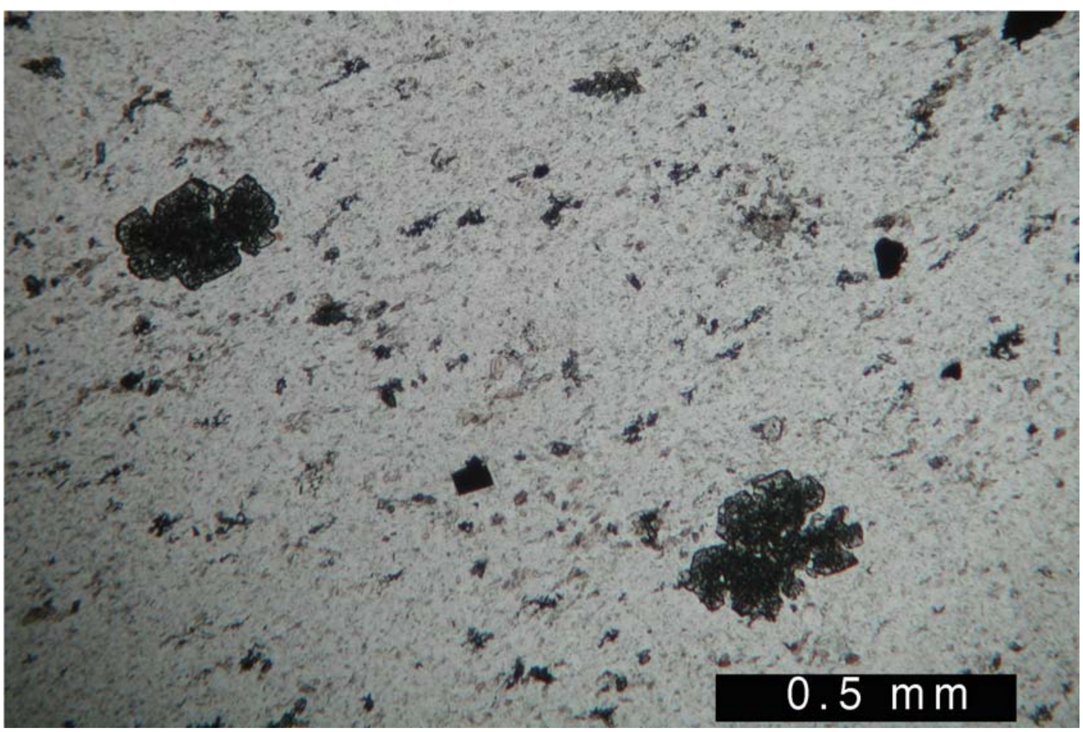

Figure 4.9. Garnet porphyroblasts in Uwharries Asheboro sample (FBL022; plane-polarized light).

more crystal-rich and slightly coarser than the Horse Trough specimens. In the Lick Mountain samples especially, the quartz phenocrysts show good β-quartz morphology, though some grains are partially resorbed (Figure 4.10). The presence of amygdules in the Horse Trough samples is indicated by ovoid polycrystalline aggregates of quartz ranging to at least 3 mm; these constitute 5-10% of the rock (Figure 4.11). Spherulites are also present in the Horse Trough samples. The specimens in this zone contain a number of metamorphic minerals, including pyrite, muscovite, epidote, titanite, chlorite, biotite, and notably actinolite. The field name is metadacite or metadacite porphyry. The normative QAP name is rhyodacite or dacite, although one sample has more than 60% normative quartz and is outside the range of igneous rocks. The TAS name is rhyolite for three of the samples; the other three have too much silica for an igneous rock and must therefore be silicified. This extra silica is at least in part present in the quartz amygdules.

Chatham Pittsboro

These six specimens are exclusively greenish-gray metasedimentary rocks, with metamudstone, metasiltstone, and less commonly very fine metasandstone. Samples contain abundant relict sedimentary features, including bedding, laminations, grading, and ripples (Figures 4.12-4.13). Grain size is generally too small to identify many of the minerals except in FBL030, a metasandstone. In this sample, clasts of quartz and plagioclase are present and are likely phenocrysts eroded from a felsic volcanic source material. The chemical analyses give some clues about the mineralogy. Metavolcanic rocks in this study, and generally metavolcanic rocks throughout the Carolina Terrane, contain less K_2O than Na_2O. In contrast, most of the Chatham Pittsboro samples, especially the finer-grained ones, have high K_2O, with more K_2O than Na_2O (Table 4.1). In fact, two of the samples have normative mineralogy that plots in the alkali feldspar rhyolite field in terms of QAP. The siltstone and mudstone represent sediment that had undergone weathering and transport for greater time and distance from the volcanic source, likely producing clay minerals such as kaolinite and illite. During metamorphism, clays would have been converted to K-mica (muscovite). It is worth noting that the coarser metasandstone contains less K_2O than Na_2O, and chemically is similar to many of the felsic volcanic rocks. The sodic plagioclase grains in this rock apparently did not have the opportunity to weather and thus were not converted to clay.

Chatham Silk Hope

These six samples include purple, dark gray, or black heterolithic volcanic breccia, tuff breccia, lapilli tuff, and crystal-lithic tuff. These unusual and especially distinctive rocks contain abundant intermediate to mafic pyroclastic fragments (Figure 4.14) as well as more abundant felsic ones. Though most identifiable lithic tephra in these samples are lapilli size, some are blocks (> 64 mm). Phenocrysts are plagioclase plus local K-feldspar. Amygdules of quartz + epidote are present as well. These samples preserve features that are generally not seen in metavolcanic rocks of the Carolina Terrane, owing to the length of geological time during which devitrification and alteration may have affected them. Some rock fragments are vitric (glassy) and contain glass shards (Figure 4.15) and flow bands. In addition to epidote, chlorite, titanite, and unidentified opaque minerals, metamorphic piedmontite is common in these samples and adds to the distinctiveness of this zone (Figure 4.16). Normative QAP rock names are rhyodacite and dacite; TAS names are rhyolite.

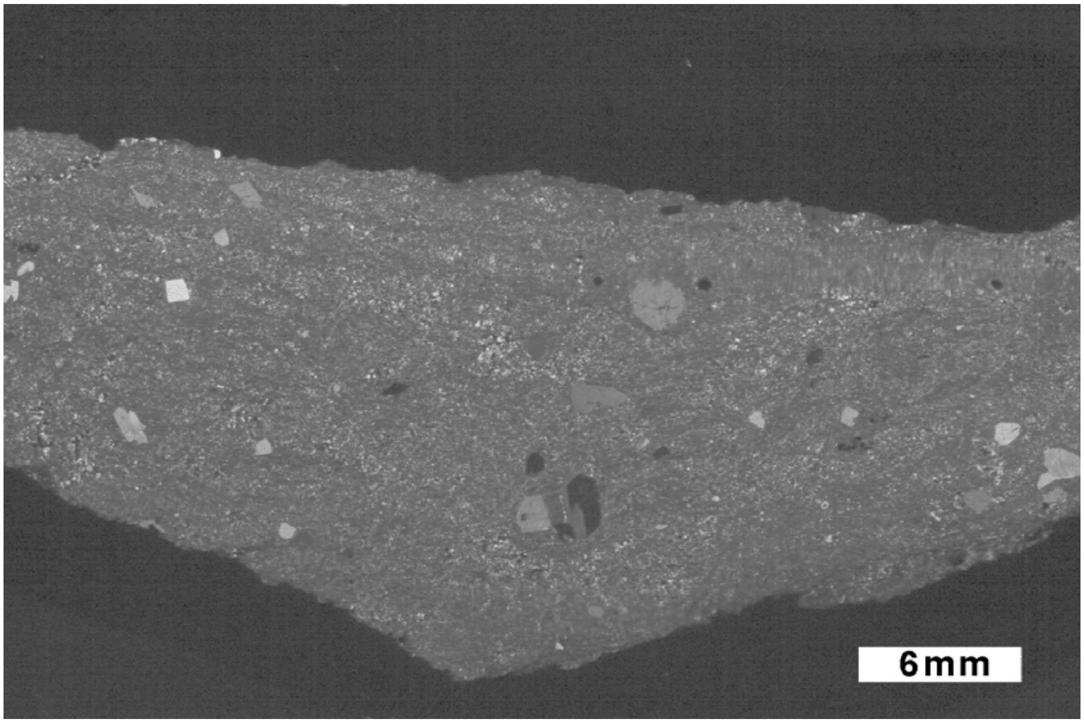

Figure 4.10. Uwharries Southeastern sample with quartz and plagioclase phenocrysts and weak banding (FBL052; scanned thin section, crossed polars).

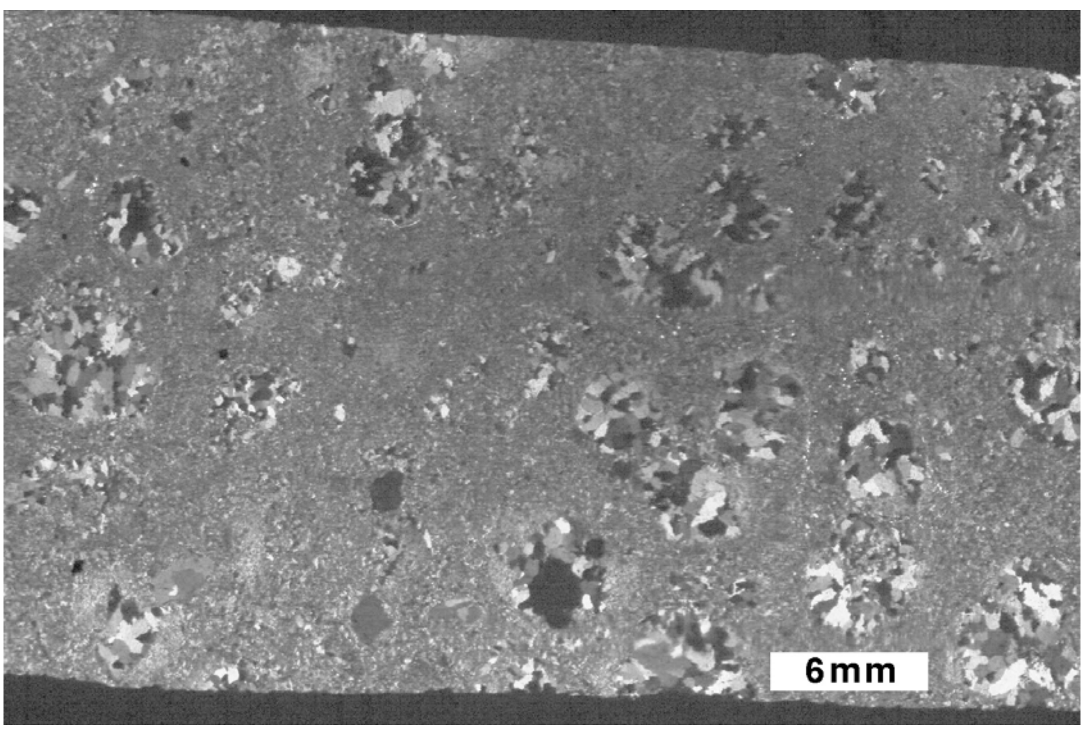

Figure 4.11. Uwharries Southeastern sample with circular quartz amygdules and sparse phenocrysts (FBL025; scanned thin section, crossed polars).

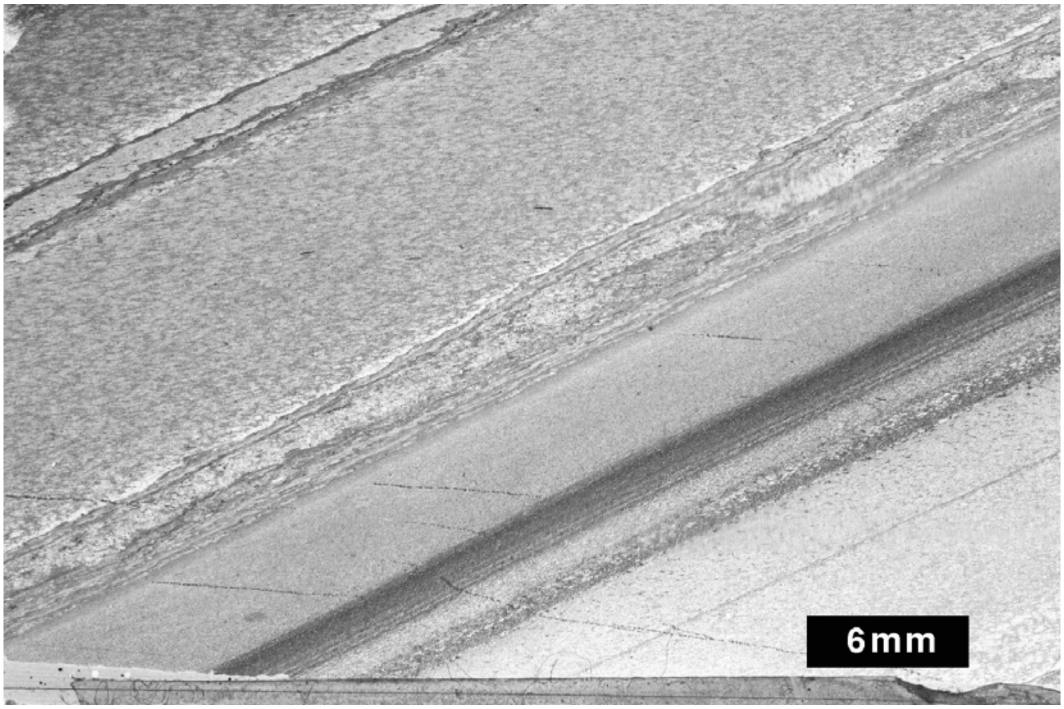

Figure 4.12. Chatham Pittsboro sample with fine laminae, grading, possible current ripples, and incipient cleavage (FBL028; scanned thin section, plane-polarized light).

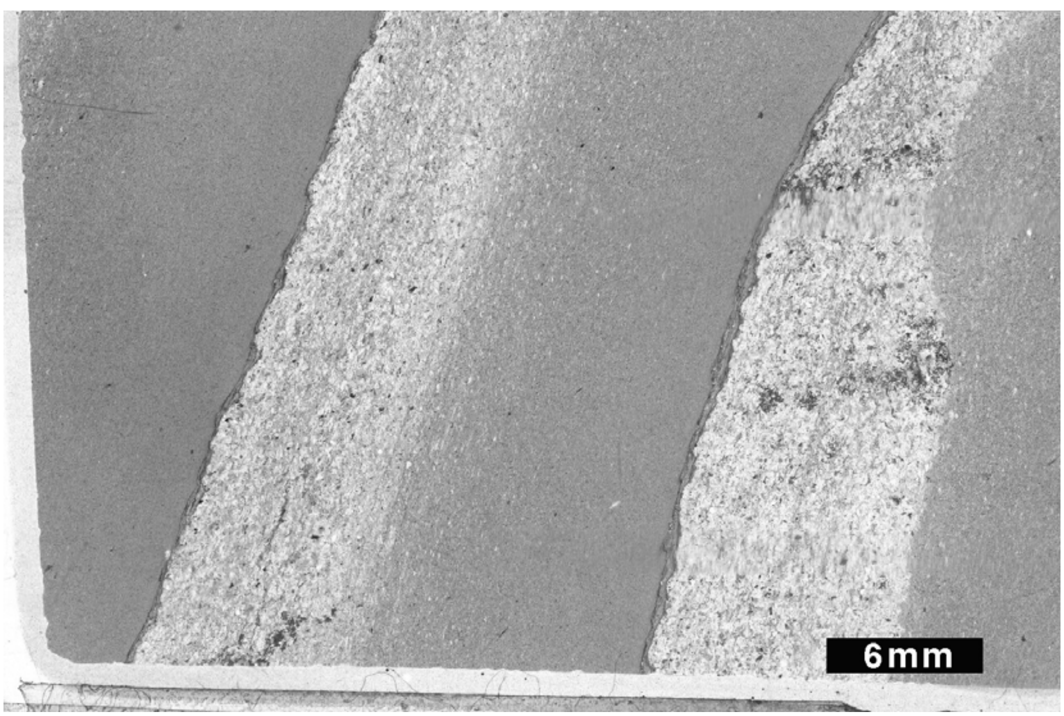

Figure 4.13. Chatham Pittsboro sample with graded bedding couplets (FBL029; scanned thin section, plane-polarized light). Stratigraphic younging direction is to the right.

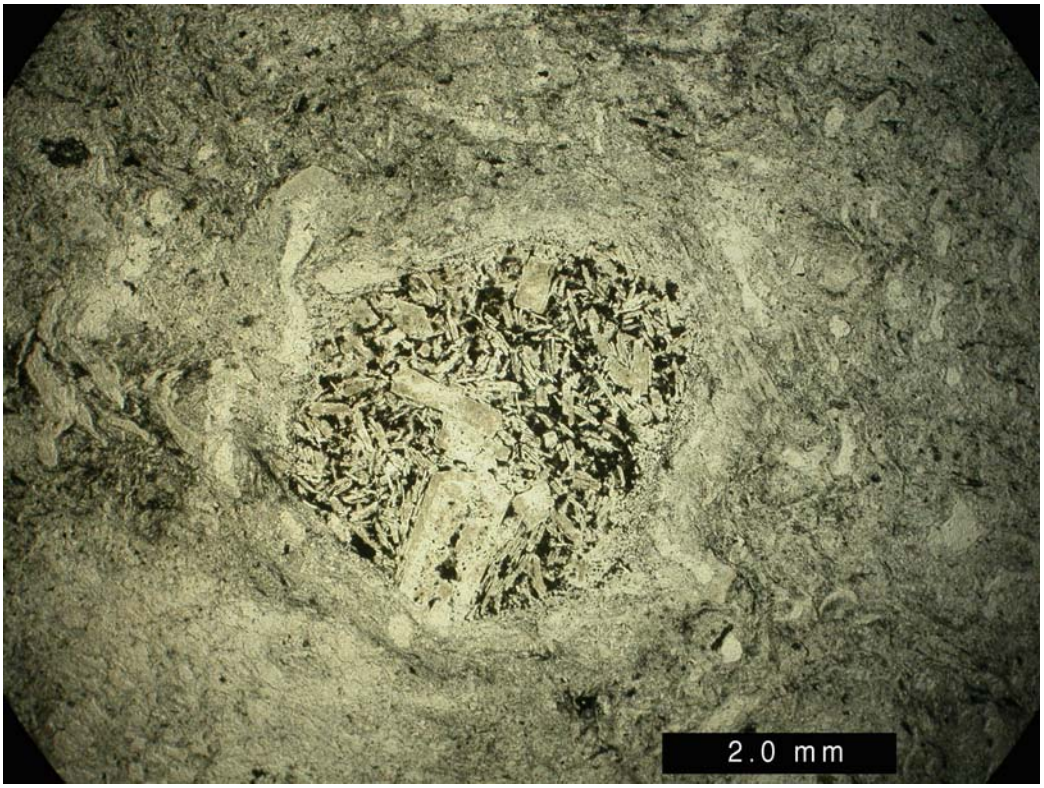

Figure 4.14. Basaltic fragment in Chatham Silk Hope sample (FBL034; plane-polarized light).

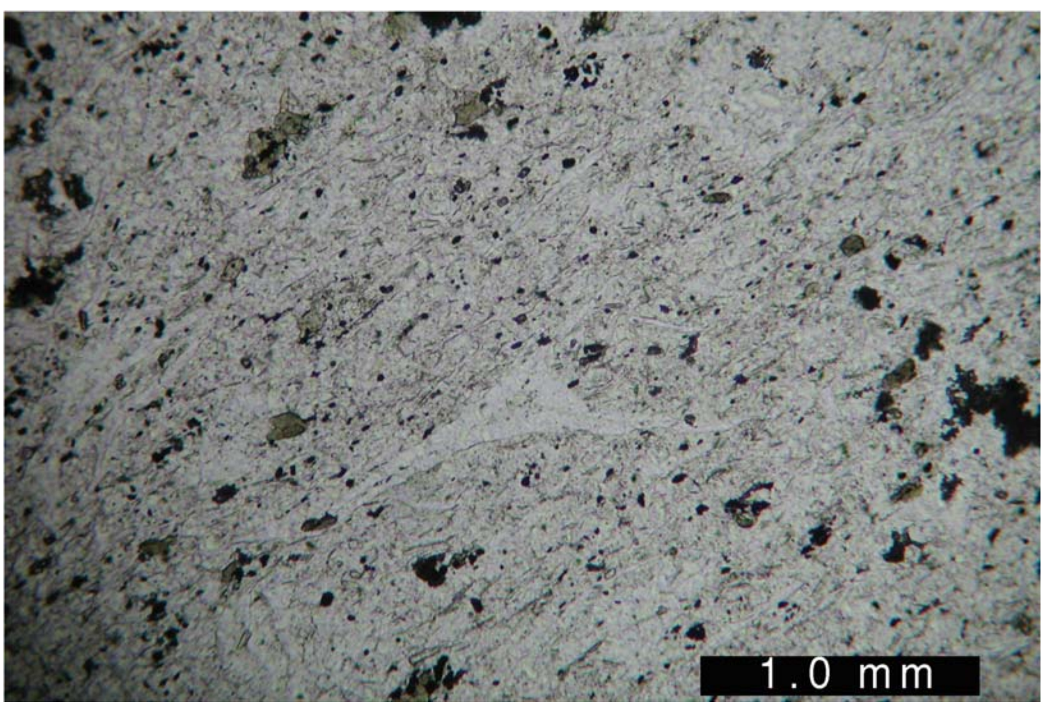

Figure 4.15. Y-shaped glass shard in Chatham Silk Hope sample (FBL031; plane-polarized light).

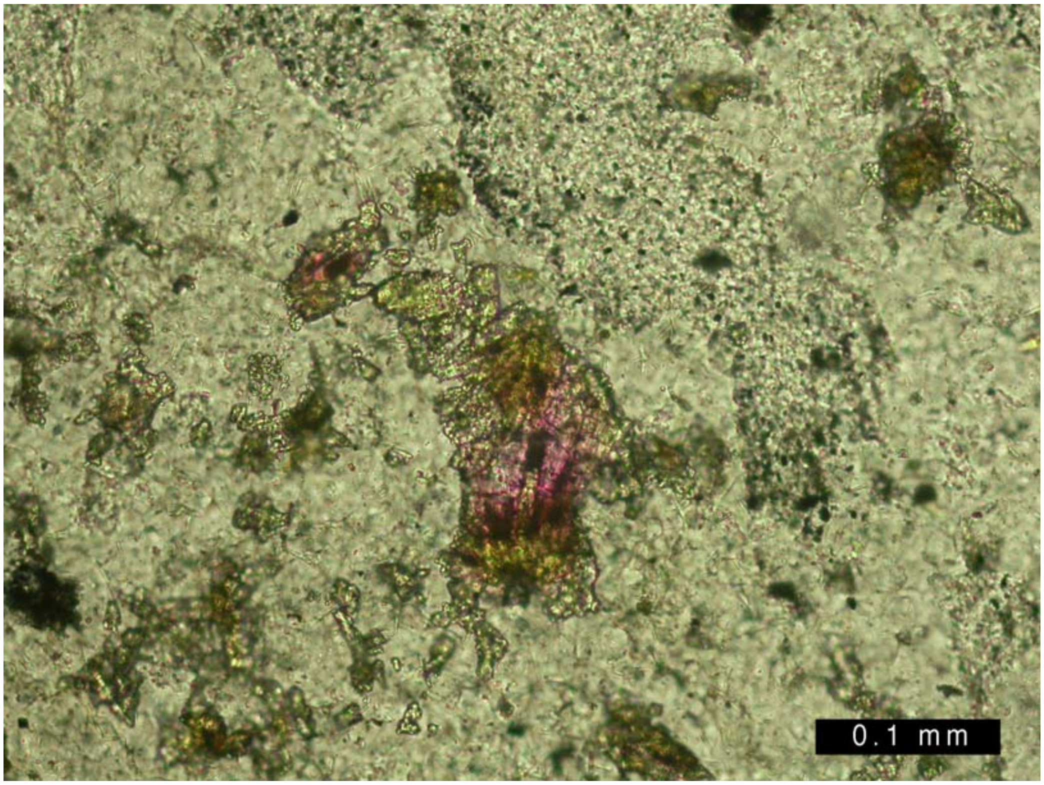

Figure 4.16. Piedmontite in groundmass of Chatham Silk Hope sample (FBL031; plane-polarized light). In color, this relatively rare mineral is bright pink and yellow pleochroic.

Orange County

This is a zone of relatively coarse-grained and crystal-rich rocks, with phenocrysts up to at least 3 mm constituting 15-20% of the volume. The six samples from this zone are distinctive and homogeneous. Phenocrysts are plagioclase, which is commonly partially saussuritized (replaced by epidote or clinozoisite), and quartz, which occurs in well-formed squat dipyramids of β morphology. Quartz phenocrysts are commonly partially resorbed, indicating late reaction with the magma during crystallization (Figure 4.17). The groundmasses of these rocks are exceedingly fine grained. Elongate and locally ovoid clots of feldspar and quartz are common in these rocks and are interpreted as devitrification features similar to spherulites. No flow banding was observed. In addition to epidote, metamorphic minerals include chlorite and calcite. The normative QAP name is dacite except for one sample, which falls just in the rhyodacite field; the TAS name for all is rhyolite. The field name is dacite porphyry or crystal-rich dacitic crystal tuff. These rocks may have originated as a shallow intrusive or an ash-flow tuff.

Durham County

Of the six samples examined, some samples possess sedimentary characteristics, including obvious clastic textures. The coarsest one is a metasandstone with subangular grains of plagioclase approximately 0.25 mm in size (Figure 4.18). However, they are poorly bedded and do not show sedimentary structures such as grading or ripples. Other samples appear to be

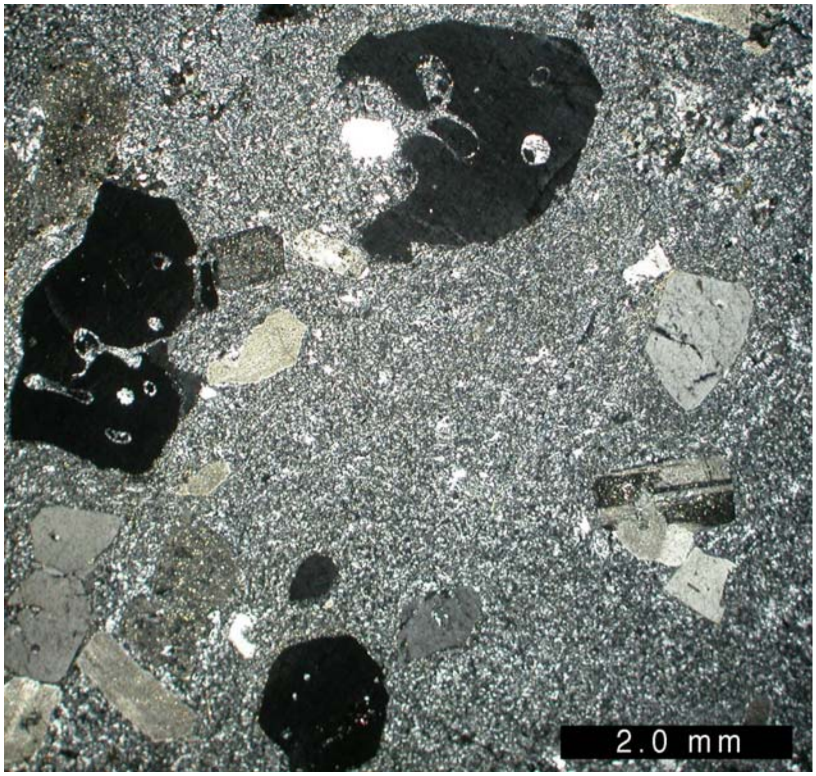

Figure 4.17. Euhedral and resorbed quartz phenocrysts, with plagioclase, in Orange County sample (FBL061; crossed polars).

crystal-lithic tuffs, with sparse plagioclase phenocrysts and volcanic lapilli. All samples contain metamorphic epidote, either replacing plagioclase, as veins, or as large clots that may be amygdules or pseudomorphs after amphibole or clinopyroxene. In addition to the epidote, these rocks contain metamorphic titanite, chlorite, and pyrite. Where sedimentary features dominate, these rocks are tuffaceous sandstones, while others are dacitic crystal-lithic lapilli tuffs. In terms of major element chemistry, this zone stands out due to extremely low K_2O, relatively high CaO and very high Na_2O, while having SiO_2 that is not particularly high. As a result the normative mineralogy, in terms of QAP, is dominated by plagioclase, placing most of this zone within the andesite/basalt field in the IUGS triangle. In terms of the TAS classification, four are rhyolites, one is a trachyte, and one is a trachydacite.

Person County

Yet another quarry of metasedimentary origin, the Person County quarry has samples that are mostly very fine-grained metamudstone and metasiltstone, although two of the specimens are sufficiently coarse grained to be very fine metasandstone. Four of the specimens contain bedding, but in two of them it is very weakly developed. Two of these specimens display graded bedding (Figure 4.19). One extremely distinctive feature occurs in FBL045. In this fine-grained sample, consistently shaped ovoid blobs about 2 mm in length are distributed throughout the section (Figure 4.20). The blobs are outlined by a thin dark band, but the grain texture and mineralogy is the same within and outside of the blobs. Although their origin is unclear, one

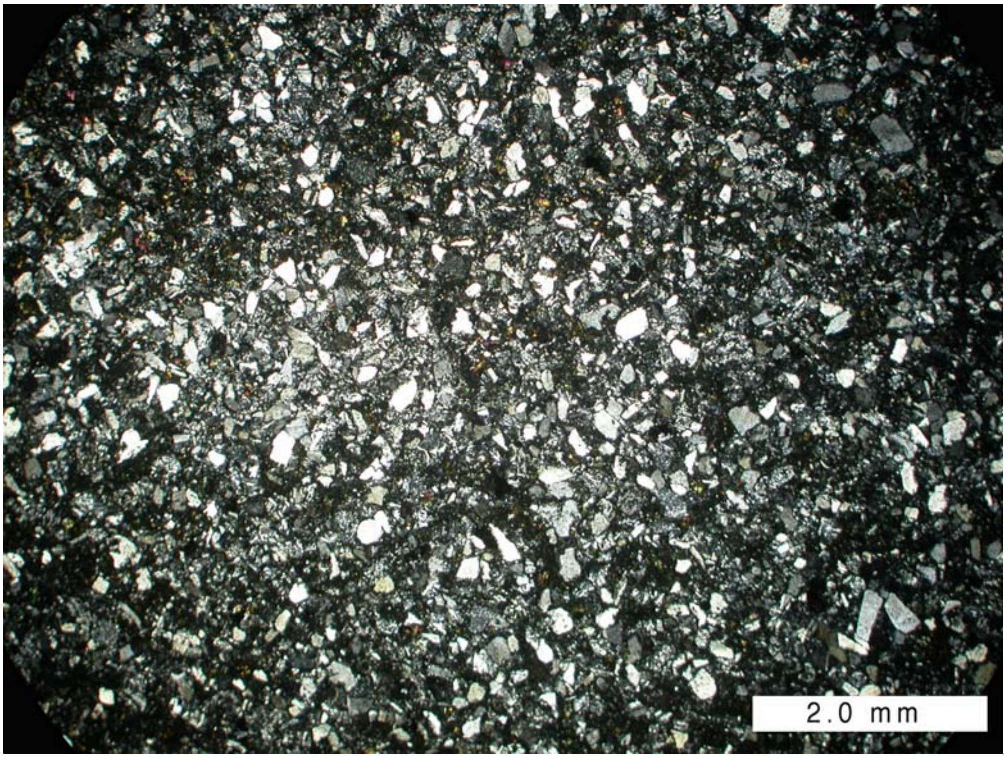

Figure 4.18. Durham County volcanic sandstone with clastic texture (FBL067; crossed polars).

possibility is that they may be trace fossils, possibly fecal pellets. In addition, tiny microfaults and veinlets of metamorphic minerals (chlorite or epidote) indicate some brittle deformation during or before metamorphism. Metamorphic calcite, pyrite, titanite, and needles of biotite or stilpnomelane also occur. In FBL046, detrital opaque grains are present and help to show grading. One sample contains possible pumice lapilli and sparse tiny plagioclase crystals and may be a tuff (FBL044), but the others are inferred to be metasedimentary. Like the Durham County samples, these rocks are chemically potassium-poor, and several plot in the andesite/basalt field using normative QAP, while the remainder are dacitic. Using TAS, one sample is a trachyte and the remaining samples are rhyolites.

Chatham Siler City

The four samples collected here include a laminated metamudstone/metasiltstone, a nonlaminated metamudstone, a volcanic crystal-lithic tuff, and a metasandstone. Samples from this diverse assemblage bear similarities to several of the other quarries, but they do not appear to have sufficient shared distinctive characteristics to make the quarry useful in sourcing. Nevertheless, only four samples have been examined; it is possible that further study might yield useful information. Sample FBL036, collected from outcrop in the Rocky River, is a dacitic or andesitic crystal-lithic tuff, with plagioclase phenocrysts up to 3 mm and relatively abundant lapilli and blocks of andesite and basalt. This specimen also contains glass shards and abundant small clusters of epidote, titanite, and opaque minerals. Many of these features are reminiscent of the Chatham Silk Hope samples, and it is likely that they may be correlative. The remaining

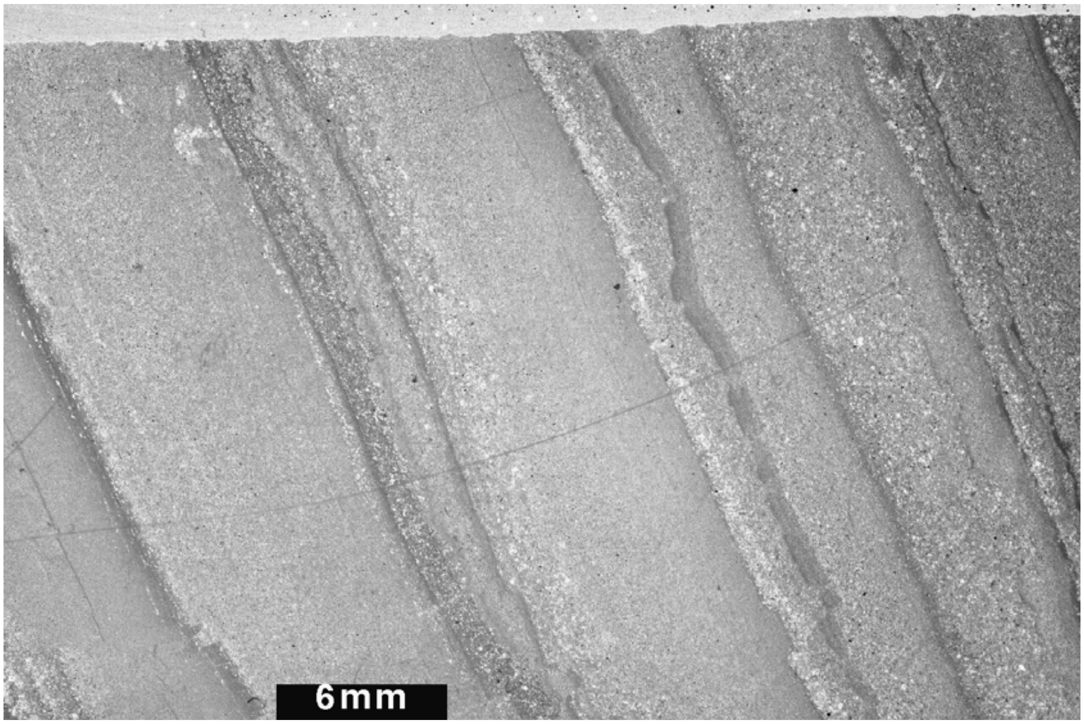

Figure 4.19. Person County sample with sedimentary laminae, grading (top to the right), and micro-faults (FBL046; scanned thin section, plane-polarized light).

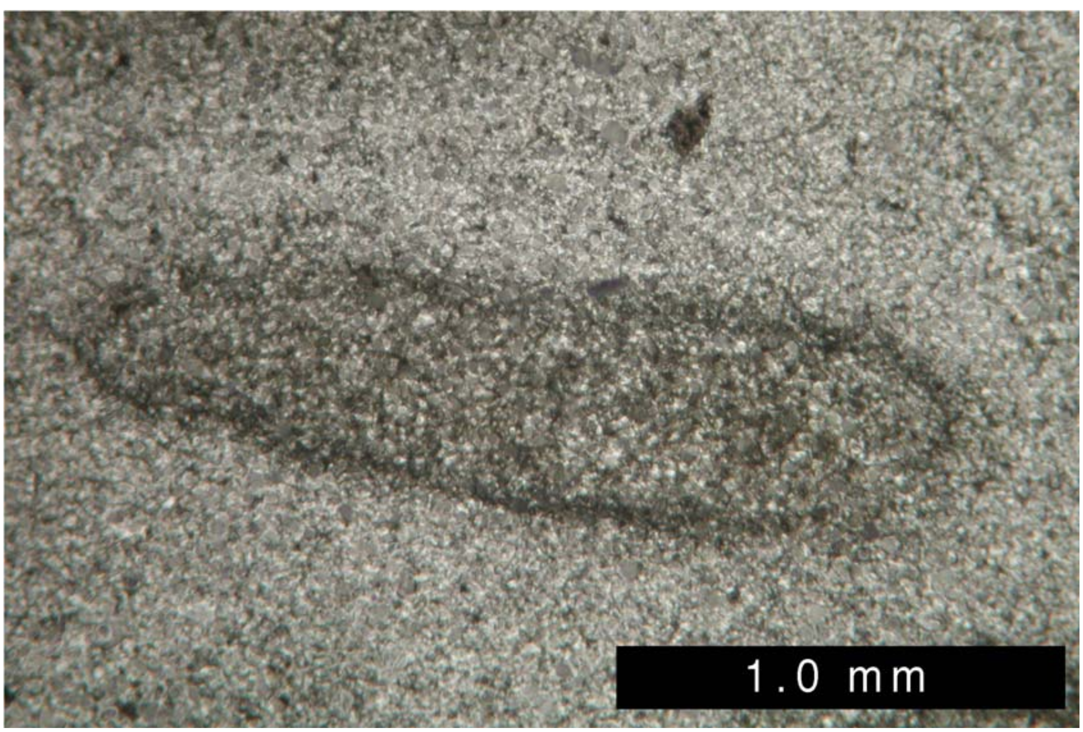

Figure 4.20. Elliptical feature (perhaps a trace fossil?) in metasiltsone from Person County (FBL045; plane-polarized light).

samples, however, resemble the Chatham Pittsboro and Person County quarries, with sedimentary laminations (FBL035), graded bedding (FBL038), and possible cross-laminations (FBL035). At least three of the four specimens contain porphyroblasts of greenish metamorphic biotite, and a weak muscovite foliation is visible throughout the groundmass. Using normative QAP percents, the volcanic rock falls just inside the andesite/basalt field; it is a rhyolite using TAS. The metasedimentary rocks are dacite, rhyodacite, and andesite/basalt using QAP, and dacite and trachyandesite using TAS.

Cumberland County

This zone of highly variable samples includes one that is probably not from the Carolina Terrane at all: sample FBL039 is a plutonic rock of granitic composition, a medium-grained muscovite aplite. It shows no evidence of metamorphism and is probably from a late Paleozoic granitic pluton. The other six samples are all consistent with having been derived from the Carolina Terrane, because they show greenschist facies metamorphic effects. Nevertheless, they are compositionally and texturally inhomogeneous. Two of the samples are metamorphosed intrusive rocks, one a metadiorite with a trachytic texture of aligned plagioclase laths, now strongly sericitized (FBL041). The other inferred metaplutonic rock is FBL071, which is thought to be highly altered metagabbro, with possible pseudomorphs after euhedral pyroxene. FBL040 is a metabasalt with a well-preserved igneous texture but having chlorite, quartz, albite, epidote, titanite and actinolite instead of the original calcic clinopyroxene and calcic plagioclase. FBL070 is an altered greenstone and FBL042 is a highly altered very fine-grained metatuff with ghosts of possible pumice lapilli. Chemical analyses of rocks from this zone, as would be expected, are inhomogeneous. The young granitic rock shows its felsic composition and plots with rhyodacite or rhyolite. The others plot as andesite/basalt using QAP and as basalt, basaltic trachyandesite, or trachybasalt using TAS. It is noteworthy that four of the five nongranite specimens have normative anorthite percentage (An%) greater than 32, by far the highest among all of the metaigneous rocks analyzed. Therefore, excluding the granite, one thing the remaining rocks at this site have in common is that they are intermediate or mafic in composition, not felsic. As mentioned earlier, the heterogeneity of this site is a consequence of the fact that it consists of large clasts removed from their bedrock sources, transported downstream, and redeposited, likely by the ancestral Cape Fear River.

Petrographic Descriptions of Artifacts

As discussed in Chapter 1, nine lithic artifacts collected on the Fort Bragg Military Reservation were analyzed petrographically for comparison to the quarry samples. Brief descriptions and discussion of these specimens follow. The most important petrographic characteristics of these nine artifacts are summarized in Table 4.5. Possible quarry sources indicated in the table are those suggested by comparison of these characteristics to those of the quarry zones described above.

FBL072

This is a fine-grained metadacite with plagioclase phenocrysts less than 1 mm in size constituting about 2% of the rock (Figures 4.21-4.22). Untwinned groundmass plagioclase

Table 4.5. Petrographic Features of Fort Bragg Artifacts.

Sample	Site	Rock Type	Textures	Phenocrysts	Metamorphic Minerals	Possible Source
FBL072	31Hk100	dacite	aligned plagioclase laths; flow banding	plagioclase (zircon inclusions)	garnet; brown biotite; stilpnomelane?	Uwharries Asheboro
FBL073	31Hk148	dacite porphyry	coarse; crystal-rich; mafic pseudomorphs	plagioclase; quartz (resorbed)	epidote; possible piedmontite	Orange County
FBL074	31Hk173	dacitic tuff	saussuritization; amygdules?; weak alignment	quartz; plagioclase (sparse)	epidote; biotite; actinolite; chlorite	Uwharries Eastern?
FBL075	31Hk182	andesite	fine-grained; saussuritization	plagioclase	epidote	
FBL076	31Hk224	dacitic tuff or siltstone	almost aphyric or featureless	plagioclase (tiny); clasts?	actinolite; epidote; brown biotite	
FBL077	31Hk737	siltstone	very fine-grained	fine clasts	green biotite	
FBL078	31Hk999	dacite crystal-lithic tuff or porphyry	flow banding; zoned, saussuritized plagioclase; mafic pseudomorphs; quartz-epidote amygdules	plagioclase; quartz	epidote; actinolite; opaque minerals	Uwharries Asheboro? Uwharries Southeastern?
FBL079	31Hk1408	dacitic tuff	crystal-poor; quartz-epidote amygdule	sparse plagioclase	brown biotite; epidote; actinolite; muscovite	Uwharries Asheboro? Uwharries Southeastern?
FBL080	Flat Creek	dacite	plagiclase lath fabric; banding	plagioclase (sparse, euhedral)	brown biotite; garnet; epidote; muscovite	Uwharries Asheboro? Uwharries Southeastern?

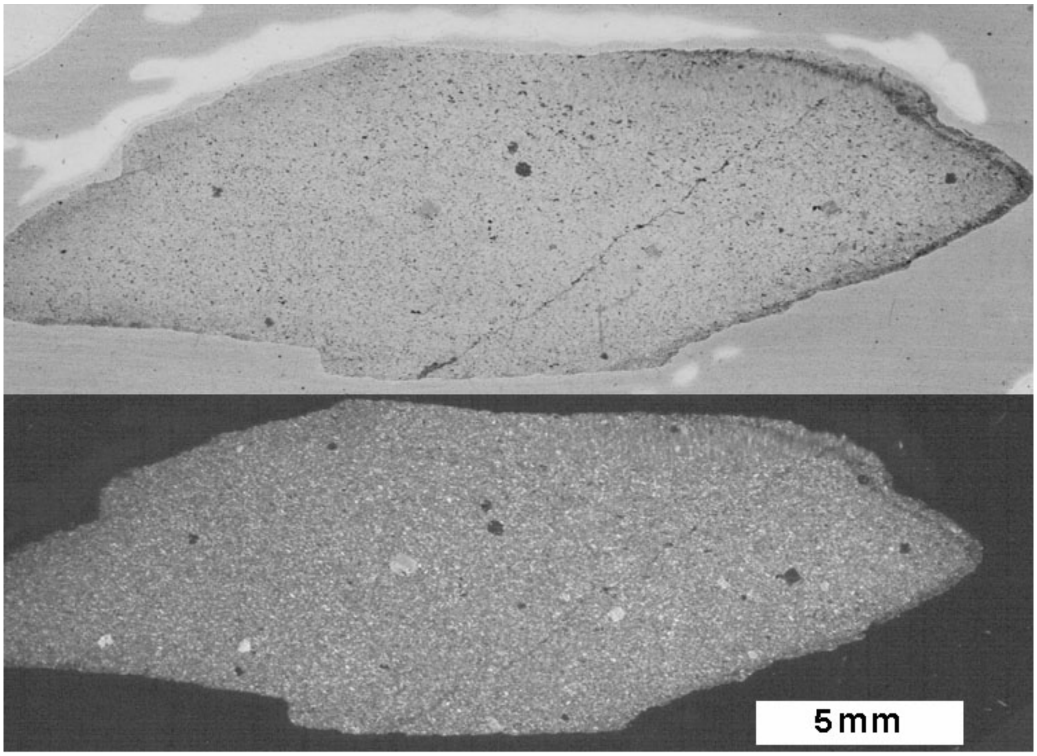

Figure 4.21. Artifact FBL072 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

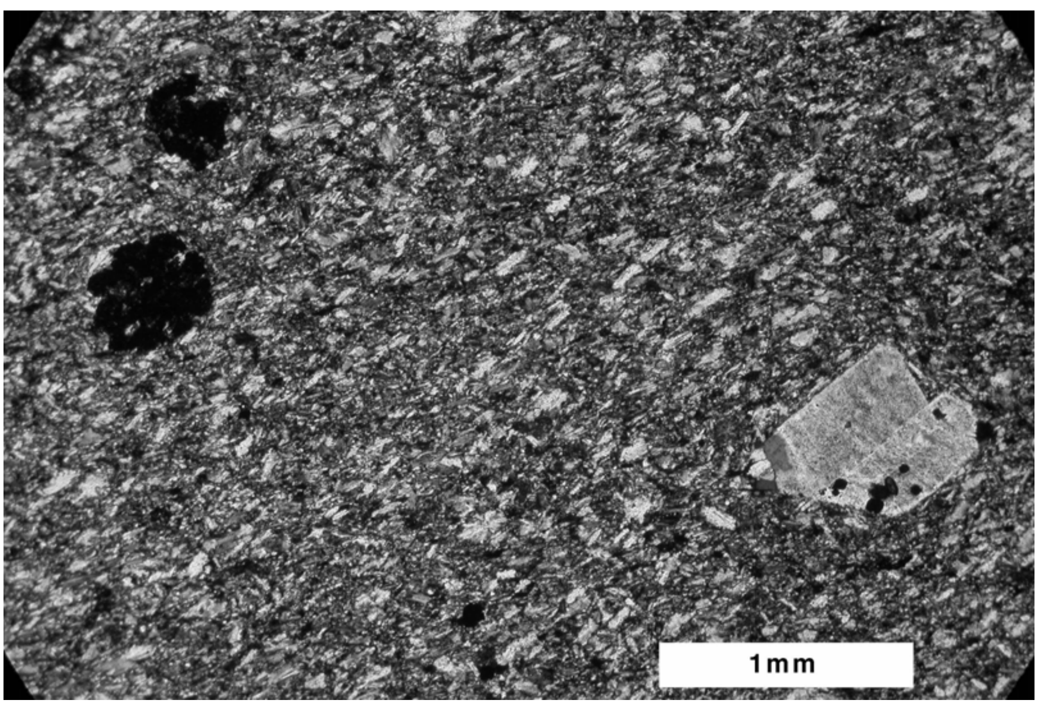

Figure 4.22. Groundmass lath alignment, plagioclase phenocryst, and garnet porphyroblasts in artifact FBL072 (crossed polars).

carries a pronounced alignment suggesting flow during emplacement. There are no quartz phenocrysts. One of the plagioclase phenocrysts has inclusions of zircon. The rock carries metamorphic brown biotite and garnet, with possible stilpnomelane, in addition to epidote and titanite. Using the normative minerals it is a dacite, and using the TAS system it is a rhyolite. Mineralogically this sample resembles the Uwharries Asheboro specimens, especially FBL055, although it is somewhat coarser grained and the garnet is more poikiloblastic. It lacks the mineral clusters that some of the Asheboro samples have, but the metamorphic mineral assemblage is identical. The major element chemistry is similar to that of FBL055 as well.

FBL073

This is a strongly porphyritic plagioclase + quartz dacite (Figure 4.23). Phenocrysts up to and in excess of 2 mm constitute about 20% of the sample. These crystals are euhedral and, in the case of the quartz, they are β-forms with common embayments. Plagioclase is clouded with minute opaque or dark minerals but is not strongly saussuritized. Epidote is common, however, locally with probable piedmontite, and is inferred to be pseudmorphous after amphibole or pyroxene. This sample bears strong resemblance to the Orange County quarry in terms of primary texture, phenocryst assemblage, and phenocryst morphology. It differs in its lack of some of the low-temperature and/or metamorphic features exhibited by the Orange County rocks, notably the saussuritization and the inferred devitrification features described above. Still, the similarities are striking, and the artifact could have been derived from a nearby outcrop. There are no metamorphic differences between FBL073 and the Orange County samples that would preclude them from coming from the same zone. The difference could be as simple as being erupted from different levels of the same magma chamber.

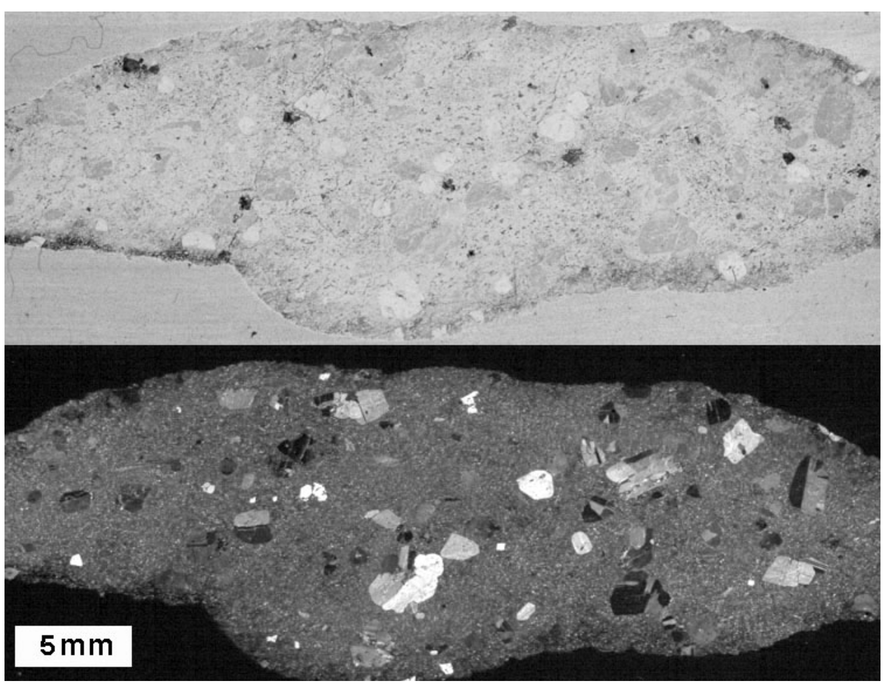

Figure 4.23. Artifact FBL073 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]). Note euhedral and resorbed quartz phenocrysts and crystal-rich texture.

FBL074

This is a sparsely porphyritic, quartz + plagioclase-phyric metadacitic tuff (Figure 4.24). The plagioclase phenocrysts are strongly saussuritized, and there are elongate epidote + quartz clots that may represent amygdules. There is alignment of the sparse phenocrysts and the epidote aggregates, but the groundmass consists of more equidimensional grains, most of which appear to be quartz. Quartz phenocrysts are relatively euhedral β-forms and do not appear to be resorbed. Phenocrysts range to 0.5 mm, with plagioclase more abundant than quartz. The metamorphic minerals include epidote, titanite, actinolitic amphibole, sparse brown biotite or stilpnomelane, and possible chlorite. Chemically it is dacite (QAP) or rhyolite (TAS). This specimen bears strongest association with the Uwharries Eastern zone but is finer grained.

FBL075

This specimen, petrographically and chemically, is of andesitic composition (Figure 4.25). It is extremely fine grained and contains sparse tiny (< 0.5 mm) plagioclase phenocrysts. The rock contains abundant epidote, and the plagioclase is saussuritized. Though the rock would appear to be altered, its chemical composition shows major oxide values (SiO_2, Al_2O_3, TiO_2, MgO, CaO, Na_2O, and K_2O) consistent with an intermediate igneous rock composition (see Appendix C). Its normative QAP plots in the andesite/basalt field, and its normative plagioclase composition is 23% An. In terms of TAS it is a dacite. The material is unlike any of the quarry specimens.

FBL076

This sample is exceedingly fine grained and lacks any petrographic characteristics of clear volcanic origin, such as flow banding or spherulites, or of sedimentary origin, such as laminations or a clearly clastic texture (Figure 4.26). The largest grains are plagioclase crystals 0.05 mm in diameter. The metamorphic minerals include abundant tiny actinolite and epidote and sparse brown biotite. The rock is either a dacitic (ash) tuff, or a tuffaceous metasiltstone/metamudstone. Chemically and petrographically this sample is similar to FBL077, and the two artifacts may well be from the same source, but FBL076 cannot be associated with one of the quarries in this study based on petrographic criteria.

FBL077

This is a fine-grained metasedimentary rock with maximum clast size about 0.05 mm (Figure 4.27). Although a clastic texture is apparent in the sample, it appears to be devoid of any distinguishing features such as laminations or grading, and the minerals are too small to be identified with any confidence. There is in abundance a green, strongly pleochroic metamorphic mineral that is probably biotite. Chemically it falls in with the dacite/rhyolite specimens. This is the only artifact that is of clear metasedimentary origin, and it lacks any features to tie it to any of the quarries. It is, however, similar to another artifact, FBL076.

FBL078

This point is from a flow-banded quartz + plagioclase phyric metavolcanic rock (Figures 4.28-4.29). The phenocrysts are relatively abundant and range larger than 1 mm. Some of the

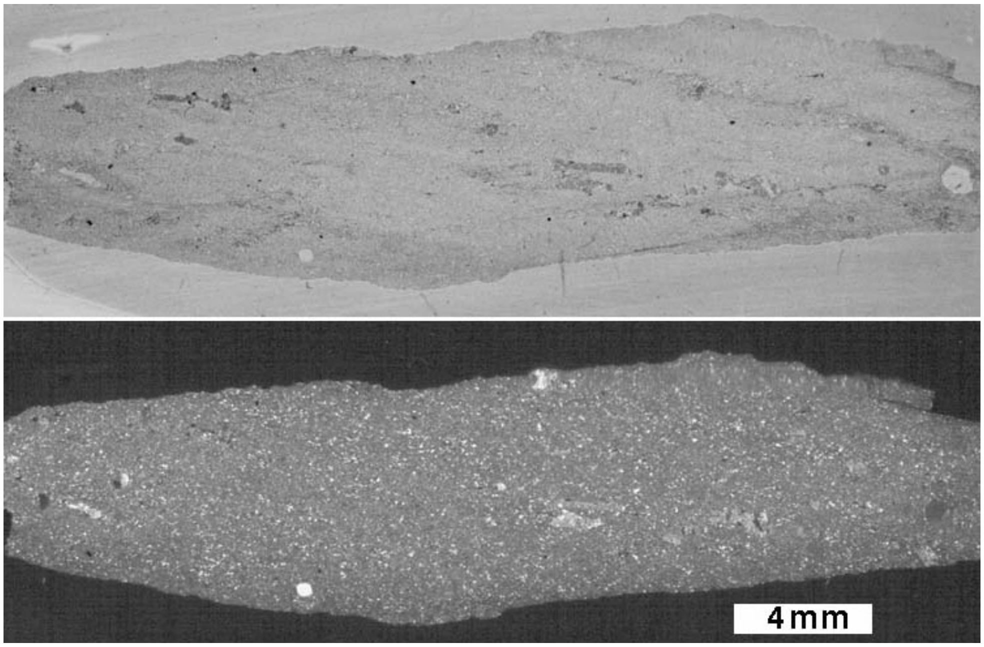

Figure 4.24. Artifact FBL074 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

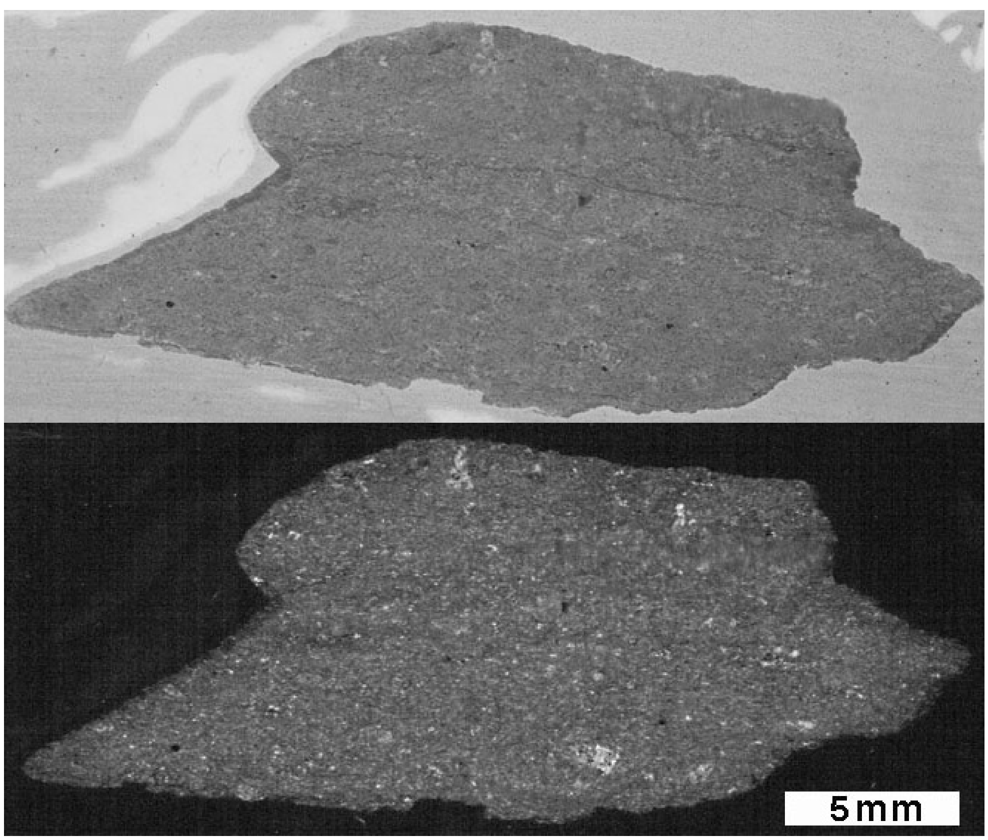

Figure 4.25. Artifact FBL075 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

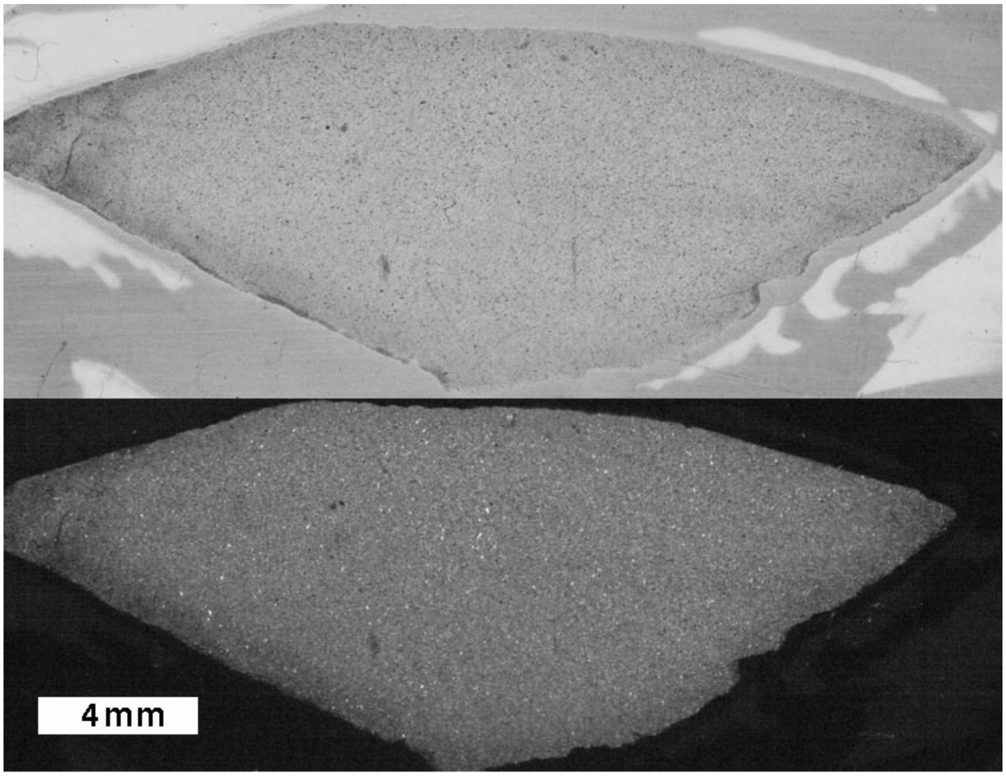

Figure 4.26. Artifact FBL076 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

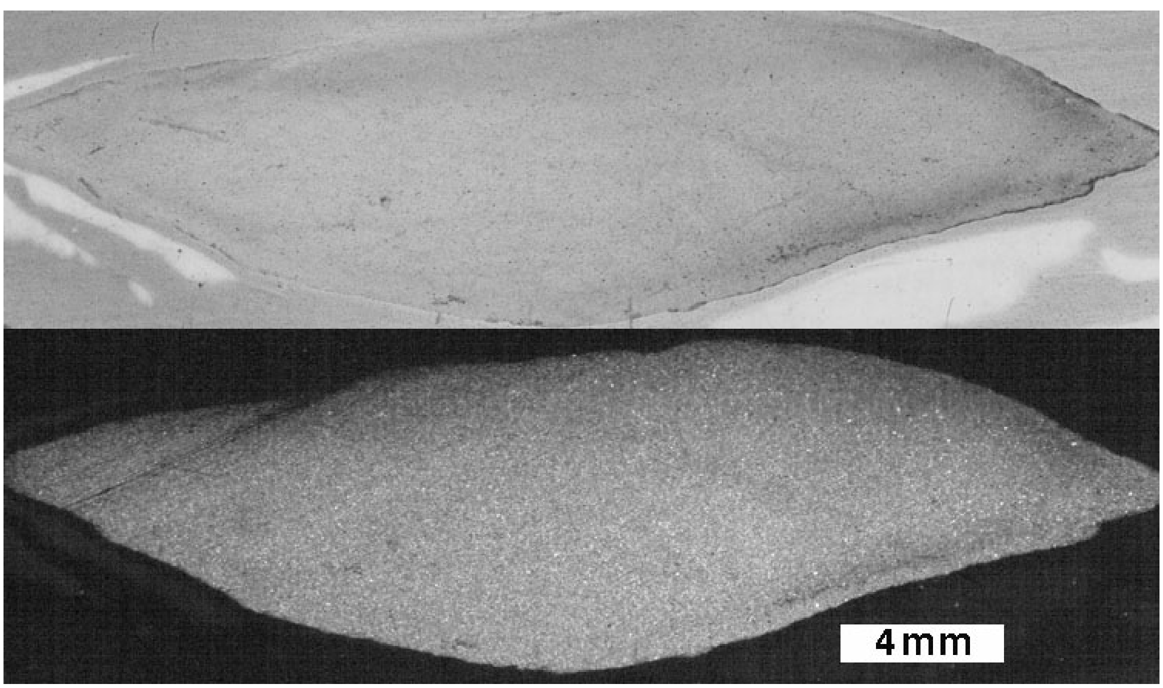

Figure 4.27. Artifact FBL077 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]). Parallel lines are saw marks.

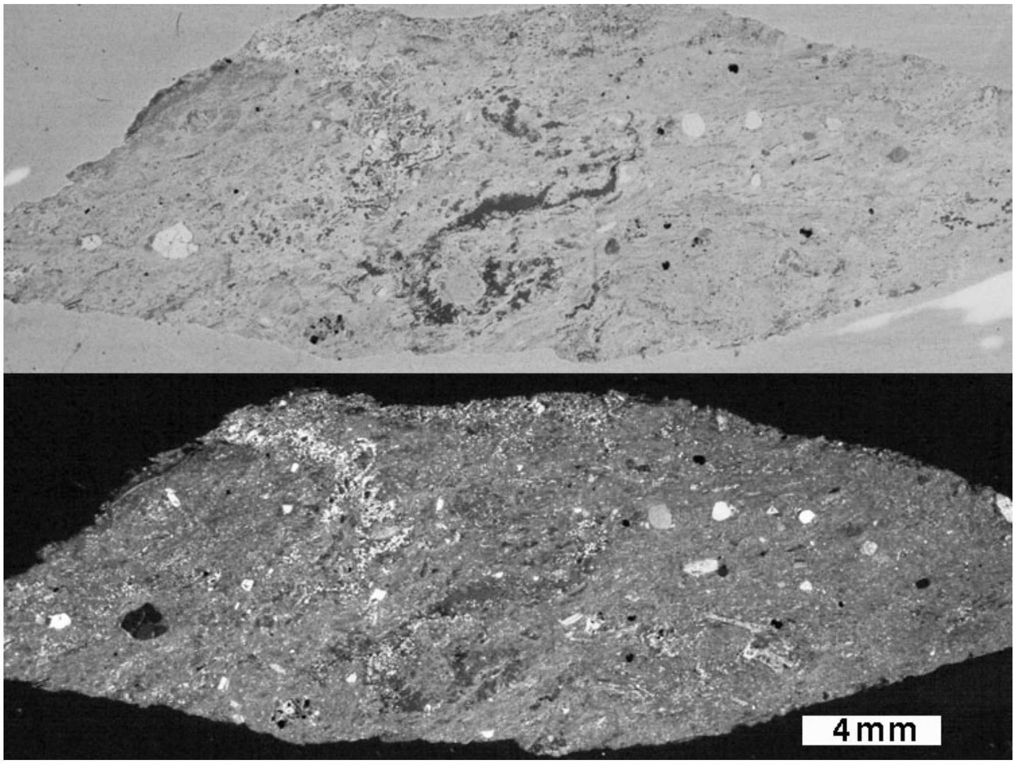

Figure 4.28. Artifact FBL078 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

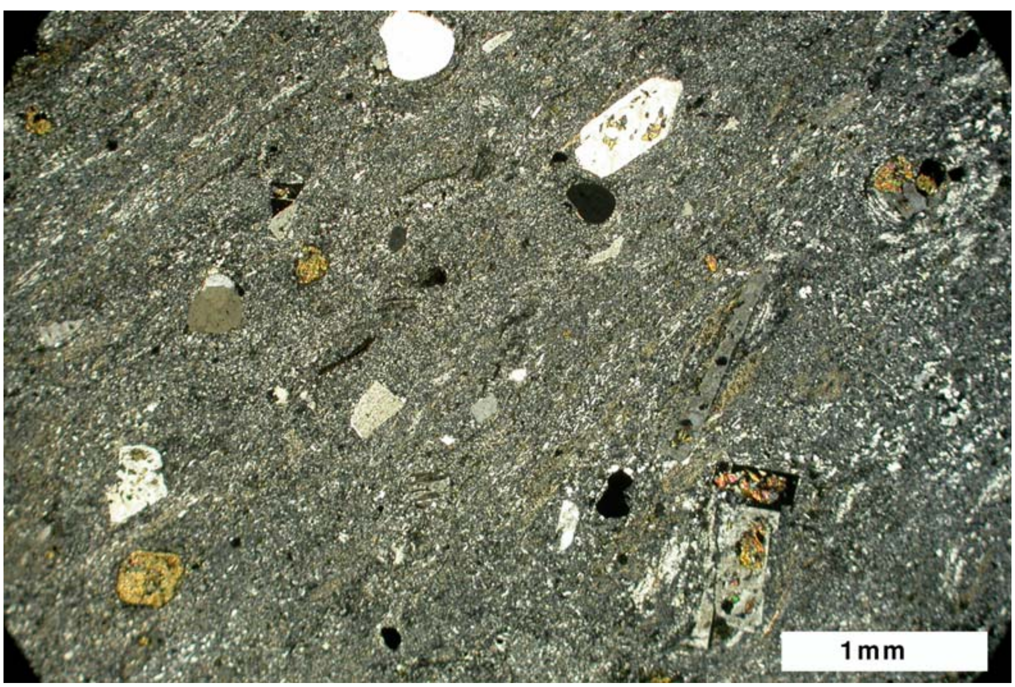

Figure 4.29. Weak alignment, phenocrysts, and pseudomorphs after amphibole or pyroxene (lower left and lower right) in artifact FBL078 (crossed polars).

plagioclase phenocrysts exhibit relict compositional zoning, manifested by the more calcic cores having been preferentially replaced by epidote-group minerals. The specimen contains at least one very nice pseudomorph of epidote after hornblende or augite. Quartz + epidote amygdules are also present, as are lapilli. In addition to abundant epidote, the rock carries considerable titanite and also chlorite. The rock is a dacitic crystal-lithic metatuff. Chemically it is similar to many of the metavolcanic rocks from the Uwharries quarries, especially the Asheboro zone, and plots as dacite using norms and rhyolite using TAS. However, the metamorphic assemblage does not match the Uwharries Asheboro zone. The presence of amygdules suggests the possibility of a source in the Uwharries Southeastern zone, although chemically the most similar rocks there appear to have been silicified.

FBL079

This is a sparsely porphyritic, fine-grained dacitic tuff containing plagioclase phenocrysts up to 0.5 mm (Figure 4.30). The groundmass contains abundant epidote, titanite, brown biotite, actinolite, and relatively coarse muscovite. At the edge of the specimen, there is one ovoid epidote + quartz cluster that may be an amygdule. It has some similarities to several of the Uwharries quarries, but no convincing petrographic connection to any.

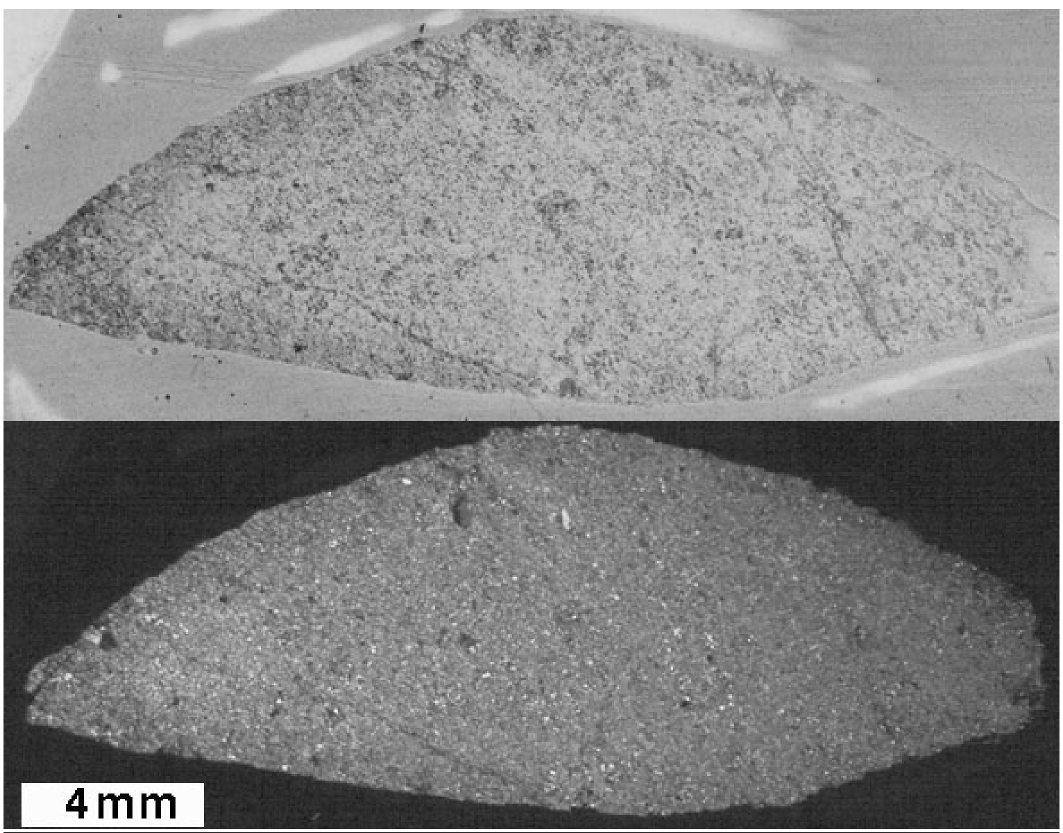

Figure 4.30. Artifact FBL079 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

FBL080

This specimen is extremely similar to the preceding one, having euhedral plagioclase phenocrysts, epidote, brown biotite, titanite, and muscovite (Figure 4.31). The major differences are that it has a well-developed alignment of its phenocrysts and groundmass plagioclase laths, and it contains sparse garnet porphyroblasts. The combination of brown biotite, actinolite, and garnet suggests that the strongest connections of this specimen (and possibly FBL079) may be to the Asheboro or Southeastern Uwharries zones.

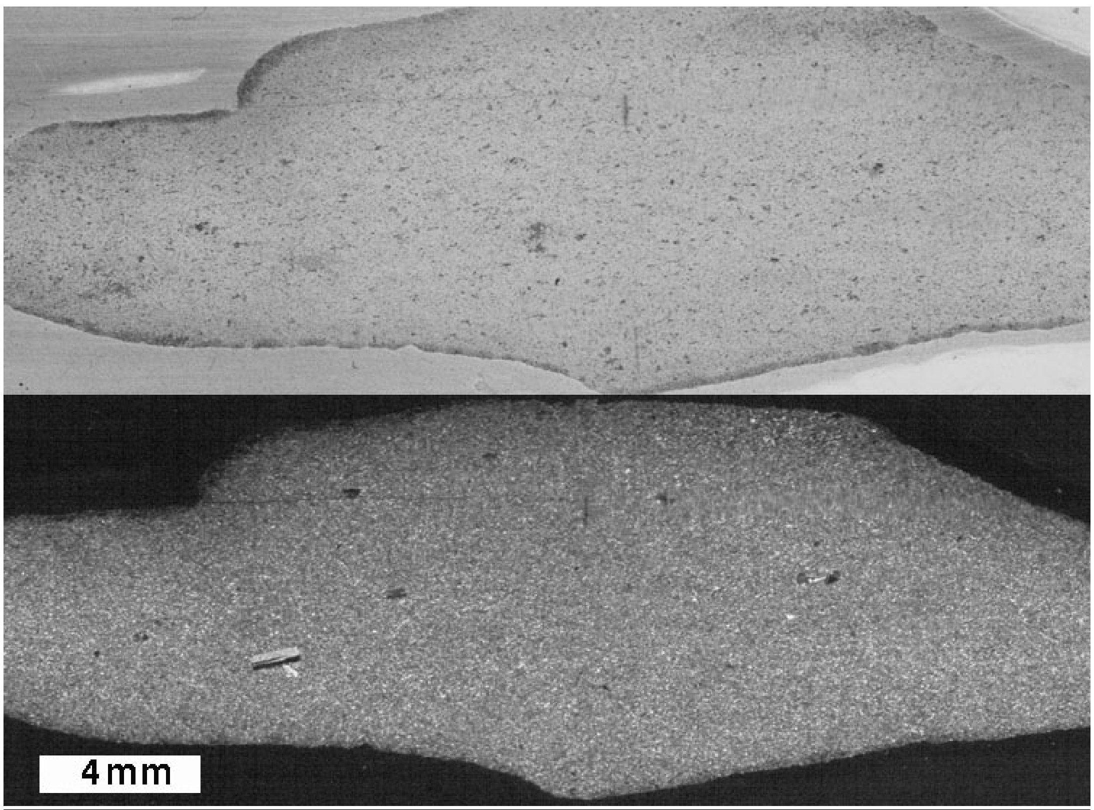

Figure 4.31. Artifact FBL080 (scanned thin section, plane-polarized light [top] and crossed polars [bottom]).

Summary

A number of archaeological quarry sites in the central North Carolina Piedmont were studied in order to characterize them petrographically for the purposes of comparison with lithic artifacts. In this study, nine artifact specimens from Fort Bragg, North Carolina were also examined. Several of them have petrographic similarities with one or more of the studied quarry sites, and some tentative correlations are offered. Perhaps with the use of trace-element and isotopic data, these suggestions may be corroborated or refuted.

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