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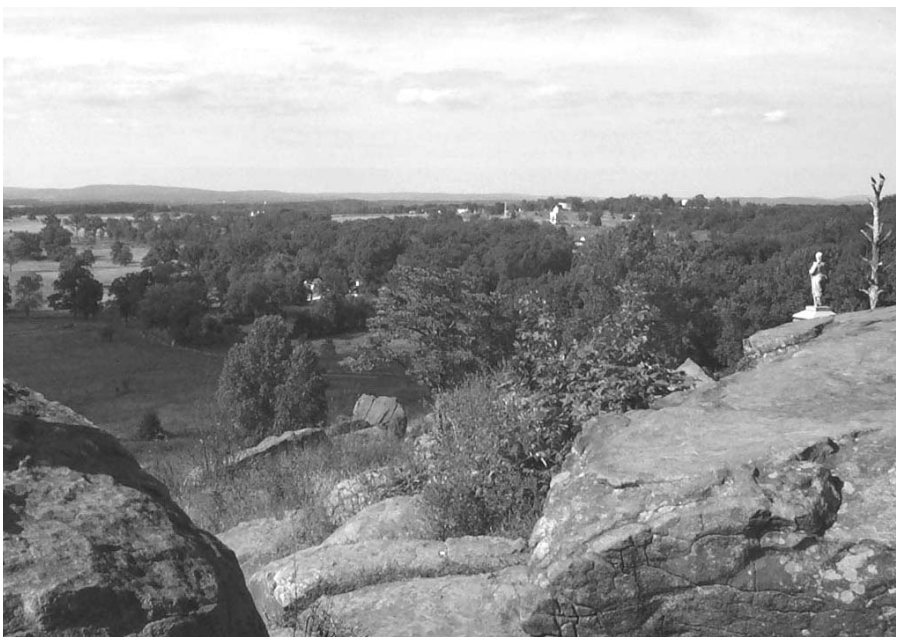

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ON THE COVER

View looking north-northwest from Little Round Top shows boulders of Jurassic York Haven Diabase in the foreground and South Mountain on the skyline. Less resistant Triassic sedimentary rocks of the Gettysburg Formation underlie the intervening valleys. These rocks are the result of a geologic rift, and the diabase provided a height advantage to the Union troops during the Battle of Gettysburg (see article on page 2). The monument on the right side of the photograph honors the 155th Pennsylvania Zouave regiment of Union Colonel Stephen Weed's Brigade, one of many troops defending Little Round Top from the Confederates on July 2, 1863. Photograph by Richard C. Keen.

PENNSYLVANIA GEOLOGY

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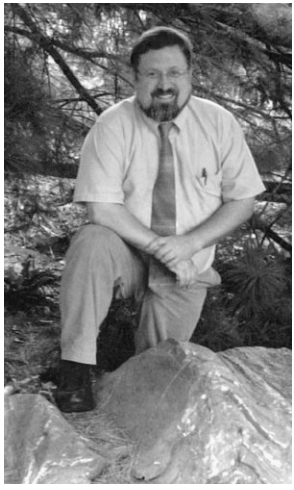
All Shook Up

The devastating earthquake and following tsunami in Indonesia has caught the attention of many Americans. One geologist friend of mine said that never have so many people asked him about plate tectonics. Much of what we know about Earth is derived from seismic data. We recently installed a seismograph at our Middletown office.

Our inexpensive seismograph in the basement of the building picked up the December 26 earthquake. It is a $500 instrument that was purchased from the Incorporated Research Institutions for Seismology (IRIS), is hooked up to an old computer, and digitally records every bump. (See www.iris.edu/edu/AS1.htm for more on a configuration such as we have.) It is my hope to have a number of such installations around the state. Perhaps you would like to set one up at your local school?

On the other hand, Ed Ianni, one of our readers from New Jersey, built his own seismograph using materials available at local stores and his computer. He suggests the following web site for more information: www.seismicnet.com. He says, "The excitement of recording your first earthquake, from somewhere on the other side of the world, in your own home or basement, can't adequately be described . . . ."

Earthquakes can represent minor tectonic adjustments or major tectonic shifts. We can monitor small tremors here in Pennsylvania or major crustal movements around the world, all with a simple instrument in the basement. Either way, we are seeing Earth in action. Someone (and nobody can seem to say definitively who) once said, "Civilization exists by geological consent, subject to change without notice." We are on a living, breathing planet. What seems immovable to us is ephemeral in geologic terms.



Jay B. Parrish
State Geologist

Regional Rifts and the Battle of Gettysburg[1]

by Robert C. Smith, II, and Richard C. Keen
Bureau of Topographic and Geologic Survey

Not counting the rift between the North and the South, there is evidence for five periods of rifting in the Mid-Atlantic Region of the Eastern United States (Figure 1). The second and fourth of these geologic rifts directly bore on the July 1–3, 1863, Battle of Gettysburg. The first had a minor influence on the prelude and postlude to the battle but adds new meaning to the word "south."

THE FIRST RIFT. Traditionally, historians date the rift between the North and the South to the firing on Fort Sumter, S. C., on April 12, 1861, or possibly earlier, to the introduction of slavery to produce labor-intensive crops. Geologists, on the other hand, recognize much earlier rifting in the Mid-Atlantic States, beginning with the introduction of the Mount Rogers Formation A-type granites and minor, possibly related, basalts about 758 million years ago (Ma) (Rankin, 1993). As noted by Rankin, the Mount Rogers is overlain by the glaciogenic Konnarock Formation. This relationship, together with Scotese's (2002) paleomagnetic reconstructions for the Late Proterozoic, places the area of the Mid-Atlantic States *far* south of its present location with only one way to go. The northward drift of Laurentia, the predecessor continent of North America, over the Mount Rogers volcanic hot spot yielded a trace marked by the Robertson River Igneous Suite (RRIS) (named after the Rob*inson* River) from 735 to 702 Ma (Tollo and Aleinikoff, 1996). These igneous rocks form a series of hills from near Charlottesville, Va., to Ashby Gap, Va. (back cover). Ashby Gap itself is underlain by Catoctin Metabasalt (see "The Second Rift," page 3), but the foothills between it and Upperville, Va., to the east are underlain by the Cobbler Mountain Member of the RRIS (Table 1). On June 20, 1863, Confederate General Longstreet (Figure 2) used Ashby Gap to take his troops westward through the Blue Ridge Mountains and join others in Lee's army on their northward march up the Shenandoah Valley.

[1]Modified from Smith and Keen (2004).

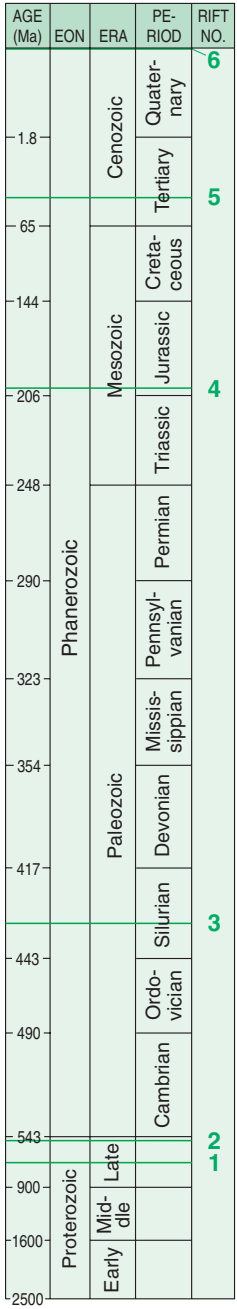


Figure 1. The six rifts (geologic and political) through geologic time.

The geochemical characteristics of the RRIS can be seen in rocks as far northeast as the Reading Prong in Berks County, Pa. (back cover). Here, bimodal volcanics include A-type felsite dikes dated 602 Ma that are geochemically similar to the RRIS and continental-initial-rifting tholeiitic basalts (Smith, 2003). Iron mining around these dikes supported the Union cause as it had previously supported an older rebel cause against Great Britain.

THE SECOND RIFT. Approximately 570 Ma (Figure 1), the Catoctin rift produced volcanic rocks (Aleinikoff and others, 1995) that now underlie parts of the Blue Ridge Mountains in an area extending from near the latitude of Charlottesville, Va., almost to Harrisburg, Pa. (back cover). The southern part of these mountains, which include the Catoctin Mountains, have a largely basaltic core. South Mountain, which is separated from the Catoctin Mountains by the Jacks Mountain-Tunnel Hill fault system (Fauth, 1978), has a more rhyolitic core. These mountains were effectively used by Lee to screen the Army of Northern Virginia from the eyes of Union cavalry as the Confederates moved north.

One of the Confederate columns, the III Corps under the command of General Hill (Figure 2), marched east from encampment areas near Cashtown Gap around 5 a.m. on July 1 with General Longstreet's I Corps following later that evening. Both commands essentially took the present trace of U.S. Route 30. This modern highway follows the Alleghanian-age Carbaugh-Marsh Creek fault zone through South Mountain. Just west of the mountain crest, the I and III Corps passed the remains of abolitionist Thaddeus Stevens' iron works, which had been destroyed by Confederate General Early's troops on June 26. At the crest, they marched over Catoctin Metarhyolite (Table 1). Some of Pennsylvania's oldest quarries are located on the ridges south of and over-

Table 1. ***Composition of Rift Volcanics Associated With the Battle of Gettysburg***

	Cobbler Mountain Member of the RRIS (about 7 mi south of Ashby Gap, Va.)	**Catoctin Metabasalt** (Pa. Route 16, west of Fountain Dale, Pa.)	**Catoctin Metarhyolite** (Pa. Route 94, 1.33 mi east of Pa. Route 34)	**Catoctin Metarhyolite** (U.S. Route 30 at Cashtown Gap, Pa.)	**York Haven Diabase** (type locality, York County, Pa.)	**Rossville Diabase** (from railroad cut through Seminary Ridge)
RIFT	First	Second	Second	Second	Fourth	Fourth
AGE (Ma)[1]	~722	~575	~575	~575	201.2	201.0
OXIDE (percent)[2]						
SiO_2	72.45	44.41	77.72	78.39	51.51	50.55
Al_2O_3	12.63	17.26	10.87	10.70	14.70	16.20
$^3Fe_2O_3$	3.72	13.14	2.95	2.91	11.51	10.83
CaO	.27	8.49	.03	.06	10.53	11.15
MgO	.08	7.73	.09	<.01	6.48	6.80
Na_2O	4.45	1.79	2.37	4.12	2.23	NA[4]
K_2O	4.83	.84	4.90	3.49	.65	.30
TiO_2	.22	1.64	.21	.20	1.12	.70
MnO	.03	.19	.02	.01	.18	.13
P_2O_5	.02	.16	.02	.01	.17	.10

[1]Ages are from the following sources: RRIS, Tollo and Aleinikoff (1996); Catoctin units, Aleinikoff and others (1995); and diabase units, Sutter (1988) and Dunning and Hodych (1990).
[2]Oxide values for the York Haven Diabase and Rossville Diabase are from Smith and others (1975).
[3]Total Fe expressed as ferric iron.
[4]NA, not analyzed, but typically 1.95±0.2%.

looking the route taken by Hill's and Longstreet's corps. These quarries were begun about 12,500 years ago by Native Americans and were worked extensively into the Late Woodland Period, ending with Colonial contact. Weapons-grade metarhyolite occurs close to the trace of U.S. Route 30, suggesting a fairly narrow fault zone. The linearity of the zone (Root and Hoskins, 1977) suggests a high-angle fault. Except for this Cashtown Gap route, which crests at approximately 1,400 feet but had a good pike with gentle slopes through it, most routes over the Catoctin Metarhyolite and capping Cambrian quartzites were rough ground, having typical elevations of 1,600±100 feet. Another potential route from southwest of Gettysburg and passing Fairfield, Pa., would have required a crossing of 1,300 feet at Blue Ridge Summit and is not known to have been used by infantry during the advance. Horses, however, were not given a vote in selecting routes, and Union General Buford's cavalry used this route to ride to Gettysburg from Waynesboro, Pa. On June 28, the cavalry encamped at Fountain Dale, Pa., at an elevation of approximately 750 feet on Catoctin Metabasalt (Table 1).

Confederate General Ewell's II Corps was also forced to cross South Mountain. Although they were fighting for the South against the North, ironically, most of this corps (excluding Early's Division)

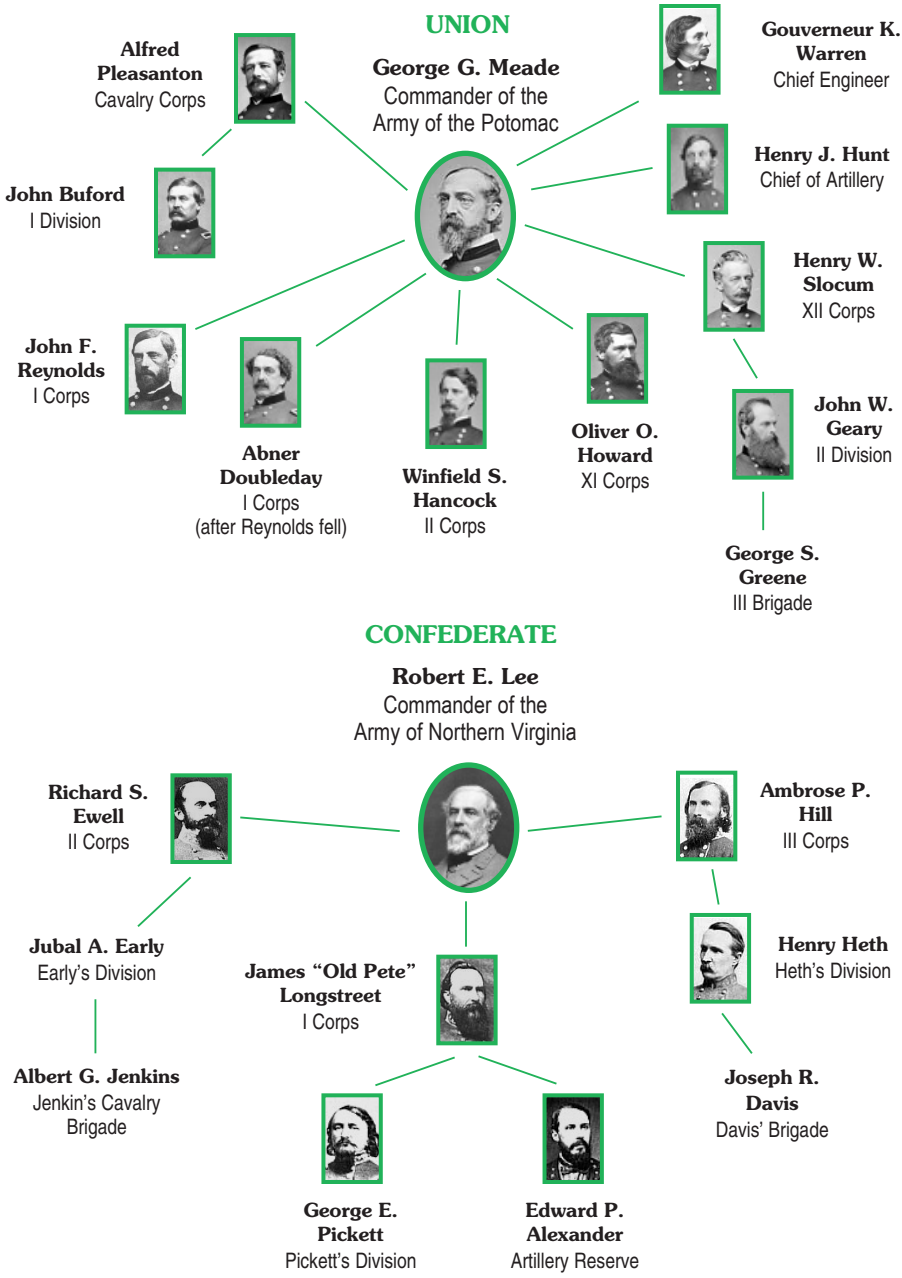


Figure 2. Commanders mentioned in the text who were involved in the Gettysburg campaign. Photographs obtained in December 2004 from web sites of the National Park Service (http://www.nps.gov/gett/getttour/day1-det.htm) and Library of Congress (http://memory.loc.gov/ammem/cwphtml/cwphome.html). Names of photographers or original sources are given on the web sites.

approached Gettysburg from the north (from Carlisle, Pa.). This is because they had followed the Great Valley around the north-northwest side of the mountain. Ewell's corps traveled south over Catoctin Metarhyolite, generally following what is now Pa. Route 34 (Table 1). Unlike Hill and Longstreet, Ewell did not have a linear fault to follow and had to cross elevations of up to 1,000 feet on more primitive rural roads. Earlier in their journey, Ewell's corps traveled from Culpeper, Va., into the Shenandoah Valley by way of Chester Gap, Va. In doing so, they likely moved between areas underlain by rocks of the fourth rift, of the second rift, of the first rift, and of the second rift again—all in an effort to support the sixth, a political, rift!

THE THIRD RIFT. The third rift occurred in the Lower Silurian (Figure 1) and is not known to have directly affected the Battle of Gettysburg. The third rifting may be a relaxational phase of the Taconic orogeny that has been associated with unusually high mantle heat flow from at least Virginia to Connecticut. The allochthonous (tectonically transported) Hamburg klippe, which was emplaced during the Taconic orogeny, includes rocks from this event. Its western edge was briefly encroached upon by General Jenkins' Confederate cavalry (Figure 2) during skirmishing before the battle in the general area of Camp Hill, Cumberland County, Pa., and during a brief reconnaissance thrust north to Enola, Pa. (both a few miles west of Harrisburg).

THE FOURTH RIFT. The fourth rift occurred during the early Mesozoic (Figure 1). Triassic sedimentation in basins up and down North America's east coast indicated the start of crustal stretching prior to the opening of the Atlantic Ocean. The rift basins include the Culpeper basin from whence Ewell's corps marched (see above), and the Gettysburg basin where the battle was fought. The Triassic sedimentary rocks in the Gettysburg basin provided the lower elevations preferred by armies, but in the Battle of Gettysburg, the armies managed to converge on an area that had been much affected by two lowermost Jurassic formations. First the York Haven Diabase, and then the Rossville Diabase, cut through the generally fine-grained reddish mudstones and shales of the Triassic Gettysburg Formation (Figure 3).

West of Gettysburg, a northeast-trending belt of the poorly defined Heidlersburg Member of the Gettysburg Formation shows evidence of an arid climate. Dinosaur footprints (Stose and Jonas, 1939), mud cracks, glauberite salt casts, and probable aeolian sand grains are all consistent with an arid, sometimes lacustrine, depositional environment for the Heidlersburg (Faill, 2003). Parts of the unit may be chemical precipitates somewhat similar to portions of the lacustrine

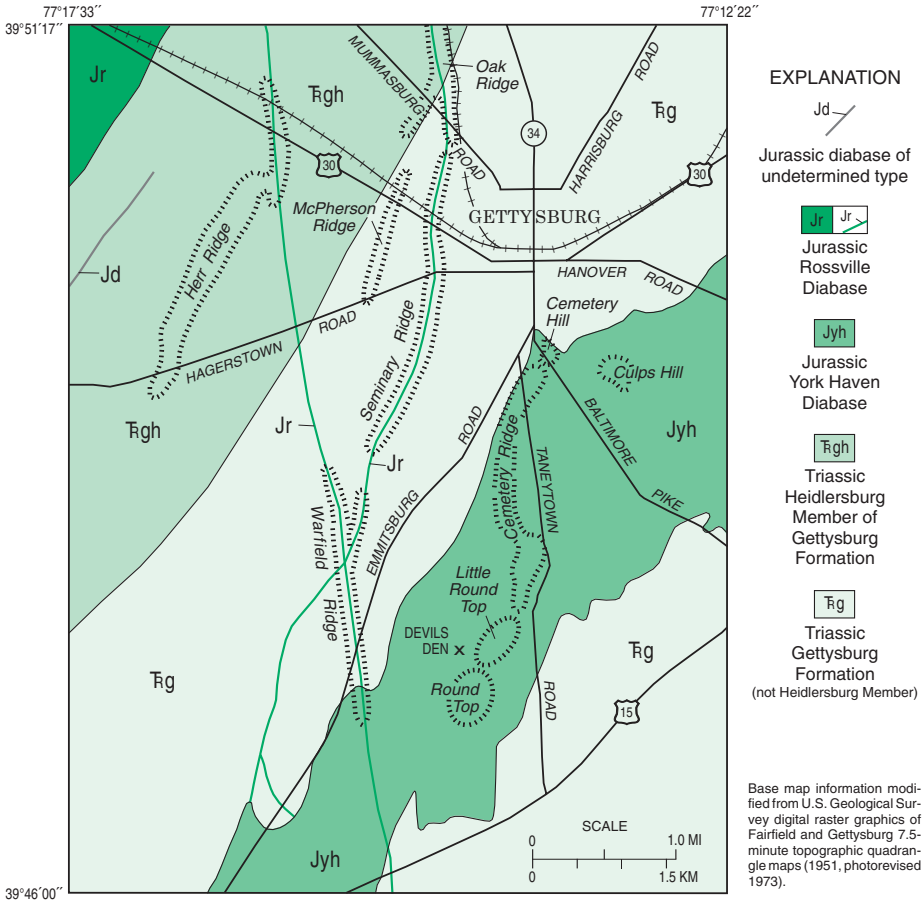


Figure 3. Geologic map showing ridges utilized by the armies in the Battle of Gettysburg. The area is underlain by rocks associated with the fourth rift. Geology from Miles and others (2001) and Froelich and Gottfried (1999, p. 202).

Lockatong Formation in the Newark basin (east-northeast of the Gettysburg basin in Pennsylvania). This implies ongoing evaporation in both the Gettysburg and Newark basins. Minor interbedded sands in the Heidlersburg form the gentle northeast-trending segment of Herr Ridge, and a Rossville Diabase dike forms the more northerly trending segment of this ridge, which crosses U.S. Route 30. The next closer ridge to town, McPherson Ridge, is underlain by sandier than normal beds of the Gettysburg Formation.

Early on the morning of July 1, Heth's Division of Confederate General Hill's III Corps (Figure 2) bumped up against Union General Buford's I Cavalry Division west of Herr Ridge. Buford's men were

pushed back to McPherson Ridge where they stubbornly held their position until relieved at approximately 10:30 a.m. by General Reynolds' I Corps. Shortly thereafter, Reynolds was killed while deploying his units and was replaced by General Doubleday. Meanwhile, the Union XI Corps under General Howard moved into position on the north side of Gettysburg. Initial Confederate success on McPherson Ridge was rebuffed by a furious Union counterattack (Figure 4). Late in the afternoon, Hill's troops drove Doubleday's troops off of McPherson Ridge and back to Seminary Ridge. Eventually, Confederate pressure forced the outnumbered Union corps to withdraw southeast through Gettysburg. Under the overall command of General Howard, remnants of the I and XI Corps secured the York Haven Diabase sheet at Cemetery Hill and Culps Hill, respectively. This was followed not long afterward by the arrival of Union General Meade and occupation of the remainder of the York Haven Diabase hills in this area. Losses in both armies were high. To gain control of McPherson Ridge and Seminary Ridge, North Carolina's 11th and 26th Regiments of Heth's Division, Confederate's III Corps, and Michigan's 24th and Pennsylvania's 151st Regiments of the Union's I Corps suffered the highest percentage losses of the entire three-day battle.

In the battlefield area, Big Roundtop, Little Roundtop, Devils Den, Cemetery Hill, Cemetery Ridge, and Culps Hill are underlain by York Haven Diabase (Figure 3). They are all noted Union positions that, with the exception of Devils Den, successfully resisted repeated Confederate assaults on July 2 and 3. At its type locality in the Gettysburg basin, the York Haven Diabase sheet has been estimated to be about 2,500

Figure 4. Confederate troops commanded by General Davis sought cover from counterattacking Union troops in this railroad cut through McPherson Ridge. Some of the Confederates were forced to surrender when Union troops blocked one end of the cut.

feet thick (Smith, 1973). Outside the battlefield area, but still in the Gettysburg basin, the York Haven Diabase also occurs as numerous 30- to 70-foot-wide dikes and is associated with one small basalt flow near Aspers, Adams County, Pa. (10 miles north of Gettysburg) (Stose, 1932).

The York Haven Diabase is resistant to weathering relative to the Triassic sedimentary rocks and is incredibly durable. Fractures through it must propagate through randomly oriented plagioclase and pyroxene laths, each having complex cleavages. Today, this diabase is a highly desired dimension stone and provides high-quality, durable railroad ballast. At the "Index House" in the Reading Prong where high levels of indoor radon were found, it was even used to provide shielding outside the basement walls from the high gamma flux produced by daughter products of thorium and uranium decay (Smith and others, 1987). Throughout the battle, the York Haven Diabase, at Devils Den or more typically as fieldstone fences, provided what little natural protection was available to the troops.

Just as the rift between the states began in the south, so too the rifting and drifting that resulted in the Mesozoic basins progressed from south to north (Withjack and others, 1998). On the other hand, diabase igneous activity of any one composition was synchronous along the entire length of the Mesozoic basins. The York Haven Diabase has been dated at 201.2 Ma from the median of three $^{40}Ar/^{30}Ar$ dates for lateral equivalents (Sutter, 1988) and from the best clear fragments of zircon by $^{206}Pb/^{238}U$ dates (Dunning and Hodych, 1990). The Rossville Diabase has similarly been dated at 201.0 Ma, the median of seven preferred zircon analyses from a small Rossville Diabase sheet (Dunning and Hodych, 1990).

The Rossville Diabase forms relatively thin sheets in Pennsylvania and Virginia. Unfortunately for Lee, no Rossville sheets were available in the area of Gettysburg, and even those located elsewhere in the Gettysburg basin are much less resistant to erosion than the York Haven Diabase (thereby forming lower hills). Typically, the Rossville Diabase occurs as subvertical, approximately 30- to 70-foot-wide dikes. The chemical compositions of the York Haven and Rossville Diabases are shown in Table 1.

Confederate positions for the second and third days of the battle were largely confined to areas underlain by the Gettysburg Formation. Unlike the Heidlersburg Member, the rest of the Gettysburg Formation is largely red shale and siltstone, has less convincing evidence of an arid climate, and is probably not lacustrine. The Gettysburg Formation supported decent to good roads for the final approach of Union columns from the southeast and south, and the Union positions on ridges of

York Haven Diabase looked down on the Confederate positions on the Gettysburg Formation northeast and west of town on the second and third days.

On July 3, Confederate General Alexander's Artillery Reserve was positioned on Seminary Ridge, a mere 50 feet above the surrounding Gettysburg Formation rocks. From this position, the Confederates shelled the Union lines to the east in preparation for a massive assault (Pickett's Charge). Smoke covered the field making it difficult for both armies to adjust their fire, and as a result, overshooting was common, causing numerous causalities and considerable damage to equipment on the back slopes of both Seminary and Cemetery Ridges. Union troops sought shelter behind fences and diabase boulders along their front line. Confederate troops, however, were massed behind their artillery batteries in wooded areas along Seminary Ridge to mask them from observation but were still exposed to heavy shelling. Union artillery, largely positioned on the York Haven Diabase heights and under the excellent command of General Hunt, dominated much of the field during the battle.

The difficult to impossible excavation characteristics of diabase generally prevented the building of significant earthworks and likely contributed to both the effectiveness of Hunt's artillery and high battle casualties in general. An exception was on the northeast side of Culps Hill, where Union earthworks were effective when manned. Fortunately for the Union, General Greene did not dissuade his troops from fortifying their position on Culps Hill despite the opposition of his commanding officer, General Geary. Hand-dug wells in the York Haven Diabase are virtually unknown, adding to the misery of troops cut off from water but providing a few opportunities for brotherly compassion.

THE FIFTH RIFT. Results of the fifth period of rifting, which occurred in the Eocene Epoch (Figure 1), consist of bimodal volcanics and doming believed to continue to the present day. These are recognized mostly in the areas of Highland County, Va., and Pendleton County, W. Va. (Southworth and others, 1993). The rough topography at McDowell, Va. (back cover), in part the result of Eocene uplift, was used skillfully by Confederate General Thomas J. "Stonewall" Jackson at the battle of McDowell, on May 8, 1862.

SUMMARY. In the Battle of Gettysburg, it was Union Generals Buford, Hancock, Howard, Warren, and others (Figure 2) who seemed to most recognize the value of topography. General Warren, for example, recounted the following in a letter he sent to Captain Porter Farley of the 140th Regiment of New York:

> At my suggestion General Meade sent me to the left to examine the condition of affairs and I continued on till I reached Little Round Top. There were no troops on it and it was used as a Signal Station. I saw that this was the key to the whole position and that our troops in the woods in front of it could not see the ground in front of them, so that the enemy would come upon them before they would be aware of it. The long line of woods on the west [east[1]] side of the Emmitsburg road, which road was along a ridge, furnished an excellent place for the enemy to form out of sight, so I requested the Captain of a rifle battery just in front of Little Round Top to fire a shot into these woods. He did so, and as the shot went whistling through the air the sound of it reached the enemies' troops and caused every one to look in the direction of it. The motion revealed to me the glistening of gun barrels and bayonets of the enemy's line of battle already formed and far outflanking the position of any of our troops, so that the line of his advance from his right to Little Round Top was unopposed. . . . I immediately sent a hastily written dispatch to General Meade to send a division at least to me, and General Meade directed the Fifth Army Corps to take position there.
>
> —Norton (1913, p. 309)

After the war, General Longstreet lamented, "The enemy had cast his lines on grounds too strong for lead and steel . . . ." (Longstreet, 1992, p. 426).

Years after the Battle of Gettysburg, retired Confederate generals were frequently asked why "the cause" was lost at Gettysburg. General Pickett is reported to have provided the slyest answer when he said that he had always been of the opinion that the Yankees had something to do with it. Perhaps the York Haven Diabase did too.

REFERENCES

Aleinikoff, J. N., Zartman, R. E., Walter, Marianne, and others, 1995, U-Pb ages of metarhyolites of the Catoctin and Mount Rogers Formations, Central and Southern Appalachians—evidence for two pulses of Iapetan rifting: American Journal of Science, v. 295, p. 428–454.

Dunning, G. R., and Hodych, J. P., 1990, U/Pb zircon and baddeleyite ages for the Palisades and Gettysburg sills of the Northeastern United States—implications for the age of the Triassic/Jurassic boundary: Geology, v. 18, p. 795–798.

Faill, R. T., 2003, The early Mesozoic Birdsboro central Atlantic margin basin in the Mid-Atlantic Region, Eastern United States: Geological Society of America Bulletin, v. 115, p. 404–421.

Fauth, J. L., 1978, Geology and mineral resources of the Iron Springs area, Adams and Franklin Counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Atlas Report 129c, 72 p.

Froelich, A. J., and Gottfried, David, 1999, Early Mesozoic—igneous and contact metamorphic rocks, chap. 12B *of* Shultz, C. H., ed., The geology of Pennsylvania: Penn-

[1]Norton (1913, p. 309) footnoted that the use of "west" in the original letter was wrong.

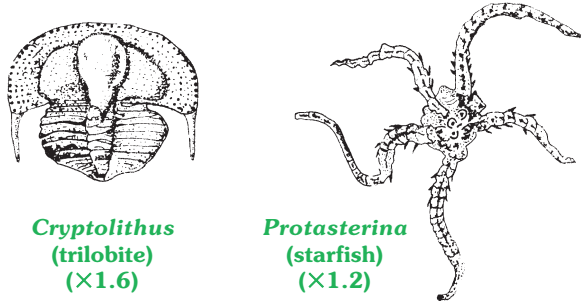
sylvania Geological Survey, 4th ser., Special Publication 1, p. 202–209. [Co-published with Pittsburgh Geological Society.]
Longstreet, James, 1992, From Manassas to Appomattox: Da Capo Press, 690 p. [Unabridged republication of edition published in Philadelphia in 1896 by J. B. Lippincott Company.]
Miles, C. E., Whitfield, T. G., Kuchinski, J. G., and others, preparers, 2001, Bedrock geology of Pennsylvania: Pennsylvania Geological Survey, 4th ser., digital dataset, scale 1:250,000 [www.dcnr.state.pa.us/topogeo/map1/bedmap.htm].
Norton, O. W., 1913, The attack and defense of Little Roundtop, Gettysburg: New York, The Neale Publishing Company, 350 p.
Rankin, D. W., 1993, The volcanogenic Mount Rogers Formation and the overlying glaciogenic Konnarock Formation—two Late Proterozoic units in southwestern Virginia: U.S. Geological Survey Bulletin 2029, p. 1–26.
Root, S. I., and Hoskins, D. M., 1977, Lat 40°N fault zone, Pennsylvania—a new interpretation: Geology, v. 5, p. 719–723.
Scotese, C. R., 2002, PALEOMAP project: www.scotese.com (accessed September 2004).
Smith, R. C., II, 1973, Geochemistry of Triassic [sic] diabase from southeastern Pennsylvania: University Park, Pennsylvania State University, Ph.D. thesis, 262 p.
_____ 2003, Late Neoproterozoic felsite (602.4±2 Ma) and associated metadiabase dikes in the Reading Prong, Pennsylvania, and rifting of Laurentia: Northeastern Geology and Environmental Sciences, v. 25, no. 3, p. 175–185.
Smith, R. C., II, and Keen, R. C., 2004, Appendix A—Regional rifts and the Battle of Gettysburg, *in* Inners, J. D., and others, Rifts, diabase, and the topographic "fishhook"—Terrain and military geology of the Battle of Gettysburg—July 1–3, 1863: Joint meeting of the Northeast-Southeast Sections of the Geological Society of America, Tysons Corner, Va., 2004, Pre-Meeting Field Trip Guidebook, p. 96–101.
Smith, R. C., II, Reilly, M. A., Rose, A. W., and others, 1987, Radon—a profound case: Pennsylvania Geology, v. 18, no. 2, p. 3–7.
Smith, R. C., II, Rose, A. W., and Lanning, R. M., 1975, Geology and geochemistry of Triassic [sic] diabase in Pennsylvania: Geological Society of America Bulletin, v. 86, p. 943–955.
Southworth, C. S., Gray, K. J., and Sutter, J. F., 1993, Middle Eocene intrusive igneous rocks of the central Appalachian Valley and Ridge province—setting, chemistry, and implications for crustal structure: U.S. Geological Survey Bulletin 1839–J, p. J1–J24.
Stose, G. W., 1932, Geology and mineral resources of Adams County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., County Report 1, 153 p.
Stose, G. W., and Jonas, A. I., 1939, Geology and mineral resources of York County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., County Report 67, 199 p.
Sutter, J. F., 1988, Innovative approaches to the dating of igneous events in the early Mesozoic basins of the eastern United States: U.S. Geological Survey Bulletin 1776, p. 194–200.
Tollo, R. P., and Aleinikoff, J. N., 1996, Petrology and U-Pb geochronology of the Robertson River Igneous Suite, Blue Ridge province, Virginia—evidence for multistage magmatism associated with an early episode of Laurentian rifting: American Journal of Science, v. 296, no. 9, p. 1045–1090.
Withjack, M. O., Schlische, R. W., and Olsen, P. E., 1998, Diachronous rifting, drifting, and inversion on the passive margin of central eastern North America—an analog for other passive margins: AAPG Bulletin, v. 82, no. 5A, p. 817–835.

The Great Swatara Gap Fossil Migration

by Stuart O. Reese, Anne B. Lutz, and James R. Shaulis
Bureau of Topographic and Geologic Survey

A BAD ENDING, BUT. . . In the early 1990s, the end had come for the fantastically popular Swatara Gap fossil locality in Lebanon County, Pa. Long known by fossil collectors as a place where exquisite Late Ordovician trilobites and the rare starfish *Protasterina* could be found (Figure 1), Swatara Gap was visited frequently by fossil enthusiasts. Unfortunately, the outcrop was adjacent to busy Interstate Route 81. Fossil hunters, some a little too zealous, removed so much material that the Pennsylvania Department of Transportation (PennDOT) considered declaring the site off-limits. Road collapse had become a serious possibility. In 1990, *Pennsylvania Geology* contained an article on the site's potential closure (Hoskins, 1990). Soon, "No Trespassing" signs appeared. Swatara Gap became a site of disappointment for arriving fossil hunters. Though originally uncovered by road construction, the locality fell victim to the highway for safety's sake.

. . . A NEW BEGINNING. But now some good news has come out of Swatara Gap. In 2003, as PennDOT initiated a reconstruction project for Interstate Route 81, the fossil locality showed up in an environmental survey as a Pennsylvania Natural Heritage Program site. Geologists William Kochanov, Gale Blackmer, and James Shaulis of the Pennsylvania Geological Survey worked with transportation officials to arrange a salvage operation of the fossiliferous shale within the Martinsburg Formation that would otherwise have been doomed to become road ballast as PennDOT rebuilt the base of the highway.



Cryptolithus **(trilobite) (×1.6)**

Protasterina **(starfish) (×1.2)**

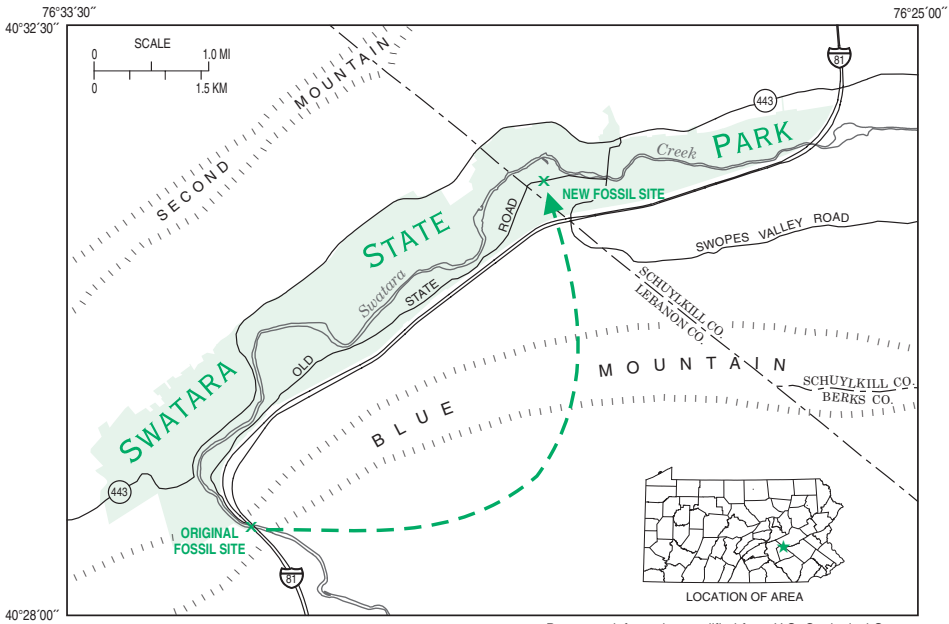
Figure 1. Sketches of two of the fossils found at the Swatara Gap site (from Hoskins and others, 1983, p. 198).

It was agreed that the rocks would be moved to a safe, accessible site in nearby Swatara State Park (Figure 2).

After months of work to get to the point where the rocks could be moved, the day arrived for the great fossil migration. On August 5, 2004, PennDOT trucks hauled tons of fossiliferous rocks to their new home (Figure 3). PennDOT transferred some 20 triaxial dump truck loads to the "Fossil Pit" located off of Old State Road. That is more than 200 cubic yards of fossiliferous rock!

The great fossil migration was completed. Ordovician fossils now rest comfortably (but unconformably) on Devonian bedrock (Figure 4). Geologists might call this an overturned sequence, but for fossil hunters and transportation officials, it is a safe place to search for fossils. Thanks to the move, the discovery of a magnificent Swatara Gap fossil still awaits the keen eye and lucky strike of the hammer.

SAFETY FIRST. Those familiar with the original site will quickly see that the rocks moved to the fossil pit are less weathered and, consequently, a fair bit harder. Over time, the forces of weathering will soften the rock. But for now, some of the rocks have sharp edges, so caution should be taken when collecting there. In addition, bedding



Base map information modified from U.S. Geological Survey (1996) digital raster graphics of 7.5-minute topographic quadrangle maps, PennDOT (2004) shapefile of state maintained roadways, and Susquehanna River Basin Commission (1998) shapefile of the Lower Susquehanna River basin (PennDOT data). Park area from Pennsylvania Department of Conservation and Natural Resources (2003) shapefile for state parks.

Figure 2. Map showing the location of the original Swatara Gap outcrop and the new fossil site in Swatara State Park.

Figure 3. The removal of Martinsburg shale from the Swatara Gap site.

Figure 4. The dumping of Swatara Gap rocks at their new resting place in Swatara State Park.

planes are uncommon, and the rocks typically break through fossils. Fossil fragments are the result. As always, eye protection should be worn when using rock hammers and chisels. Please also be courteous to those who come after you by limiting what you take.

THANKS. Special thanks are given to John M. Bachman, Senior Project Manager for Highway Design at PennDOT, Brian Moore of Michael Baker Associates, Patricia Waidelich Riley of JMT Engineering, and William C. Friese, Park Manager, Pennsylvania Bureau of State Parks, all of whom gave considerable effort to make this happen. For more information about the great fossil migration, see our web page at www.dcnr.state.pa.us/topogeo/collecting/.

REFERENCES

Hoskins, D. M., 1990, The unfortunate rewards of success—fossil collecting at Swatara Gap site to end: Pennsylvania Geology, v. 21, no. 1, p. 1.

Hoskins, D. M., Inners, J. D., and Harper, J. A., 1983, Fossil collecting in Pennsylvania (3rd ed.): Pennsylvania Geological Survey, 4th ser., General Geology Report 40, 215 p.

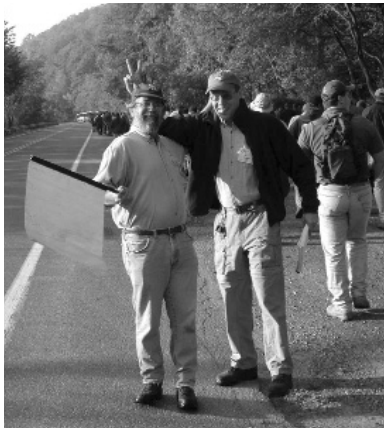
GEOFACTS

The Peculiar Habits of Geologists

by James R. Shaulis and Gary M. Fleeger
Pennsylvania Geological Survey

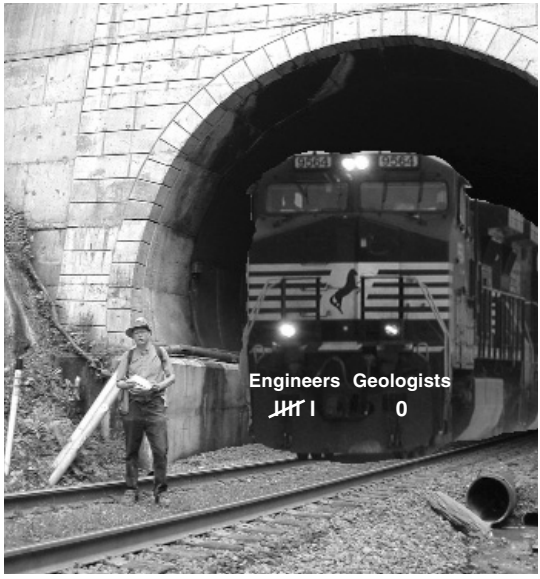
Geofact 4

Geophysicists frequently suffer complete breakdowns when exposed to real rocks.



Geofact 5

A geologist holding a flag instead of his hammer is considered defenseless and gets no respect.



—Photograph by Viktoras W. Skema, modified by Gary M. Fleeger.

Geofact 6

Proving the old axiom, "It's easier to train a geologist in the field than in the classroom."

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“REGIONAL RIFTS AND THE BATTLE OF GETTYSBURG”
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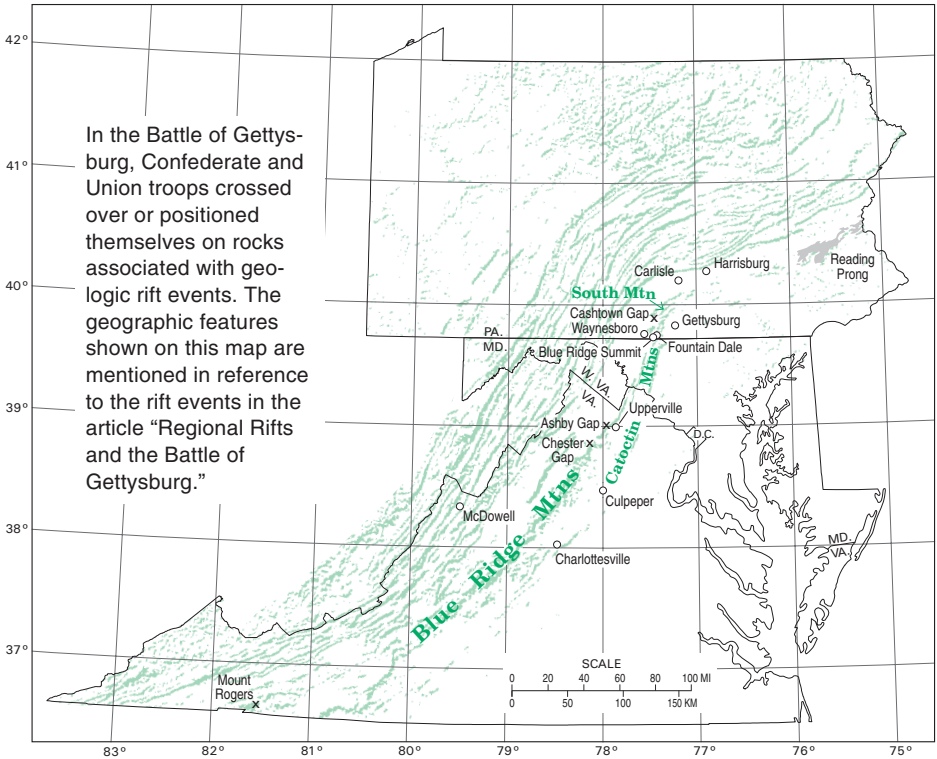
(See article on page 2.)



Most map information modified from shapefiles and shaded-relief image obtained from http://nationalatlas.gov.

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