Metamorphosed melange terrane in the eastern Piedmont of North Carolina

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ABSTRACT

The Falls Lake melange crops out in the eastern Piedmont of North Carolina between the Carolina slate belt and the Raleigh belt. The melange is composed of mafic and ultramafic blocks and pods of diverse shapes and sizes, dispersed without apparent stratigraphic continuity, in a matrix of pelitic schist and biotite-muscovite-plagioclase-quartz gneiss. Textures and structural relationships suggest formation by a combination of sedimentary and tectonic processes, perhaps in the accretionary wedge of a convergent plate margin. The Falls Lake melange and the overlying late Proterozoic to Early Cambrian volcanic-arc terrane of the Carolina slate belt were thrust upon a probable continental terrane of the Raleigh belt before overprinting by late Paleozoic folding and metamorphism.

INTRODUCTION

A melange terrane, the Falls Lake melange (Horton et al., 1985a, 1985b), has been recognized in the eastern Piedmont of North Carolina along the boundary between the Carolina slate belt and the Raleigh belt. Rocks of this newly recognized melange have been previously assigned to the Raleigh belt (Parker, 1978), to the Carolina slate belt (Wylie and Stoddard, 1984), or to a volcanogenic sequence in the "Raleigh block" considered to be an eastward continuation of lithologies occurring in the Carolina slate belt (Farrar, 1985a). The Falls Lake melange (Fig. 1) has been mapped in detail from near Wilton in Granville County, North Carolina, southward for about 40 km to the west side of Raleigh in Wake County, North Carolina (Carpenter, 1970; Horton et al., 1985a, 1985b; J. W. Horton, Jr.; and D. E. Blake, unpub. mapping). It may extend 35 km farther south into Harnett County to include nonbedded conglomeratic rocks interpreted by Parker (1979) as diamictite. The present thickness of the melange is about 3.5 km, and it has an outcrop width of 4 to 8 km.

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MATRIX, BLOCKS, AND INTERNAL FABRIC

The Falls Lake melange is a metamorphosed terrane composed of mafic and ultramafic blocks and pods of diverse shapes and sizes, from about 1 cm to 7 km in length, dispersed without apparent stratigraphic continuity in a matrix of schist and gneiss. The dominant variety of melange matrix is biotite-muscovite schist containing quartz and plagioclase. Biotite is typically more abundant than muscovite, and chlorite is a

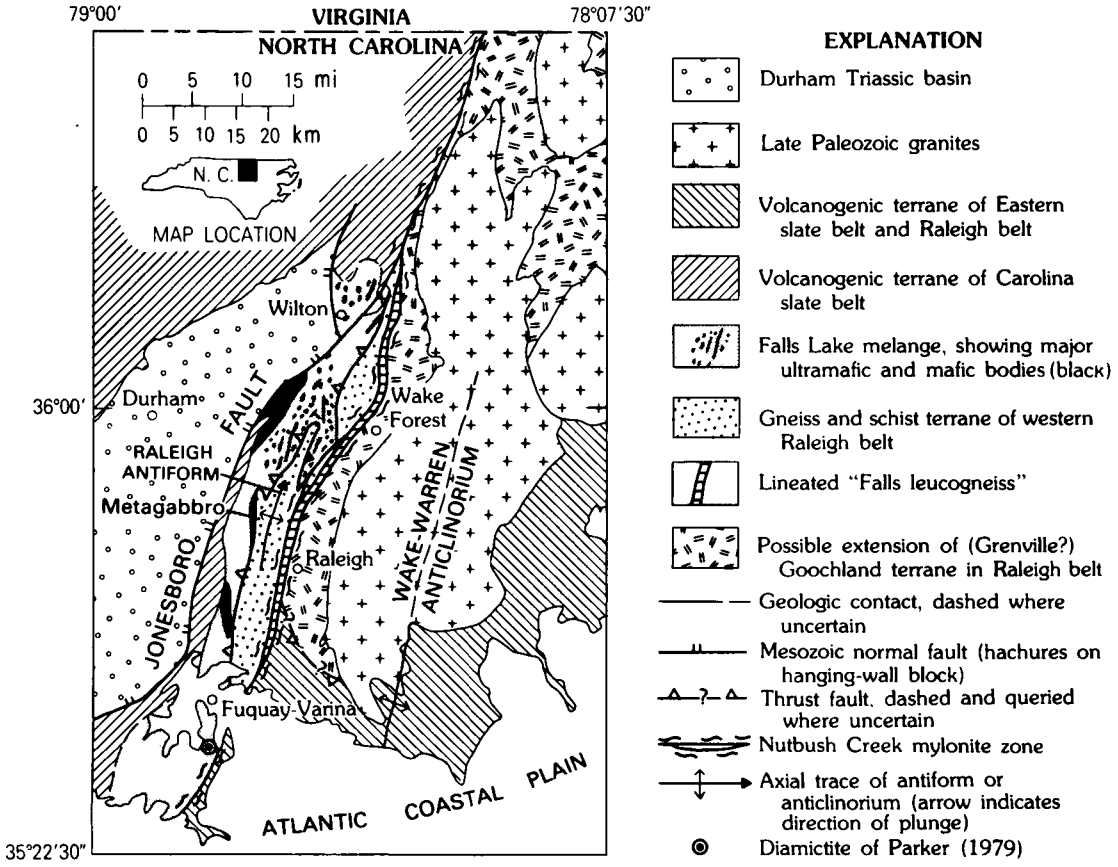

Figure 1. Generalized geologic map of north-central North Carolina, locating Falls Lake melange with respect to major geologic features of eastern Piedmont. Adapted in part from North Carolina Geological Survey (1985), Farrar (1985a), Carpenter (1970), and Druhan (1983).

common minor constituent. Garnet is common; kyanite and staurolite are less common. This pelitic schist, interpreted as a metamorphosed mudstone, is locally interlayered with biotite-muscovite-plagioclase-quartz gneiss which is considered a metagraywacke.

Pods and lenses of amphibolite and lesser amounts of hornblende gneiss and hornblende-biotite gneiss make up about 10%–15% of the melange unit. These mafic rocks contain hornblende, plagioclase, and locally one or more of epidote, chlorite, biotite, and quartz. Relict igneous minerals and/or textures have been observed in some blocks of the melange. For example, relict ophitic textures (also described by Farrar, 1985b), observed in a large mafic body west of Raleigh (Fig. 1) and in smaller bodies to the north, indicate gabbro protoliths for these bodies. Other mafic blocks, including thinly banded hornblende gneiss and hornblende-biotite gneiss, may be volcanic in origin.

Ultramafic fragments include serpentinite, chlorite-actinolite schist, soapstone or talc schist, and hornblendite. These are most abundant north of Raleigh where they constitute 15%–20% of the melange. The serpentinite is fine grained and massive. It contains thin streaks of magnetite, fibrous tremolite, and, less commonly, relict(?) olivine and chromite (Parker, 1979; Moye, 1981). In the chlorite-actinolite schist, either actinolite or chlorite may predominate; talc plates and magnetite octahedra are common in minor amounts. The soapstone and talc schist contain talc, varied amounts of chlorite and actinolite, locally a carbonate mineral whose former presence is indicated by rhombohedral cavities, and rare (relict?) clinopyroxene. The hornblendite is composed of hornblende and minor epidote and garnet, but no quartz.

Previous workers have interpreted the larger, map-scale ultramafic bodies as intrusions (Carpenter, 1970; Parker, 1979) or tectonic slices (Farrar, 1985b). Many of these ultramafic bodies have chlorite-rich or leucocratic metasomatic rims, but none have thermal contact aureoles. North of Raleigh the ultramafic rocks occur as fragments as small as 1 cm, and all, regardless of size, are confined to a single host unit (i.e., the Falls Lake melange; Fig. 1). Clearly, they are fragments of larger bodies. It has been suggested (Moye, 1981; Stoddard et al., 1982) that the ultramafic rocks are dismembered ophiolite fragments.

The lenticular shapes, concordant schistosity, and pinch-and-swell structure (Fig. 2) characteristic of most ultramafic and mafic blocks can be explained as boudinage resulting from a ductility contrast between blocks and matrix. The boudinage is clearly a deformational feature. Some of the small blocks, however, have rounded to angular shapes and embayed margins (Fig. 3) that suggest a sedimentary origin. Furthermore, the earliest schistosity recognized in the matrix, and parallel leucosomes cut across these blocks without deflection (Fig. 2); this fact indicates that the fragment-in-matrix fabric predates the schistosity. These observations suggest that the Falls Lake melange, like many others (Silver and Beutner, 1980; Cloos, 1982; Raymond, 1984; Cowan, 1985), formed by a combination of sedimentary and tectonic processes.

Metamorphic conditions in the blocks and matrix before and during the emplacement of the melange by thrusting (discussed below) are uncertain. The mineral assemblages characteristic of intermediate-pressure, upper greenschist facies to middle amphibolite facies regional metamorphism were produced by a late Paleozoic (Alleghanian) overprint (Russell et al., 1985; Stoddard et al., 1985a). Evidence of subsequent, lower greenschist facies retrogressive metamorphism is widespread (Wylie, 1984).

BOUNDARIES OF THE MELANGE TERRANE

The Falls Lake melange is allochthonous, and the contacts are clearly defined lithologically. The poorly known terrane of the Raleigh belt west of the Nutbush Creek mylonite zone but immediately east of and structurally beneath the melange in the core of the north-plunging Raleigh antiform (Fig. 1) contains no ultramafic rocks. Rocks there consist of quartzofeldspathic gneiss, which may have felsic igneous and/or arkosic sedimentary protoliths of continental provenance as suggested by Stoddard et al. (1978), and beds of aluminum-rich graphitic mica schist, which may have originated as muds deposited in a restricted basin. The presence of these rock types, as well as the regional gravity low in the area, suggests ensialic material of possible continental origin. Farrar (1985a) has suggested that gneisses of the Raleigh belt east of the "Falls leucogneiss" (see Fig. 1) may be a southern extension of the Goochland terrane of eastern Virginia, which has relict granulite-facies mineral as-

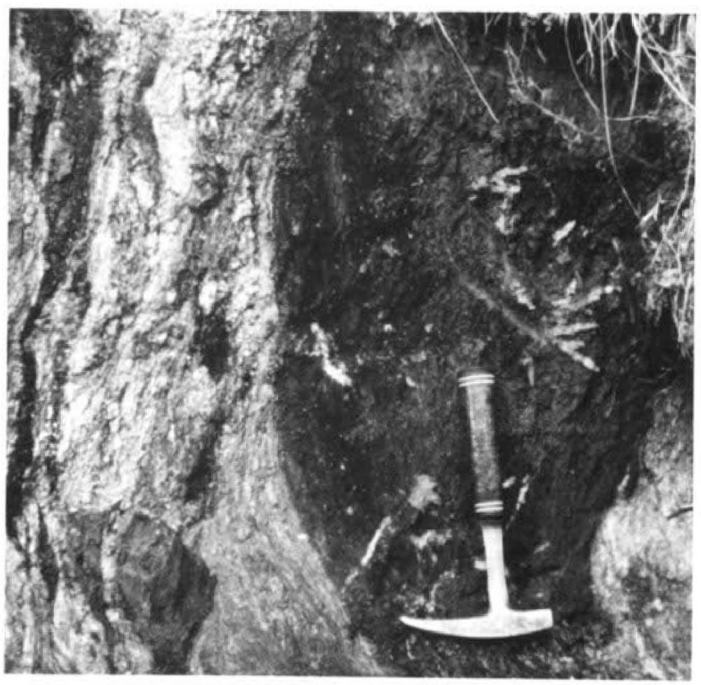

Figure 2. Saprolite exposure showing fragments of actinolite-chlorite rock (dark) in biotite-muscovite schist matrix (light). Foliation in fragments and in matrix is parallel. Schistosity and parallel leucosomes cut across a partly rounded, equant block (lower left) without deflection; this indicates that block was fragment (sedimentary clast?) before schistosity and leucosomes formed. Thin, lenticular fragments that show pinch-and-swell structure (along left margin) are deformational features. Preservation of both predeformational and syndeformational fragments in a single outcrop is attributed to heterogeneous strain.

Figure 3. Angular blocks of amphibolite (top) and hornblendite in quartzose biotite-muscovite schist matrix. Schistosity dips west (right) and cuts across block margins. Angular shapes and embayed margins (e.g., top of block below lens cap) cannot be explained by deformational fabric and suggest partly sedimentary origin. Lens cap diameter is 5 cm.

semblages and which he interprets as Grenville in age. Still, the ages of, and structural relations between, the rocks of these areas are unresolved.

The basal contact of the Falls Lake melange with the underlying terrane is interpreted to be a folded thrust fault (Wylie, 1984; Wylie and Stoddard, 1984; Horton et al., 1985a, 1985b; Stoddard et al., 1985b). This fundamental discontinuity, mapped earlier by Parker (1979) as an angular unconformity, was not mapped by Farrar (1985a, 1985b), who included the rocks on both sides within his informally named Smithfield formation. Rocks on the lower plate adjacent to the thrust include a thinly banded biotite quartzofeldspathic gneiss consisting of black biotite-rich and white biotite-poor discontinuous compositional layers less than 10 mm thick, as well as fine-grained, thinly laminated leucocratic quartzofeldspathic gneiss with polycrystalline quartz ribbons. These rocks are interpreted as annealed mylonites (Wylie, 1984; Stoddard et al., 1985b). This thrust is folded by the upright Raleigh antiform (Fig. 1) and transected by younger, Alleghanian-age metamorphic isograds (Parker, 1979; Russell et al., 1985; Stoddard et al., 1985a). The melange and its folded basal thrust are truncated on the east by the Nutbush Creek mylonite zone (Fig. 1).

Recently proposed tectonic models suggest that the Carolina slate belt, lying to the west of and structurally above the Falls Lake melange (Fig. 1), originated in a volcanic-arc setting associated with subduction (Kish and Black, 1982). However, the nature of the upper contact of the melange with stratified volcanogenic rocks of the Carolina slate belt (Cary sequence of Parker, 1979) has not been determined. The Falls Lake melange is similar in tectonic position to the Macon melange of Higgins et al. (1984) which reportedly underlies allochthonous rocks of the Carolina slate belt in Georgia.

TECTONIC SIGNIFICANCE

Fossils reported by Secor et al. (1983) indicate that the Carolina slate belt is an exotic terrane that in Cambrian time was located away from North America. The Falls Lake melange and this overlying, accreted volcanic-arc terrane of the Carolina slate belt were thrust upon a probable continental terrane of the Raleigh belt, which may or may not represent part of ancestral North America. Overprinting by late Paleozoic folding and metamorphism followed.

The Falls Lake melange fits the description of Cowan's (1985) type III melange and may have formed by any of several processes in an accretionary wedge, or even by processes not restricted to convergent margins. It may or may not represent a subduction melange (e.g., Cloos, 1982) in which the mafic and ultramafic fragments are oceanic material, perhaps derived from the underpinnings of the Carolina slate belt volcanic arc (Stoddard et al., 1985b). Studies of the geochemistry of the blocks, the internal fabric of the melange, and its upper contact with stratified rocks of the Carolina slate belt, as well as studies to characterize adjacent terranes of the Raleigh belt, are being designed to test such models.

REFERENCES CITED

Carpenter, P.A., III, 1970, Geology of the Wilton area, Granville County, North Carolina [M.S. thesis]: Raleigh, North Carolina State University, 106 p.

Cloos, Mark, 1982, Flow melanges: Numerical modeling and geologic constraints on their origin in the Franciscan subduction complex, California: Geological Society of America Bulletin, v. 93, p. 330–345.

Cowan, D.S., 1985, Structural styles in Mesozoic and Cenozoic melanges in the western Cordillera of North America: Geological Society of America Bulletin, v. 96, p. 451–462.

Druhan, R.M., 1983, The southwestern Raleigh belt and the Nutbush Creek fault zone in North Carolina [M.S. thesis]: Chapel Hill, University of North Carolina, 69 p.

Farrar, S.S., 1985a, Tectonic evolution of the easternmost Piedmont, North Carolina: Geological Society of America Bulletin, v. 96, p. 362–380.

——1985b, Stratigraphy of the northeastern North Carolina Piedmont: Southeastern Geology, v. 25, p. 159–183.

Higgins, M.W., Atkins, R.C., Crawford, T.J., Crawford, R.F., III, and Cook, R.B., 1984, A brief excursion through two thrust stacks that comprise most of the crystalline terrane of Georgia and Alabama: Georgia Geological Society, 19th Annual Field Trip Guidebook, 67 p.

Horton, J.W., Jr., Stoddard, E.F., Wylie, A.S., Jr., Moye, R.J., Jr., and Blake, D.E., 1985a, Melange terrane in the eastern Piedmont of North Carolina: Geological Society of America Abstracts with Programs, v. 17, p. 96.

Horton, J.W., Jr., Blake, D.E., Wylie, A.S., Jr., and Stoddard, E.F., 1985b, The Falls Lake melange, a polydeformed accretionary complex in the North Carolina Piedmont: Geological Society of America Abstracts with Programs, v. 17, p. 613.

Kish, S.A., and Black, W.W., 1982, The Carolina slate belt: Origin and evolution of an ancient volcanic arc—Introduction, *in* Bearce, D.N., Black, W.W., Kish, S.A., and Tull, J.F., eds., Tectonic studies in the Talladega and Carolina slate belts, southern Appalachian orogen: Geological Society of America Special Paper 191, p. 93–97.

Moye, R.J., Jr., 1981, The Bayleaf mafic-ultramafic belt, Wake and Granville Counties, North Carolina [M.S. thesis]: Raleigh, North Carolina State University, 122 p.

North Carolina Geological Survey, 1985, Geologic map of North Carolina: North Carolina Department of Natural Resources and Community Development, Geological Survey Section, scale 1:500,000.

Parker, J.M., III, 1978, Structure of the west flank of the Raleigh belt, North Carolina, *in* Snoke, A.W., ed., Geological investigations of the eastern Piedmont, southern Appalachians (Carolina Geological Society field trip guidebook 1978): Columbia, South Carolina Geological Survey, p. 1–7.

——1979, Geology and mineral resources of Wake County: North Carolina Department of Natural Resources and Community Development, Geological Survey Section, Bulletin 86, 122 p.

Raymond, L.A., ed., 1984, Melanges: Their nature, origin, and significance: Geological Society of America Special Paper 198, 170 p.

Russell, G.S., Russell, C.W., and Farrar, S.S., 1985, Alleghanian deformation and metamorphism in the eastern North Carolina Piedmont: Geological Society of America Bulletin, v. 96, p. 381–387.

Secor, D.T., Jr., Samson, S.L., Snoke, A.W., and Palmer, A.R., 1983, Confirmation of the Carolina slate belt as an exotic terrane: Science, v. 221, p. 649–650.

Silver, E.A., and Beutner, E.C., Conveners, 1980, Melanges (Penrose Conference report): Geology, v. 8, p. 32–34.

Stoddard, E.F., Cavaroc, V.V., and McDaniel, R.D., 1978, Status of geologic research in the Raleigh belt, *in* Snoke, A.W., ed., Geological investigations of the eastern Piedmont, southern Appalachians (Carolina Geological Society field trip guidebook 1978): Columbia, South Carolina Geological Survey, p. 8–12.

Stoddard, E.F., Kite, L.E., and Moye, R.J., 1982, Ophiolitic terranes of the eastern Piedmont of North Carolina and their tectonic implications: Geological Society of America Abstracts with Programs, v. 14, p. 86.

Stoddard, E.F., Wylie, A.S., Jr., and Boltin, W.R., 1985a, Polymetamorphism in the eastern North Carolina Piedmont: Geological Society of America Abstracts with Programs, v. 17, p. 138.

Stoddard, E.F., Wylie, A.S., Jr., and Blake, D.E., 1985b, Basal thrust contact of the accreted Carolina Slate belt volcanic arc, southern Appalachian Piedmont: Geological Society of America Abstracts with Programs, v. 17, p. 728.

Wylie, A.S., Jr., 1984, Structural and metamorphic geology of the Falls Lake area, Wake County, North Carolina [M.S. thesis]: Raleigh, North Carolina State University, 79 p.

Wylie, A.S., Jr., and Stoddard, E.F., 1984, The Falls Lake mylonite zone: A pre-Alleghanian lithotectonic boundary in the eastern North Carolina Piedmont: Geological Society of America Abstracts with Programs, v. 16, p. 702.

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Reviewer's comment

Reveals that melanges can be recognized in high-grade terranes, that the tectonic history of the Appalachian-Caledonian orogen has yet another similarity to Cenozoic orogenic belts, and that melanges may pervade the geologic record.

L. A. Raymond