Bald Hill Bentonites A, B, and C
History and New Data Since 1988

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History

Observing that both the Tioga Ash Beds (Way et al., 1986) and Ordovician bentonites of central Pennsylvania followed substantial periods of carbonate deposition, Smith hypothesized that the top of the Helderberg Group might include volcanic layers as well. Accordingly, J.H. Way and family visited L. Rickard's "Kalkberg Bentonite" at Cherry Valley, N.Y. on 3/31/86. Smith and Way then recognized the equivalent layers at Bald Hill, Frankstown, Blair County, on 4/2/86. These became known as the "Bald Hill Bentonites" (BHB) because "Kalkberg" was well established as a formation name. On 5/2/86, they found the three BHB's in the Clites quarry at Hyndman, Bedford County, PA. Smith and family then visited Cherry Valley 6/26/86 where he recognized BHB B and C and prepared a preliminary stratigraphic section and again on 8/11/86 to refine the stratigraphic section and take photographs. On 8/23/86 Smith returned to Cherry Valley with Berkheiser who provided bed by bed carbonate descriptions and depositional environments. This and other field work by all three authors resulted in the paper published in 1988.

Since then, Roden and Miller (1989) used apatite from two samples of BHB C for fission track analyses. Berkheiser and Smith found and described an excellent section at Black Oak Ridge, Bedford County (Smith and Berkheiser, 1992. Abstract herein as Figure 1.) Combinations of Smith and Berkheiser and/or Way found and described additional usable sections Jersey Shore, Lycoming County; Selinsgrove Junction (SE limb of anticline), Northumberland County; and Monterey, Highland County, Virginia. Benjamin Hanson (1995) attempted to study melt inclusions in phenocrysts from the Bald Hill and other bentonites as noted below. Also, Tucker et al. (1998) dated Bald Hill Bentonite A at Cherry Valley.

BALD HILL BENTONITES, BLACK OAK RIDGE, BEDFORD COUNTY, PENNSYLVANIA

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A roadcut on the northwest side of U.S. Route 220 (40° 06′ 43", 78° 31′ 29") provides an outstanding Lower Devonian exposure of the lower Mandata, Corriganville (New Scotland, 3.1 m), New Creek (Coeymans, 3.9 m), Keyser (51 m), and the upper Tonoloway formations. Bald Hill Bentonite (BHB) C occurs 18 cm above the base of the Mandata Fm as a sheared, 1 mm-thick, olive-black, mudstone that contains euhedral biotite, sparse relict feldspar, and rare glauconite. BHB B is a 1 cm-thick, waxy, olive-gray, glauconitic mudstone which occurs at the Mandata-New Scotland contact draping an 18 cm-thick phosphate nodule zone. Sparse biotite is present. BHB A occurs 58 cm below BHB B and is a 2.5 cm-thick, grayish-orange, waxy claystone containing sparse glauconite.

This foreland basin sequence of Helderberg rocks records a regional transgressive event (supratidal Tonoloway to basinal Mandata) with the pyroclasts signaling the shut down of the carbonate factory. The BHB zone represents a time of slow to non-deposition in a deep ramp to basinal setting. The phosphate nodular zone is time transgressive to the southwest with a slope of 3 mm per km.

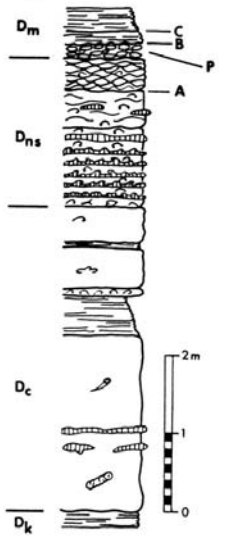


Figure 1. Black Oak Ridge, Bedford County, PA, description and section from Smith and Berkheiser (1992).

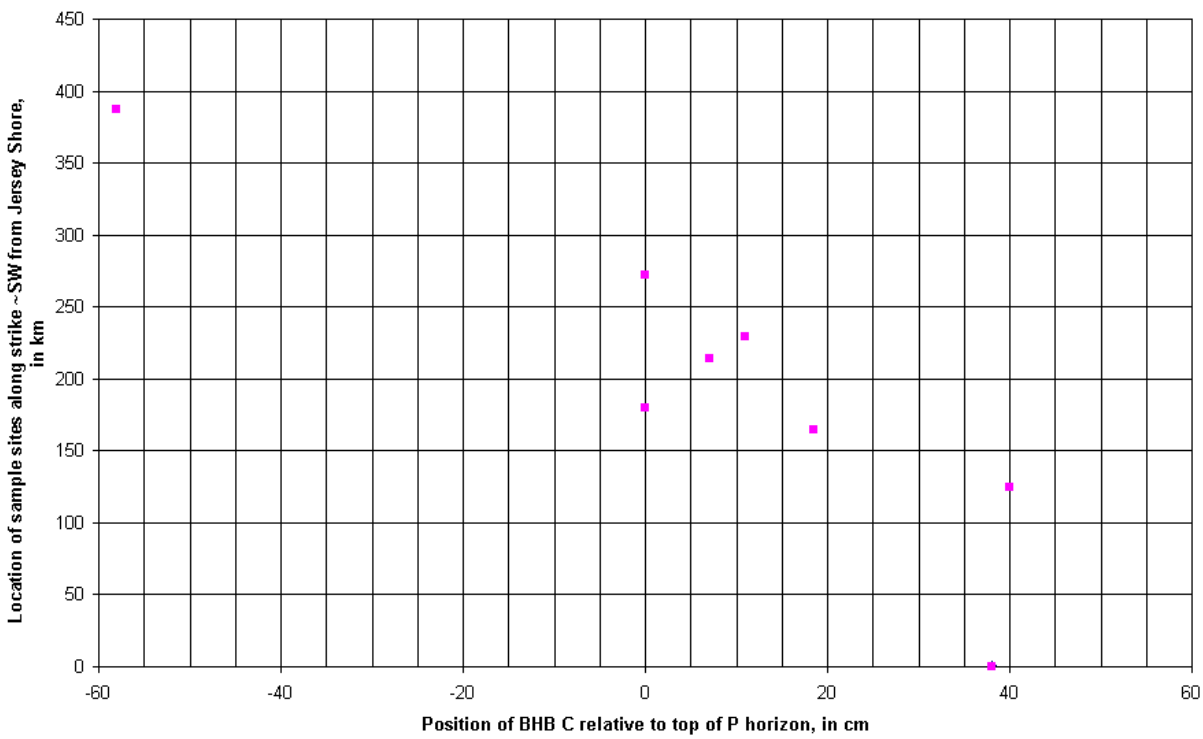
Smith, R.C II, Berkheiser, S.W., and Way, J.H. (2003) Bald Hill Bentonites A, B, and C- history and new data since 1988, *in* Way, J.H. and others, eds., Geology on the edge: selected geology of Bedford, Blair, Cambria, and Somerset Counties, Guidebook, 68th Annual Field Conference of Pennsylvania Geologists, Altoona, PA, p. 73 – 77.

New Data

Roden and Miller (1989) separated apatites from BHB C at Hyndman and Bald Hill supplied by Way and Smith. They were found to have Cl/F + Cl ratios of 0.21 and 0.20, respectively. This is similar to what Roden and Miller found for apatites from Tioga Ash Bed B suggesting, that with some caution, fission track unloading data from BHB C might be included with data from Tioga B. Roden and Miller did this and found an average cooling to ~120^0 C by 225 Ma in complete agreement with data for Tioga Ash Bed B away from the anthracite overthrust (Smith, 2003, this guidebook).

One of the primary uses of bentonites (mostly clay, commonly including smectite) or ash beds (mostly quartz, feldspars, and micas), is as time lines for correlation and as datum to test various theories of deposition. In the case of the Tioga Ash Beds (Way et al., 1986), seven layers not uncommonly can be excavated at one locality, tend to alternate in relative thickness, and to have an individual character. To date, exposures of the Bald Hill Bentonites yielded three, field-recognizable layers at any one locality: BHB A tends to be a few cm thick and consist of light-colored smectite-illite clay having a soapy feel and which contains glauconite grains, especially near the base., B which tends to be about 1 cm thick and to contain biotite having a slightly purplish color and sub-mm glauconite; and C which tends to be about 1 cm thick, coarser than the others, and to contain euhedral biotite and not uncommonly feldspar. In addition, bentonitic layers of material apparently reworked by storms from highlands now appear as pronounced reentrants weathered back into the outcrop, as for example, one 23 cm above C at Cherry Valley, New York. At all but the Cherry Valley section, the phosphate nodule horizon adds a fourth marker, but it is not a time line. For example, see Figure 2, which shows how facies, represented by the phosphate nodule horizon, slopes at 3mm/km (which equals only 3 ppm) and even cuts BHB C. Smith et al. (1988, p 221), noted that equivalence of A, B, and C from New York and West Virginia had not been proven and encouraged the finding of additional localities and verification of the identity of the individual beds.

Figure 2. Slope of phosphate nodule horizon relative to BHB C



Considering the depositional environment and wide geographic spread, the 4 additional sections observed by Smith, Berkheiser, and Way generally fit the patterns they reported earlier. They also collected, to the degree possible in such thin layers, true channel samples of each accessible layer. These were dried, disaggregated to – 1 cm, hand-picked to remove any rootlets, visible calcite, etc., and ground in an agate mortar and pestle to –100 mesh. These were commercially analyzed for, among others, TiO_2, an element believed to be relatively immobile since eruption and likely to differ from one layer to another. Because of the potential for contamination by calcite, all TiO_2 data were recalculated to a somewhat arbitrary 1 % CaO. The results are shown in Table 1.

Table 1. TiO_2 analyses for Bald Hill Bentonite beds from 10 localities in New York, Pennsylvania, Maryland, West Virginia, and Virginia. All analyses calculated to 1% CaO in an attempt to correct for dilution by carbonate mud and/ or hydrothermal calcite.

Locality	BHB A % TiO_2	BHB B % TiO_2	BHBC % TiO_2	Stratigraphic position of BHB C relative to phosphate nodule horizon
Cherry Valley, Otsego Co., NY	0.38	0.84	0.62	
Jersey Shore, Lycoming Co., PA	0.51???	0.80	0.72	38 cm above top
Selinsgrove Junction, (SE limb of anticline) Northumberland Co., PA	0.37	N.A.	N.A.	
Bald Hill, Blair Co., PA	0.36	0.79	0.48	40 +/-1 cm above top
Black Oak Ridge, Bedford County, PA	0.37	0.80	0.75	18.5 +/-1 cm above top
New Paris, Bedford Co., PA	0.56???	0.84	0.53	directly on top
Hyndman, Bedford Co., PA	0.44	0.82	0.60	7 cm above top
Corriganville, Allegany Co., MD	0.36	0.54???	0.66	11 cm above most pronounced P nodule layer in shale , but most faulted of sections used.
New Creek, Mineral Co., WV	0.36	0.56???	0.57	directly on top
Monterey, Highland Co., VA	0.62???	0.61???	0.58	30 cm below base of 28 cm P nodule–bearing bed
Apparent range for correctly identified samples	0.37 +/- 0.01	0.81 +/-0.03	0.62+/- 0.14	

In general, layers believed to be BHB A contained 0.37+/- 0.01% TiO_2, BHB B 0.81 +/- 0.03, and C 0.62 +/- 0.14. C has a much larger TiO_2 range than desired, but is coarser and was deposited in a higher energy environment which locally might have selectively winnowed light vs. heavy minerals. Three samples of BHB A appear to be problematic: Jersey Shore, New Paris, and Monterey. Three samples of BHB B also appear to be problematic: Corriganville, New Creek, and Monterey. It should be noted that the 6 problematic samples have %TiO_2 contents of: 0.51, 0.56, 0.62, 0.54, 0.56, and 0.61 or 0.56 +/-0.05 %. General appearance and a limited range for TiO2 suggest that this represents one pyroclastic layer and not just random shaly partings. It now seems likely to be a previously unrecognized, distinct bentonite or bentonitic layer, perhaps with a southerly source. It is hoped that a locality might be found where four

layers were deposited and are preserved well enough for sampling and analyses. Difficulty in finding B at the three most southerly sections studied suggests that it may have a more northerly source. BHB C remains a preferred time line because it is typically easiest to locate in the field. However, the odds of samples containing 0.37 +/- 0.01 % TiO_2 not being BHB A are remote as are the odds of samples containing 0.81 +/- 0.03 % TiO_2 not being BHB B. As a package that includes the phosphate nodule horizon, the Bald Hill Bentonites are a robust correlation tool.

On the Th-Hf/3-Ta classification diagram of Wood (1980) all of the BHB's plot in the field for destructive plate margins magmas such as those produced by island arcs. This, the 395 Ma date reported for biotite from BHB A by $^{87}Rb/^{87}Sr$ (Miller and Senechal, 1965, on the Kalkberg bentonite of Rickard found by D.W. Fischer circa 1955 and identified by W.E. Brownell), and the recent reconstructions of C.R. Scotese suggest the possibility of island arcs in the sea being closed between eastern North America and Africa near the end of the Helderbergian.

Within routine sampling analytical error, chondrite-normalized diagrams for the BHB's typically show an increase in lanthanides from BHB A to B to C for each locality. This suggests the possibility that the crustal magma chambers evolved over time. Raw lanthanide data for some of the critical sections are summarized in Table 2. The possibility of fractionation within BHB C is suggested by a plot having K/Rb on the ordinate and Sm/Nd on abscissa. For most samples, this plot looks very much like a location map. It may be a statistical fluke or reflect some combination of fractionation within a crustal magma chamber and air elutriation by prevailing wind during eruption.

	A	A	A	A	A	C	C	C	C	C
	Cor.	Hynd.	B.O.R.	B.H.	C.V.	Cor.	Hynd.	B.O.R.	B.H.	C.V.
La	6.3	10.5	8.1	10.7	8.8	24.1	33.5	27.2	22.9	21.6
Ce	10	13	12	15	19	44	57	43	41	29
Lu	.11	.29	.24	.21	.27	.39	.55	.39	.43	.31

Table 2. Selected lanthanide data in ppm for Bald Hill Bentonite sections: Corriganville, Hyndman, Black Oak Ridge, Bald Hill (BHB A resampled and reanalyzed since 1988.), and Cherry Valley.

Hanson (1995) attempted to fingerprint several sets of bentonites including the BHB's. This was attempted primarily by analyzing rhyolitic melt glass trapped in quartz crystals growing in the magma. This is a potentially elegant approach as long as only relatively pure bentonites are sampled. Unfortunately, such quartz-encased glass also survives moderate transport and can be redeposited from highlands into the next storm-generated bentonitic parting. Despite detailed, measured sections, photographs, telephone conversations and a FAX provided by the authors, Hanson did not sample the type BHB layers. Figure 2-7 of Hanson (1995) indicates that at Cherry Valley he sampled a pronounced parting 23 cm above BHB C. Indeed, there is a pronounced parting 3.68 m above BHB A at Cherry Valley, NY, but BHB C is 3.43 m above BHB A. Hanson's Figure 2-43 of the Bald Hill, PA, indicate that he attempted to sample BHB C 1.14 m too high and did not use the significant updates Smith and Berkheiser prepared for the 1992 GSA NE meeting: C unchanged, B chemically recognized in the 9-cm subunit of the .38 m unit below C, and A chemically recognized 0.80 m below C in what was originally field-identified as B As a result of these changes and his preference for more pronounced partings or PAC's (?), his correlations are not useful for the BHB's. If the other bentonites he studied in NY are associated with pronounced partings, then that work likely has more utility. Hanson was successful in finding a new exposure of BHB's near Smoke Hole, VA.

In a study of the Devonian Period, Tucker et al. (1998) sampled the ~8 cm Bald Hill Bentonite A at Cherry Valley, NY. Ten zircon fractions were separated and analyzed from this bed within the *Icriodus woschmidti* lowest Devonian conodont zone. Four yielded concordant $^{207}Pb/^{208}Pb$ dates and 5 others were only 2 to 3 % discordant. They report a weighted mean for the nine of 417.6 +/- 1.0 Ma. Further conodont

and radiometric dates of the Bald Hill Bentonites at Bald Hill and Black Oak Ridge are recommended to further resolve this apparent very old beginning of the Devonian.

Though it is hard to reconstruct the evolution of the concept, it appears that groups of bentonites and ash beds may have influenced the Alleghanian deformation of the Ridge and Valley. Excavations of bentonites in the Antes black shale at the base of the Reedsville Formation near Cito, Fulton County, by R.P. Nickelsen and the senior author suggested that they were observing a jump in the level of a major decollement there. Earlier, the same geologists observed countless duplexes in Tioga Ash Bed B in a crosscut to a Ridgeley Formation glass sand open cut near Mapleton, Huntingdon County. Field work in BHB sections suggests the possibility that there has been much deformation at that level at Bald Hill, Blair County. Thus, the hypothesis should be considered that a major decollement follows the Ordovician ash beds until a belt following Alleghanian curvature is reached, perhaps at approximately 65 km W to N of Gettysburg, that it then follows the Tioga Ash Beds to somewhere beyond 100 km, and then possibly jumps to the Bald Hill Bentonites at a distance of 125 km. In a wider sense, these same three zones include massive amounts of highly deformed Reedsville, Marcellus, and Mandata black shales in their hanging walls that might have been source areas for both hydrothermal ore solutions and hydrocarbons.

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