AN UNCONFORMITY IN THE CAROLINA SLATE BELT OF CENTRAL NORTH CAROLINA: NEW EVIDENCE FOR THE AREAL EXTENT OF THE CA. 600 MA VIRGILINA DEFORMATION

by

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(ABSTRACT)

Detailed mapping in the Ramseur, N.C. 7 1/2' quadrangle has shown that lithostratigraphic units of the Virgilina sequence, units II and III (Glover and Sinha, 1973) in the Roxboro-Durham, N.C. area can be extended into central North Carolina.

The volcanic stratigraphy is composed of the Hyco, Aaron and Uwharrie Formations, all of which have been subjected to greenschist facies metamorphism. The oldest map unit, the Hyco Formation, consists of intermediate(?) lava flows, pyroclastic and volcaniclastic rocks. Deposition of these units was in a subaqueous environment although some units are indicative of transient subaerial conditions. The Aaron Formation is a volcanic epiclastic sequence composed of conglomerate, pebbly and feldspathic arenite with intercalated siltstone, argillite and vitric tuff. The arrangement of sedimentation packages in the Aaron Formation are analogous to those of a coarse grained retrogradational submarine fan sequence. In the western part of the map area the Uwharrie Formation unconformably overlies the Hyco Formation. The Uwharrie consists of a bimodal (felsic-mafic) sequence of lava flows, pyroclastic and volcaniclastic rocks, all of which were deposited in a subaqueous environment.

Structural data indicates that the older units of the Hyco and Aaron Formations were folded (F_1) and faulted during the Virgilina deformation (D_1). The entire volcanic sequence of Hyco, Aaron and Uwharrie Formations was subsequently folded (F_2) and metamorphosed during the Taconic deformation (D_2). Associated with the Taconic event is the development of a pervasive spaced anastamosing cleavage (S_2) in the volcanic lithologies.

Previous regional correlations preferred by Wright and Seiders (1980) are thought to be incorrect. It is proposed in this paper, as first suggested by Glover (1974), that an angular unconformity separates the older volcanic strata of the Virgilina sequence from the younger units of the central N.C. sequence. The presence of an unconformity is indicated by 1) the truncation of lithologies comprising the Hyco Formation at the contact between the Hyco and Uwharrie Formations, 2) the deviation of macroscopic fold trends from the Hyco and Aaron Formations to the adjacent Uwharrie Formation and 3) the intrusion of felsic dikes equivalent to those comprising the Uwharrie Formation, which crosscut the older units and structures of the Virgilina sequence.

The Virgilina deformation is probably correlative in time with the Late Precambrian Monian, Cadomian and Pan-African orogenies which effect similar age volcanic terranes like the older Carolina slate belt. In this study it is proposed that the name Virgilina deformation should have precedence over the term Avalonian event, because of the relation of the former to compressional tectonics versus the extensional tectonism prevalent in the latter. The Virgilina deformation may be attributed to active plate margin tectonics associated with a former volcanic arc.

ACKNOWLEDGEMENTS

> "There is a time in every man's education when he arrives at the conviction that envy is ignorance; that imitation is suicide; that he must take himself for better for worse as his portion; that though the wide universe is full of good, no kernel of nourishing corn can come to him but through his toil bestowed on that plot of ground which is given to him to till. The power which resides in him is new in nature, and none but he knows what that is which he can do, nor does he know until he has tried."
>
> -Ralph Waldo Emerson,
> from Self Reliance, 1841

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INTRODUCTION

Presently an accurate and clear scheme for correlation of the major lithostratigraphic units within the Carolina slate belt of North Carolina is tentative and conflicting. Two distinct volcanic sequences are represented by the older (ca. 700 - 600(?) Ma) volcanic rocks and sediments of the Roxboro-Durham, N.C. area (Virgilina sequence) and the younger units (ca. 590 - 540 Ma) of the Albemarle-Troy-Asheboro, N.C. area (Central N.C. sequence) as shown in Figure 1. Proposed correlation schemes which might attempt to relate these two areas must account for the effects of the (ca. 600 Ma) Virgilina deformation as documented by Glover and Sinha (1973) in the Roxboro-Durham area.

Wright and Seiders (1980) proposed three models for correlating the lithologies and structural events of the two areas: 1) The two volcanic sequences are in part correlative, with the Virgilina deformation being synchronous with deposition of the upper part of the central N.C. sequence, but the deformation did not extend into the central N.C. area. 2) The two sequences are correlative, with the Virgilina deformation being younger than the Central N.C. sequence. 3) The central N.C. sequence is entirely younger than the Virgilina deformation, in which the volcanic rocks of the central N.C. area may represent the effusive phase of the plutonism in the Roxboro-Durham area.

Wright and Seiders (1980) decided that interpretation 1 was the best solution based on generalized lithologic correlations and ages of

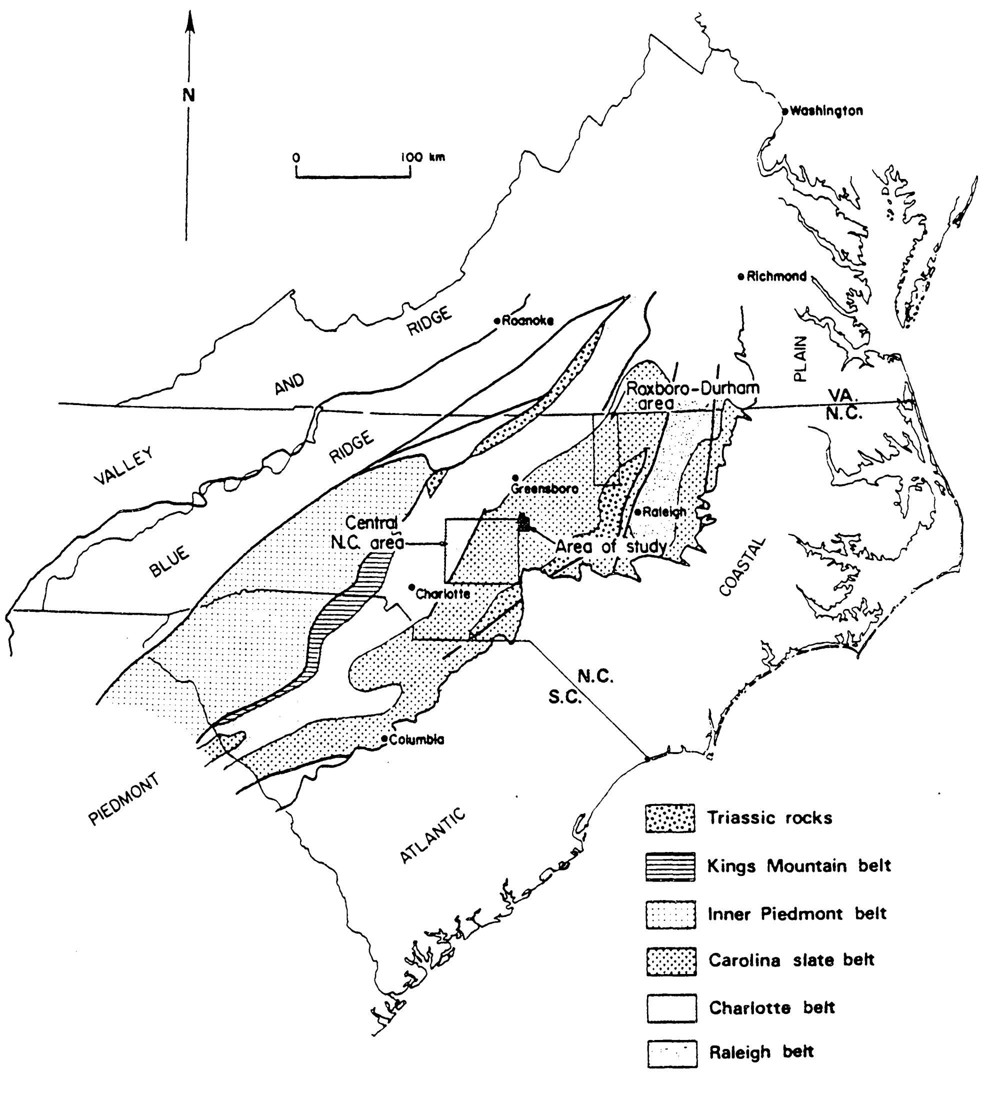


Figure 1 : Geologic belts and geologic physiographic provinces of the Southeastern United States. Location of study area is indicated and shown in relation to the previously mapped Roxboro-Durham and Central N.C. areas in the Carolina slate belt.

units. The authors concluded that a decisive correlation of the two volcanic sequences would not be possible until the previously reconnaissance-mapped geologic terrane separating the two areas was examined in detail. This study based on detailed mapping in the Ramseur, N.C. 7 1/2' quadrangle (study area shown in Fig. 1) demonstrates that of the three proposed correlation schemes of Wright and Seiders (1980), interpretation 3 is the correct one. This study affirms the earlier proposed model of Glover (1974) and Briggs, Gilbert and Glover (1978), in which they postulated that an unconformity separates the lithologies of the Virgilina sequence from those of the central N.C. sequence. Those units correlative with Units II and III (Glover and Sinha, 1973) of the Virgilina sequence herein are named the Hyco and Aaron Formations respectively, which are exposed adjacent to and east of the Uwharrie Formation.

This study will review the stratigraphic data which is useful for interpreting the depositional environments and processes responsible for the lithologic units observed. Features unique to each rock unit may serve to differentiate and collectively subdivide them into the formations, members and facies of this paper. These formations may then be correlated and compared with other lithostratigraphic units of the Carolina slate belt. Recognition of lithologic differences in the volcanic sequence may indicate in the area of central North Carolina the lateral extent of the Virgilina deformation. Finally, the Virgilina deformation is thought to be comparable to other Late Precambrian orogenic events and may be attributed to active plate margin tectonic mechanisms. In light of the stratigraphic and structural data available from the study area and adjoining mapped areas it is possible to construct a tectonic evolutionary scenario which may be applicable to the entire Carolina slate belt.

Regional Geologic Setting

The area of study is located in the central Carolina slate belt, adjacent to the previously mapped central North Carolina area and approximately 75 km southwest of the Roxboro-Durham area of North Carolina (Fig. 1). The Carolina slate belt is an elongate northeast-southwest oriented terrane (approximately 150 km wide by 640 km long) consisting of volcanic and intercalated sedimentary rocks of generally volcanic derivation. All lithologies have been subjected to regional greenschist facies metamorphism. West of and adjoining the slate belt is the Charlotte belt, which is composed of intrusive and high grade metamorphic rocks. The extensive Piedmont portion of the Carolina slate belt is bordered on the east by Triassic basins and the higher grade metamorphic rocks of the Raleigh belt. An eastern extension of the Carolina slate belt, the Eastern slate belt, adjoins the Raleigh belt.

STRATIGRAPHY AND TERMINOLOGY

The volcanic rocks of the Carolina slate belt in the Ramseur area herein are subdivided into three formations and comprise a total thickness of approximately 3000 to 4000 meters. From oldest to youngest they include the Hyco, Aaron and Uwharrie Formations respectively. The Hyco and Uwharrie are subdivided into members based on rock type and textural differences, whereas the Aaron Formation is subdivided into facies which are grouped together as facies associations. All volcanic and sedimentary units are of limited areal extent. Rocks of Early Cambrian (?) to Jurassic age intrude the volcanic strata.

All pre-Mesozoic age rocks have been subjected to greenschist facies metamorphism. Nevertheless deformation and recrystallisation have not been sufficient to destroy relict igneous, pyroclastic and sedimentary textures. Because of this, the prefix "meta" hereafter is deleted from the descriptive nomenclature for all rock types.

Classification and naming of volcanic and intrusive rocks is tentative and is based on modal mineral assemblages and relict igneous textures observed in thin section. The nomenclature used is that of the IUGS subcommission on igneous and volcanic rocks (Streckeisen, 1973,1979). Terminology for pyroclastic rocks is from Fisher (1966) and that for sandstones from Dott (1964). Chemical analysis of volcanic rocks in the Ramseur quadrangle has not been performed, although data of Seiders (1978) and Tingle (1982) of rocks in adjoining quadrangles are thought to be from units similar to those described in this report.

The distribution of major lithologic units is shown in the geologic map and cross section of Figure 2 and in more detail in Plate 1. Selected localities which are represented in the lithologic columns accompanying the descriptions of the various formations, are lettered and numbered.

Andesite and dacite as well as the modifiers andesitic and dacitic are terms used to describe quartz poor, blue-green, purplish-gray to blue-gray lithologies which may occur as either pyroclastic or effusive rocks. Textures and minerals observed in thin section in the effusive rocks include: 1) phenocrysts of zoned and unzoned plagioclase, 2) altered and replaced mafic minerals plus opaques, originally pyroxene(?) or amphibole(?) and magnetite, and 3) isolated phenocrysts or glomeroporphyritic clusters of phenocrysts in a hyalopilitic to trachytic groundmass of plagioclase microlites. Former mafic minerals in the ground mass are now recrystallised to epidote + chlorite + biotite + leucoxene and sphene. Pyroclastic rocks such as lapilli tuff and lapillistone contain ubiquitous lithic clasts of probable intermediate composition. The nomenclature used is tentative and may change when chemical analyses of rock samples are available. Nonetheless, available analyses from nearby unamed and reconaissance mapped units (probably part of the Hyco Formation) are within the compositional range of andesite and dacite (Seiders, 1978 and A. Carpenter, person. communication, 1981).

Explanation

T̄Rd Diabase dikes			Triassic/Jurassic
Hydrothermally altered lithologies			Cambrian(?)
Intrusive Rocks			
€(?)pg Pyroxene gabbro sills			
€(?)fd Felsic dikes			
€(?)md Mafic dikes			
€(?)qdt Quartz diorite and tonalite			
€pcg Parks Crossroads granodiorite			
p€–€uf Felsic Member	UWHARRIE FORMATION		Cambrian / Late Precambrian(?)
p€–€um Mafic Member			
Unconformity			
p€a undivided	AARON FORMATION		Late Precambrian
p€he Member E	HYCO FORMATION		
p€hd Member D			
p€hc Member C			
p€hb Member B			
p€ha Member A			

Symbols

CONTACTS

——— Known

— — — Approximate

---------- Inferred

FAULTS

▬▬▬ Inferred

(2) Locality of diagrammatic section in the Hyco Formation, refer to Fig. 3

[B] Locality of Facies association in the Aaron Formation, refer to Fig. 4

⟨A⟩ Locality of diagrammatic section in the Uwharrie Formation, refer to Fig. 5

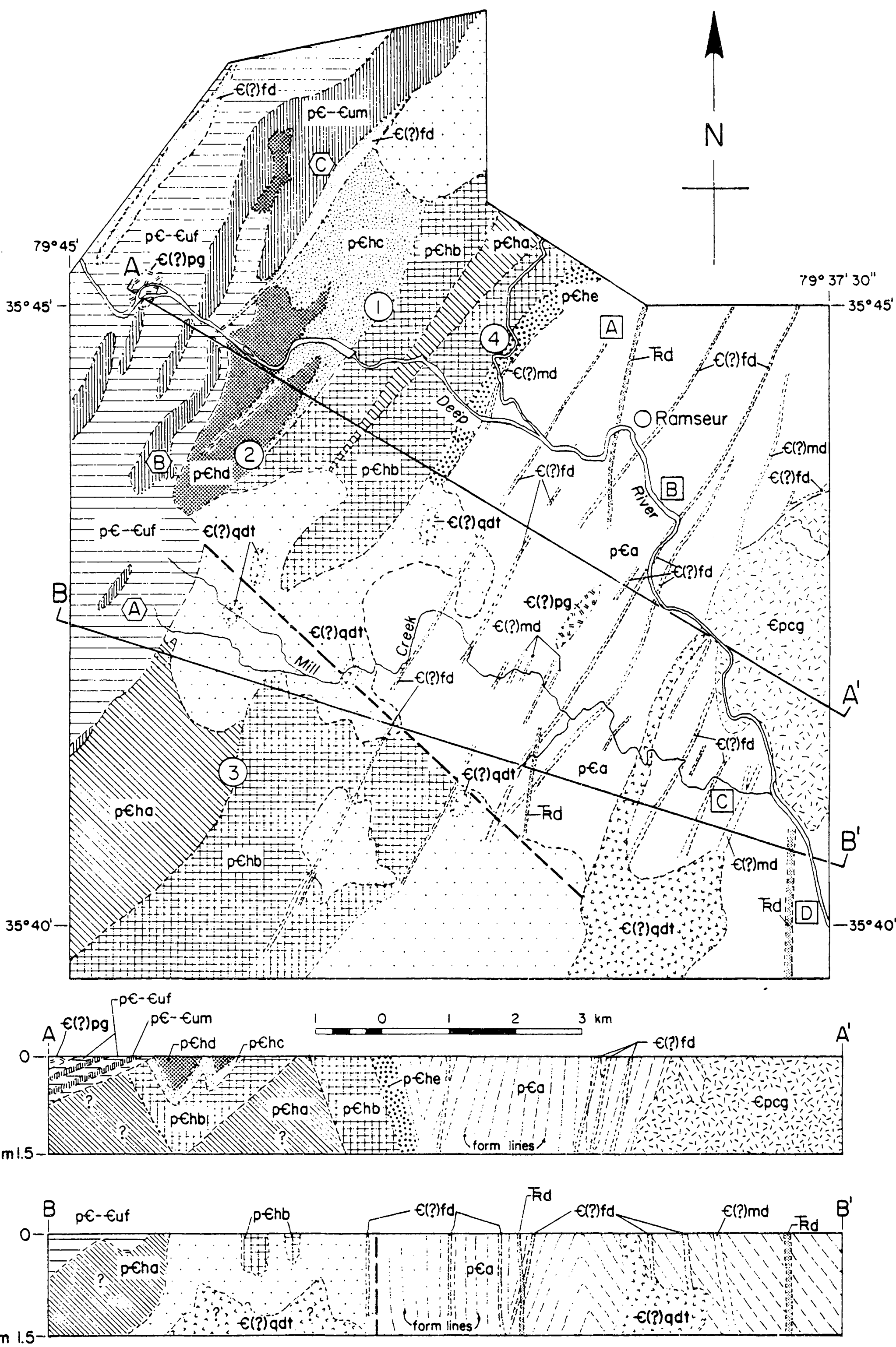


Figure 2 : Generalized geologic map and cross section of the Ramseur area. Localities for stratigraphic sections incorporated in Figures 3, 4 and 5 are shown.

HYCO FORMATION

The Hyco Formation is composed of intermediate (andesitic to dacitic) lava flows, pyroclastic and volcaniclastic rocks. The formation strikes northeast and is exposed in the western half of the Ramseur Quadrangle (Fig. 2 and Plate 1). It is approximately 2000 meters thick and the base of the formation is not exposed in the study area. In the Ramseur area informal members herein are defined in the Hyco Formation and given letter designations. The complex interfingering, folding and paucity of bedded lithologies makes it difficult to discern a chronological order for the different members.

The Hyco Formation originally was named the Hyco Quartz Porphyry by Laney (1917) for its exposures near the Virginia-North Carolina border along the Hyco River. The protolith at this locality was believed to be largely felsic lava flows. Later work by Glover and Sinha (1973) and Kreisa (1980) revealed that the equivalent lithologies of the Hyco Quartz Porphyry included felsic, intermediate and mafic pyroclastic rocks and lava flows. Glover and Sinha (1973) included all lithologies of Laney's Hyco Quartz Porphyry in their map Unit II, Kreisa (1980) subsequently named it the Hyco formation. Mapping to the south of the Virgilina area by Wright (1974) and McConnell and Glover (1982) revealed the dominance of intermediate lithologies in Unit II near Durham, N.C. Therefore, it is apparent that intermediate lithologies increase along strike to the south. It is proposed in this report that the oldest mapped units in the Ramseur quadrangle are equivalent to the Hyco Formation of the Durham, N.C. area because of their lithologic similarity and position beneath a distinctive stratigraphic unit that is similar to Unit III, (Aaron Slate of Laney,1917) in the Virgilina sequence. Early reconnaissance mapping by Bain (1964) equated intermediate lithologies in the map area with the Efland Formation. In this report the name Efland Formation is not recognized because of the priority of the Hyco as first defined by Laney (1917).

The base of the Hyco Formation presently is undefined. Tobisch and Glover (1969,1971) and Glover and others (1971) observed that the Hyco Formation (Unit II) is gradational with amphibolite facies gneisses of the Charlotte Belt. A zircon age of 740 Ma. was obtained for Charlotte Belt gneisses (Glover and others, 1971) along the slate belt boundary. The textural and compositional similarities of both high and low metamorphic grade volcanic rocks suggested to them that the Charlotte Belt gneisses are equivalents of the Carolina slate belt volcanic sequence.

Kreisa (1980) assumed the upper contact with the overlying epiclastic-rich unit,the Aaron Formation (Unit III of Glover and Sinha, 1973) to be conformable. Recent mapping by Green and others (in press) and M.C. Newton (person. commun.,1981) suggests that an unconformity may separate the Aaron Formation from the Hyco Formation. This is indicated by the presence of intermittent conglomeratic units along the contact. In the Ramseur area the relation is equivocal because the contact is covered though conglomerate is locally present.

The Hyco formation is Late Precambrian in age as documented in the Virgilina area by a zircon age of 620±20 Ma. (Glover and Sinha, 1973) and the presence of Ediacarian fauna (Cloud and others,1976) near Durham, N.C..

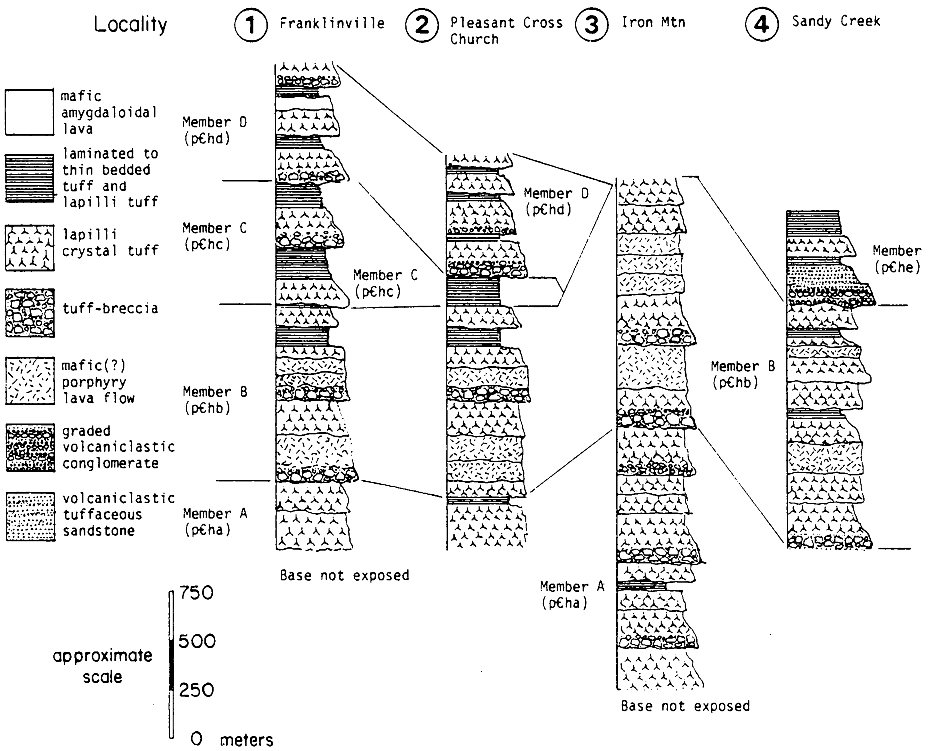
A summary of lithologic members of the Hyco Formation and correlation of units is provided in Fig 3.

Member A (p€ha)

Member A (Fig. 3) is composed of andesitic to dacitic pyroclastic rocks, which consist of tuff-breccia, lapilli tuff and crystal tuff. It is differentiated from previously described units by the presence of abundant broken crystals of plagioclase and subsidiary quartz. Nevertheless it is megascopically similar to Member B, though it contains a different clast component. Member A may grade laterally into Member B. The thickness, 1000 to 1500 m, of Member A is difficult to estimate because of the paucity of bedded lithologies.

Tuff-breccia consists of subangular to subrounded lithic fragments, as large as 0.5 m maximum dimension, in a matrix of lithic and vitric lapilli and broken crystals. Clasts include: andesite porphyry, laminated vitric tuff and granodiorite(?). These deposits often exhibit weak size grading into adjacent lapilli tuff.

Blue-gray dacitic lapilli crystal tuff is composed of vitric lapilli in a matrix of broken plagioclase and quartz crystals and devitrified ash. These units are massive, poorly sorted with only minor size grading of fragmental material. Additionally this pyroclastic unit contains subround to angular lithic clasts, less than 6 cm longest dimension, of



Member	Estimated thickness (meters)	Lithologic Description
E	Variable 300 to 500	Dark gray-green volcaniclastic conglomerate with intercalated volcaniclastic tuffaceous sandstone and tuff of mafic(?) composition. Conglomerate units are thick to medium bedded, horizontally stratified to massive, and contain clasts of both volcanic and plutonic rock. Intercalated tuffaceous sandstones are lithic and crystal rich, thin bedded to laminated and horizontally stratified. Lithic lapilli crystal tuff and tuff of felsic to mafic(?) composition are interbedded with the previous units.
D	500	Primarily mafic(?) dark gray-green to blue-green lapilli tuff and tuff-breccia, all of which contain ubiquitous plutonic clasts. The tuff-breccia varies from massive and ungraded to normally graded. Interbedded units, up to 10 m thick, consist of thin bedded to laminated, normally graded lapilli tuff and crystal tuff. Minor components include mafic(?) amygdaloidal lava and mafic lapilli tuff (approx. 30 m thick units).
C	Variable 100 to 700	Felsic light blue-gray to gray tuff-breccia with interbedded vitric tuff and lapilli crystal tuff. Tuffaceous units vary from massive and thick bedded to thin bedded and laminated, horizontally stratified lithologies. Lapilli tuff is normally graded, though composite units are doubly graded.
B	1000(?)	Lowest unit of this member consists of mafic(?) dark blue-gray conglomeratic breccias, 2 to 5 m thick, which contain subround to angular lithic clasts in a lapilli and crystal rich matrix. Overlying this unit are blue-gray to purplish-gray mafic(?) porphyry lava flows with intercalated lithic to pumiceous lapilli tuff and crystal tuff. Minor thin bedded to laminated tuff (5 to 10 m thick) is interbedded with the above lithologies.
A	1000(?)	Dominantly felsic(?), light blue-gray to medium blue-gray lapilli crystal tuff, tuff and tuff-breccia. Coarser size fraction pyroclastic rocks are massive, contain abundant lithic clasts and are either ungraded or normally graded. Interbedded tuffaceous units, approximately 3 to 5 m thick, are thin bedded to laminated and horizontally stratified. Minor light gray, felsic lithic lapilli crystal tuff and lapilli tuff, both less than 5 m thick, are intercalated with the previous lithologies.

Figure 3 : Lithologic members of the Hyco Formation. Vertical sections are only approximate since outcrop is limited. Members are indicated in their inferred stratigraphic order.

dacite porphyry, andesite porphyry, granodiorite(?) and laminated vitric tuff. Intercalated with the dacitic lapilli crystal tuff are thin bedded to laminated dacitic crystal tuff and vitric tuff.

Locally intercalated within the intermediate units are light gray felsic (dacitic) pyroclastic rocks, which consist of massive lapilli crystal tuff and laminated vitric tuff. The lapilli crystal tuff contains pumice lapilli and vitric and lithic clasts in a matrix of broken quartz and plagioclase crystals and devitrified ash.

Depositional environment

The limited occurrence of bedded and graded lithologies, the poor sorting, and the large clast size suggest deposition of Member A near its source. Most of the fragmental material was probably entrained in pyroclastic flows. The random orientation of pumice and lithic fragments, predominance of dense lithic and vitric material, presence of minor laminated tuff beds between massive lapilli tuff and tuff-breccia suggests that Member A was deposited in a subaqueous environment. These units are similar to pyroclastic flows in the Ohanepecosh Formation described by Fiske (1963) and Fiske, Hopson and Waters (1963). The authors attributed these deposits to subaqueous phreatic eruptions.

Member B (p€hb)

Member B (Fig. 3) is composed of andesitic and minor dacitic pyroclastic rocks, andesitic lava flows and volcanic breccias and conglomerates. It is estimated to be less than 1000 m thick. The upper contact of Member B is demarcated by a change to a more siliceous dacitic pyroclastic rock.

The basal part of Member B consists of poorly sorted volcanic breccias and conglomerates. The breccias contain subrounded to angular clasts, as large as 20 cm maximum dimension, of tonalite, dacite porphyry, andesite porphyry, basalt and dacitic tuff. These clasts are floating in a matrix of broken crystals, ash and lithic lapilli. Conglomerates are differentiated from the breccias by rounding of clasts and dominance of andesite and basalt. Both units are less than 10 m thick.

Overlying the conglomerates are andesite to basalt porphyry lava flows. These units are medium blue gray to purplish gray and contain 20 to 30 percent plagioclase phenocrysts in an aphanitic matrix. Some lavas exhibit features suggestive of auto-brecciation in which units of disaggregated angular to rounded fragments of andesite porphyry are intercalated with the homogeneous lava flows.

Andesitic and dacitic lithic lapilli crystal tuff, crystal tuff and vitric tuff are intercalated with and overlie the lava flows. Pyroclastic rocks are massive, poorly sorted and reddish gray to blue gray in color and may grade upward into laminated to thin bedded, tuffaceous rocks.

Depositional environment

Some of the units in Member B may have been deposited in a subaqueous environment as inferred by the presence of normally graded, horizontally stratified, laminated to thin bedded tuff.

Intercalated breccias and conglomerates may represent debris flow deposits of confined channels. Both lithologies may have been deposited on the flanks of a subaerial to subaqueous volcanic edifice.

Andesitic lava flows are not pillowed, therefore their depositional environment is uncertain. The inclusion of oxidized units and debris in Member B indicates subaerial conditions were possible. Nevertheless, welded pyroclastic units were not observed.

Member C (p€hc)

Member C (Fig. 3) consists of dacitic(?), pumiceous lapilli crystal tuff, tuff-breccia and vitric tuff. Interbedded with the massive units are laminated to thin bedded, horizontally stratified, lapilli tuff, vitric tuff and crystal tuff. Member C is approximately 500 m thick along the Deep River but thins abruptly to the south where it is characterized by laminated to thin bedded vitric tuff and crystal vitric tuff. Soft sediment folding plus later tectonic folding of thin bedded tuffaceous rocks, which might serve as useful stratigraphic markers, makes it difficult to differentiate the oldest from youngest units of this member. The base(?) of Member C consists of light gray to greenish gray thin bedded to massive vitric tuff which interfingers laterally with a blue gray lapilli crystal tuff and tuff-breccia. The tuff-breccia is composed of dacitic crystal-rich pumice (6 to 15 cm long dimension), subround to subangular blocks of welded dacitic ash flow tuff (max. dimension of 1.0 m), clasts of flow layered dacite and laminated vitric tuff (max. dimension less than 15 cm). All clasts are contained in a matrix of dacitic pumice, broken crystals of magnetite(?), plagioclase and quartz.

Adjacent to the tuff-breccia is a sequence of blue-gray lapilli crystal tuff and vitric tuff which is thick bedded to laminated. Some of these units are doubly graded and normally graded. Fiske and Matsuda (1964) define double grading in a subaqueous pyroclastic unit as the overall normal grading of one composite flow unit in which each individual bed or laminae within that composite unit is normally graded. The lapilli crystal tuff often contains rafted blocks (dimensions of 1.0 m X 0.25 m) of laminated vitric tuff which are derived from earlier deposited units in Member B.

Depositional environment

The dominance of pyroclastic debris, which varies from massive to delicately laminated, normally to doubly graded and the presence of soft sediment deformation structures strongly suggests that Member B was deposited in a subaqueous environment. Fiske and Matsuda (1964) attributed doubly graded pyroclastic deposits in the Tokiwa Formation, which is similar to those of this study, to subaqueous phreatic eruptions. Pyroclastic material entrained in the subaqueous eruption column is deposited in close proximity to the vent site. Unstable accumulations of this material may then be transported away from the vent site by turbidity currents into the surrounding basin. Higher density water saturated pumice, vitric and lithic debris form the base of the flows, whereas lower density ash is deposited in a series of thin beds, which are analogous to the products of low density turbidity currents (Fiske and Matsuda, 1964). In Member C, the inclusion of coarse lithic debris in the subaqueous pyroclastic flows, indicates deposition of material proximal to the vent site.

Member D (p€hd)

Pyroclastic rocks comprise the major proportion of member D (Fig. 3). They consist of andesitic to basaltic(?) tuff-breccia, lapilli tuff and crystal tuff. A distinctive feature of these units is the presence of ubiquitous plutonic clasts. Locally Member D is approximately 500 meters thick and may be interbedded with Member C.

Andesitic blue-gray to greenish-gray tuff-breccia, lapillistone and lapilli tuff occur in massive, ungraded poorly sorted deposits approximately 10 to 20 m thick. Approximately fifty percent of the fragmental component includes subangular to subround clasts as much as 20 cm maximum dimension, of dacitic crystal-rich pumice, quartz diorite(?) to tonalite(?), amygdaloidal basalt or andesite, quartz arenite, dacite porphyry and some basaltic bombs(?). The clasts are contained in a matrix of broken plagioclase crystals, devitrified ash and long tube pumice lapilli.

Interbedded with the andesitic rocks are 10 to 15 m thick units of dacitic(?) lapilli crystal tuff and crystal tuff. These units are invariably thin bedded to laminated and normally graded.

A variant which is more siliceous than the previously described units and variably distributed is a dacitic lapilli crystal tuff which contains vitric lapilli, broken plagioclase crystals and abundant lithic dioritic clasts. This unit is massive and approximately 30 to 50 m thick. Size grading is nonexistent and sorting is poor.

Amygdaloidal basalts, which are minor in occurrence in Member D are dark green to greenish-gray, massive and contain quartz amygdales 1 cm in diameter. Intercalated with these flows is basaltic(?) lapilli tuff which contains lithic fragments of dacite(?) and basalt porphyry in a matrix of saussuritized plagioclase and devitrified ash.

Depositional environment

Member D was probably deposited in a subaqueous environment. Observations supporting this conclusion include: normal grading in pyroclastic rocks from lithic lapilli tuff to horizontally stratified thin bedded to laminated crystal tuff and vitric tuff, lack of welding in the units and the dominance of dense lithic and crystal rich material minus pumiceous material.

Pumice that is present ,when viewed in polished slabs, is identical to long tube pumice lapilli as described by Fiske (1969). Long tube pumice lapilli would preferentially be incorporated in subaqueous pyroclastic flows because the long interconnected gas filled cavities in the pumice results in its rapid saturation with water and subsequent deposition. Conversely, bubble wall pumice with non-interconnected gas cavities would float and not be incorporated in a subaqueous pyroclastic flow (Fiske, 1969).

Water depths for deposition of the rock units in Member D were probably no greater than 800 m as indicated by the presence of intercalated amygdaloidal basalts which are not pillowed. Moore (1965) suggests that at depths greater than 800 m vesicles in basalts do not form because of excess hydrostatic pressure. Nevertheless vesicle formation may occur at variable depths depending on the vapor content of the basaltic magma.

The large size of lithic lapilli plus great abundance of massive deposits of tuff-breccia and lapilli tuff suggest close proximity to a subaqueous vent site. The inclusion of subvolcanic plutonic clasts and rare quartz arenite(?) suggests the eruption column entrained accidental material from a presently unexposed terrane. Plutonic clasts may represent cognate xenoliths ejected from the magma chamber.

Member E (p€he)

Member E (Fig 3.) is represented by a sequence of volcaniclastic conglomerate, lithic crystal-rich arenite and tuffaceous siltstone. Intercalated with the sediments are dacitic lapilli crystal tuff and vitric tuff. Member E is of limited areal extent in the north central part of the Ramseur quadrangle east of Franklinville, N.C. (Fig. 2) and is approx. 300 m thick.

The volcaniclastic conglomerate is clast supported, thick to medium bedded and exhibits weakly developed horizontal stratification. Clasts which are subrounded to angular include: dacite porphyry, andesite porphyry, dacitic welded tuff, andesitic to dacitic crystal tuff and lapilli tuff, laminated vitric tuff, vein quartz and granodiorite(?). Maximum clast size does not usually exceed 15 cm. Normal size grading is almost nonexistent in the conglomerate while overall sorting is poor.

Interbedded with the conglomerate are horizontally stratified, thinly bedded lithic feldspathic arenites. The arenite contains lithic and pumice lapilli, and broken plagioclase, quartz and magnetite crystals in a matrix of now recrystallised ash. Composite units consist of normally graded arenite capped by thinly bedded to laminated tuffaceous siltstone.

Blue-gray dacitic lapilli crystal tuff and vitric tuff are intercalated with the previous lithologies. The lapilli crystal tuff invariably forms massive units whereas the vitric tuff varies from laminated to massive. Lithic clasts in the lapilli crystal tuff include dacite porphyry and flow-layered dacite.

Depositional environment

Member E represents the erosional product of many of the previously described members of the Hyco Formation and may be transitional to the overlying epiclastic-rich sequence of the Aaron Formation. Some of the clastic component is derived from presently unmapped and unexposed units. The inclusion of oxidized fragments in the sediments indicates erosion of a subaerially-exposed source terrane.

The volcaniclastic conglomerates in Member E may be debris flows, whereas the normally graded arenites might represent finer grained lithologies deposited from concentrated turbulent sediment gravity flows (Middleton and Hampton, 1973). The relatively poor sorting and very immature nature of the sediments indicates that only minor reworking occurred prior to their deposition. The intercalation of horizontallly laminated tuffaceous siltstone suggests deposition of all of these units near or in an aqueous environment. Periodic volcanic activity results in the intercalation of pyroclastic rocks and sediments.

AARON FORMATION

The Aaron Formation (p€a) consists of lithic volcanic arenite, volcanic siltstone and argillite. Sporadically intercalated within all of these units are cobble to pebble rich conglomerate and vitric tuff. The contact between the Aaron and Hyco Formations is unexposed. In the Ramseur quadrangle the formation is approx. 1.5 km thick and is best exposed along the Deep River and Mill Creek (Fig. 2 and Plate 1).

The Aaron Formation originally was named the Aaron Slate by Laney (1917) for outcrops along Aaron Creek in Virginia. Laney (1917) considered that the Aaron Slate interfingered with the Virgilina Greenstone, a series of dominantly mafic pyroclastic rocks and lavas. Later work by Glover and Sinha (1973) equated the epiclastic-rich sequence with their Unit III, while the overlying mafic and felsic volcanics were included in Unit IV. Kreisa (1980) combined the lithologies of Unit III and Unit IV into the Aaron Formation. However it is felt by the author that because of distinct lithologic differences and the relative thicknesses of the units, Unit III and IV should not be combined. It is herein proposed that the dominantly epiclastic sequence be named the Aaron Formation while the overlying lithologies be included in a different formation, the Virgilina Formation. In the Ramseur area only the Aaron Formation is exposed.

The Aaron Formation is Late Precambrian to Early Cambrian(?) in age though fossils have not been found to assist in an age determination. Nevertheless the Aaron Formation is no younger than Late Precambrian/Early Cambrian in age as bracketed by the ages of the underlying Hyco Formation (620±20 Ma, Glover and Sinha, 1973) and younger plutonic intrusions into the Aaron (Roxboro metagranite, 575±20 Ma, Glover and Sinha, 1973 and the Parks Crossroads granodiorite, 566±46 Ma, Tingle, 1982).

An important feature of the Aaron Formation is the abundance of epiclastic rocks. Epiclastic as defined by Fisher (1966) refers to mechanically deposited sediments (gravel, sand and mud) consisting of weathered products of older rocks of any type. The Aaron is composed dominantly of volcanic detritus, but it does include non-volcanic material, such as quartz arenite and granodiorite clasts. This observation agrees with the previous work of Laney (1917), Bain (1964), Conley and Bain (1965), Glover and Sinha (1973) and Kreisa (1980).

Plutonic clasts probably indicate significant denudation of the source terrane to expose volcanic magma chambers. The origin of the quartz arenite however is problematical. Present work suggests that occurrences of quartzite are rare in the Carolina slate belt, excepting those in the Eastern slate belt as reported by Stanley and others (1977) and in the slate belt of South Carolina in the Richtex Formation (Secor and Snoke, 1978). Pyroclastic units of this study in the Hyco Formation do contain rare lithic clasts of quartz arenite which could subsequently be recycled during erosion of the Hyco. The presence of quartz arenite as a clastic component in the Aaron suggests that a source terrane of continental affinity is adjacent to or underlies the

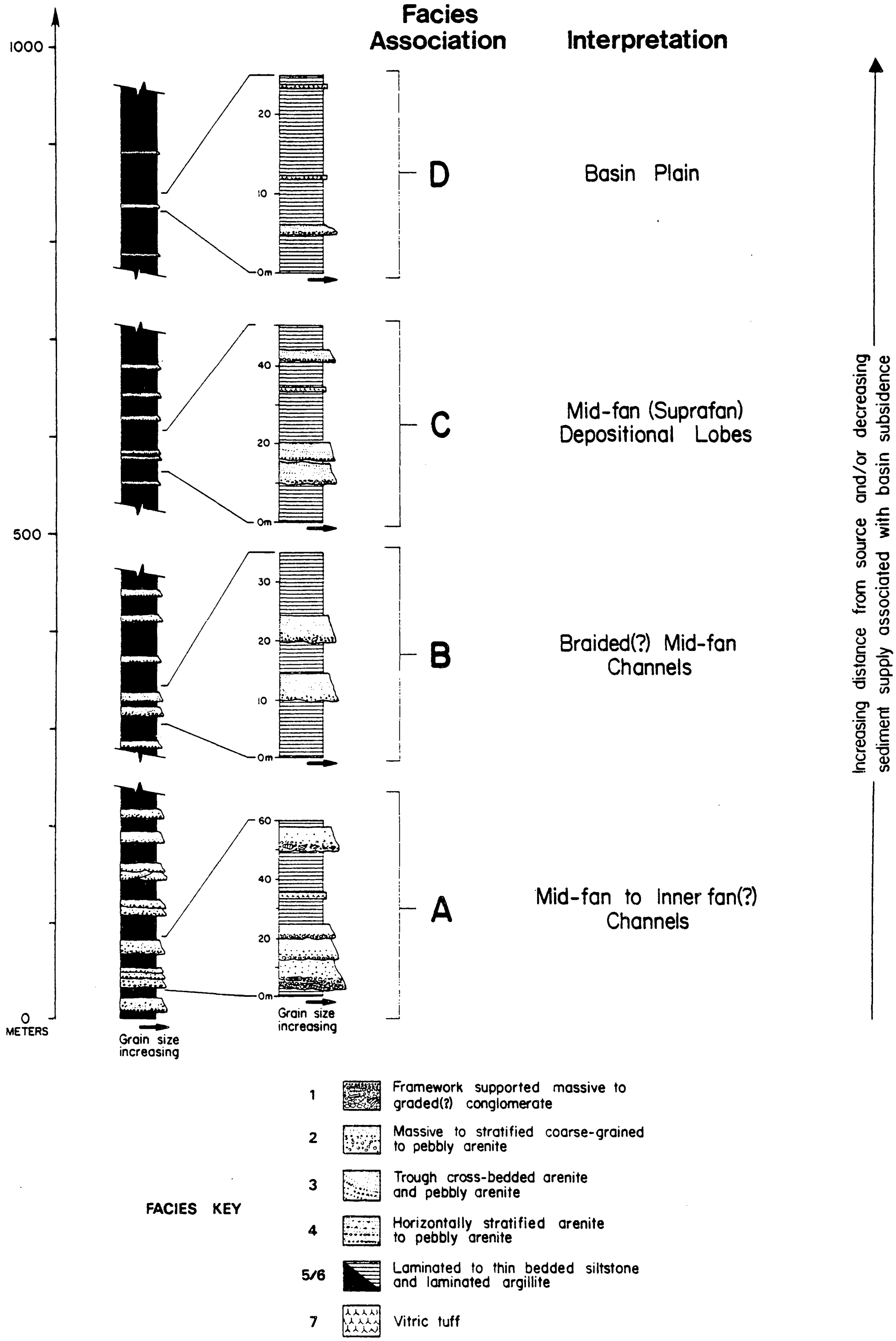
Carolina slate belt (Glover and Sinha, 1973).

Sedimentology

Detailed sedimentological studies in the Aaron Formation are not possible because of the paucity of extensive outcrop in the study area. Such features as bed thicknesses and geometry are difficult to discern. These limitations preclude characterizing the depositional environment in a rigorous manner. It is however possible to subdivide and document the occurrence of seven different facies and relate these in a general stratigraphic sequence as shown in Figure 4. The term facies is used strictly in an observational sense to describe features of a particular sedimentary rock such as grain size, internal sedimentary structures, color, bedding thicknesses and textures. In this report short descriptions are given for each facies.

These subdivisions may then be combined into facies associations (summarized in Fig. 4) which are defined as recurring groups of facies found in particular localities within the study area. These associations suggest the sequence of sedimentary lithologies are analogous to those of a coarse-grained submarine fan sequence described by Link and Nilsen (1979). A more detailed examination of the sedimentology of the Aaron Formation is in preparation.

Figure 4 : Facies and facies associations of the Aaron Formation. Insets from the larger column show in greater detail individual facies present within each association.



Facies Association
Interpretation
1000
500
0
METERS
Grain size increasing
D
Basin Plain
C
Mid-fan (Suprafan) Depositional Lobes
B
Braided(?) Mid-fan Channels
A
Mid-fan to Inner fan(?) Channels
Increasing distance from source and/or decreasing sediment supply associated with basin subsidence
FACIES KEY
1 Framework supported massive to graded(?) conglomerate
2 Massive to stratified coarse-grained to pebbly arenite
3 Trough cross-bedded arenite and pebbly arenite
4 Horizontally stratified arenite to pebbly arenite
5/6 Laminated to thin bedded siltstone and laminated argillite
7 Vitric tuff

Description of Facies

Facies 1: Massive to graded(?) conglomerate

Framework supported conglomerates are 1 to 3 m thick and contain subrounded to angular clasts (less than 5.0 cm max. dimension) which constitute approximately seventy percent of the rock. Clasts are contained in a matrix of siltstone, shale chips, and broken crystals of plagioclase, quartz and magnetite. The clast component includes intermediate volcanic rocks, granodiorite, quartz arenite and ripped-up siltstone and argillite.

Facies 2: Massive to stratified coarse-grained arenite

The coarse-grained to pebbly arenites consist of pebbly volcanic lithic arenite and feldspathic arenite which often contain concentrates of angular clasts of siltstone and argillite at the base of units. Thicknesses of sedimentation units may vary from one to tens of meters. Erosional bases for the sedimentation units are suggested by the presence of ripped-up siltstone and argillite clasts. Lithic clasts in the pebbly arenite are less than 5.0 cm in diameter and include intermediate to mafic volcanic rocks, quartz arenite and granodiorite.

Facies 3: Trough cross bedded pebbly arenite

Coarse to medium grained trough cross bedded lithic and feldspathic arenite contain trough sets up to 1 m in thickness.

Internal foresets in the troughs are 2 to 5 cm thick. Lower foresets of the troughs contain argillite and siltstone chips and subrounded volcanic pebbles. The base of these units is erosional as indicated by the inclusion of siltstone and argillite clasts.

Facies 4: Horizontally stratified arenite

Facies 4 consists of coarse to medium grained lithic and feldspathic arenites and pebbly arenites of similar composition. Composite units are tabular, 1 to 3 m thick, usually fine upward and may be exposed laterally in discontinuous outcrops for several hundred meters. Horizontal stratification is defined in these units by planar to gently undulating, 1 to 3 cm thick beds which are usually normally graded, although some may be reverse graded. Near the base of composite sedimentation units are subrounded volcanic pebbles and subangular ripped-up clasts of siltstone. An erosional contact defines the base of the composite sedimentation units and consists of a planar to gently inclined surface.

Facies 5: Laminated to thin bedded siltstone

Laminated to thin bedded siltstones are invariably intercalated with all of the previously described coarser grained sedimentation units. The siltstones are composed of subangular broken crystals of plagioclase and quartz and a finer grain-size fraction (formerly clays and glass(?)) which is now recrystallised. Thin beds of siltstone are 2 to 5 cm thick and are composed of laminae as thin as 1 mm. Scours, loading and flame structures are common on basal contacts. Internal sedimentary structures in the siltstones include ripples and horizontal stratification. Composite units are greater than 2 m thick.

Facies 6: Laminated argillite

Lithologies described as argillaceous may not consist exclusively of clay but may contain vitric ash and a minor silt-size fraction. Argillites consist of laminae from 1 to 5 mm thick which are usually normally graded. Microfaulting, with displacements of less than 0.5 cm are common in the argillaceous units. Composite units of argillite may be on the order of several hundred meters thick.

Facies 7: Vitric tuff

Thin to medium bedded units of vitric tuff infrequently are intercalated within the argillites and siltstones. Vitric tuff is differentiated from the argillite and siltstone because it is more siliceous, thicker bedded and more resistant to weathering. It may be either massive or laminated. Deposits of vitric tuff are attributed to periodic ash falls into water from distant volcanic eruptions.

Facies associations and depositional environment

The Aaron Formation is subdivided into facies associations A through D, which are summarized in Figure 4. Facies association A consists of facies 1) conglomerates, 2) massive to stratified pebbly arenite and intercalated 5) siltstones (Fig. 4). Association A, which is composed of fining-upward sequences of facies 1, 2 and 5, is considered to be analogous to inner fan(?) or mid-fan channels.

Facies 5 may represent overbank deposition adjacent to the braided channnels containing facies 1 and 2.

Association B (Fig. 4) consists of facies 2) massive to stratified pebbly arenite, 3) trough cross bedded arenite, 4) horizontally stratified arenite and 5) siltstone. There are only minor occurrences of facies 2 in association B. As in Association A, facies 2,3 and 4 may be analogous to braided mid-fan channels of Walker and Mutti (1973) and Walker (1978), although they overlie association A.

Association C contains facies 2) massive to stratified pebbly arenite, 4) horizontally stratified arenite capped by 5) siltstone and 6) argillite (Fig. 4). Randomly intercalated with the previous facies are facies 7) vitric tuff. Facies 2 and 4 are somewhat thinner and less abundant in association C compared to their ocurrence in associations A and B. Association C is interpreted to be similar to the mid-fan depositional lobes of Walker and Mutti (1973) and Walker (1978) because of the relative thinness of units (2 m) and their infrequent recurrence in the vertical sequence.

Association D includes minor occurrences of facies 2) pebbly arenites but is dominated by facies 5) siltstone, 6) laminated argillite and 7) vitric tuff (Fig. 4). Erosionally based facies 2 pebbly arenites fine upward over a distance of 20 cm to 1 m to facies 5 and 6. Facies 2 pebbly arenites may represent the marginal equivalents of the mid-fan depositional lobes of Association C whereas facies 5, 6 and 7 may be analogous to the basin plain deposits of Walker and Mutti (1973), Walker (1978) and Link and Nilsen (1979).

Conclusions

The apparent stacking of facies associations A through D in the vertical stratigraphic sequence suggests that the inferred submarine fan sequence of the Aaron Formation is retrogradational. The sedimentary sequence of the Aaron Formation is quite similar to the coarse grained submarine fan sediments of the Eocene Rocks Sandstone of California (Link and Nilsen, 1979) for the following reasons: 1) dominance of mid-fan thinning and fining-upward sequences, 2) rather abrupt change from mid-fan channels and depositional lobes to basin plain sediments and 3) apparent lack of the inner fan and outer fan facies of Walker and Mutti (1973).

In conclusion, the environment of deposition for the Aaron Formation sediments was probably a deep marine basin marginal to a formerly active volcanic arc. As suggested by Dickinson (1974), Dickinson and Suczek (1979) and Dickinson (1982) deposition of sediments of magmatic arc affinity may occur within either a fore-arc, intra-arc or marginal basin.

UWHARRIE FORMATION

The Uwharrie Formation is composed of felsic pyroclastic rocks and porphyritic, flow-layered spherulitic lavas. Intercalated with the felsic units are subordinate mafic pyroclastic rocks and amygdaloidal or pillowed lavas. These lithologies are aligned as a series of northeast striking interlayered units in the western one-third of the Ramseur Quadrangle (Fig. 2 and Plate 1). From observed field relations the Uwharrie Formation unconformably overlies the Hyco Formation. The maximum thickness of the Uwharrie in the study area is less than 600 m.

Bain (1964) and Conley and Bain (1965) first named the Uwharrie Formation for outcrops of felsic volcanic rocks in the vicinity of Uwharrie, N.C.. Subsequent work by Seiders (1978) and Seiders and Wright (1977) in the Asheboro, N.C. area resulted in detailed mapping and description, isotopic dating (Wright and Seiders, 1980) and chemical analysis (Seiders, 1978) of lithologies in the Uwharrie Formation. Seiders (1978) observed that the top of the Uwharrie interfingered with the overlying mudstones of the Tillery Formation.

The Uwharrie Formation is Late Precambrian(?) to Early Cambrian in age. An Rb-Sr whole rock age of 535±50 Ma was obtained by Hills and Butler(1969), and recalculated to 565±50 Ma by Fullagar (1971), from felsic rocks in the Uwharrie. Later U-Pb isotopic dating of zircons from felsic pyroclastic rocks yielded an age of 586±10 Ma (Wright and Seiders, 1980).

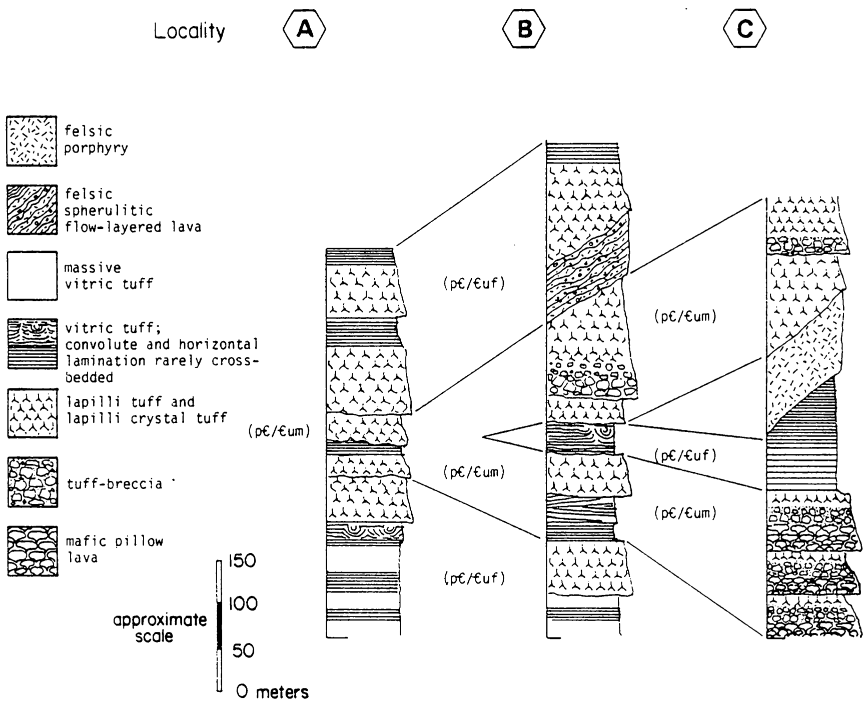
For simplicity lithologies are subdivided into felsic and mafic members which herein are named informally the Uwharrie mafic (p€-€umm) and felsic (p€-€ufm) members respectively. A summary of rock units and their probable stratigraphic arrangement is given in Fig 5.

Uwharrie Felsic Member (p€-€ufm)

Felsic, dacitic(?) to rhyodacitic(?), pyroclastic rocks include lapilli crystal tuff, tuff-breccia, crystal tuff and vitric tuff (Fig. 5). These units are light gray to medium gray in color and vary from massive to stratified. Interbedded with or intrusive into the pyroclastic rocks are felsic, porphyritic to spherulitic flow-layered lavas.

The lowermost exposed felsic lithology consists of massive vitric tuff and laminated to thin bedded tuff and crystal tuff (Fig. 5). Horizontal stratification is dominant, although convolute lamination and dewatering structures do occur. Intercalated within the tuffaceous rock is dark gray lapilli crystal tuff which is less than 10 m thick. Pumiceous lapilli, size less than 7 cm, constitute approximately fifty percent of the rock and are contained in a matrix of broken plagioclase and quartz crystals and devitrified ash. Flattening of the pumice imparts a pseudo-eutaxitic texture to the rock, reminiscent of welded ash flows as described by Ross and Smith (1960). However evidence for welding, such as vapor phase zones or vitrophyre are absent.

Overlying the lapilli crystal tuff is thin bedded to laminated vitric



Member	Estimated thickness (meters)	Lithologic Description
Felsic (p€/€uf)	Variable 50 to 450	Lowest exposed units consist of laminated to massive vitric tuff which is greenish-gray to medium gray in color. Internal sedimentary structures include: convolute and horizontal lamination plus diaparic structures. Overlying and intercalated with the above units is dark gray pumiceous lapilli crystal tuff which contains approx. forty percent pumice lapilli in a crystal rich matrix of plagioclase and quartz. The upper portion of the felsic member consists of thick to thin bedded, medium to light gray reworked lithic lapilli crystal tuff, which is massive to stratified. The lapilli tuff consists of angular to sub-rounded lithic and vitric clasts and pumice lapilli, contained in a matrix of approx. fifty percent angular to subrounded crystals of plagioclase and quartz. Intrusive(?) into the felsic pyroclastic/resedimented lithologies are felsic spherulitic flow-layered lavas(?) and porphyry dikes.
Mafic (p€/€um)	Variable 50 to 150	Composite units at base of mafic member consist of blue-gray to dark blue-green pillow lava and intercalated tuff-breccia and lapilli tuff. The complete package of repetitive units is less than 100 m thick. Interbedded with the pyroclastic rocks of the felsic member are blue-gray, thick bedded to massive mafic lapilli tuff and tuff-breccia, which may be normally to inversely graded. Lithic clasts which are less than 0.5 m max. dimension in the tuff-breccia include: felsic porphyry, gabbro(?), laminated vitric tuff and crystal tuff and microphaneritic felsic intrusive rock. Mafic vitric tuff which is intercalated with the previous rocks is thin bedded to laminated, horizontally stratified and rarely cross bedded. Amygdaloidal to massive lavas, which are not pillowed, are interlayered with the mafic lapilli tuff.

Figure 5 : Lithologic members of the Uwharrie Formation. Thicknesses and stratigraphic order as shown in vertical sections is approximate as outcrop is incomplete.

tuff, which is interbedded with 10 to 30 m thick light gray lithic lapilli crystal tuff and crystal tuff. The lithic lapilli crystal tuff contains approx. sixty percent plagioclase and quartz crystals (size less than 3 mm) whereas the remainder of the rock consists of subangular to subround lithic and vitric clasts, which are less than 3 cm in max. dimension. The clast component includes dacite porphyry, basalt(?), spherulites, flow-layered dacite, devitrified glass fragments and pumice lapilli. Horizontal stratification is common in thin bedded units of intercalated crystal tuff, which is composed of plagioclase and quartz crystals. The rounding of clasts and crystals suggests that resedimentation of fragmental material may have been possible, although it was probably minimal.

Siliceous dacitic tuff-breccia consists of poorly sorted subangular to angular lithic clasts, maximum dimension less than 15 cm, of flow-layered dacite porphyry in a matrix of devitrified ash. This unit is less than 5 m thick and is interbedded with the felsic pyroclastic rocks.

Dacitic(?) spherulitic to flow-layered lava is dark gray to black and is interbedded with and may be intrusive into the surrounding pyroclastic units (Fig. 5). Spherulites, as much as 2 cm in diameter, are elliptical to spherical in shape and flattened and stretched due to later tectonic deformation. Phenocrysts of plagioclase and quartz often serve as nucleating points for the spherulites. The glass matrix has since devitrified and now consists of microcrystalline plagioclase, quartz, biotite, white mica and sphene.

Depositional environment

The felsic volcaniclastic/pyroclastic rocks of the Uwharrie Formation were probably deposited in a subaqueous environment as indicated by the sedimentary structures present in tuffaceous units and the absence of welding in pumice rich units.

Doubly graded pyroclastic flows which are diagnostic of subaqueous conditions do not occur in the Uwharrie, an observation first substantiated by Seiders and Wright (1977). The lack of double grading sugests that an extensive water column may not have been present to result in significant sorting of the pyroclastic debris to yield separate size fractions for subsequent deposition as subaqueous pyroclastic flows. Another striking feature of many of the pyroclastic units of the Uwharrie Formation is that they consist dominantly of crystals and vitriclasts and only minor pumice lapilli. The limited occurrence of pumice may be attributed to: 1) the near complete crystallisation of the eruptive magma, in which vesiculated glass is not produced, or 2) the preferential removal of pumice in a water column by flotation.

Some lithic, vitric and crystal rich units resemble mass-flow volcaniclastic deposits described by Cas (1979) and Cas and others (1981) from the Lower Devonian Merrions Tuff and Kowmung Volcaniclastics of Australia. Cas (1979) equates the thick-bedded volcaniclastic arenites with the depositional products of high concentration density currents which may be analogous to a modified Bouma a division. Cas (1979) subdivides the a division into a1) basal, reverse-graded, massive division, a2) non-graded, massive division and a3) normal, continuous size-graded division. The sedimentation units in the Uwharrie are analogous to the a2 and a3 divisions which are capped by laminated to thin bedded tuffaceous rocks. It is inferred in this study that most volcaniclastic units of the Uwharrie are locally derived because of the inclusion of clasts of and close proximity to flow-layered felsic lavas or domes. The volcaniclastic sedimentation units may represent resedimented material derived from erosion of unconsolidated near vent pyroclastic rocks and/or decrepitation and disintegration of the felsic lavas or domes.

Flow-layered and spherulitic lavas may be consanguineous with the surrounding felsic pyroclastic rocks. This is inferred from proximity of the two rock types and the inclusion of components of the lavas in the pyroclastic rocks. It is probable that these lavas represent vent or near-vent facies.

Normally graded tuffaceous units may represent airfalls of ash into an aqueous environment. Interbedded pumiceous-rich lapilli crystal tuff with a pseudo-eutaxitic texture may have been deposited in a subaqueous pyroclastic flow. Alignment of pumice lapilli may be attributed to subsequent compaction within the unit. Sufficient heat may have been retained in the flow unit to yield a texture resulting from a minimum degree of welding (Mutti, 1965, Lowman and Bloxam, 1981). Nevertheless, Wright and Mutti (1981), in a re-examination of the submarine tuffs described by Mutti (1965), concluded that welding did not occur and that the pyroclastic deposits were emplaced in a cold state.

In conclusion convincing evidence for subaerial deposition of felsic lithologies in the Uwharrie Formation is lacking. However, water depths were probably shallow and some vent sites may have produced temporary islands.

Uwharrie Mafic Member (p€-€umm)

Mafic pyroclastic rocks include lapilli tuff, tuff-breccia and vitric tuff. Associated with the pyroclastic units are amygdaloidal and pillowed mafic lavas. Mafic lithologies are interbedded with the felsic rocks (Fig. 2, 5 and Plate 1) and form resistant pavements, ledges and low cliffs, as much as 15 m high. Maximum thickness of individual mafic units, does not exceed 40 m.

Pillow basalt, breccia and associated tuff comprise the lowest exposed units of the mafic member. Pillow basalts are less than 5 m thick, while maximum dimension of pillows does not exceed 15 cm. Intercalated with the pillow lava are massive, ungraded breccias of disaggregated pillows or lava, and lapilli tuff of similar composition usually less than 3 m thick. Repetitive sequences of pillow basalt, breccia and lapilli tuff are up to 75 m thick.

Above this sequence, basaltic lapilli tuff, vitric tuff and thin amygdaloidal lavas are prevalent. Dark blue-gray lapilli tuff consists of lithic and pumice lapilli contained in a matrix of broken plagioclase crystals, quartz and devitrified glass. Inverse grading of lapilli is common in thick bedded pyroclastic units. Rafted clasts, less than 15 cm in maximum dimension, of laminated tuff are contained in the lapilli tuff. Non-pillowed amygdaloidal basalt contains small (3 to 4 mm) elliptical to spherical vesicles now filled with chlorite, zoisite, quartz and albite.

Basaltic tuff-breccia consists of a variety of lithic clasts in a matrix of lapilli. Sorting is poor and size grading in these deposits is not evident. Clasts with maximum dimensions less than 0.5 m, are subrounded to angular and include: gabbro, felsic porphyry, microphaneritic felsic intrusive rock, laminated crystal tuff and felsic vitric tuff. The tuff-breccia is intercalated with the basaltic lapilli tuff.

Depositional environment

Available evidence points strongly to subaqueous deposition for the mafic rocks of the Uwharrie Formation. The presence of pillow lava, interbedded breccias and lapilli tuff provide unequivocal evidence for subaqueous deposition. Carlisle (1963) described similar lithologies from Quadra Island, British Columbia in which subaqueous basaltic volcanism generated interlayered sequences of pillow basalt, pillow-breccia, lapilli tuff and tuff. Pillow-breccia is attributed to slump and flow of pillows and matrix away from the vent site during extrusion, whereas lapilli tuff and tuff may be due to condensate from the turbulent cloud of suspended material produced by the flow (Carlisle, 1963). If a sufficient volume of water has access to the vent, violent phreatic explosions may occur, which could produce basaltic breccia and lapilli tuff (Lajoie, 1979). Padang and Richards (1959) as well as Carlisle (1963) suggest that eruptions in water shallower than 500 m yields ejecta and steam expelled to considerable heights above sea level, abundant floating pumice, and the appearance of ephemeral islands. One may envisage that subaqueous basaltic eruptions were the dominant mechanism for producing both the pillow basalts and mafic pyroclastic rocks of the Uwharrie Formation. Intensity of the eruptions may have varied, the more violent ones yielding pyroclastic debris. Nevertheless water depths probably did not exceed 800 m, because of the presence of amygdaloidal basalts. Formation of vesicles in the basalt would be suppressed by excess hydrostatic pressure at much greater depths (Moore, 1965). Nevertheless vesicle formation is contingent upon the vapor pressure of the basaltic magma, which might result in vesicle formation at variable depths.

Inverse size grading is common in the mafic pyroclastic rocks of the Uwharrie Formation but these units are not doubly graded like the subaqueous pyroclastic flows of the Tokiwa Formation (Fiske and Matsuda, 1964). In felsic subaerial ignimbrites, dense lithic clasts are normally graded, whereas pumiceous debris is inversely graded (Sparks, 1975, Lajoie, 1979). Similar grading may also occur in subaqueous pyroclastic flows. Since basaltic eruptions would have a tendency to produce less pumiceous material, their eruptive products might be more analogous to grain flows than ignimbrites. In grain flows inverse grading is attributed to grain to grain interaction during the flow and/or kinetic sieving during waning movement of the flow (Middleton and Hampton, 1973).

Vitric tuff which contains low angle foreset crossbeds is somewhat unusual when compared to most units in the volcanic stratigraphy which contain no evidence of traction produced structures. The crossbedding may be attributed to subaqueous currents moulding essentially unconsolidated previously deposited tuffaceous material or low relief erosional and depositional surfaces produced by the migration of a turbulent overriding low concentration suspension cloud (Stow and Shanmugam, 1980).

INTRUSIVE ROCKS

Intrusive lithologies consist of mafic, intermediate and felsic dikes, sills and small stocks. These units are of probable Early Cambrian(?) to Jurassic age and are variably distributed throughout the Ramseur quadrangle (Fig. 2 and Plate 1). Igneous rocks are classified according to the system proposed by the IUGS Subcommission (Streckeisen, 1973,1979). All lithologies, excepting those of Mesozoic age, have been subject to greenschist facies regional metamorphism and variable degrees of deformation and alteration. None are so pervasively deformed as to have totally destroyed relict igneous textures and phases. Nonetheless, retrograde metamorphic mineral assemblages are common.

Chemical analyses of rocks in the study area are not available, although some lithologies are megascopically similar to those analysed by Seiders (1978) and Tingle (1982). Additionally, isotopic age dating is limited to the Parks Crossroads granodiorite stock in the adjoining Coleridge quadrangle (Rb-Sr whole rock), of which the western margin lies within the map area (Fig. 2 and Plate 1). A summary of age relationships and a brief description of intrusive lithologies are provided in Table 1.

Parks Crossroads biotite, hornblende(?) granodiorite

The Parks Crossroads granodiorite (Tingle, 1982) consists of a variety of compositional and petrographic phases. Its most common

Table 1: Age relationships and description of intrusive rocks.

LITHOLOGY	AGE	DESCRIPTION
Pyroxene diabase dikes	Triassic/ Jurassic	Dark gray to black microphaneritic rocks composed of plagioclase and pyroxene plus opaques
Pyroxene(?) gabbro sills	Cambrian(?)	Medium gray phaneritic to hypidiomorphic granular rocks composed of pyroxene (pseudomorphed by actinolite) and plagioclase.
Mafic porphyry dikes	Cambrian(?)	Dark greenish-gray to dark gray porphyritic dikes containing phenocrysts of plagioclase and pyroxene (pseudomorphed by actinolite) in an aphanitic matrix.
Felsic porphyry dikes	Cambrian(?)	Medium to dark gray porphyritic dikes containing phenocrysts of plagioclase + quartz ± perthitic alkali feldspar in an aphanitic glassy matrix.
Quartz diorite(?) and tonalite	Cambrian(?)	Medium gray to dark blue gray hypidiomorphic granular rocks composed of plagioclase + quartz + biotite ± amphibole or pyroxene (now replaced by actinolite and chlorite) ± opaque.
Parks Crossroads granodiorite	Early Cambrian	Variable composition phases include: Granite - light gray to pink microphaneritic hypidiomorphic granular rock composed of plagioclase + alkali feldspar + quartz + biotite. Granodiorite - light gray porphyritic to hypidiomorphic granular rock composed of plagioclase + quartz + alkali feldspar + biotite ± amphibole or pyroxene (now replaced by actinolite, chlorite and opaques). Diorite(?) or Gabbro(?) - dark gray-green hypidiomorphic granular rock containing plagioclase + quartz + amphibole or pyroxene (now replaced by actinolite, chlorite and opaques).

phase consists of a light gray phaneritic, hypidiomorphic granular granodiorite composed of subequant plagioclase and quartz, size less than 3 mm, with interstitial green biotite and chlorite (replacing original hornblende and pyroxene (?)) and opaques. Potassium feldspar (microcline) is found in interstitial aggregates between plagioclase and quartz and in aplitic veins cross-cutting the intrusion.

A light gray to pink granitic phase occurs on the western margin of the stock. It is a microphaneritic, hypidiomorphic granular biotite granite which consists of subequal plagioclase and potassium feldspar, with interstitial quartz and biotite.

A third phase consists of diorite(?) or gabbro which is composed of actinolite (originally pyroxene or amphibole), plagioclase (now sericitized and saussurtized) and interstitial quartz.

The margins of the Parks Crossroads granodiorite exhibit relatively sharp contacts with the enclosing country rock where exposed, although contact metamorphic effects are possible. This is suggested by the presence of a silicified zone, several hundred meters wide, separating the intrusion from the sediments of the Aaron Formation.

Depth levels for intrusion of the Parks Crossroads granodiorite are difficult to estimate. Presently no effusive volcanic rocks, excepting dikes of similar composition, are present. The limited occurrence of granophyric phases suggest that the intrusion was not surface breaking (i.e. subvolcanic magma chamber), but may have crystallised at shallow depths.

A tentative age for the Parks Crossroads granodiorite is Early

Cambrian. As mentioned previously, from Rb-Sr whole rock analyses, Tingle (1982) interpreted its age to be 566±46 Ma. It is probable that the other phases of the intrusion are of similar age.

Felsic porphyry dikes

Felsic porphyry dikes (dacite and rhyodacite (?)) are light blue gray to dark gray in color and contain phenocrysts of plagioclase (albite-oligoclase) + quartz + biotite (altered to chlorite) ±perthitic potassium feldspar, all of which are contained in an aphanitic recrystallised matrix. Texturally the rock is porphyritic hiatal with phenocrysts arranged in glomeroporphyritic clusters. Phenocrysts commonly served as nucleating points for spherulites in the groundmass of the dikes. Dikes in close proximity to the Parks Crossroads granodiorite usually contain abundant comblike granophyric intergrowths of alkali feldspar and quartz, which are concentrated around perthitic potassium feldspar and quartz phenocrysts. Other consanguineous phases associated with the porphyry dikes include porphyritic flow-layered lavas. Tentative classification of these lithologies indicates they are quartz keratophyres, although their protolith was probably dacite and rhyodacite.

The lateral extent of the dikes as discontinuous outcrops is less than 5 km and their width does not exceed 20 m. Field relations indicate that the felsic dikes postdate the intermediate volcanic rocks of the Hyco Formation, sedimentary rocks of the Aaron Formation and some of the older units in the Uwharrie Formation. The dikes may be Early Cambrian in age, which is equivalent to the ages reported for the Parks Crosssroads granodiorite and felsic rocks of the Uwharrie Formation.

Mafic porphyry dikes

Dikes of dark-green to dark-gray andesitic(?) basalt to basalt porphyry are variably distributed in the eastern quarter of the Ramseur area (Fig. 2 and Plate 1). Megascopically the dikes are porphyritic hiatal with phenocrysts of plagioclase (zoned) and actinolite (pseudomorphing pyroxene) contained in an intersertal to hyalopilitic matrix of microlites and glass, now epidote + actinolite + chlorite + albite + sphene + opaque. The dikes are less than 10 m wide, strike in a north-south to northeast-southwest direction and extend laterally for approx. 1 km. Field relations indicate that they cross cut the older lithologies and structures of the Hyco and Aaron Formations. Some of the mafic porphyries intrude and therefore postdate the Parks Crossroads granodiorite.

Pyroxene(?) gabbro sills

Gabbros are dark gray-green, hypidiomorphic granular to porphyritic, medium to coarse grained rocks. They are composed of plagioclase (heavily sericitized and saussuritized) and actinolite (pseudomorphing amphibole or pyroxene) with interstitial quartz, micas and opaques. Nevertheless, the mineral phases present are products of the regional metamorphism. The gabbro is exposed in two localities (Fig. 2 and Plate I) as seemingly concordant to bedding, tabular sills as much as 50 m thick. Lateral extent is less than 0.5 km.

Seiders (1978) and Seiders and Wright (1977) documented the occurrence of thick tabular gabbroic sills within the Tillery and Uwharrie Formations in the Asheboro area which are similar to those of this report. It is uncertain whether the sills are related to the mafic dikes, pyroclastic rocks and lava flows of the Uwharrie Formation.

Quartz diorite, tonalite and granodiorite

Quartz diorite or tonalite is a light-blue gray to gray, hypidiomorphic granular phaneritic to microphaneritic rock. It is composed of subhedral plagioclase, albite and oligoclase (size less than 3 mm), quartz, biotite, chlorite, actinolite and epidote. Micrograñophyre is limited in occurrence to the groundmass between subhedral plagioclase crystals. Primary igneous minerals, biotite, amphibole and pyroxene have been pseudomorphed by metamorphic biotite, actinolite and chlorite.

Invariably the quartz diorite to tonalite intrusions are exposed as resistant outcrops within zones of hydrothermal alteration and are aligned along a northwest trending zone (Fig. 2 and Plate 1). They comprise small irregularly distributed bodies less than 2500 sq.m in area. Contacts with the surrounding altered volcanic rocks may be sharp or gradational, as observed in one locality. It is probable that the hydrothermal alteration of the country rock may be attributed to these intrusions.

Porphyritic granodiorite occurs at the eastern margin of this trend of intrusive rocks. This lithology is gradational between porphyritic hiatal intrusive dacite and phaneritic hypidiomorphic granular tonalite or granodiorite. The porphyritic granodiorite consists of euhedral to subhedral plagioclase and quartz crystals which are less than 4 mm in size and are contained in an interstitial aggregate of subhedral, though tectonically fractured, microcline, quartz and biotite. As with the tonalitic lithologies this intrusion is adjacent to a zone of hydrothermal alteration and silicification. The transition from a porphyritic to phaneritic phase may be indicative of variable rates of crystallization of the intrusion at depth.

From observed field and map relations, it is probable that this series of intrusive rocks postdates deposition of both the Hyco and Aaron Formations. It is possible that they may be comagmatic if not the same age as the Parks Crossroads granodiorite. Some may be syn-volcanic to post volcanic magma chambers associated with the Hyco Formation. Isotopic age dating of these units may provide a more definitive answer.

Diabase dikes

Dark gray to black diabase is equigranular, microphaneritic and composed of plagioclase and pyroxene. The two dominant phases are intergrown in a subophitic, diabasic texture. Minor accessories inlude: quartz, apatite and magnetite. Pyroxenes may contain relict inclusions of olivine, while myremekitic intergrowths of plagioclase and quartz are minor in occurrence. Alteration, which is minor, consists of retrogression of clinopyroxene to chlorite and sericitization of plagioclase.

The diabase dikes are aligned in a north-south direction; are less than 30 m wide and have a lateral extent of less than 3 km (Fig. 2 and Plate 1). It is apparent because of the lack of extensive retrogressive metamorphic mineral assemblages and the orientation of the dikes counter to the dominant structural trends that they clearly postdate the surrounding volcanic lithologies. The dikes are probably of Triassic or Jurassic age.

STRUCTURE

The volcanic and sedimentary units of the Ramseur area have probably been subjected to two phases of deformation. The deformational events and related structural features are summarized in Table 2. A more detailed description of structural information is discussed under the ensuing headings of major deformational events.

D_1 Virgilina Deformation

The first structural episode in the study area is confined to the Hyco and Aaron Formations and may be equivalent to the Virgilina deformation of Glover and Sinha (1973). In the Ramseur area evidence for the Virgilina deformation is indicated by the truncation of the Hyco Formation at the contact with the Uwharrie Formation as well as distinct divergence in trend and orientation of map scale folds east of this contact. The discontinuity which occurs indicates a multiple deformation history would be necessary in the local area to explain the existing relationships of rock units. Additional reasons for this conclusion include lithologic similarity and stratigraphic position of the Hyco and Aaron Formations of this study and the correlative units of the Roxboro-Durham, N.C. area, Units II and III, which were folded and faulted during the ca. 600 Ma Virgilina deformation. The age of this deformation in the Roxboro-Durham area is bracketed in the time interval of 620 to 575 Ma (620 Ma age of felsic rocks at the top of Unit II and 575 Ma age of the Roxboro metagranite which intrudes Units II

Table 2: Chronology of structures and deformation events in the Ramseur area

DEFORMATION	FOLD GENERATION, TYPE AND ORIENTATION	WAVELENGTH (estimated)	TECTONIC FABRIC AND ORIENTATION	FAULTING	DUCTILE DEFORMATION ZONES (DDZ)	UNITS AFFECTED
D_1: Virgilina deformation (ca. 600 Ma, Glover and Sinha, 1973)	F_1- tight to close folds; approximate axial trace orientation N 40 to 52 E; axial planes overturned to NW or SE	2 to 3 km	None	Reverse(?) or lateral wrench faulting	None	Hyco and Aaron Formations
D_2: Taconic deformation (ca. 480 - 440 Ma, Kish and others, 1979)	F_2- close to open folds; approximate axial trace orientation N 20 to 40 E; axial planes upright or overturned to SE; also as inferred second order folds on limbs of larger F_1 and F_2 folds.	Variable: Macroscopic- 1 to 2 km Mesoscopic- 3 m to 20 cm	S_2- cleavage orientation N 35 to 45 E with dominant steep, >75° NW dip. Cleavage type- spaced anastamosing disjunctive to continuous rough or smooth.	Possible high angle reverse faults related to DDZ's.	Localized zones of extensive shortening, attenuation and recrystallisation of volcanic rock units associated with pre-existing hydrothermal alteration zones. Orientation- N 30 to 40 E Dimensions- Width: 100 m to ≈1 km Length: Max. ≈3 km	Hyco, Aaron and Uwharrie Formations
Late D_2(?)			S_3(?)- crenulated and microfolded S_2 localized in ductile deformation zones.			Hyco and Aaron Formations
Post D_2: Mesozoic to Recent(?)	None	------	None	Mesozoic Age extensional faulting facilitating the intrusion of diabase dikes. Recent(?) brittle faulting of deeply weathered units	None	Hyco, Aaron and Uwharrie Formations

and III; Glover and Sinha, 1973). In the Ramseur, N.C. area a post Virgilina deformation stock, the Parks Crossroads granodiorite (566 ±46 Ma, Tingle, 1982) intrudes the Aaron Formation. Present work in the study area suggests that cleavage formation and regional metamorphism did not accompany this deformation.

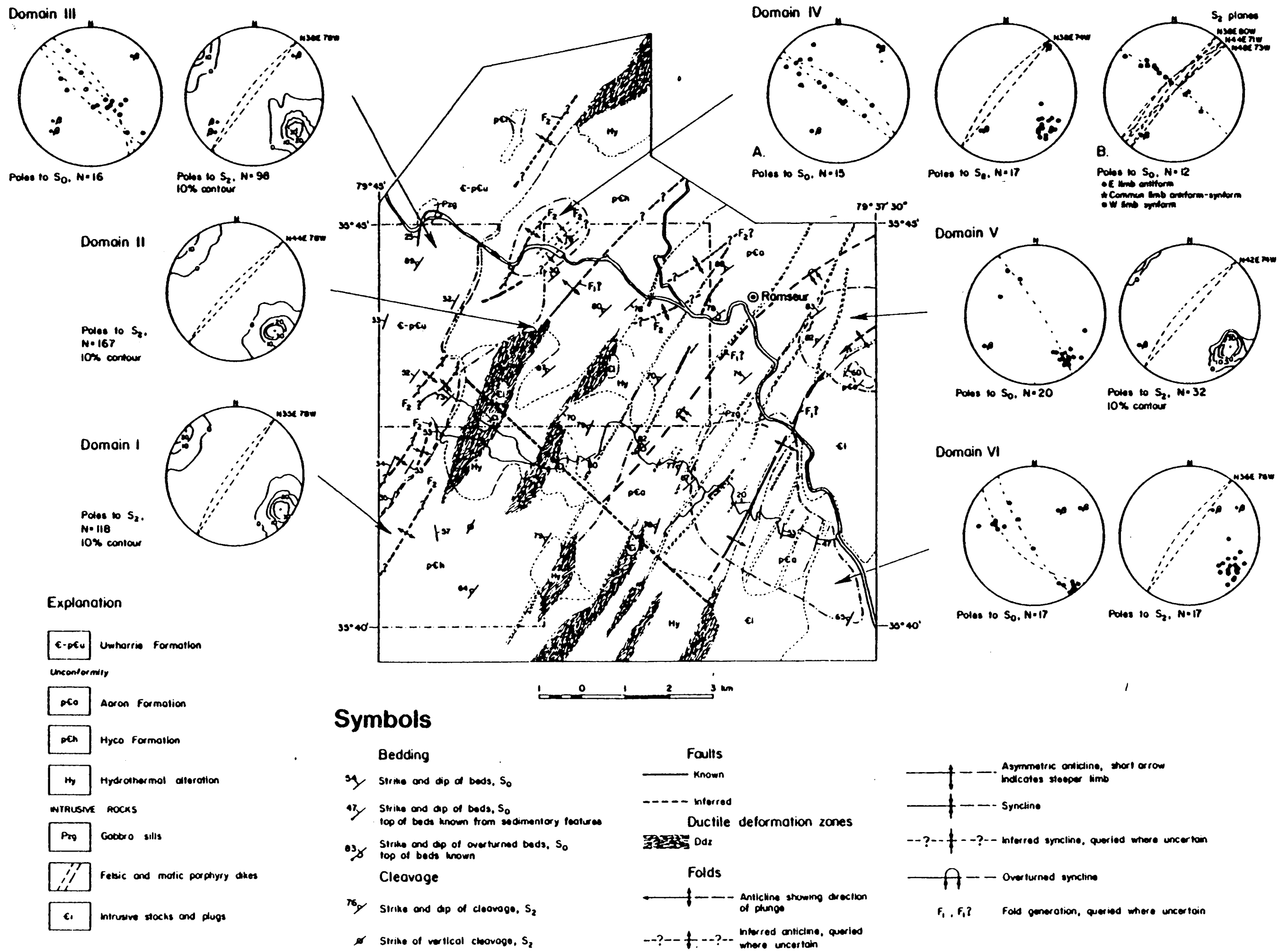
F_1 Folds

Map scale F_1 folds are oriented approximately N 40 to 52 E and are found in the eastern and north central parts of the map area (Fig. 6). These folds plunge less than 30 degrees to the northeast and southwest and have wavelengths of less than 3 km. The southeast limbs of the F_1 folds are commonly overturned to the southeast, as indicated by facing relationships of graded beds in the Hyco and Aaron Formations. The folds may be classified as tight to close folds (after Ramsay, 1967) with interlimb angles usually not exceeding 40 degrees. The map area F_1 folds are on the northwest limb of a northeast striking regional synclinorium which has been mapped in reconnaisance by Green and others (1982).

Faulting

A northwest trending fault zone offsets the stratigraphic units of the Aaron and Hyco Formations as shown in Figure 6. Similar apparent displacement of lithologic units was not observed in the Uwharrie Formation. Because of poor exposure the fault trace was not located in the field , although several other features indicate the presence of this zone. These features include: 1) termination of F_1

Figure 6 : Structural map of the Ramseur area illustrating major structural features including faults, folds and low grade ductile deformation zones. Structural domains comparing S_0 and S_2 , as well as S_2 over larger domains of the study area are shown. Refer to text for discussion of figure.



Domain III
Poles to S_0, N=16
Poles to S_2, N=98
10% contour
Domain II
Poles to S_2,
N=167
10% contour
Domain I
Poles to S_2,
N=118
10% contour
Domain IV
A.
Poles to S_0, N=15
Poles to S_2, N=17
B.
Poles to S_0, N=12
S_2 planes
Domain V
Poles to S_0, N=20
Poles to S_2, N=32
10% contour
Domain VI
Poles to S_0, N=17
Poles to S_2, N=17
79°45'
79° 37' 30"
35°45'
35°40'
Ramseur
€-p€u
p€a
p€h
Hy
Pzg
€i
0
1
2
3 km
Explanation
Uwharrie Formation
Unconformity
Aaron Formation
Hyco Formation
Hydrothermal alteration
INTRUSIVE ROCKS
Gabbro sills
Felsic and mafic porphyry dikes
Intrusive stocks and plugs
Symbols
Bedding
Strike and dip of beds, S_0
Strike and dip of beds, S_0 top of beds known from sedimentary features
Strike and dip of overturned beds, S_0 top of beds known
Cleavage
Strike and dip of cleavage, S_2
Strike of vertical cleavage, S_2
Faults
Known
Inferred
Ductile deformation zones
Ddz
Folds
Anticline showing direction of plunge
Inferred anticline, queried where uncertain
Asymmetric anticline, short arrow indicates steeper limb
Syncline
Inferred syncline, queried where uncertain
Overturned syncline
F_1, F_1?
Fold generation, queried where uncertain

folds in the Aaron Formation intersecting this zone, 2) hydrothermal alteration concentrated in close proximity to this trend and 3) alignment of a series of small plugs of granodiorite and tonalite along this zone.

Discussion and interpretation

Interpreted F_1 folds may have been tightened by the later Taconic deformation, though this inference may be tempered by the idea of localized variability in deformation. The tight folds in the Aaron Formation may be due to its close proximity to a rigid competent lithologic unit, the Parks Crossroads granodiorite. Additionally, limited outcrop may bias the interpretation of the data base. F_1 folds may be classified as transected folds (Powell's terminology, 1974), since the cleavage is not axial planar to the fold axes (domain VI, Fig. 6). This problem is addressed in the section on the Taconic deformation (D_2). Faulting may be concomitant with or postdate the initial folding event. In the study area, existing evidence suggests that the faulting postdates the early folding of the Hyco and Aaron Formations, because of the discontinuity in F_1 folds. The fault zone may serve as a fracture system for the localization of the small intrusive plugs and associated hydrothermal alteration.

D_2 Taconic Deformation

The Taconic deformation and related metamorphism affects all stratigraphic units in the map area, and postdates the Virgilina deformation. Associated with this deformation are the development of F_2 folds, a spaced anastomosing cleavage S_2, and greenschist facies metamorphism. Zones of selective ductile deformation, zones of extreme flattening and possible shearing(?) of the volcanic lithologies, are also attributed to this event.

F_2 Folds

F_2 folds are variably developed in the Hyco and Aaron Formations and consist of both megascopic short wavelength (tens of meters to centimeters) structures and macroscopic F_2 folds, which are oriented N 20 to 40 E and have wavelengths of less than 1 km (Fig. 6). Map scale F_2 folds in the study area within the Uwharrie Formation are open to close folds with interlimb angles greater than 45 degrees and wavelengths of 1 km. Within both the Hyco and Uwharrie Formations smaller scale class 1C, asymmetric, inclined, gently plunging F_2 folds, occur on the limbs of macroscopic F_2 and F_1 folds. In the adjoining Asheboro Quadrangle mapped by Seiders (1978) inferred F_2 folds of the Uwharrie Formation are moderate wavelength (greater than 2 km) open folds, whose axial traces are oriented approximately N 20 E.

S_2 Cleavage

The spaced anastamosing cleavage commonly developed in all litholgic units is herein defined as S_2. Previous authors, Glover and Sinha (1973) as well as Wright (1974) and McConnell and Glover (1982) have recognized that the pervasive cleavage, they labelled as S_1 , postdates the early F_1 folding of the Virgilina deformation and is associated with a later deformational event. Since the cleavage has been demonstrated to be axial planar to F_1 folds in the Virgilina area (Glover and Sinha, 1973) it may be logically labelled as S_2 produced during D_2.

Megascopic cleavage development is variable in intensity, depending on the lithology affected. Felsic intrusive rocks contain a poorly developed widely spaced stylolitic to anastamosing fabric (Powell's terminology, 1979) whereas felsic tuffs may contain no visible cleavage. Felsic lapilli tuff does however possess a moderately developed widely spaced anastomosing cleavage. The pelitic, arenaceous and conglomeratic units of the Aaron Formation exhibit a close to widely spaced anastamosing cleavage with a distinct refraction of the cleavage between fine and coarse grained lithologies. Intermediate rocks of the Hyco Formation exhibit a similar cleavage fabric in which pyroclastic fragmental material is rotated and aligned parallel to the cleavage. Hydrothermally altered rocks contain a closely spaced to continuous, smooth to rough cleavage.

The average strike of the S_2 cleavage varies from N 35 E to N 44 E (domains I & II, Fig. 6) and has a dominant steep northwest dip. From examining the stereoplots of domains I and II as shown in Figure 6, there is a distinct dextral bend in the S_2 cleavage of nine degrees, from south to north in the study area. The cleavage also defines a poorly developed nearly vertical fan (refer to stereoplots of S_2 in Fig. 6), though in mesoscopic folds a distinct cleavage fan is not evident. The cleavage is nearly axial planar to some mesoscopic and macroscopic F_2 folds in the Uwharrie Formation and Hyco Formation, Member C (domains III and IV A and B, Fig. 6). In the Aaron Formation varible transection of F_1 (?) folds is indicated by the failure of the β axis, as defined by poles to bedding S_0, to plot on the plane defined by the cleavage.

Ductile Deformation Zones

Zones of ductile deformation are confined to hydrothermally altered volcanic lithologies of the Hyco and Aaron Formations (Fig. 6). Transitions from ductilely deformed rocks to those which are mildly deformed are abrupt. Zones of ductile deformation in this study are defined as those litholgies which have undergone extreme flattening, attenuation, shortening and recrystallisation, in which relict or primary igneous, pyroclastic and sedimentary fabrics may be unrecognizable. These zones contain phyllosilicate minerals, quartz, sphene, calcite, and opaques. The micaceous minerals define a closely spaced anastamosing to continuous and smooth cleavage fabric. Ductile deformation zones strike N 30 to 40 E, extend laterally for up to 3 km and vary in width from 100 m to 1 km. Massive quartz veins and quartz-epidote-potassium feldspar veins are present within these zones, both of which are folded and aligned subparallel to the cleavage S_2.

Crenulated mesoscopic to microscopic S_3 fabrics are localized within the ductile deformation zones. The orientation of the small scale microfolds varies from perpendicular (N 40 to 50 W) to subparallel to the S_2 cleavage. In thin section it is evident that the crenulated fabrics have recrystallized in response to metamorphism. Also visible in the microfabric are porphyroblasts of albite and quartz which contain asymmetric pressure fringes (terminology of Simpson, 1982), suggesting some sense of shear movement in these zones. Nonetheless, lateral or vertical displacement which may occur in the ductile deformation zones is difficult to estimate because of limited outcrop and inability to trace distinct marker units across these zones.

Discussion and interpretation

The separation of Taconic and younger structures and fabrics from those attributed to the earlier Virgilina deformation is a fundamental problem encountered in the Carolina slate belt. The axial planes of F_2 folds where observed are subparallel or parallel to the cleavage S_2 whereas inferred F_1 folds are not always axial planar to the S_2 fabric. F_1 folds may be interpreted as transected folds thus indicating they may predate the Taconic folding and cleavage forming event. Transected folds are defined as folds in which the cleavage surface can be traced from one limb across the axial surface of the fold to the other limb (Powell, 1974). Powell (1974) and Borradaile (1978) have indicated that cleavage transection of fold axes does not necessarily imply that polyphase deformation has affected a particular geologic terrane. Fold transection may be a product of a coaxial or non-coaxial deformation in which the development of the cleavage relative to the timing of folding is either synchronous or asynchronous (Powell, 1974, Borradaile, 1978 and Gray, 1981).

Present mapping does not indicate the expected interference patterns in folds which might indicate a multiple deformation history in the study area. This factor may be complicated by the apparent near coaxiality of the two deformations. In the map pattern of large scale macroscopic folds there is a distinct divergence in the trends of folds in the Uwharrie Formation versus those in the Hyco and Aaron Formations. Additionally there is a difference in fold style and orientation between the two sequences of volcanic strata. This observation was first suggested by Conley and Bain (1965) in which they noted that the rocks east of the Uwharrie Formation, which now comprise the Hyco and Aaron Formations, were distinctly more deformed.

Zones of ductile deformation are probably inherited from the earlier fractures and fault systems related to the Virgilina deformation. Renewed deformation during the Taconic orogeny is concentrated along the previous zones of hydrothermal alteration. The hydrothermally altered lithologies, because of their earlier recrystallisation to clays and phyllosilicates, are probably not competent units and therefore rather easily deformed. The crenulated microfabrics present in these zones may be attributed to late semi-brittle or ductile movement along these zones (Platt and Vissers, 1980).

<u>Post Taconic Deformation</u>

The only deformation noted which postdates the Taconic orogeny is represented by younger northeast trending brittle faults in deeply weathered units of the Hyco and Aaron Formations (Fig. 6). Displacement on these normal or reverse faults is difficult to estimate because of the lack of lithologic control across the fault zone. Faults may be traced laterally for up to 1 km. Associated with the Mesozoic age continental rifting event are extensional fracture systems which facilitated the intrusion of pyroxene-diabase dikes which strike N 10 E to due north.

Conclusions

The inferred chronology of structures and deformation in the stratigraphic sequence suggests that a structural or stratigraphic discontinuity occurs along the contact between the Hyco and Uwharrie Formations. It is also probable that the differences in fold style in the Hyco and Aaron versus the Uwharrie Formation indicates the volcanic sequence in this part of the Carolina slate belt may have been subjected to polyphase deformation. The preference for polyphase versus single phase deformation for the volcanic sequence in the study area is indicated for the following reasons: 1) divergence of interpreted F_1 and F_2 fold trends, 2) transection of F_1 folds in the Aaron and Hyco Formation, 3) pre-Taconic faulting of the Hyco and Aaron Formation which is not observed in the overlying Uwharrie Formation and 4) zones of hydrothermal alteration which are ductilely deformed are confined to the Hyco and Aaron Formations. Similar alteration zones have not been reported in the Uwharrie Formation.

In this paper it is interpreted that an unconformity separates the

Uwharrie Formation from the underlying Hyco and Aaron Formations, based on the reasons stated above. The contact between the Uwharrie and Hyco Formation is not exposed, but can be located within 50 to 100 m. It is possible but not probable that a fault may separate the two formations, although this has not been observed.

METAMORPHISM

Pre M_1 Hydrothermal Alteration

Zones of hydrothermal alteration predate the regional metamorphism in the Ramseur area. These zones are contained exclusively within the Hyco and Aaron Formations and are spatially associated and concentric with the intrusion of pre-metamorphic (greater than 500 Ma) tonalitic to granodioritic plugs and stocks. The zones of alteration are equant to elongate in surface outcrop, approximately 2 to 6 sq. km in area and are distributed in the central and southern parts of the map area (Figure 2). Ridges such as Fox, Iron and Pilot Mountain define the zones of altered rock.

Altered rocks in outcrop vary from schistose blue-gray and white to massive pinkish-gray. Minerals present include: quartz, hematite, white mica, chlorite, pyrophyllite, andalusite, chloritoid, albite, calcite and pyrite. Schmidt (1982) has also reported the occurence of topaz, rutile and diaspore in the vicinity of Pilot Mountain on the southeast margin of the study area. Protoliths for the hydrothermal lithologies include intermediate pyroclastic rocks and lava flows of the Hyco Formation plus intermediate to felsic composition sedimentary rocks of the Aaron Formation.

In the Ramseur area lithologies within the alteration zones can be subdivided into those which are schistose or massive. Within each subdivision there are a variety of mineral assemblages present. These same subdivisions can be discerned in megascopic samples as well as in thin section. Mineral assemblages present in the schistose lithologies include:

1) white mica + quartz + chlorite + opaque + hematite

2) white mica ± pyrophyllite(?) + opaque

3) albite + sphene + chlorite + white mica + quartz + opaque ± calcite

Non-schistose, massive, granoblastic lithologies may include the following mineral assemblages:

1) chloritoid ± pyrophyllite + opaque + quartz + white mica

2) andalusite + quartz + white mica + sphene

3) andalusite + pyrophyllite + hematite

In the massive granoblastic lithologies relict cores of andalusite are corroded and altered on their margins to white mica. Chloritoid forms radiating stellate clusters intergrown with pyrophyllite in the granoblastic assemblage 1).

Quartz veins varying from a centimeter to meter in width are usually associated with the zones of hydrothermal alteration. Those crosscutting the regional schistosity are invariably folded and deformed.

It is probable that the zones of hydrothermal alteration are pre-metamorphic in origin as are some of the mineral assemblages, too. This is suggested for the following reasons: 1) observed retrogression of andalusite to white mica, 2) preservation of the relict, non-schistose, massive parts of these zones, 3) enclaves of non-hydrothermally altered regionally metamorphosed, intermediate volcanic rock within the zones and 4) deformation and reorientation of quartz veins originally associated with the hydrothermal alteration.

The genesis of the aluminous mineral assemblages in the Carolina slate belt may be difficult to infer (as pointed out by Sykes and Moody, 1978, in their study of the Hillsborough, N.C. deposit) because of the later recrystallisation caused by regional greenschist facies metamorphism. McDaniel (1976) suggested that the aluminous minerals present at the Glendon, N.C. deposit were re-equilibrated during the regional metamorphism but that the original deposits may have been generated by hot spring fumarolic systems. Circulating hot acidic ground water, associated with a shallow level magmatic heat source, results in extreme leaching and alteration of the pre-existing volcanic lithologies (Meyer and Hemley, 1967, Jahns and Lance, 1950). Fe, Mg, Ca and Na are removed from the host rock which is subsequently recrystallised to quartz, kaolinite, sericite and adularia (McDaniel, 1976). Meyer and Hemley (1967) indicate that hydrothermal alteration may be variable in intensity and can be described in terms of silicification, sericitization and intermediate to advanced argillic alteration. Associated with the varying degrees of alteration are several different mineral assemblages other than those listed by McDaniel for the Glendon, N.C. deposit, such as: andalusite, topaz, diaspore, alunite, dickite and pyrophyllite. Hildebrand (1961 a, b) has observed the occurrence of these minerals in Tertiary(?) age hydrothermal greisen in Puerto Rico.

Later regional metamorphism, no doubt has overprinted and produced new aluminous mineral assemblages including chloritoid and pyrophyllite within these zones in the Carolina slate belt as suggested by Stuckey (1925, 1928), Spence (1975), McDaniel (1976), Sykes and Moody (1978) and this study.

Conclusions

It is therefore inferred from examination of textural features in thin section and megascopic samples that the hydrothermal zones are pre-metamorphic in origin as first suggested by Stuckey (1925). However, clays and other minerals which may have been present are now recrystallized to phyllosilicate assemblages typical of regional greenschist facies metamorphism. The transition from highly schistose lithologies to massive relict ones indicates deformation and recrystallization was not pervasive. It is probable too, that some of the aluminous minerals present in the massive zones were stable during the regional metamorphism.

M_1 Greenschist facies metamorphism

Generally all lithologies of the Carolina slate belt were metamorphosed to greenschist facies. However, incomplete re-equilibration of minerals is common in the Ramseur area and is reflected in the presence of relict minerals, such as andalusite and topaz plus phenocrysts of calcic plagioclase (andesine), potassium feldspar, and biotite.

In the volcanic rocks examined in this study, compositional variations in the protoliths, felsic, intermediate, and mafic, results in the various mineral assemblages which are listed as follows:

1) Felsic: albite + quartz + chlorite ± biotite + epidote-clinozoisite + sphene + white mica + opaque + leucoxene ± calcite ± spessartine garnet

2) Intermediate: albite + chlorite ± biotite + sphene + epidote ± opaque + quartz + leucoxene + white mica ± calcite

3) Mafic: albite + chlorite ± biotite + sphene + epidote-zoisite ± actinolite + quartz + hematite + calcite

The dominantly epiclastic lithologies of the Aaron Formation contain similar metamorphic mineral asemblages though with minor variations, which are listed as follows:

1) Argillite: chlorite + white mica + quartz + epidote + albite + sphene + calcite

2) Siltstone: chlorite + quartz + white mica + epidote ± biotite + albite + sphene + calcite

3) Arenite: albite + quartz + chlorite + white mica ± biotite + epidote + sphene + opaque ± calcite

The metamorphism in the Ramseur area is interpreted to be retrogressive because of the high temperature mineralogy of the volcanic protoliths. Primary igneous fabrics in most lithologies are preserved. Indicators of retrogression include: 1) albitization and epidotization of calcic plagioclase, 2) chloritization of mafic minerals and glass, 3) pseudomorphing of pyroxene by actinolite, 4) alteration of opaque minerals titanomagnetite and ilmenite to leucoxene plus sphene and 5) alteration of potassium feldspar to sericite. The metamorphism has been pervasive enough to result in the recrystallization of matrix material within all lithologies to chlorite, muscovite, quartz, sphene, epidote, ± biotite and albite.

Phyllosilicate minerals in the volcanic plus sedimentary lithologies define a spaced anastamosing disjunctive to rough cleavage (Powell's terminology, 1979) attributed to tectonic deformation and metamorphic recrystallization. In the Aaron Formation, pelitic lithologies commonly contain biotite porphyroblasts which are randomly oriented in a fine-grained aligned fabric of phengite(?), chlorite , epidote and quartz. Porphyroblasts of epidote, chlorite and actinolite in other volcanic lithologies exhibit similar random orientations. Groundmass quartz is recrystallized into polygonized strain free aggregates. This suggests that thermal recrystallization of the phyllosilicates and other minerals may have occurred in a hydrostatic stress field after initial deformation. This is similar to an example described by Powell (1970) in the Siamo Slate of Michigan.

Distinct isograds within the Ramseur area are difficult to define because of the random appearance of key indicator minerals of metamorphic grade, such as biotite and chlorite. In the Uwharrie Formation on the western margin of the study area, biotite is common, whereas in the Hyco and Aaron Formations its occurrence is random. Biotite is present in most intrusive rocks in the study area. It is inferred as suggested by Miyashiro (1973) that variances in composition (estimated from petrography) of the volcanic rocks may be controlling the occurrence of particular minerals. Thus metamorphic grade may not vary significantly across the study area.

Post Taconic retrogression of metamorphic minerals is indicated in several rock types by the replacement of biotite by chlorite, especially along the margins and cleavage lamellae of individual crystals. This may be similar to retrograde features described by Briggs and others

(1978) in the Roxboro metagranite, which the authors attributed to a later regional metamorphic event.

The timing of regional metamorphism is uncertain in the study area, because no mineral isotopic age dating has been performed. An age of 483±15 Ma was obtained by Kish and others (1979) from whole-rock K-Ar dating of fine grained metasediments from the younger Albemarle Group (Stromquist and Sundelius, 1969) of the Carolina slate belt. Black (1977) determined a whole-rock Rb-Sr isochron age of 459±5 Ma from Late Precambrian metadacite volcanic rocks (probably equivalents of the Hyco Formation in the vicinity of Hillsborough, N.C.). The relative similarity in metamorphic ages from different parts of the Carolina slate belt implies that the Early to Middle Ordovician (Taconic) metamorphism was regional in extent within the slate belt (Glover and others, in press).

SUMMARY AND DISCUSSION

To recapitulate, the major map units as presented in the text include the Hyco, Aaron and Uwharrie Formations. The Hyco Formation is composed of intermediate(?) to felsic, volcaniclastic and pyroclastic rocks and intercalated lava flows. Volcanic units in the Hyco may record transient subaqueous to subaerial conditions of deposition. Overlying the Hyco with apparent erosional disconformity is the Aaron Formation which is analogous to a retrogradational submarine fan sequence. The Aaron is derived from erosion of the Hyco Formation, plutonic rocks and quartz arenite. The overlying Uwharrie Formation is a bimodal (felsic/mafic) dominantly felsic sequence of volcaniclastic and pyroclastic rocks with intercalated lava flows and dikes. The depositional environment for the Uwharrie is inferred to be exclusively subaqueous.

The ensuing topical discussion which includes: 1)correlation of lithostratigraphic units in light of an unconformity in the slate belt, 2) a tectonic evolutionary scenario for the central N.C. area and 3) the Virgilina deformation ; are designed to apply the conclusions of the smaller scale study area in the context and construction of an expanded regional geologic overview for the Carolina slate belt.

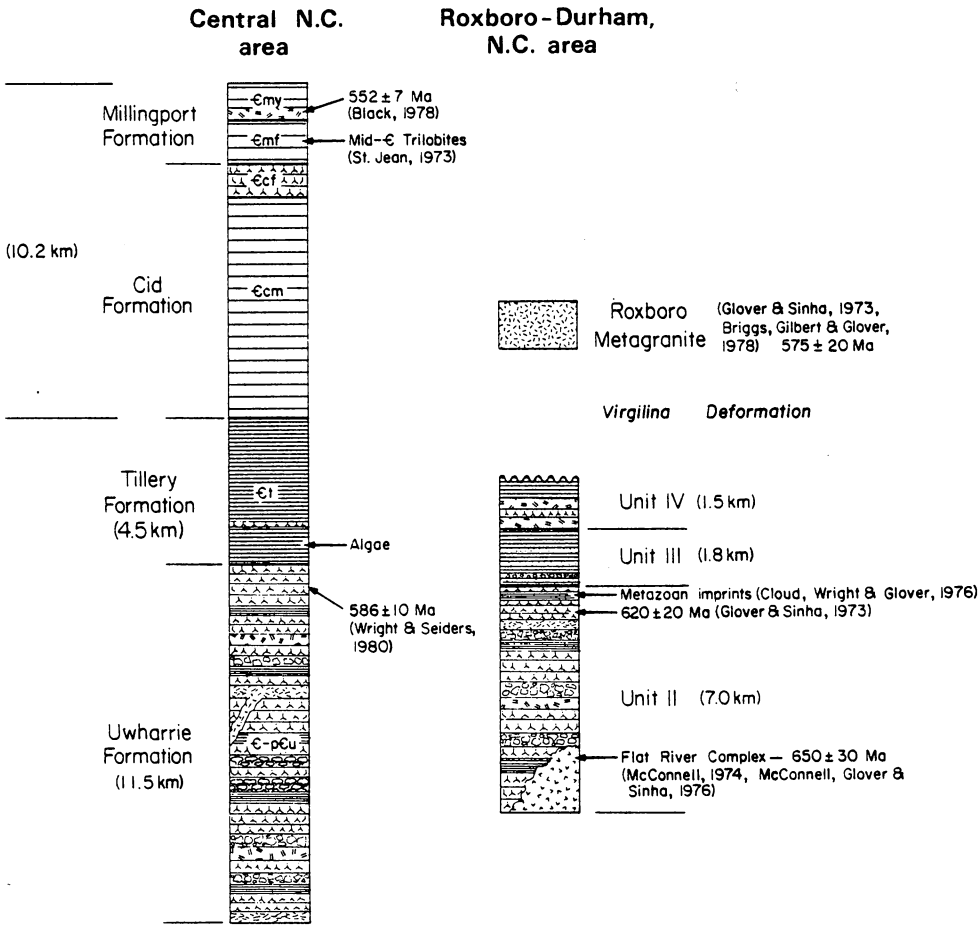
Unconformity in the Carolina slate belt

From the geologic mapping of this study it is now possible to demonstrate that the lithologic equivalents of the Virgilina sequence, Units II and III of Glover and Sinha (1973), extend into the central North Carolina area. The data from this study indicates that the Uwharrie Formation unconformably overlies the Hyco and is inferred to also overly the Aaron based on intrusive relationships which are discussed in the next paragraphs. Lithologic differences which support this interpretation include: 1) the Uwharrie Formation is a bimodal (felsic-mafic) dominantly felsic volcanic sequence whereas the Hyco Formation consists of intermediate volcanic rocks, 2) the Uwharrie Formation contains no detritus of non-volcanic origin (Seiders and Wright, 1977, Wright and Seiders, 1980) whereas the Hyco and Aaron Formations both contain lithic fragments of quartz arenite, tonalite and granodiorite (Glover and Sinha, 1973, M.C. Newton, person. commun. 1982, and this study) and 3) the clastic component of the sediments of the Aaron Formation indicates derivation from the Hyco Formation and not the Uwharrie.

Structural features and intrusive relations which suggest the presence of an unconformity include: 1) Divergence in trend of map scale F and F fold axes, 2) transection of F folds in the older Virgilina sequence, 3) faulting in the Hyco and Aaron Formations which cannot be traced into the adjoining Uwharrie Formation and 4) intrusion of felsic dikes, equivalent to those in the Uwharrie Formation, which crosscut the folds in the Aaron Formation.

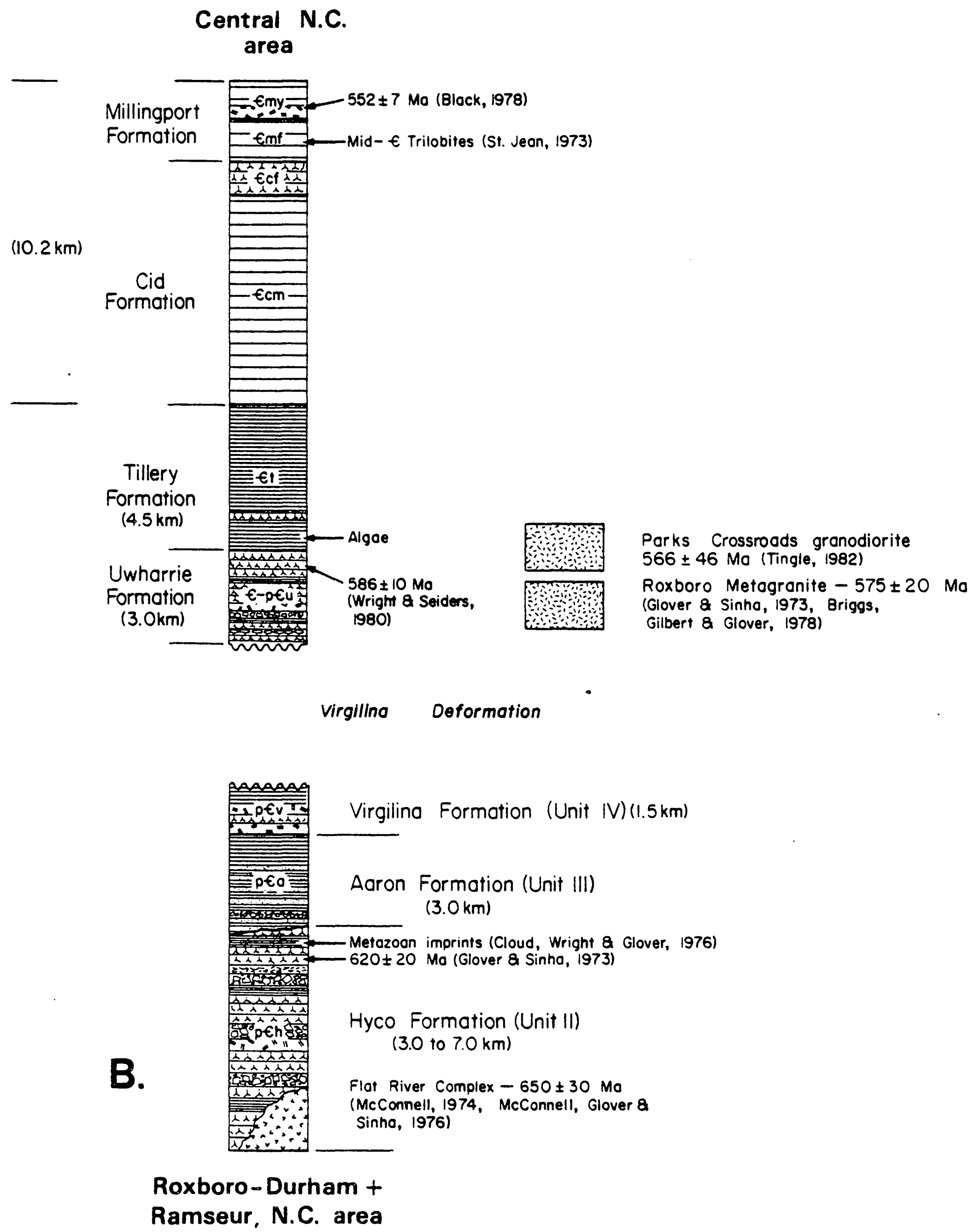
Correlation of lithostratigraphic units in the slate belt

Depicted in Figure 7A is one of the three proposed correlation models developed by Wright and Seiders (1980) which the authors



A.

Figure 7 : Correlation schemes for major lithostratigraphc units of the Carolina slate belt. A. Wright and Seiders (1980) preferred correlation model. B. Model developed based on this study which is identical to the previous schemes of Glover (1974) and Briggs, Gilbert and Glover (1978). Refer to text for discussion of figure.


Central N.C.
area
Millingport
Formation
€my
552 ± 7 Ma (Black, 1978)
€mf
Mid- € Trilobites (St. Jean, 1973)
€cf
(10.2 km)
Cid
Formation
€cm
Tillery
Formation
(4.5 km)
€t
Algae
Uwharrie
Formation
(3.0km)
€-p€u
586 ± 10 Ma
(Wright & Seiders,
1980)
Parks Crossroads granodiorite
566 ± 46 Ma (Tingle, 1982)
Roxboro Metagranite — 575 ± 20 Ma
(Glover & Sinha, 1973, Briggs,
Gilbert & Glover, 1978)
Virgilina Deformation
p€v
Virgilina Formation (Unit IV) (1.5 km)
p€a
Aaron Formation (Unit III)
(3.0 km)
Metazoan imprints (Cloud, Wright & Glover, 1976)
620 ± 20 Ma (Glover & Sinha, 1973)
p€h
Hyco Formation (Unit II)
(3.0 to 7.0 km)
Flat River Complex — 650 ± 30 Ma
(McConnell, 1974, McConnell, Glover &
Sinha, 1976)
B.
Roxboro-Durham +
Ramseur, N.C. area

thought provided the best explanation for relating the two disparate volcanic sequences of the Carolina slate belt. They inferred that the Uwharrie Formation plus Albemarle Group (Tillery, Cid and Millingport Formations) was approximately coeval and similar in a gross sense to the Virgilina sequence (Units II, III, IV) of Glover and Sinha, 1973). The vertical sucession in the two volcanic sequences; a basal unit of pyroclastic rocks and lavas followed by epiclastic sediments which are overlain by mafic and felsic volcanic rocks which are capped by more sediments, led the authors to conclude that correlation of the two sequences was possible. A detailed examination of the two juxtaposed terranes in the Ramseur area reveals that they are not similar. A complicating factor in the proposed correlation scheme of Wright and Seiders (1980) was accounting for the areal extent of the Virgilina deformation as documented by Glover and Sinha (1973) in the Roxboro-Durham, N.C. area. Wright and Seiders (1980) could find no convincing evidence such as, systematic deviation between cleavage and folds (Glover and Sinha, 1973) and the presence of epiclastic conglomerates (Glover and Sinha, 1973 and this study), in the Central N.C. sequence to indicate that the Virgilina deformation had extended into that area. Since the two volcanic sequences are separated by approx. 90 km, Wright and Seiders (1980) inferred that the effects of the Virgilina deformation did not extend into the Central N.C. area.

Shown in Figure 7B is a revised correlation scheme in which an unconformity separates the two stratigraphic sequences of the slate belt. This model is similar to one previously rejected by Wright and Seiders (1980), but it is identical to the ones of Glover (1974) and

Briggs, Gilbert and Glover (1978). From field mapping in the study area it is now evident that those units comprising the Virgilina sequence are exposed adjacent to and east of the Uwharrie Formation. Intermediate rocks previously mapped as Uwharrie (Seiders, 1978) are now included in the Hyco Formation. Additionally, the Uwharrie Formation is somewhat thinner (3.0 km versus 11.5 km) than estimated by Seiders and Wright (1977), Seiders (1978) and Wright and Seiders (1980). The former essentially homoclinal sequence of the Uwharrie is reinterpreted by this author to be a series of short wavelength (3 to 4 km) macroscopic folds which repeat certain lithologic units. The felsic pyroclastic and effusive rocks of the Uwharrie are probably coeval products of shallow to surface breaking magma chambers (as first suggested by Glover, 1974 and Briggs, Gilbert and Glover, 1978) such as the Roxboro metagranite and the Parks Crossroads granodiorite.

In light of the unconformity postulated to separate the major stratigraphic sequences of the Carolina slate belt, the lateral continuity and extension of the Virgilina sequence into the central North Carolina area is illustrated in Figure 8. However, more detailed mapping may be necessary in this particular region of the slate belt to resolve which map units of the Virgilina sequence (Hyco, Aaron and Virgilina Formations) are present.

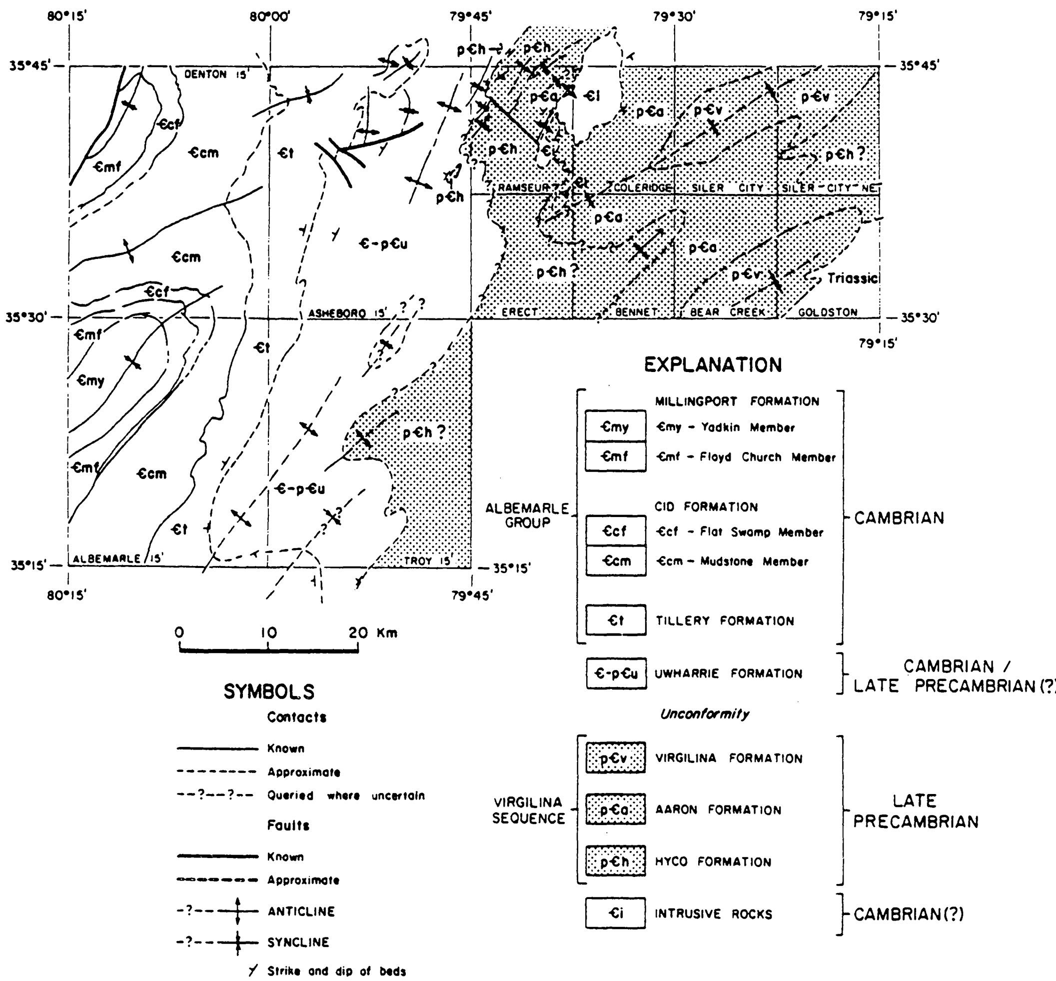


Figure 8 : Generalized regional geologic map of the Carolina slate belt in the Central North Carolina area. The map illustrates the proposed relationships between the younger central N.C. sequence and the older Virgilina sequence. Data compiled from Conley and Bain (1965); Fodor, Burt and Stoddard (1981); Green, Cavaroc, Stoddard and Abdelzahir (1982); Seiders (1978); Stromquist and Sundelius (1969); Tingle (1982); Wright and Seiders (1980).

Evolutionary history of the Carolina slate belt

Based on the interpretation of the map units described in the stratigraphy and structural sections of this paper the following evolution of the Carolina slate belt is summarized in Figure 9. This includes:

1) Eruption and deposition in a mixed subaerial to subaqueous environment the intermediate to felsic volcanic rocks of the Hyco Formation (Fig. 9a).

2) Differential uplift and subsidence due to faulting(?), resulting in erosion of the Hyco Formation, generating the epiclastic sediments of the Aaron Formation which is accompanied by regional subsidence and apparent cessation of volcanism (Fig. 9b).

3) Renewed bimodal volcanism recorded by deposition of the Virgilina Formation (Fig. 9b).

4) Initiation of the 600 Ma Virgilina deformation which results in folding and faulting of the above units (Fig. 9c).

5) Post Virgilina deformation, intrusion of tonalitic to granodioritic stocks and plugs which may result in hydrothermal alteration in the Hyco and Aaron Formations. Concomitant with the plutonic activity are the intrusion of felsic and mafic porphyry dikes and time equivalent eruption and deposition of volcanic rocks of the Uwharrie Formation (Fig. 9d).

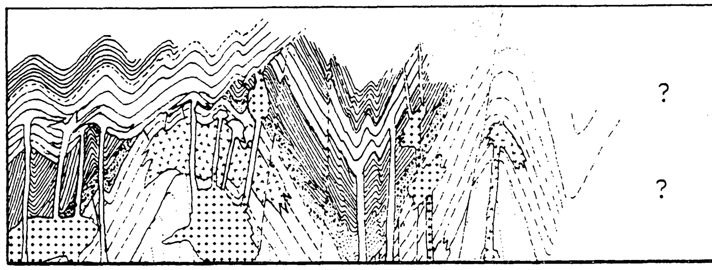
6) Sedimentation, accompanied by intermittent volcanism in the Albemarle Group of the central Carolina slate belt (Fig. 9d).

7) Taconic, ca. 480 to 440(?) Ma deformation and metamorphism of the entire slate belt stratigraphy (Fig. 9e).

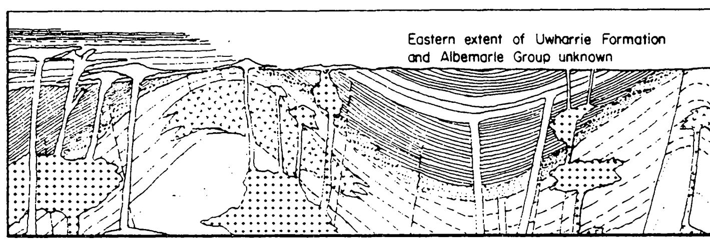
8) Mesozoic rifting and intrusion of diabase dikes in the Carolina slate belt.

Figure 9 : Tectonic evolutionary history of the Carolina slate belt. Diagrams illustrate postulated sequential events (excepting Triassic-Jurassic rifting) which occurred from the Late Precambrian to the Middle Ordovician.

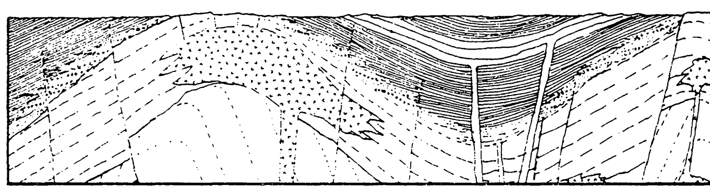
e. Early to Middle Ordovician ca. 480 to 440(?) Ma Taconic deformation and metamorphism of the entire volcanic-sedimentary sequence of the Carolina slate belt.



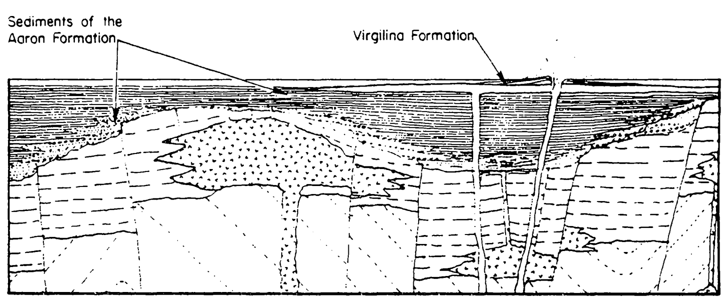
d. Late Precambrian to Middle Cambrian ca. 590 to 540 Ma volcanism and sedimentation of the Uwharrie Formation and Albemarle Group accompanied by regional subsidence.



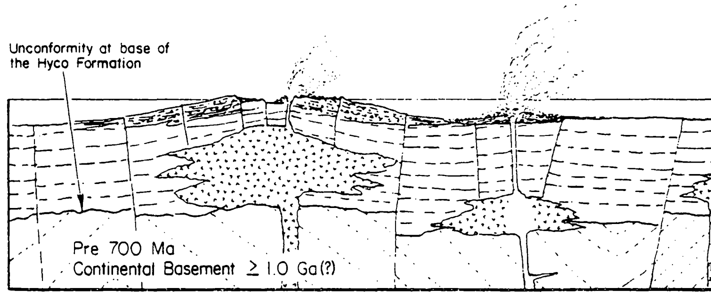
c. Late Precambrian ca. 600 to 590(?) Ma Virgilina deformation resulting in folding, faulting, uplift and concomitant erosion of the Virgilina sequence.



b. Late Precambrian ca. 620 to 600 Ma differential uplift and subsidence resulting in erosion of the Hyco Formation generating the retrogradational submarine fans of the Aaron Formation. Renewed volcanism is represented by the Virgilina Formation.



a. Late Precambrian, ca. 700 to 620 Ma, magmatic arc(?) of the Hyco Formation



Virgilina Deformation

The ca. 600 Ma Virgilina deformation is the only late Precambrian/Early Cambrian(?) compressional orogenic event recognized in the southeastern Appalachians (Glover and Sinha, 1973). It may be correlative in time with the Avalonian event of Newfoundland, although King (1980), has suggested that the Avalon terrane is one of extensional rather than compressional tectonics. It is suggested in this paper that the name Virgilina deformation should have precedence over the Avalonian event because of the relation of the Virgilina to compressional tectonics versus taphrogeny as recorded in the Avalon terrane.

The Virgilina deformation may be correlative with other orogenic events of Late Precambrian/Early Cambrian age , which include: 1) the Monian of Wales and Cadomian of France (Rast and others, 1976, Rast, 1980) and 2) the Pan-African of Africa (Caby and others, 1977, Stern, 1981). These deformations affect volcanic strata similar in age and composition to those lithologies which comprise the Virgilina sequence in the slate belt.

The Virgilina deformation may be attributed to intra-plate movement associated with a tectonically active volcanic arc located on or marginal to a continent which may have existed in the ca. 700 to 600 Ma time interval (Glover and Sinha, 1973). Initial subduction(?) and related volcanism of basalt-andesite-dacite of the Hyco Formation is followed by intra-arc(?) basin formation (sediments of the Aaron Formation) with renewed generally bimodal volcanism represented by the Virgilina Formation. The inferred sequence of events is similar to a model proposed by Black (1978) for the older Virgilina sequence, although the younger volcanic sequence of the Central N.C. area does not represent an accreted arc terrane as suggested by Black (1978), but unconformably overlies the older volcanic terrane. The pattern of volcanism and sedimentation for the Virgilina sequence is analogous to a scenario proposed by Karig and Jensky (1972) for the development of the proto-gulf of California . Compressional deformation of the Virgilina sequence at approximately 600 Ma may reflect the final effects of closure of the inferred intra-arc basin. The deformation may record the effects of microplate(?) collision and subsequent transcurrent(?), high angle reverse or normal(?) faulting. The overlying bimodal volcanic rocks of the Uwharrie Formation may represent renewed initiation of extensional tectonism.

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Plate I: GEOLOGY OF THE RAMSEUR AREA, NORTH CAROLINA*

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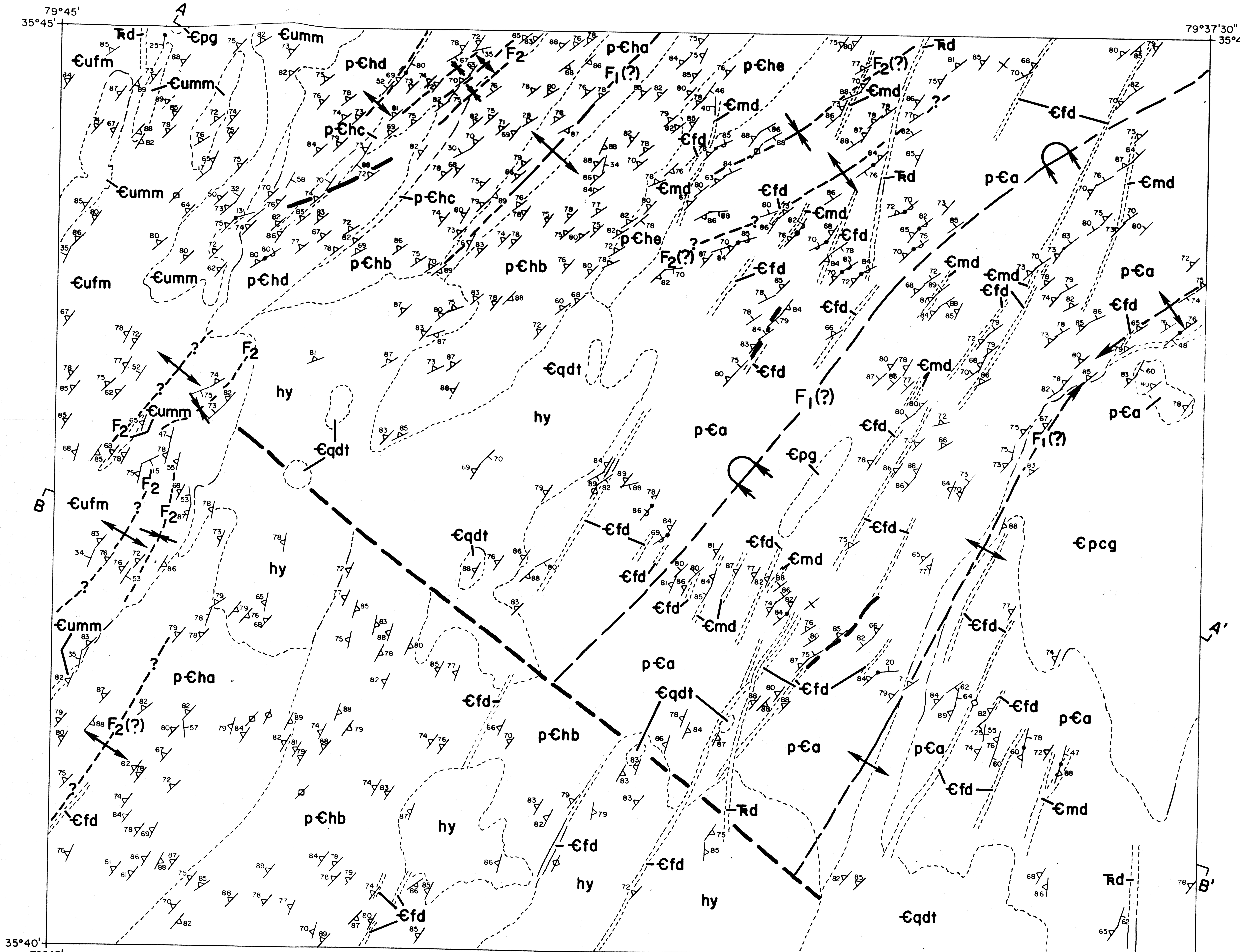
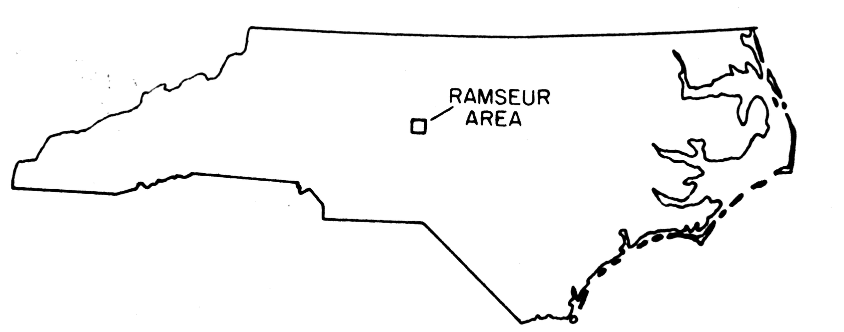
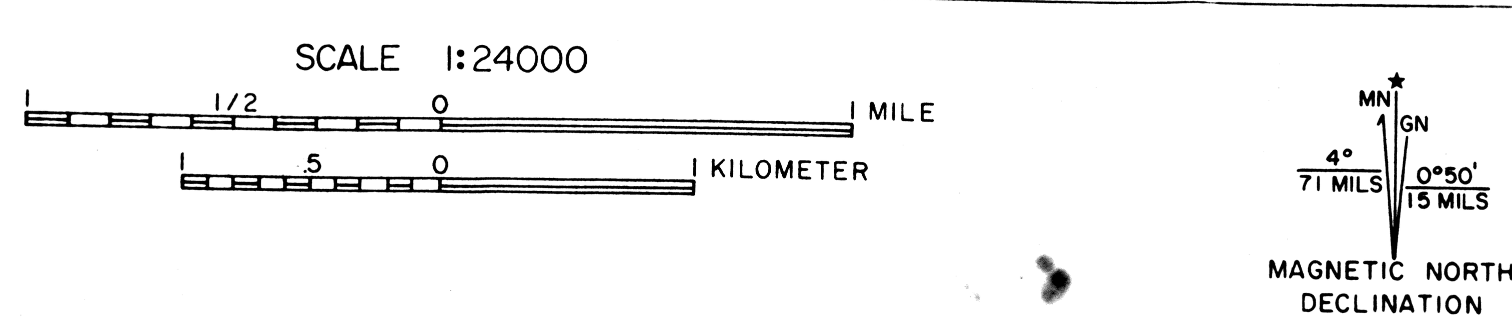
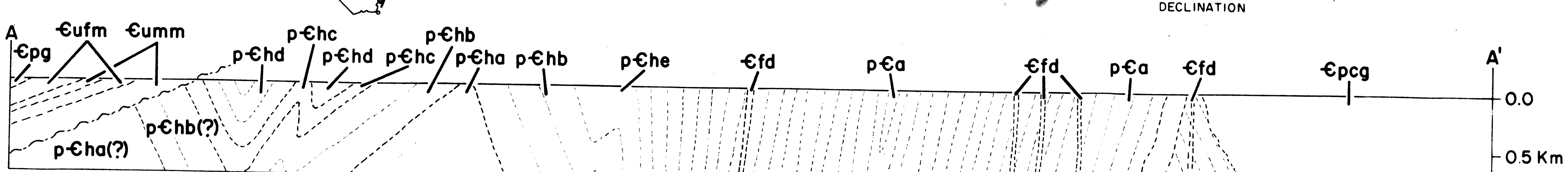
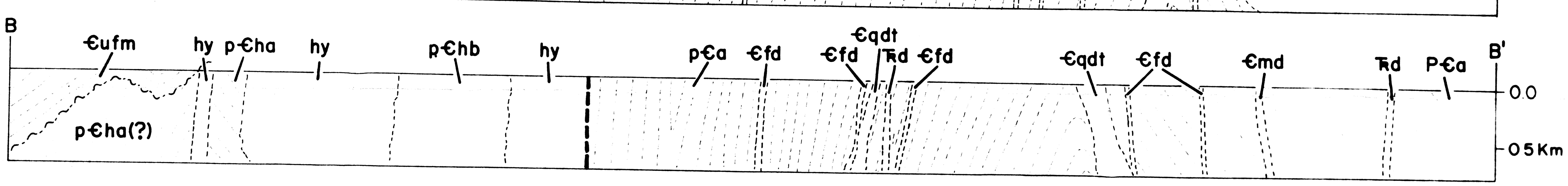
1982











EXPLANATION

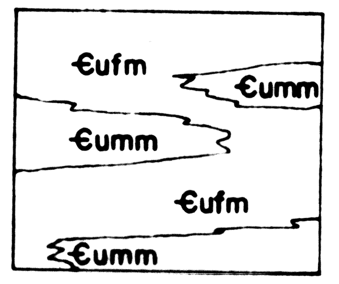
TRIASSIC / JURASSIC

Ŧd — Pyroxene diabase dikes

CAMBRIAN / LATE PRECAMBRIAN(?)

€pg — Pyroxene gabbro sills

Uwharrie Formation



€ufm — Felsic, medium gray to light gray lapilli tuff, lapilli crystal tuff and tuff in thick to thin-bedded or laminated units. Also included are flow-layered lavas.

€umm — Mafic, dark green to blue-green amygdaloidal lavas, tuff-breccia, lapilli tuff and tuff in thick to thin-bedded units which are intercalated with €-p€ufm

€fd — Felsic porphyry dikes

€md — Mafic porphyry dikes

€pcg — Parks Crossroads granodiorite

hy — Hydrothermal alteration

€qdt — Unnamed quartz diorite/tonalite

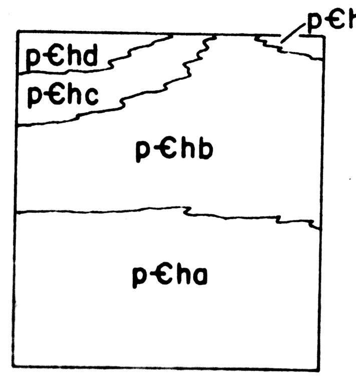
Unconformity

LATE PRECAMBRIAN

Aaron Formation

p€a — Aaron Formation undivided: epiclastic rocks which consist of conglomerate, lithic and feldspathic arenite, siltstone and argillite.

Hyco Formation



p€he — Dark gray-green volcaniclastic conglomerate and sandstone with intercalated lapilli crystal tuff and thin-bedded to laminated tuff of intermediate(?) to felsic composition.

p€hd — Dark gray-green to blue-green tuff breccia, lapilli crystal tuff and lapillistone, all of which contain ubiquitous plutonic clasts. Thinner intercalated units include thin-bedded to laminated lapilli tuff and crystal tuff.

p€hc — Felsic (dacitic?) light blue-gray tuff breccia with intercalated thin-bedded to laminated, normally to doubly graded, lapilli tuff and tuff.

p€hb — Basal conglomeratic breccia, are overlain by intermediate(?) porphyry lava flows. Variably intercalated are lithic to pumiceous lapilli tuff and vitric tuff.

p€ha — Felsic (dacitic?) massive blue-gray lapilli crystal tuff, tuff and tuff breccia, which are either massive or rarely normally graded.

SYMBOLS

Bedding

- 75 — Strike and dip of beds, S_0
- 48 — Strike and dip of beds, S_0, top of beds known from sedimentary features
- 82 — Strike and dip of overturned beds, S_0; top of beds known
- Strike of vertical beds, S_0

Cleavage

- 77 — Strike and dip of cleavage, S_2
- Strike of vertical cleavage, S_2

Contacts, dashed where approximate, short dash where inferred.

Faults, dashed where inferred.

--?--- F1(?) **Anticline** showing direction of plunge, short arrow indicates steeper limb, axis-dashed where inferred, queried where uncertain. Fold generation indicated.

Overturned syncline

*from: An unconformity in the Carolina slate belt of central North Carolina: New evidence for the areal extent of the ca. 600 Ma Virgilina deformation (M.S. Thesis)