K/AR DATING OF BLUE RIDGE THRUSTING AND ITS INFLUENCE ON SEDIMENT INPUT TO TWO PENNSYLVANIAN-AGE DEPOCENTERS IN THE APPALACHIAN BASIN

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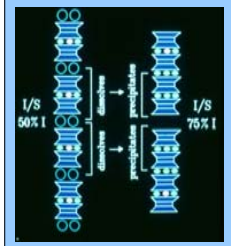
Martinsburg Fm. Slates (and interbedded metabetonites) with near vertical axial plane cleavage on east flank of Massanutten Synclinorium near Front Royal, VA. The Blue Ridge Fault brings up Blue Ridge 10km behind the viewer.

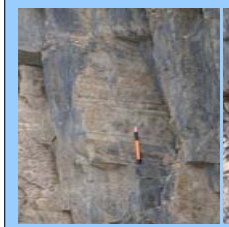
Abstract

Significant uncertainty exists in the timing of the emplacement, uplift and deformation of the Blue Ridge-Piedmont terrane of the Appalachians. The timing of the emplacement of the Blue Ridge-Piedmont terrane is a potential factor influencing the source of sediments in the central and southern Appalachian Basin. Here I constrain the timing of this event by K/Ar dating for metamorphosed illite in the Deicke and Millbrig K-bentonites. Along the eastern edge of the Basin these widespread mid-Ordovician bentonites occur just in front of the Blue Ridge Thrust in both northeastern Georgia and northern Virginia where they have been tectonically metamorphosed by over-thrusting. The Horseleg Mountain, GA locale lies in a window beneath the Rome thrust, which is the first (eastern-most) of a series of imbricate thrusts in front of the Blue Ridge (locally called the Great Smokey) Thrust. Radiometric ages for the Horseleg Mountain, GA sample have K/Ar dates of 273 Ma ± 7 Ma. This early Permian age can be taken as the time of over-thrusting in this location, and is contemporaneous with the dates of emplacement. The K-bentonite site from northern Virginia is from within the Martinsburg Formation located only 10 km to the east of the Blue Ridge on the Massanutten Syncline where the Martinsburg is involved in folding and has a well developed axial plane slaty cleavage. However, the measured ages of the K-bentonite increase with increases in grain size, a pattern consistent with the bentonite having been contaminated by a mixture of Taconic age (~450 Ma) or older detrital illite during its deposition. The youngest and least contaminated fraction is the finest (<0.2 µm) which produces an age close (276 ± 7 Ma) to the concordant set of Horseleg, GA dates.

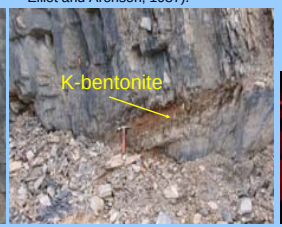
Detrital muscovites provide information about the source of sediments following uplift. The K/Ar dates for detrital muscovites in sandstone and siltstones of the Pottsville formation in the Black Warrior Basin, AL suggest a variation in sediment source from the Appalachians to the Ouachitas (Horsey 1981). The results show Black Warrior Pottsville Formation to contain the first appearance of Alleghanian-aged detrital muscovites in the Appalachian Basin. In contrast, dates of detrital muscovites from the Pottsville Formation of the north central Appalachian basin give very uniform Acadian Orogen dates of 360 ± 10 Ma and suggest significant and uniform input of sediment from Acadian terranes to the northeast. The muscovite dates in the Black Warrior Basin appear to be unique (compared to elsewhere in the Appalachian Basin) in preserving a record of derivation from rocks in uplifted parts of the Alleghanian Orogen that are both older and younger then the Acadian Orogeny.



•Bentonites are formed from the alteration of volcanic ash to smectite (Si4Al1.5Mg0.5O10(OH)2Ca0.25) and Kaolinite (Al2Si2O5(OH)4.), depending on the acidity of the environment of deposition.
•Smectite in K-bentonite is driven to mixed layer illite/smectite with increased pressure and temperature (burial or tectonic metamorphism).
•This figure (left) shows hydrated Na+ and Ca+ (open circles) being replaced by K+ (filled circles) as smectite in K-bentonite is driven to mixed layer illite/smectite with increased pressure and temperature. The K+ ion is locked into the crystal structure of illite, so that K/Ar dating determines the time of conversion.
•Potassium for illitization is likely to have come into the bentonite layer by pore fluids from host rocks like shales containing K-bearing minerals such as feldspars and muscovite whose breakdown also supplies the necessary Al (Aronson and Hower, 1976, Altaner 1984, Elliot and Aronson, 1987).



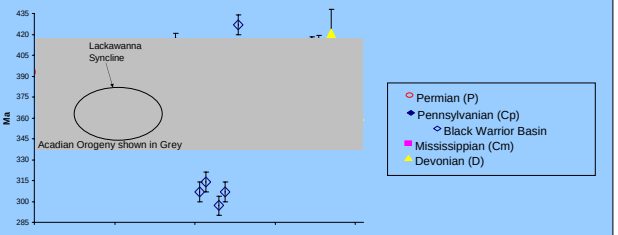
Close-up showing axial plate cleavage perpindicular to bedding on eastern limb of Massanutten Synclinorium. Illite should neoform during the development of axial plane cleavage.



One of the two unidentified Ordovician K-bentonites in the Martinsburg slate at the Massanutten locality clearly showing axial plane cleavage is perpendicular to bedding.

Degassing (below) bentonite separates (above) for Ar Analysis

Detrital Mica Results



Northern Basin (Lackawanna syncline) Pottsville detrital mica dates are Acadian (approximately 365 ± 8 Ma). These detrital mica dates represent the youngest Acadian dates recorded in the Appalachian Basin.

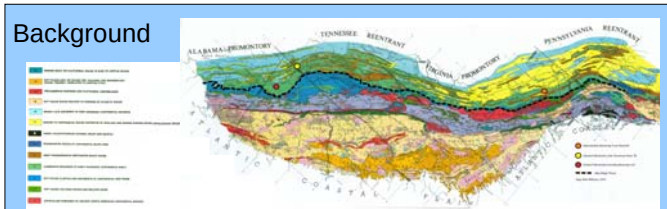
In the Southern Basin, Pottsville detrital mica dates range widely from late Taconic or Early Acadian 415 ± 7 to Alleghanian 297 ± 7 Ma. This may represent a complex input of sediment to the basin from Ouachita and Souther Blue Ridge / Piedmont sources (Horsey, 1981, Thomas, Personal Communication). The Alleghanian set of detrital dates (306 ± 7 Ma) represents the first reported occurrence of Alleghanian age detrital micas in the Appalachian Basin.

Conclusions

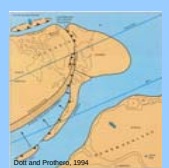
1. Concordant ages (with grain size) on the Horseleg Mountain, GA and Little Tenn. River, GA Dikie bentonite samples indicate a lack of contamination with detrital illite.
2. Radiometric K/Ar ages for illites from Horseleg Mountain, GA and Little Tenn. River, GA, show that the Blue Ridge – Piedmont thrust sheet was emplaced at 274 ± 7 Ma.
3. The older age with grain size pattern for the Front Royal, VA samples indicate a small amount of detrital contamination of probable Ordovician illite. The youngest, finest (<0.2 µm) and least contaminated fractions give an average age of 276 ± 7 Ma.

1. Potassium/Ar dates for detrital muscovites in the northern Appalachian Foreland basin are uniform (365 ± 8 Ma) and suggest sediment input is entirely from Acadian terranes.
   - These micas are likely to be metamorphic (they coincide with 360 Ma 40Ar/39Ar ages for Acadian metamorphism):(Dallmeyer, 1981).
   - These samples may also represent an average of early and late Acadian activity.
2. In contrast, K/Ar dates for detrital mica in the southern Appalachian Basin (Black Warrior Basin) are variable spanning pre-Acadian to Alleghanian ages (427 ± 7 to 297 ± 7). The 297 ± 7 Ma age represents the first input of Blue Ridge or Ouachita metamorphic detritus of Alleghanian age to the Appalachian basin.
   - Potassium/Ar and Rb/Sr Ages for greenschist faces metamorphism in the southern Appalachian Talladega belt range from 417 to 329 Ma (Tull, 1982). The Talladega metamorphic belt could be a source for some of the Black Warrior Pennsylvanian aged sediments.

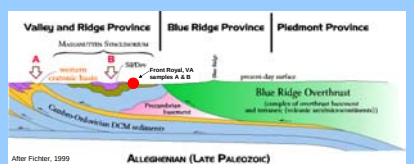
Background



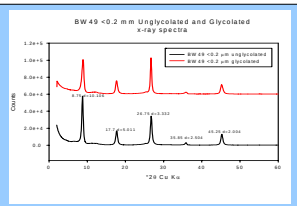
Seismic refraction profiles in the southern Appalachian Mountains have suggested that the Blue Ridge-Piedmont terrane is an extensively traveled crystalline thrust sheet riding on a low angle thrust fault (Cook et al., 1979). This thrust sheet is responsible for the surface deformation expressed by the Ridge and Valley Province to the west. Although the date of the Alleghanian Orogeny is moderately well constrained based on the dating of associated igneous and metamorphic rock units that were emplaced in the southern Piedmont, the timing of thrust sheet emplacement is not well constrained, and a sparse record is available on which to base this record. In fact, direct evidence of thrust sheet emplacement dates as early Permian or later comes from the gentle folding of the youngest strata in the Appalachain Baisn (the Permian Dunkard Formation on the Allegheny plateau).



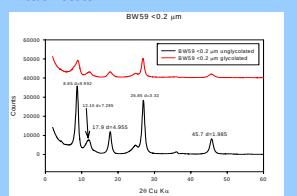
A collision (300–265 Ma) between North American and Africa (Gondwana), leading to the emplacement of a large crystalline body of rock - The Blue Ridge-Piedmont thrust sheet.



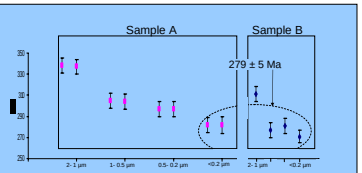
Seismic Evidence form Cornell University Consortium for Continental Reflection Profiling (COCORP) suggests a master decolment (or sole fault) at depths of 6 to 15 km and distances of horizontal displacement of 100 to150 km (Hatcher et al. 1989, Cook et al., 1979).



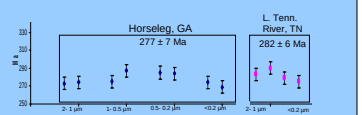
X-ray spectra of an unidentified Ordovician K-bentonite (Front Royal, VA) in the <0.2 µm size fraction. The top spectra are ethylene glycol solvated. The sample is ~100% illite in illite/smectite.



X-ray spectra for the Horseleg Mountain, K-bentonite in the <0.2 µm size fraction. The top spectra is ethylene glycol solvated. The sample is ~85% illite in illite/smectite with 30% kaolinite.



Age vs. size for K-bentonites in the Massanutten Martinsburg Slate. Discordant age with size fraction suggests increasing detrital illite contamination with size in both samples. The concordance of the finer size fractions in the two samples suggests they may be uncontaminated and register Blue Ridge emplacement at Front Royal, VA at 279 ± 5 Ma.



Age (Ma) vs. size fraction (µm) for the Deicke K-bentonite : (1) from Horseleg Mtn. GA; and (2) Little Tenn. River, TN. Concordant age with size fraction suggest no detrital contamination in either sample, and that they register the time of neoformation of illite and emplacement of the Blue Ridge at 279 ± 7 Ma ago.

Acknowledgments

Dartmouth College Earth Sciences, Sara Cavin

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