Vol. 48, No. 1

Pennsylvania Geology

Table of Contents

The critical high ground on the Gettysburg and Solferino battlefields, two important mid-nineteenth-century battle sites. Top, panorama (in 2013) of Solferino ridge at Solferino, Italy, a higher end moraine of Late Pleistocene age surrounded by lower till plains, as seen from 3.5 kilometers east-northeast of that village (also Cuffey, Inners, Fleeger, and others, 2006). Bottom, Cemetery Ridge from Seminary Ridge at Gettysburg, Pa. (in 2003), a low rise held up by an Earliest Jurassic diabase sill flanked by Late Triassic softer redbeds, as seen from about one mile to the west (also supplemental pages in Cuffey, 2014) (see article on page 3).

—Photographs by Roger J. Cuffey

EDITORIAL

Life on a Dynamic Planet

Gale C. Blackmer, State Geologist
Pennsylvania Geological Survey

Civilization exists by geological consent, subject to change without notice.
—Will Durant

I have never felt an earthquake. Once, when I was a kid in Delaware, my mother woke up to the closet doors rattling from one of the small tremors that regularly shake the mid-Atlantic. I slept through it. While I was at Penn State, my fellow graduate students in our third-floor office felt the building sway, but I was outside and didn't notice. When the Mineral, Va., quake emptied office buildings in Harrisburg, I was again outside and felt nothing. As a geologist, I feel cheated. As a human being, though, I'm not sure I miss not feeling the earth's more violent changes.

A couple of events featured in the news these days brought this to mind. Kilauea in Hawaii is erupting again. In the space of a few weeks, something like 20 fissures have opened, spewing lava across what used to be a quiet subdivision, destroying houses and roads and livelihoods. Neighborhoods have been evacuated because of toxic volcanic gases, and there is a threat of violent steam eruptions from the main crater if the level of the lava lake falls below the water table and groundwater floods over the lava. Most of the people affected recognize that events like this are a risk when you live on the flanks of an active volcano. Still, I'll bet they wish their little piece of civilization wasn't subjected to so much "change without notice."

Closer to home, it seems like all of Pittsburgh's steep hillsides are trying reach equilibrium at the same time. An unusually rainy winter and early spring triggered landslides all around the city, taking out houses, apartment buildings, neighborhood streets, and busy highways. No lives have been lost, but the trappings of civilization have suffered to the tune of more than $18 million in damage.

It is worth noting that geologic changes are just events, until we erect our civilizations within their zones of influence and turn them into hazards (if a landslide happens in the wilderness, does it make a noise?). Although we can identify areas that might be at general risk for geologic change, the details are hard to pin down (that's the "without notice" part). Geologic processes are bigger and stronger than we are, they have been here longer, and they will continue after we're gone. Perhaps we will recognize that someday, and temper our habit of building on steep slopes and volcanoes and floodplains and fault lines without first looking for "geological consent." Until then, buy good insurance and hope for the best.

Gale C. Blackmer

Geology of the Mid-Nineteenth-Century Solferino (Italy) and Gettysburg (Pennsylvania) Battlefields—Similarities, Differences, and Possible Influences

Roger J. Cuffey[1]
The Pennsylvania State University

INTRODUCTION

Solferino, up until then the largest battle in mid-nineteenth-century Europe, was the decisive war-winning engagement in one of the wars for Italian unification. Gettysburg, four years later, was the turning-point battle in the American Civil War.

Both Solferino and Gettysburg involved enemy-held high ground being bombarded by many cannons, and then assaulted by large infantry formations. Solferino succeeded for the attacking French, but Gettysburg did not for the attacking Confederates.

Solferino and Gettysburg exhibit certain striking similarities, suggesting the possibility that Robert E. Lee may have known about that earlier battle when considering his options at the later one (Cuffey, 2004, p. 27; 2008, p. 165–167; 2013, p. 92–94; Cuffey, Inners, Fleeger, and others, 2006, p. 10; Inners and others, 2004, p. 90; 2006, p. 92a–92b).

Hence, our purpose here is to compare and contrast salient features of both battlefields as discovered from literature and fieldwork, so that possible connections between the two can be explored. More on Solferino is discussed, because Gettysburg's extensive documentation (Cuffey, 2004, 2008, 2013, 2015; Cuffey, Inners, Fleeger, and others, 2006; Inners and others, 2004, 2006; many references in each) can allow briefer summations for Pennsylvania geologists. Additional information on both battlefields is in Cuffey (2018) as well as the supplemental pages attached to Cuffey (2014). The Appendix starting on page 17 of this issue presents details about the battles.

Distances at Solferino are given in metric units but are in English units for Gettysburg, following the practices of previous scholars. Equivalences are given for the critical places and can be calculated by the reader using the following: 1 km = 0.6 mi, 1 mi = 1.6 km, 1 m = about 3 ft, and 1 ft = about 0.3 m.

BACKGROUND

Achieving Italian unification and independence (*risorgimento*) took from 1831 until 1870 (Borghi, 2012; Societa Solferino e San Martino, 1989). The 1859 war climaxed at the Battle of Solferino, won by the French with Piedmontese (northwest Italian) allies against the Austrians (who then controlled north-central and northeast Italy).

The Piedmontese contribution is considered by modern Italians as the separate Battle of San Martino, fought at the same time along the northern edge of the Solferino battlefield. The critical town there has been renamed "San Martino of the Battle" (*"San Martino del Battaglia"*).

Almost a hundred years after achieving independence from Britain, the United States became embroiled in a bitter Civil War (1861–65), fought to keep the nation as one and to end slavery. At its

[1]Professor Emeritus of Paleontology, Department of Geosciences, 412 Deike Building, University Park, PA 16802, rcuffey@psu.edu.

midpoint, Gettysburg turned back the South's invasion of the North, and along with the simultaneous Union victory at Vicksburg, began the prolonged wearing down of the Confederate forces.

LOCATION

Solferino village is in north-central Italy (Figure 1), 43 km (27 mi) west-southwest of Verona, on the Po River floodplain, south of the southern edge of the Alps. The battlefield is approximately a square that is 17 km (11 mi) on a side, with Solferino roughly its center. Valeggio and Castiglione delle Stiviere mark its eastern and western extent, and San Martino and Guidizzolo its northern and southern extent (Figure 2).

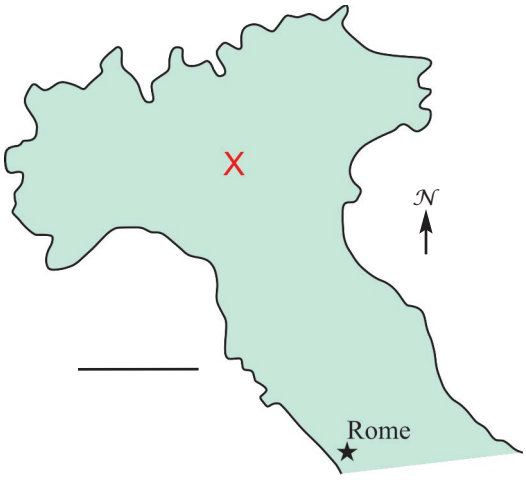


Figure 1. Outline map of northern Italy, showing the location of Solferino (X); scale bar is 160 km (100 mi); base from Williams (1960, p. 68).

Gettysburg is in Adams County, south-central Pennsylvania, 39 mi (60 km) south of Harrisburg (the state capital). It sits on low ground east of the northern end of the Blue Ridge (here, in southern Pennsylvania and northern Maryland, called South or Catoctin Mountain). The Gettysburg battlefield is basically a square that is 5.5 mi (9 km) on each side (Clark and the editors of Time-Life Books, 1985; Cuffey, Inners, Fleeger, and others, 2006; Inners and others, 2004, 2006). Gettysburg is in its northern part; its limits are marked by topographic highs south of town rather than villages.

TOPOGRAPHY

The center of the Solferino battlefield is dominated by a narrow, steep-sided ridge, Solferino ridge, just west of the village of that name, rising approximately 100 m (330 ft) above low plains to the north and south (cover [top]; Figure 3) (Geoportale Nazionale, 2014; Wanderkarte, 2014), thus noticeably higher than Gettysburg's Cemetery Ridge (cover [bottom]; Figure 4) that has 60 ft (20 m) of relief (Cuffey, 2008, p. 165; 2013, p. 92; Cuffey, Inners, Fleeger, and others, 2006, p. 9, 11; U.S. Army Map Service and U.S. Geological Survey, 1951).

GEOLOGY

No bedrock crops out around Solferino. Instead, its ridge is a glacial end or terminal moraine, one of the outermost of the morainal ridges concentric around the southern end of Lake Garda (Castiglioni, 2004, p. 210) (Figure 5), deposited by the alpine glacier that filled that lake basin late in Pleistocene time.

Solferino ridge itself is of late ("young") Riss age (~150 ka), 3rd Glacial, equivalent to the United States' classical Illinoian (Figure 6). The low ground to the north is underlain by younger ground moraine (Würm, 70–15 ka, 4th Glacial, Wisconsinan), and to the south by weathered older drift (Mid-Pleistocene, ~300–600? ka) (Castiglioni, 2004, p. 210).

The Solferino ridge consists of till, which is massive brown clay and silt containing many cobbles and pebbles, unsorted, floating in that matrix. The till is hard, indurated, and compact, and would have been difficult to dig battlefield fortifications into, just as at Gettysburg, though from very different materials.

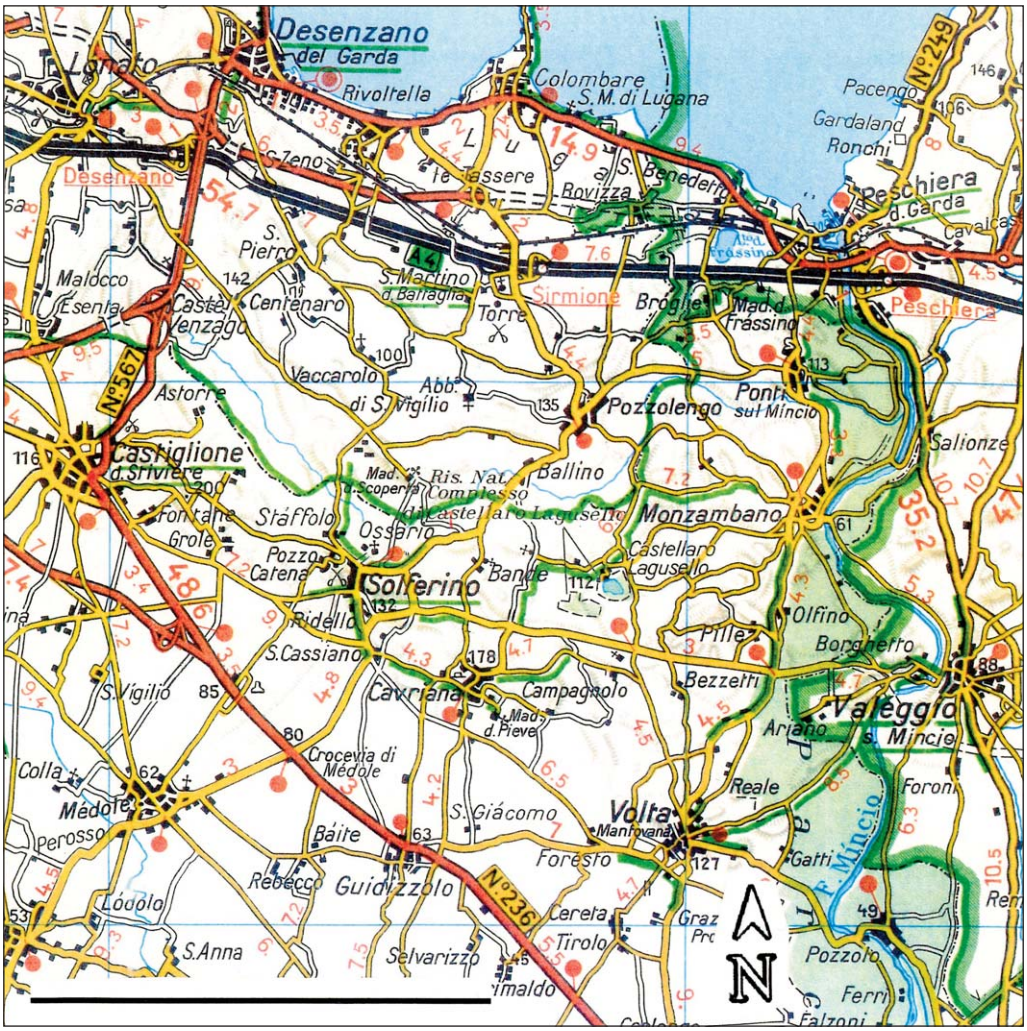


Figure 2. Towns and villages around Solferino, Italy, where the battle was centered; the battlefield extends from Castiglione delle Stiviere on the west to Valeggio on the east, south to Medole, Rebecco, and Guidizzolo, and north to San Martino and Pozzolengo; the large lake farther north is Lago di Garda; thin blue-green north-south and east-west lines are merely the map's place-locator grid (not latitude/longitude); red numbers along roads are in kilometers; scale bar is 10 km (6 mi); modified from Touring Club Italiano (2008).

The cobbles are subrounded rather than angular, suggesting water washing in ancient/ancestral Lake Garda before having been picked up by the glacier and moved farther south.

Their lithologies vary from place to place, but overall include many volcanics (50–75 percent [field estimates by the author]; red and gray), some carbonates (25–50 percent; mostly light-gray dolomitic micrite and minor shelly limestone), a few crystallines (10–25 percent; pink granite and gray schist), and occasional tan quartzite (~1 percent). These proportions seem consistent with what bedrock types are exposed in the Alps mountains to the north of the battlefield.

Although the ridge is now heavily overgrown, these materials can be seen in a few roadbanks and also in the oldest structures (the tower, retaining walls, and house exteriors) built from the only locally available stone (entirely these glacial cobbles).

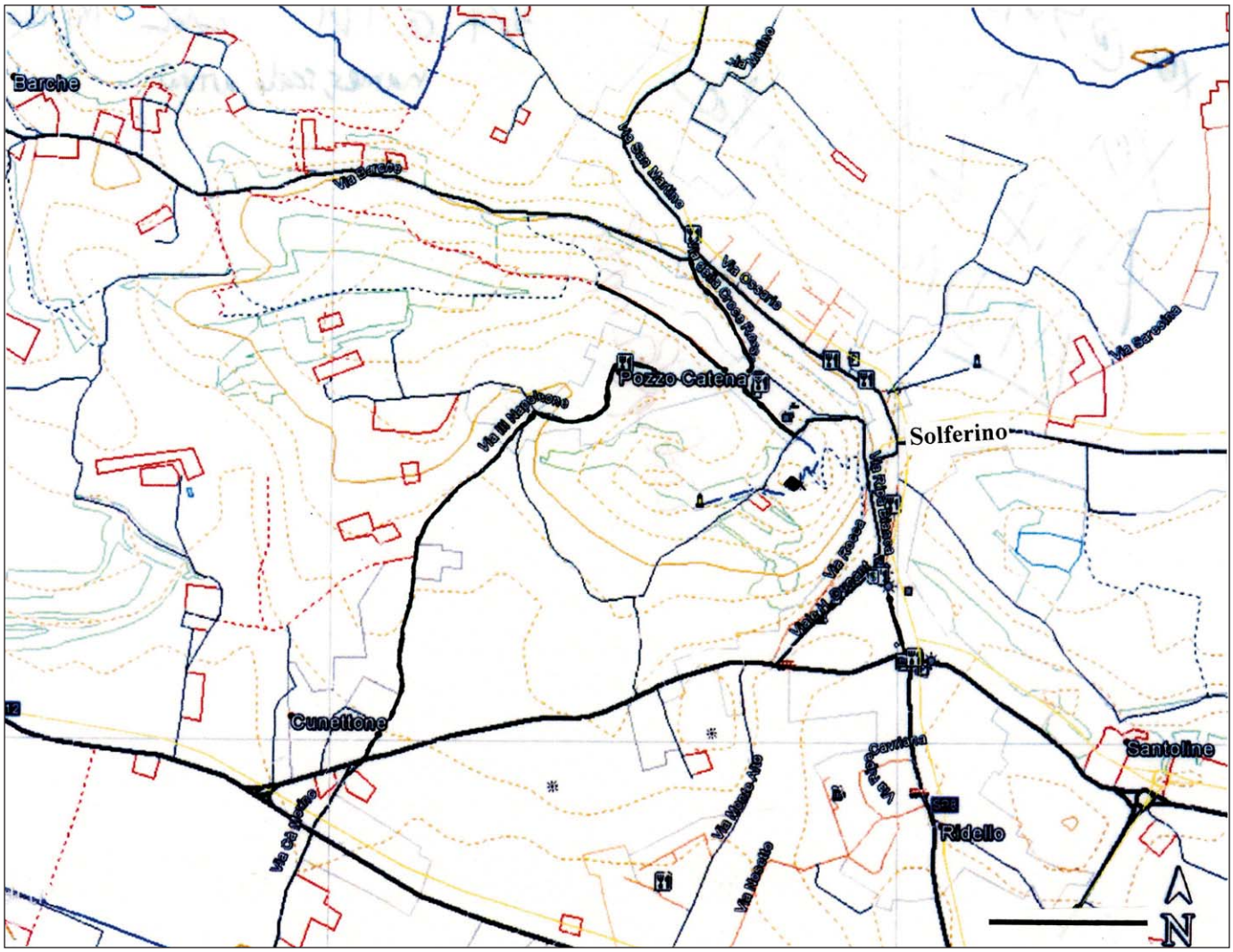


Figure 3. Solferino ridge, the critical high ground there, shown by contours (the solid contour is 150 m [493 ft] in elevation, supplemented by dashed intermediate contours at intervals of 10 m [33 ft]); scale bar is 1 km (0.6 mi); modified from a print-out from Wanderkarte (2014). The road (black line) running northwest through the "n" in Pozzo Catena marks the narrow ridgetop northwest of the medieval tower (black diamond) on the highest point at the southeastern end of the ridge.

In sharp contrast, Gettysburg's landforms are directly controlled by the underlying bedrock (Late Triassic erodable redbeds vs. Earliest Jurassic resistant diabase, 220–200 Ma) (Figures 7 and 8) (Cuffey, Inners, Fleeger, and others, 2006, p. 5, 7; Inners and others, 2006).

BATTLEFIELDS TODAY

Atop the Solferino moraine, the most conspicuous feature is its stone tower, Solferino tower or The Rock (i.e., the Fortress; *La Rocca*), or The Spy of Italy (*La Spia d'Italia*), because of the long-range, all-around views from its flat top (Borghi, 2012, p. 18; Societa Solferino e San Martino, 1989, p. 136, 150, 151, back cover). It rises 23 m (70 ft) high, sits on the highest point on the southeastern end of the ridge, and was built in medieval times (1022 AD) of cobbles locally available from the till below.

From the tower's top, the terrain critical to the battle can be seen: the low ground to the west across which the French attacked in the morning, the ridge crest (Brooks, 2009, p. 61, 69) which they assaulted

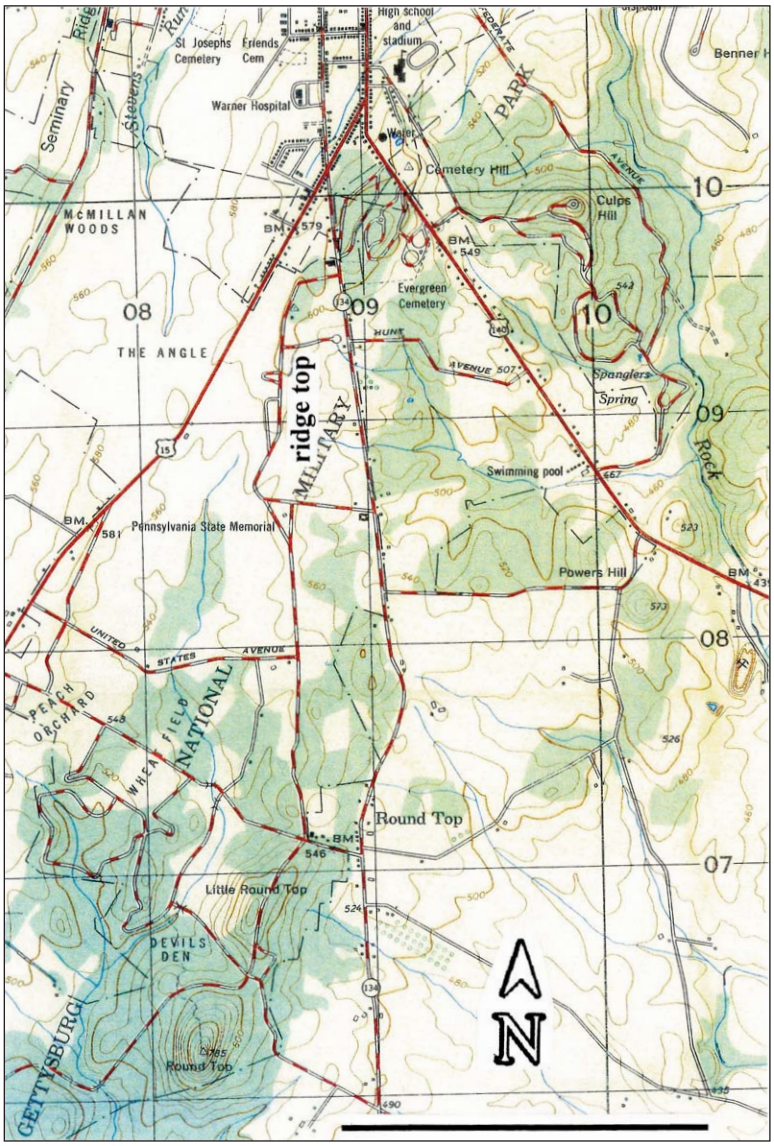


Figure 4. Cemetery Ridge, the critical high ground immediately south of Gettysburg, outlined by 560-ft (171-m) contours in the center of the map, stretching from Round Top and Little Round Top in the south, to Cemetery and Culps Hills in the north; contour interval is 20 ft (6 m); scale bar is 1 mi (1.6 km); squares are Universal Transverse Mercator (UTM) 1,000-m grid; modified from U.S. Army Map Service and U.S. Geological Survey (1951); topography on later civilian editions partly obscured by shading to mark the legal boundaries of Gettysburg National Military Park.

from the west at midday and from the north-northeast in midafternoon, the lower terrain to the east and southeast across which the Austrians retreated late in the day, and far to the north where the Piedmontese were fighting. Farther to the north, Lake Garda and the Alps are visible, beyond the limits of the battlefield.

Immediately below the Solferino tower, the ridge top and slopes are now heavily wooded. Paved streets go through the castle square (*piazza castello*), on out to the cemetery (*cimitero*), and down into the villages below (Solferino on the east, Pozzo Catena on the west). The cemetery, although important in the battle, has not been conserved but, rather, has been completely rebuilt so as to serve the present community.

A modern steel-framed tower having enclosed observation decks formerly overlooked the Gettysburg battlefield until recently, when it was demolished to return the site to 1863 appearance.

The countryside surrounding Solferino, agricultural with scattered houses and large farm estates, and a few low hills, looks much as it must have 150 years ago. Solferino itself, stretching along the eastern foot of the ridge and around its southeastern and southern end, has a densely settled core

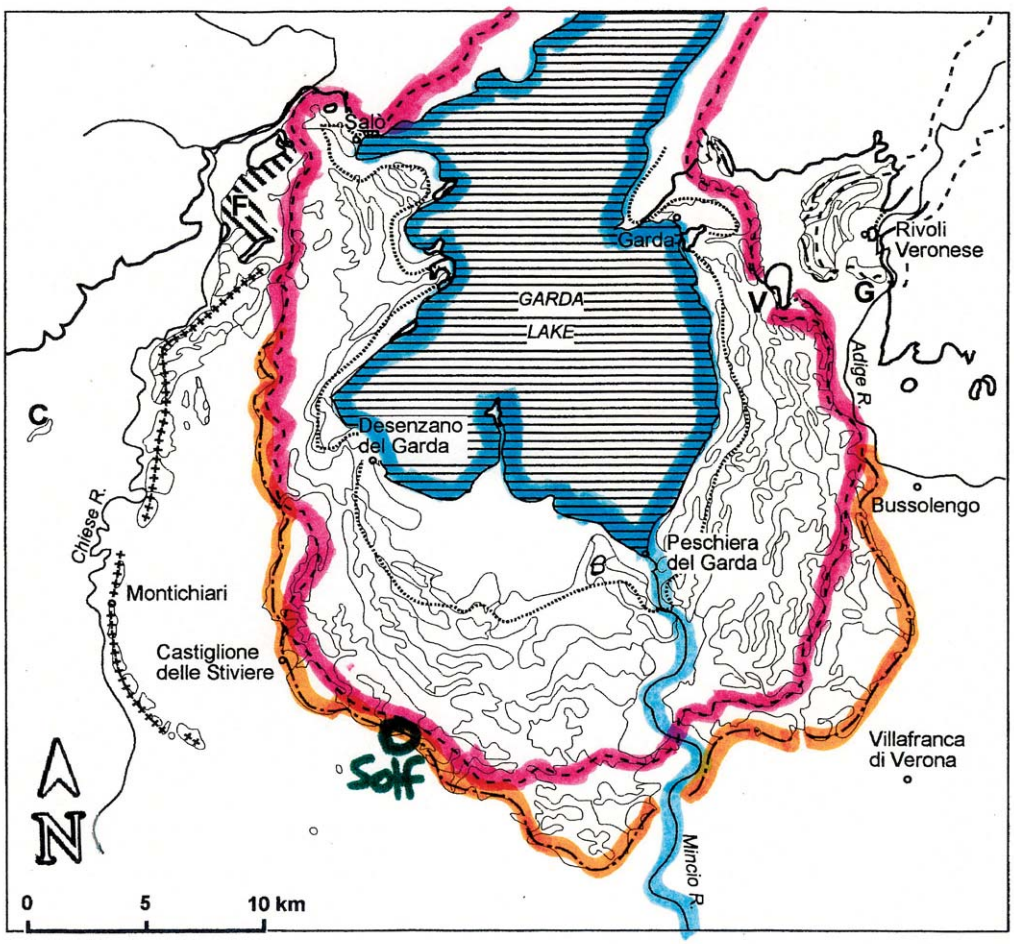


Figure 5. Surficial geology and end moraines of the Solferino (green "Solf") area; orange, Late Riss moraines; pink, Würm moraines; blue, lake shores and principal river channels; modified from Castiglioni (2004, p. 210).

characterized by very narrow streets and multistoried old buildings flanked by wider streets and more spread-out, lower modern houses and businesses.

Similar things can be said about Gettysburg as well, except that many cannons and monuments have been positioned all over that battlefield by the National Park Service, which give it a Civil War atmosphere much more pronounced than one gets around Solferino, which has few memorials and no cannons outside now.

Only a couple of buildings at Solferino show shell holes from the battle (one is at the entrance to the castle square on the ridgetop) (Brooks, 2009, p. 91). Gettysburg's Trostle Farm barn is famous for its artillery damage in its upper end wall (Cuffey, 2015, p. 574–575; Inners and others, 2004, p. 37; 2006, p. 37).

BATTLE GENERALITIES

The Solferino battle was illustrated entirely by paintings and drawings. These vary greatly in accuracy, from almost photographic to so inaccurate that matching their purported location to the terrain observable today is difficult or impossible. On the other hand, the Gettysburg battle was partly

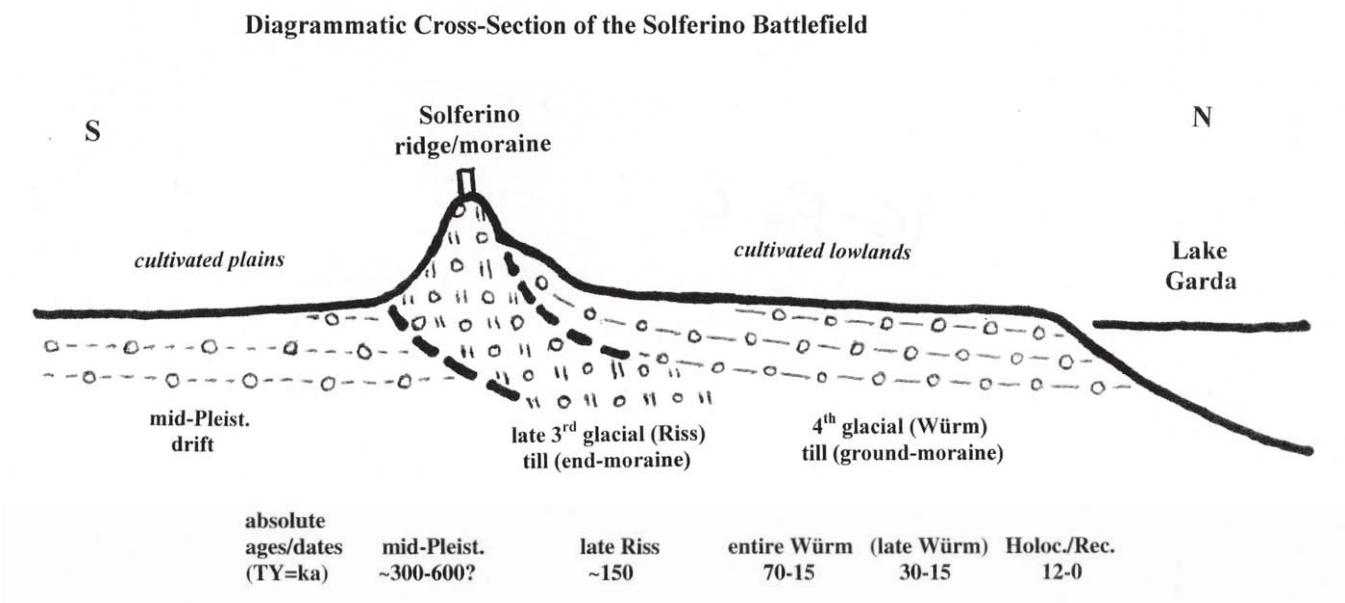


Figure 6. Diagrammatic geologic cross section of Solferino ridge/end moraine and surrounding lower countryside; not to exact scale (drawing by the author, 2013).

illustrated by the first widespread use of battlefield photography, as well as by paintings (still being done today), whose accuracy—particularly in landscapes—seems to have been encouraged by comparison with actual photographs.

The most obvious consequence of the Battle of Solferino was the almost immediate end of the major 1859 war in France's and Piedmont's favor. This outcome was probably communicated quickly across the Atlantic, where Robert E. Lee would likely have heard about it and wondered about the reasons for their victory.

The strength of the French component of the Allied army is best estimated (Morris, 2004) at about 130,000 Allies (~70 percent French, the rest Piedmontese) vs. 120,000 Austrians. Total casualties (killed, wounded, and missing) were about 18,000 Allied (mostly French) vs. 22,000 Austrian (around 2,500 and 3,000 dead, respectively).

At Gettysburg, the invading Confederates numbered 75,000, and the defending Union, 90,000. Total casualties were about 28,000 and 23,000, respectively; the numbers of dead were around 4,000 and 3,000 (U.S. Department of the Army, 1956, p. 245–251).

Napoleon III's major innovation in the Solferino battle was his greatly increased use of artillery, a fact that may well have caught Lee's attention before Gettysburg. The French had recently developed a new rifled 86-mm 4-pounder cannon (*pièce de quatre*) (Borghi, 2012, p. 17–18; Societa Solferino e San Martino, 1989, p. 64, 114, 133), which was more maneuverable, longer range, more accurate, and thus superior to the older Austrian smoothbores. These new French guns were slightly smaller and lighter than the types used at Gettysburg shortly afterwards (smoothbore Napoleons, Parrott rifles, and ordnance rifles).

Napoleon's massed artillery pounding a defended ridgetop in support of a large infantry attack certainly suggests a cannonade and assault, much like what happened on the third day at Gettysburg four years later. The overall similarity is quite striking.

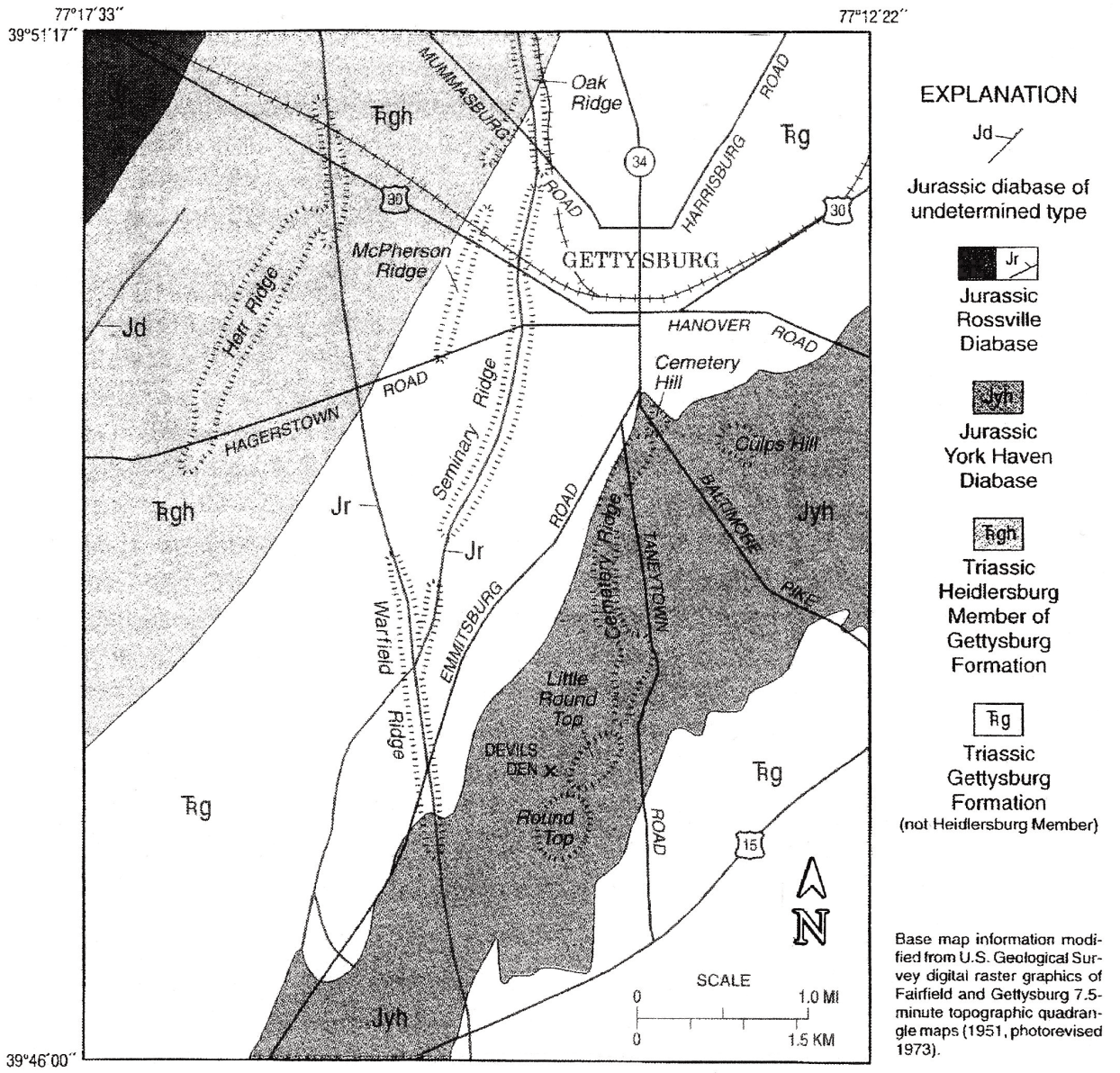


Figure 7. Bedrock geology and landforms of the Gettysburg battlefield; modified from Cuffey, Inners, Fleeger, and others (2006, p. 5).

BATTLE SUMMARY

The Battle of Solferino was shorter (one day) than Gettysburg (three days); it ended the 1859 war decisively within a few days, while Gettysburg was followed by two more years of difficult combat. Both were fought on stiflingly hot days in midsummer. Both centered on a fight for the high ground, Solferino ridge (moraine) and Cemetery Ridge (sill).

Published Solferino battle maps emphasize the midday climax around Solferino ridge, or try to include all positions occupied at any time during the entire day (Uffindell, 1999, p. 109). However, after visiting the battlefield and its museums, one can draw a set of much more detailed maps showing the hour-by-hour progress of the action, from which can be seen the most significant events within that battle.

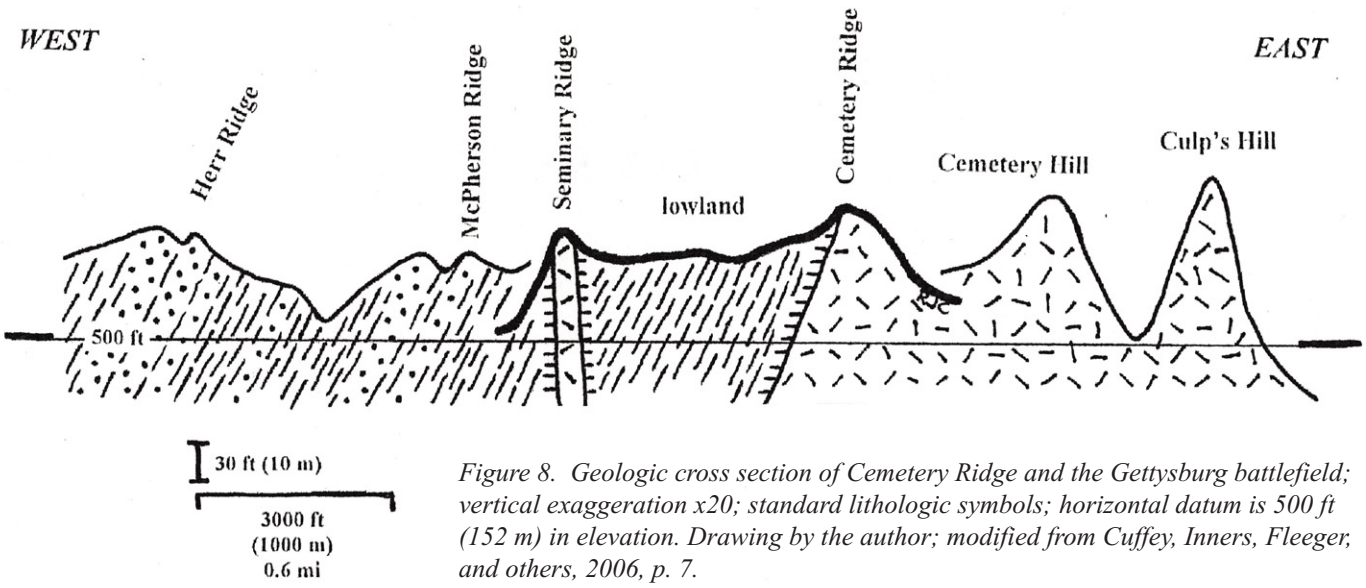


Figure 8. Geologic cross section of Cemetery Ridge and the Gettysburg battlefield; vertical exaggeration x20; standard lithologic symbols; horizontal datum is 500 ft (152 m) in elevation. Drawing by the author; modified from Cuffey, Inners, Fleeger, and others, 2006, p. 7.

The Solferino battle overall was simple, the French merely pushing steadily eastward against the Austrians throughout the day, in concept diagrammable in brief schematic fashion (Cuffey, 2004, p. 27; 2008, p. 166; 2013, p. 93; Inners and others, 2006, p. 92a). From the hour-by-hour maps, three critical events (Figure 9) can be seen to have shaped its final outcome for the French: their initial massive artillery bombardment against the Austrians up on the Solferino ridgetop (Figure 10); their midday infantry assault up the west slope of that ridge (Figure 11); and their midafternoon infantry assault up its north-northeastern slope (Figure 12). These actions cleared the Austrians off the commanding high ground and forced them to retreat off to the east. Simultaneous with all these, the Piedmontese and other Austrians engaged in a daylong seesaw battle over level ground around San Martino to the north (Figure 13).

In contrast, Gettysburg's progress has long been well mapped (Figure 14) and clearly understood.

That battle overall involved several distinct phases or maneuvers (U.S. Department of the Army, 1956, p. 249; Cuffey, Inners, Fleeger, and others, 2006, p. 3): retreat through town, two flank attacks (uncoordinated), and final central assault (cannonade, then charge). It is these last, the third day's operations, which so resemble the Solferino battle. Pictures of the Gettysburg battle can be seen in our previous guidebooks (Cuffey, 2004, 2008, 2013, 2015; Cuffey, Inners, Fleeger, and others, 2006; Inners and others, 2004, 2006; and many references in each).

In the final settlement after Solferino, Lombardy (north-central Italy) went to Piedmont, while Austria retained Veneto (northeastern Italy). Moreover, this eventually led to the establishment of the International Red Cross, the drafting of the Geneva Convention (still with us today), and more wars before Italy was finally unified. After Gettysburg, the Civil War continued for two more years before the Confederates finally surrendered.

ACKNOWLEDGMENTS

Colleagues too numerous to mention have encouraged my interest in comparing Gettysburg and Solferino. A couple of my great-grandfathers participated as ammunition bearers at the Solferino battle. GIS (Geographic Information Systems) specialists at The Pennsylvania State University's map library,

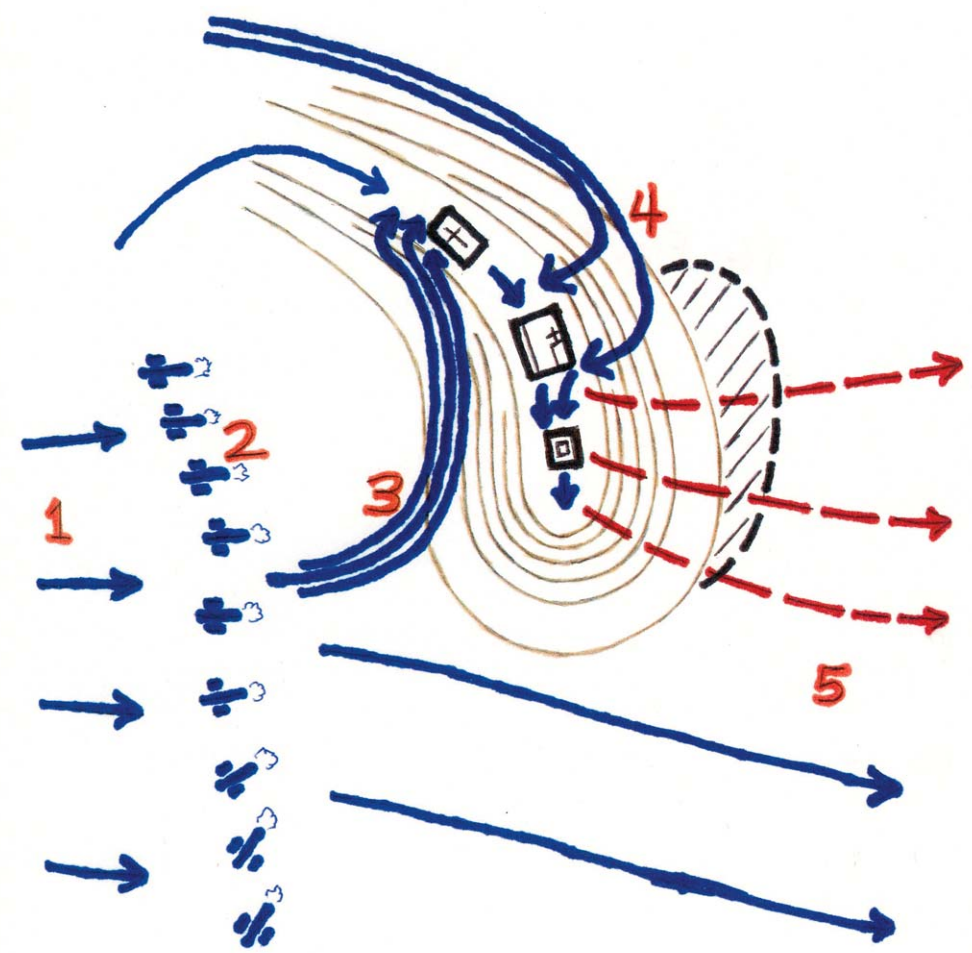


Figure 9. Schematic summary of critical events at the center of the Battle of Solferino, not to exact scale, but indicating the important topography (Solferino ridge) and troop maneuvers. 1, Initial French advance from the west; 2, midmorning French artillery bombardment; 3, midday French assault up the west slope; 4, midafternoon French assault up the northeast slope; 5, late-day Austrian retreat and French follow-up to the east. Structures shown (northwest to southeast): cemetery, castle square with church, Solferino tower, and Solferino village (black dashed line enclosing diagonally lined area). North is toward the top of the page. Drawing by the author, 2013.

J. Coons, T. Lalonde, H. Ross, L. Nolan, and L. Musser, retrieved many maps of the Solferino area to illustrate its topography. Jon Inners and Anne Lutz (both retired from the Pennsylvania Geological Survey) reviewed this manuscript, and the latter edited the final manuscript.

REFERENCES CITED

Borghi, B., 2008, 24 giugno 1859—Solferino e San Martino, Le Pietre Raccontano La Storia [volume for the 150th anniversary]: Societa Solferino e San Martino and Tipolitografia Ciessegrafica, Montichiari, 107 p.

_____ ed., 2012, 24 giugno 1859, La battaglia di Solferino e San Martino, I luoghi della memoria; Quadderno didattico: Societa Solferino e San Martino, Desenzano del Garda, 31 p.

Brooks, R., 2009, Solferino 1859—The battle for Italy's freedom (Campaign 207): Oxford, U.K., Osprey Publishing, 96 p.

Castiglioni, G. B., 2004, Quaternary glaciations in the eastern sector of the Italian Alps, *in* Ehlers, J., and Gibbard, P. L., eds., Quaternary glaciations—Extent and chronology, Part I—Europe: Amsterdam, Elsevier, p. 209–214.

Clark, C., and the editors of Time-Life Books, 1985, Gettysburg—The Confederate high tide: Alexandria, Va., Time-Life Books (Civil War Series), 176 p.

Figure 10. The midmorning artillery bombardment by French cannons southwest of Solferino ridge (note the tower on the distant skyline); Napoleon III is sitting on his horse just as Robert E. Lee did at Gettysburg on the third day's cannonade; nineteenth-century painting by Jean-Louis-Ernest Meissonier. Online at https://commons.wikimedia.org/w/index.php?curid=1206853 *(also reproduced in Borghi, 2008, p. 16, and Salamida, 2005, p. 56).*

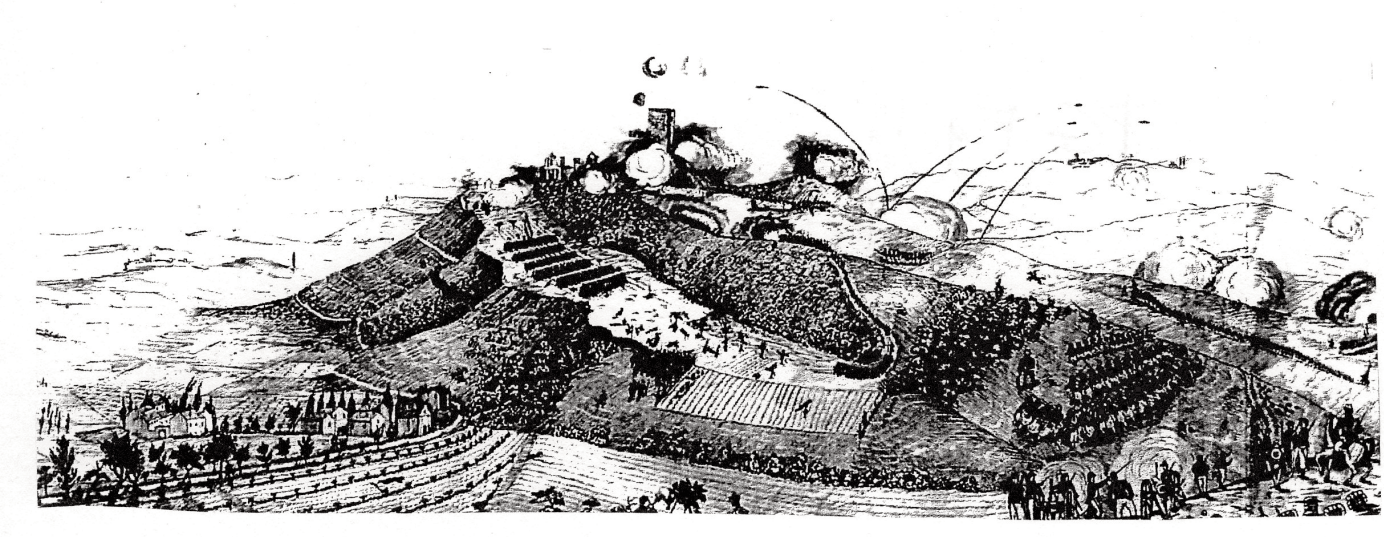


Figure 11. Midday French assault up the western slope of Solferino ridge, while French shells burst over the ridgetop; modified from Borghi (2008, p. 13). (Nineteenth-century contemporaneous drawing/lithograph.)

Figure 12. Midafternoon French assault up the northeast slope of Solferino ridge, illustrated here by a similar upslope attack elsewhere on the battlefield (because none of the available sources show that particular action). Nineteenth-century painting, online at https://www.google.com/search?q=solferino+paintings&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwiCsuH76KXaAhVqxoMKHSW2BLsQ7AkIMg&biw=1197&bih=779#imgrc=Os6JOhRtjH8q5M *(also in Borghi, 2008, p. 55).*

Figure 13. The daylong seesaw battle over level ground at San Martino north of Solferino; modified from Brooks (2009, p. 66). (Nineteenth-century painting.)

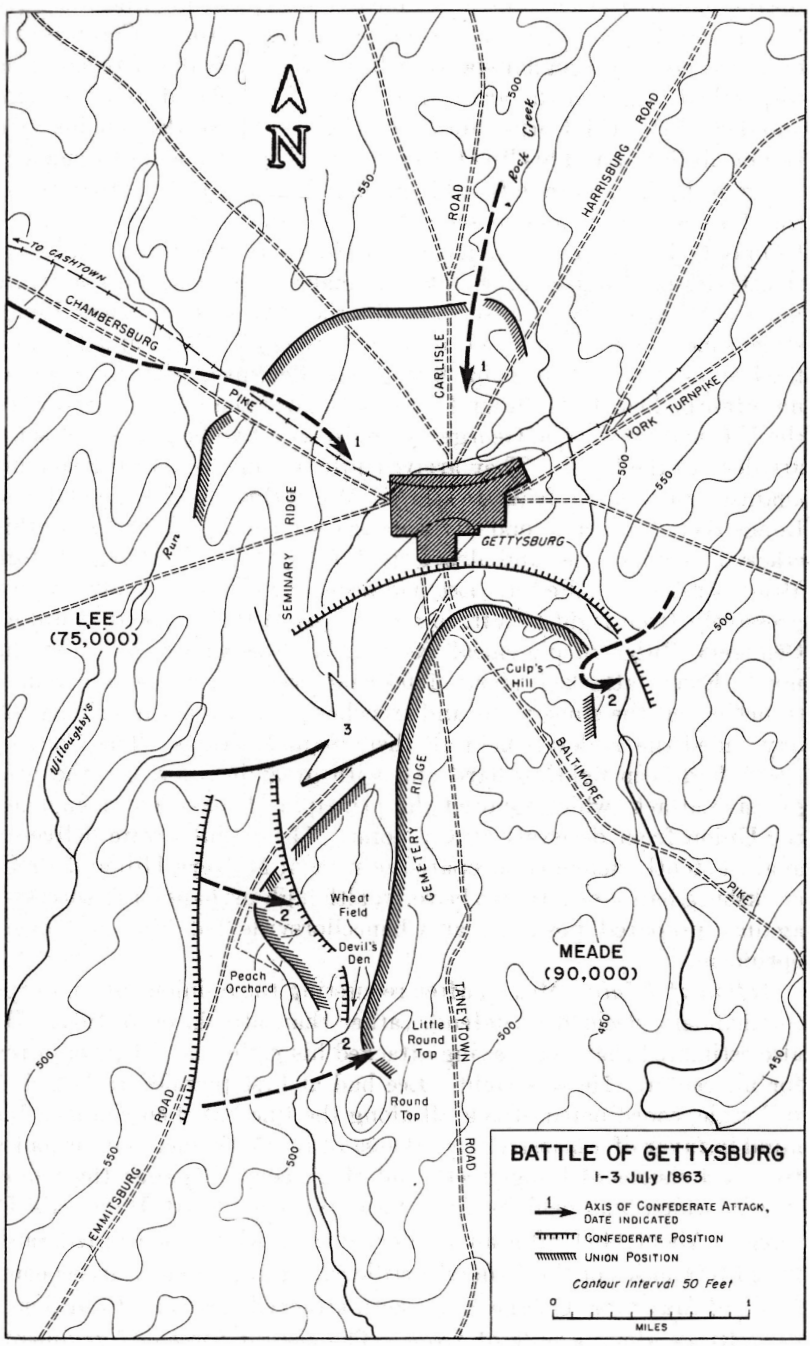


Figure 14. Major phases in the Battle of Gettysburg; arrows mark Confederate attacks, numbered according to both the date in July 1863 and the day within the battle sequence. 1, Initial fighting northwest and north of town, followed by late afternoon Union retreat through town and evening establishment of defensive line south of town (note "inverted fishhook" shape of main line); 2, uncoordinated unsuccessful attacks on the Union flanks, first in the afternoon on the south at Little Round Top, and later in the evening and night on the northeast at Cemetery and Culps Hills; 3, intense cannonade, followed by an unsuccessful massive infantry assault (Pickett's Charge) on the Union center on Cemetery Ridge. Modified from U.S. Department of the Army (1956, p. 249).

Crane, S., 1900, Great battles of the world: Philadelphia, Lippincott, 278 p.

Cuffey, R. J., 2004, Gettysburg Battlefield—Condensed field guide (May 2004): Privately distributed, 39 p.

_____ 2008, Virginia/Lee Memorial, Pickett's Charge, and the Battle of Solferino, *in* Fleeger, G. M., ed., Geology of the Gettysburg Mesozoic basin and military geology of the Gettysburg Campaign: Annual Field Conference of Pennsylvania Geologists, 73rd, Gettysburg, Pa., Guidebook, p. 164–167.

_____ 2013, Virginia/Lee Memorial, Pickett's Charge, and the Battle of Solferino, *in* Fleeger, G. M., ed., Rifts, rocks, and Rebs—Terrain and military geology of the Civil-War Battle of Gettysburg, 1–3 July 1863: American Association of Petroleum Geologists, Guidebook, p. 91–94.

_____ 2014, Geology of the Solferino (Italy 24 June 1859) and Gettysburg (Pennsylvania 1–3 July 1863) battlefields—Comparisons, contrasts, and possible connections: Geological Society of America Abstracts with Programs, v. 46, no. 2,

p. 46. [Abstract accompanied by 31 pages of supplemental material, online at https://gsa.confex.com/gsa/2014NE/webprogram/Paper235356.html, accessed April 13, 2018.]

Cuffey, R. J., 2015, Introduction and update for the "Geology of the Gettysburg battlefield" and geology's influence on military history, *in* Brezinski, D. K., and others, eds., Tripping from the Fall Line: Geological Society of America Field Guide 40, p. vi, 573–577.

_____ 2018, Geology and history of the Solferino, Italy (June 24, 1859), and Gettysburg, Pennsylvania (July 1–3, 1863), battlefields—Comparisons, contrasts, and possible connections: Pennsylvania Geological Survey Open-File General Geology Report 18–01.0, 39 p.

Cuffey, R. J., Inners, J. D., Fleeger, G. M., and Lane, J. A., 2006, The Gettysburg battlefield—Geology's impact upon military history: Geological Society of America Abstracts with Programs, v. 38, no. 7, p. 301–302.

Cuffey, R. J., Inners, J. D., Fleeger, G. M., and others, 2006, Geology of the Gettysburg battlefield—How Mesozoic events and processes impacted American history, *in* Pazzaglia, F. J., ed., Excursions in geology and history—Field Trips in the Middle Atlantic States: Geological Society of America Field Guide 8, p. 1–16.

Dunant, H., 1862 [reprinted in 2010], A memory of Solferino (English translation of *Un souvenir de Solferino*): Geneva, International Committee of the Red Cross, 147 p.

Geoportale Nazionale [Italia] [Italian National Geoportal], 2014, online at www.pcn.minambiente.it/GN/, accessed April 13, 2018, or www.pcn.minambiente.it/viewer/funzioniStampa/stampa.php, accessed in 2013.

Inners, J. D., Cuffey, R. J., Smith, R. C., II, and others, 2004, Rifts, diabase, and the topographic "Fishhook"—Terrain and military geology of the Battle of Gettysburg—July 1–3, 1863: Geological Society of America Field Trip Guidebook 4, 105 p.

_____ 2006, Rifts, diabase, and the topographic "Fishhook"—Terrain and military geology of the Battle of Gettysburg—July 1–3, 1863, Pennsylvania Geological Survey, 4th ser., Open-File Report 06–02, 105 p.

Morris, G., 2004, The Battle of Solferino: Battlefield anomalies, online at https://battlefieldanomalies.com/the-battle-of-solferino/, accessed April 13, 2018.

Salamida, J. C., 2005, Artists on war—Meissonier's passion for the military: MHQ, The Quarterly Journal of Military History, v. 17, no. 3, p. 52–57.

Societa Solferino e San Martino [Society for Solferino and San Martino (Battlefields)], 1989, Guida ai Monumenti di San Martino e Solferino: Lonato, Societa Solferino e San Martino and Litografia Benacense, 153 p.

Touring Club Italiano [Italian (Auto-) Touring Club], 2008, Carta stradale d'Italia: Milano, Lombardia sheet (foglio 2), 1:200,000.

Turner, Ted, 1993, Gettysburg [movie]: Screenplay by Maxwell, R. F., based on a novel by Shaara, M., Esparza/Katz Productions and Turner Pictures, distributed by New Line Cinema.

Uffindell, A., 1999, Glory costs too much: MHQ—The Quarterly Journal of Military History, v. 12, no. 1, p. 102–111.

U.S. Army Map Service and U.S. Geological Survey, 1951, Pennsylvania 1:25,000 [not 1:24,000] Gettysburg 7.5-minute topographic quadrangle (sheet 5563 I SW, series V831, 6th ed.).

U.S. Department of the Army, 1956, American military history, 1607–1953 (ROTCM 145–20): Washington, D.C., 510 p.

Wanderkarte, 2014, Reit und Wanderkarte GPS Hiking Map: Alpenraum set, sheet 88220250, online at www.wanderreitkarte.de/garmin_de.php, accessed April 13, 2018.

Williams, J. E., 1960, Prentice-Hall world atlas: Englewood Cliffs, N.J., Prentice-Hall, 122 p.

APPENDIX—BATTLE DETAILS

Solferino Battle's Progress. The Battle of Solferino is unfamiliar to most American readers, and so the following concisely outlines that battle (Borghi, 2008, 2012; Brooks, 2009; Crane, 1900; Cuffey, 2008; Dunant, 1862; Inners and others, 2006; Salamida, 2005; Societa Solferino e San Martino, 1989; Uffindell, 1999).

In mid-1859, the French and Piedmontese armies invaded Lombardy (today's north-central Italy) from the west, and the Austrian army came in from the east (to defend what was then part of their empire's territory).

The afternoon and night before the battle (June 23–24), the two forces moved into the Solferino area, the French somewhat off to the west, but the Austrians setting up guns on the Solferino ridgetop. Neither army expected to encounter the other yet (similar to before Gettysburg's first morning).

Before dawn on the 24th, advance patrols from each army ran into each other. Napoleon III rushed forward to observe these initial clashes, which marked the start of the Battle of Solferino proper. Meanwhile, to the north, the Piedmontese moved southeast through San Martino to attack the Austrians at Pozzolengo, starting the Italians' Battle of San Martino, although there was little coordination with the French to the south.

Soon, the French brought artillery to Fontane and began bombarding the Solferino ridgetop (Figures 10 and 15). Austrian guns up there fired back enough that the situation turned into a stalemate. Napoleon III promptly deployed many more cannons along a north-south line from Grole down to Rebecco, setting off a big artillery duel. About this time, the Piedmontese in the north were repulsed by the Austrians (under von Benedek) outside Pozzolengo and fell back toward San Martino.

In the late morning, French infantry (under Baraguey d'Hilliers) pushed toward the ridge and began their assault up its west slope (Figure 11) (reminiscent of Pickett's Charge later), while French shells continued to burst spectacularly over the ridgetop (which GREATLY impressed contemporary journalists!). Simultaneously, at San Martino, the retreating Piedmontese rallied around King Victor Emmanuel II (Winfield Scott Hancock rallying the Union troops coming out of Gettysburg comes to mind) and reattacked the Austrians, but ended up in a back-and-forth stalemate for the rest of the day (Figure 13).

By early afternoon, the French infantry was on top of Solferino ridge at its northwest/left end at the cemetery, and began pushing the Austrians southeast/right along the crest. Meanwhile, off to the east, Franz-Josef belatedly arrived on the battlefield from Valeggio.

Over the next couple of hours, fighting continued around the tower on the southeast end of the ridgetop. Simultaneously, another large French infantry force (under MacMahon) on the plain below swept east-southeast around the southern end of that ridge and into San Cassiano and Solferino villages.

By midafternoon, on the north flank of the French army, Ladmirault's division came east along the north side of Solferino ridge, turned sharply right, and attacked up the northeast slope of the ridge (Figure 12), linking up with the French troops already on top, so that they finally took the Solferino tower, thus clearing the Austrians completely off the ridgetop. (Note that this favorable culmination of events—cannonade and assault—might have suggested to Lee that Pickett's Charge really could succeed.) The Austrians retreated northeast and east into the lowlands.

In the late afternoon, Austrian cavalry in the center vigorously counterattacked toward San Cassiano and Solferino but failed to stop the advancing French, who continued on southeast into Cavriana.

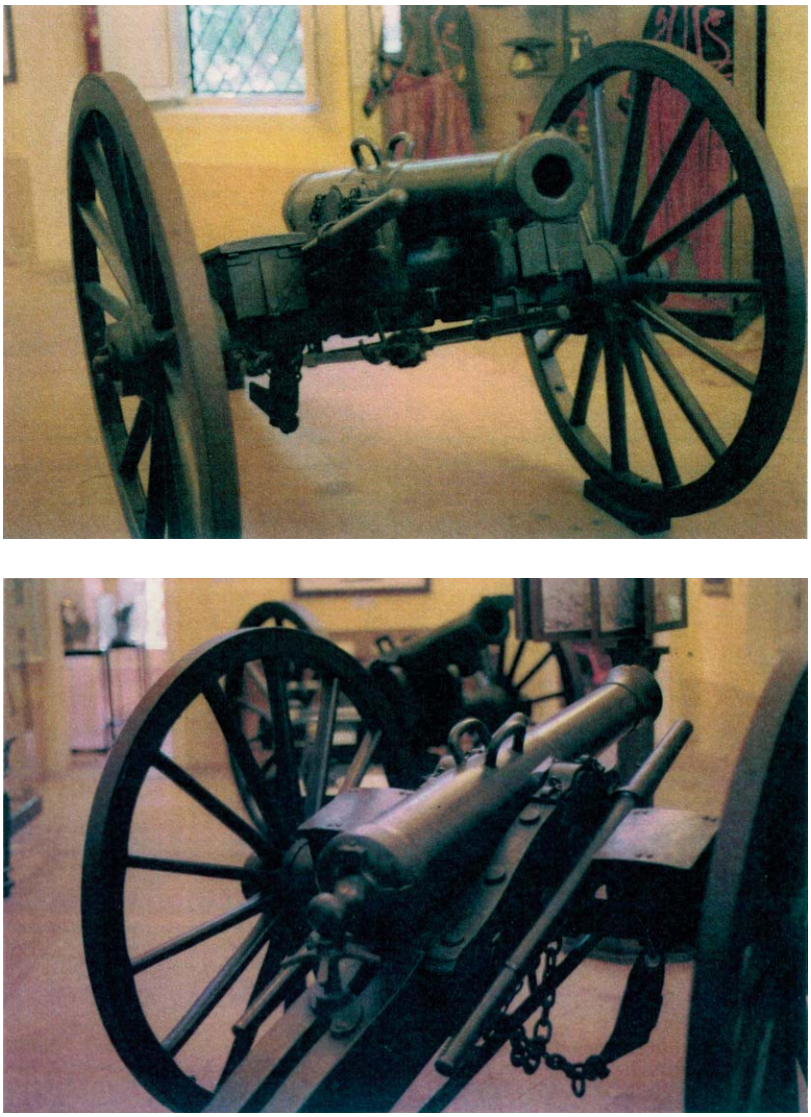


*Figure 15. New rifled cannon used by the French at Solferino (86 mm, 4 pounder); example preserved in the Solferino Museum (*Museo di Solferino*); slightly smaller than the more common types at Gettysburg (smoothbore Napoleons, Parrott rifles, and ordnance rifles; one of the last is shown in Figure 19 looking west from Cemetery Ridge at The Angle) (photographs by the author, 2013).*

Suddenly, at around 5:00 or 6:00 p.m., a heavy rainstorm (remember the day after Gettysburg) drenched the entire battlefield, bringing fighting to a halt.

After the downpour, some fighting resumed. The French got through Cavriana, where Napoleon III ended the day. A few kilometers farther east, Franz-Josef ordered a general withdrawal. To the north, the Piedmontese advanced southeast again from San Martino against the Austrians, who—by the end of the day—had also fallen back (to Pozzolengo).

The night after the battle (June 24–25), the Austrians continued retreating and exited the battlefield to the east, leaving the Allies in control of the entire area. Exhausted soldiers on both sides lay down and slept wherever they found themselves.

During the days after the battle, everyone on all sides was shocked and horrified by the large number of killed and wounded, as well as by the nearly complete destruction of everything on the battlefield. (Little did anyone suspect that Gettysburg four years later would be even more horrific.)

Napoleon III therefore decided that the war could NOT continue, and offered a cease-fire to Franz-Josef, who readily accepted. Two weeks later (July 11, 1859), the two emperors met on the road outside of Villafranca, several kilometers off the eastern edge of the battlefield, and finalized the armistice that ended this war in France's favor (and likely caught Lee's attention over here).

In the final settlement, Lombardy (north-central Italy) went to Piedmont, while Austria retained Veneto (northeast Italy). Moreover, this eventually led to establishment of the International Red Cross, the drafting of the Geneva Convention (still with us today), more wars before Italy was finally unified, and removal of many skulls and bones into ossuaries (*ossario*) (Figure 16).

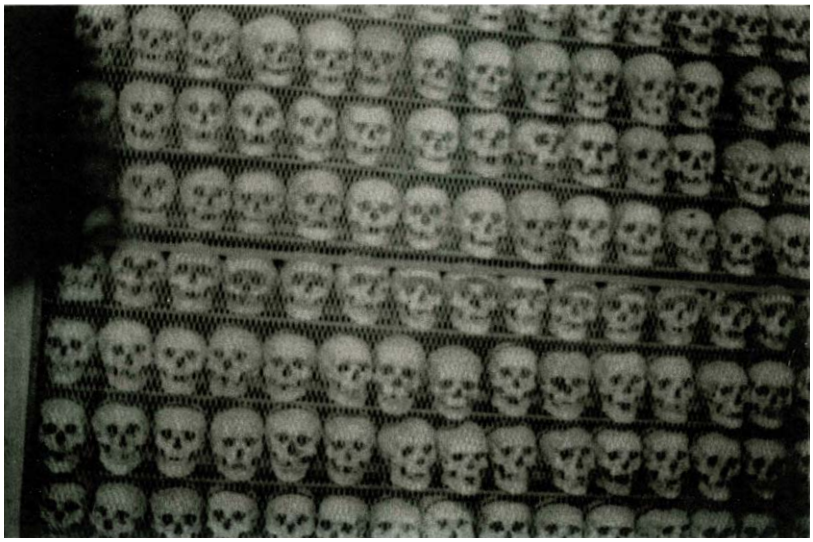


*Figure 16. Interior wall of Solferino ossuary chapel (*ossario*), completely lined floor to ceiling with human skulls retrieved from the battlefield, behind an open-mesh wire screen (photograph by the author, 2013).*

Gettysburg Battle's Progress. The Battle of Gettysburg is well known to American readers, and so only a brief summary is needed here (Cuffey, 2004, 2008, 2013, 2015, 2018; Cuffey, Inners, Fleeger, and Lane, 2006; Cuffey, Inners, Fleeger, and others, 2006; Inners and others, 2004, 2006; U.S. Department of the Army, 1956).

In mid-1863, the Confederate Army of Northern Virginia, under General Robert E. Lee, moved north, shielded behind the Blue Ridge-Catoctin Mountain-South Mountain barrier. Invading Pennsylvania could isolate Washington D.C., ultimately threaten New York and Philadelphia, and wreak havoc on the agriculturally important northern countryside.

Meanwhile, the Union Army of the Potomac, newly under General George G. Meade, also moved north but out on the Piedmont lowlands east of the mountain barrier, in order to protect the Federal capital to the south.

A couple of days before the battle, the Confederates began filtering east through the mountains at Cashtown Gap just north of the Pennsylvania line.

By the afternoon before (June 30), a few scattered contacts between outlying patrols were occurring, but the main forces still did not yet realize how close the other was.

Early on July 1, medium-sized Confederate detachments approaching Gettysburg from the northwest, reportedly looking for supplies in the town, unexpectedly ran into advance Union cavalry units coming north along the west side of Gettysburg. Fighting broke out and quickly escalated, as more and more units from both sides were fed into the developing battle throughout the middle of the day.

Finally, late in the afternoon, the Union troops retreated in disarray southeast back through the town. As they came out of the southern edge of the town, early in the evening, they rallied and established defensive positions on the high ground there (Cemetery Ridge and Cemetery Hill). At the same time, the Confederates spread out southward along the narrow ridge (Seminary Ridge) just southwest of town.

July 2 saw the Confederates make two major attacks against the flanks of the Union position along Cemetery Ridge. These were not coordinated in time, and hence failed to break the Union defenses in spite of fierce fighting for many hours. In the afternoon, the southerners struck the southern flank of the Union line at Little Round Top. Later, that evening and into the following night, they struck the northern flank on Cemetery and Culps Hills.

At a midnight conference, Meade predicted that the next day would bring an attack on his center.

Midday on July 3, the Confederates on Seminary Ridge began a massive artillery cannonade (Figure 17) against the Union center up on Cemetery Ridge. After an hour, the artillery fire slackened, the Confederates' because they were running low on ammunition, and the Union's because they were saving half their ammunition to use later against the big attack which they expected would come soon.

Figure 17. Reenactment of Confederate cannonade, massed artillery firing, preceding Pickett's Charge on the third day at Gettysburg; modified from Turner (1993); image online at <Images for Gettysburg 1993 Confederate artillery bombardment>.

And indeed it did—about 15,000 Confederates under General George E. Pickett formed mile-wide ranks and started marching eastward across the lowland toward Cemetery Ridge. This was "Pickett's Charge," the climax of the entire battle. As they neared the ridge (Figure 18), the Union cannons atop Cemetery Ridge (Figure 19) opened up a devastating fire with their saved ammunition, inflicting horrendous casualties, so that in the end only a few Confederates reached the Union line at The Angle (and they were immediately cut down or captured). The surviving Confederates melted back across the lowland to Seminary Ridge.

Consequently, the charge failed to break the Union defenses, and with that, the overall battle was lost for the Confederates.

This outcome was the opposite of Solferino's, because the weight of the Union gunfire—due to their bigger supply of saved ammunition—was much greater than the Austrians had had atop Solferino ridge four years earlier. In addition, the quality of the Union cannon may also have been significantly better than the older Austrian smoothbores, and there may have been substantially more artillery pieces on Cemetery Ridge.

Figure 18. Pickett's Charge approaching from the left (west) toward the Union cannons on the crest of Cemetery Ridge (right); modified from Clark and the editors of Time-Life Books (1985, p. 124).

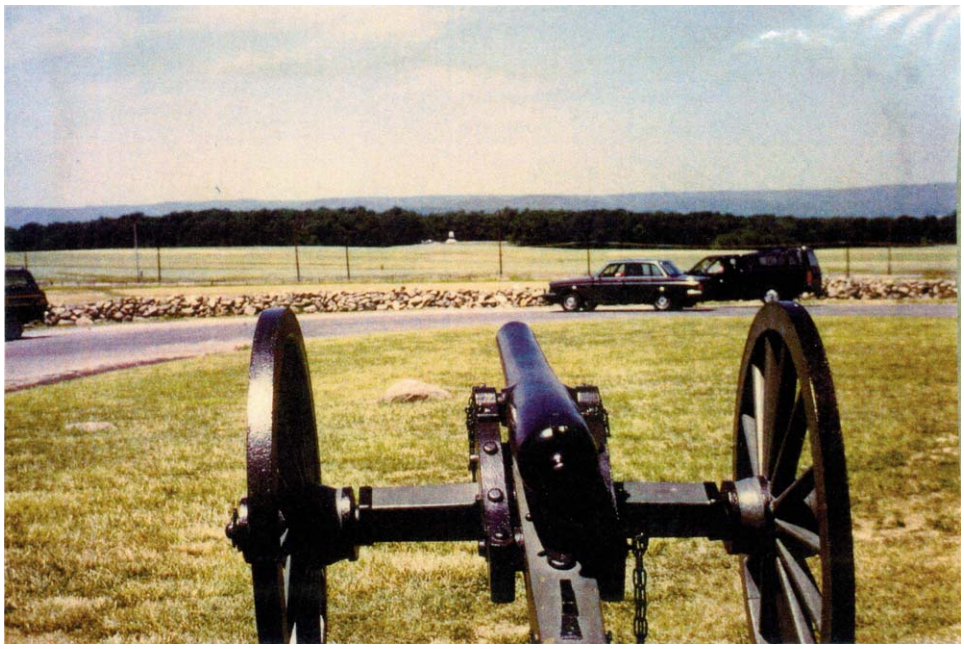


Figure 19. View from the crest of Cemetery Ridge at The Angle, looking west at the lowland across which Pickett's Charge came; the white statue is Lee on horseback watching that assault (Virginia Memorial) in front of the dark tree line (Seminary Ridge); the distant skyline is South Mountain (the northern end of the Blue Ridge); the cannon in the foreground is a 3-inch ordnance rifle (compare with a somewhat smaller French cannon in Figure 15) (photograph by the author, 1988).

So Much for Conventional Wisdom in Mineralogy— Hercynite Spinel? Inclusions in Corundum from Shimersville, Lehigh County, Pennsylvania

Robert C. Smith, II, and John H. Barnes
Pennsylvania Geological Survey, retired
and
Joe A. Dague
Chambersburg, Pa.

Having grown up as a mineral collector in Lehigh County, Pa., the senior author long accepted the conventional wisdom that the small, dark, metallic inclusions that were commonly found in corundum crystals (Al_2O_3) collected from fields near Shimersville were spinel, or, if one wanted to sound more erudite, "hercynite spinel" ($Fe^{2+}Al_2O_4$). Everyone knew that! Everyone from the senior mineral collectors such as Floyd R. Faux to the next generation like Bill W. Heacock and down to the very youngest, referred to as "pebble pups" (probably intended to be a diminutive version of the more familiar term, "rockhound").

Indeed, the noted mineralogist Sam G. Gordon, in his *Mineralogy of Pennsylvania* (1922, p. 51–52 and p. 209) had reported spinel in corundum from Shimersville. That account was based on a chemical analysis by George M. Lawrence that was reported by the famed mineralogist of the Second Pennsylvania Geological Survey, F. A. Genth (1882). Thus, one could safely assume that there must be some hercynite, an iron-rich aluminum spinel, at Shimersville. It would seem, however, that the factual evidence that there was hercynite spinel at Shimersville became extended, by conventional wisdom, to include the common millimeter-sized dark inclusions in corundum crystals.

The idea that these dark spots are spinel might be conventional, but it might not be wisdom. When recently subjected to quantitative SEM–EDS (scanning electron microscopy/energy dispersive X-ray spectroscopy) analysis, the "spinel" in the crystals that were collected by Bob Smith, II, with his mother, Irene E. Smith, in the early 1950s, and with Larue Diehl in the 1960s, all turned out to be rutile (TiO_2) , based on their composition (Figure 1). This conclusion is supported by their color in high-intensity light at 50x magnification. The inclusions are fairly pure rutile at that. For additional verification, Joe Dague was asked to go through the Shimersville corundum crystals in his collection. They had been collected by well-known collectors Bryon N. Brookmyer and Donald W. Schmerling and by former Lafayette College mineralogist Arthur Montgomery at different times. Under an intense light and viewed through a binocular microscope, the inclusions in the Dague collection crystals also appear to be rutile. There is not a spinel octahedron in the lot. This is not to say that somewhere there isn't such a spinel inclusion in corundum from Shimersville. The absence of proof isn't the same as proof of absence.

This leads one to wonder how many other bits of conventional wisdom about mineral species in Pennsylvania need to be checked. Perhaps some clues might be found in classical mineralogical literature. For example, the senior author noted for the first time while writing this article that E. F. Smith's 1883 analysis of corundum from Shimersville included 2.74 percent TiO_2, also known as titania, which also happens to be the chemical formula of rutile (rutile is the deep reddish-brown to blackish polymorph of titania).

Figure 1. Image of one of many areas of rutile analyzed by SEM–EDS. The rutile is the medium-gray mineral. The + sign indicates the spot that was analyzed. The row of dots near the lower right corner of the image represents 100 micrometers (approximately 0.004 inch). Note the rather anhedral (irregular) habit of the rutile. A habit such as this would be most unusual for spinel group minerals, which tend to form octahedrons. The euhedral grains, which are the brightest ones in the image, are zircons, based on their composition ($ZrSiO_4$). Zircons occur as inclusions in most of the rutile grains examined from Shimersville. The rutile grains tend to be visible to the unaided eye, but the zircons are only rarely visible, even with a hand lens. Zircons in rutile in corundum, such as these, may be ideal candidates for U-Pb dating of late-stage igneous activity in the Reading Prong.

REFERENCES

Genth, F. A., 1882, Contributions to mineralogy: Proceedings of the American Philosophical Society, v. 20, p. 381–404.

Gordon, S. G., 1922, The mineralogy of Pennsylvania: Academy of Natural Sciences of Philadelphia Special Publication 1, 255 p.

Smith, E. F., 1883, Minerals from Lehigh County, Pa.: American Chemical Journal, v. 5, p. 272–279.

BUREAU NEWS

Bureau Staff Members Volunteer as Judges at the Capital Area Science and Engineering Fair

Staff geologists Victoria Neboga and Toni Markowski had the pleasure of category judging Earth Science, Energy-Transportation, and Environmental projects along with 142 other judges at the Capital Area Science and Engineering Fair (CASEF). This year the fair was held at Harrisburg Area Community College on March 6–9, 2018. The fair expanded its service to 342 aspiring young scientists from more than 60 schools in 41 counties, where they exhibited 297 independent and 24 team projects. More than $600,000 in prizes and scholarships were awarded to the CASEF students, including 89 four-year scholarships for participating 11th and 12th graders.

Neboga judged nine senior projects, where students showcased their creativity and knowledge in areas such as trout habitat assessment, water quality of creeks, effect of salt on microorganisms, and energy usage with light-emitting diodes (LED) to optimize plant growth. Neboga recommended the latter senior project, "Optimizing Hydroponic Plant Growth and Energy Usage with Light-Emitting Diode Spectral Manipulation" for the Dr. George Hayward Love, Sr., Judges' Award. The student studied LED lighting sources to produce hydroponic starter plants to reduce energy and its costs. The project won a Grand Champion prize in the Environmental category.

Markowski judged 12 junior and senior exhibits, including five in the Earth Science and seven in the Energy-Transportation categories. Communication talents became apparent through presentations on weather forecasting and topography, the effect of water pH on rock erosion, fuel cells fueling the future, new ways to make batteries last longer, how solar activity and international winter temperatures affect climate change, the impact of coverage material densities on glacial melting rates, food waste as a sustainable energy source, creating electricity from salt water, and animal waste as an alternative fuel source. Three senior projects were nominated for Grand Champion and the Dr. George Hayward Love, Sr., Judges' Award: "How Coverage Material Densities Impact Ice Melting Rates Under Glacier Conditions," "Wasted Energy," and "Creating Electricity from Salt Water." Three junior projects received nominations for various regional awards from the American Meteorological Society, the National Oceanic and Atmospheric Administration, and the Society for In Vitro Biology. Other award nominees included two senior Energy-Transportation projects, one for the Association for Women Geoscientists and one for the Yale Science and Engineering Association.

Seventy-six scientific, professional, industrial, educational, and governmental organizations also offered 294 special awards at the CASEF. Michelle Bell Curry (Department of Environmental Protection retiree and Department of Conservation and Natural Resources conservation volunteer) presented the Harrisburg Area Geological Society special award of $100 to Vy Le, a ninth grader at Cumberland Valley High School. His Earth Science project on "How Coverage Material Densities Impact Ice

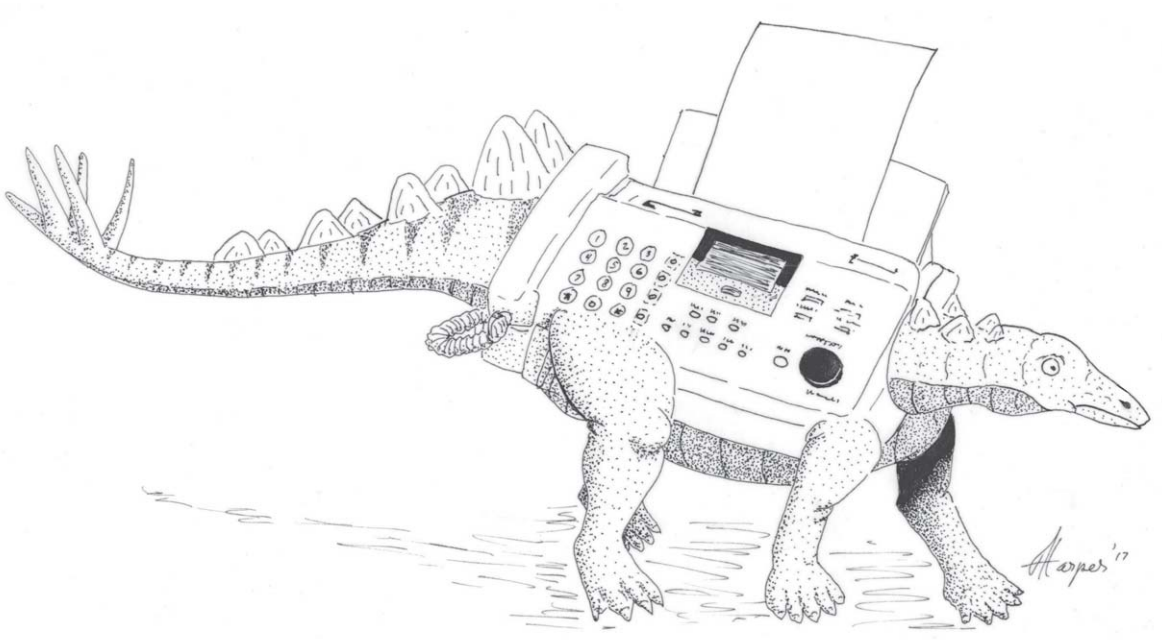
Melting Rates Under Glacier Conditions" shows how glaciers can be protected from rapid melting in order to preserve sources of fresh water (presumably derived from glaciers). Le was motivated to pursue this project after he had read about a current glacial study in Switzerland.

Four CASEF students presented their projects at the 69th Intel International Science and Engineering Fair in Pittsburgh, Pa., on May 13–18, 2018. Three junior division students were selected as national semifinalists for BroadcommMASTERS, a national science competition affiliated with the Society for Science and the Public for the top 10 percent of United States middle school students.

New judges, special awards, and sponsorships are always welcome—especially a sponsor for the judging portion of the fair. Please consider joining the Bureau staff at next year's judging day on Tuesday, March 5. Anyone interested should contact Valerie Knowles (CASEF Director) at director@casef.org or 717–580–3812. For further information about CASEF, see www.casef.org/ or e-mail casef@hacc.edu. ***The future of science and engineering holds a promise as bright as these young minds!***

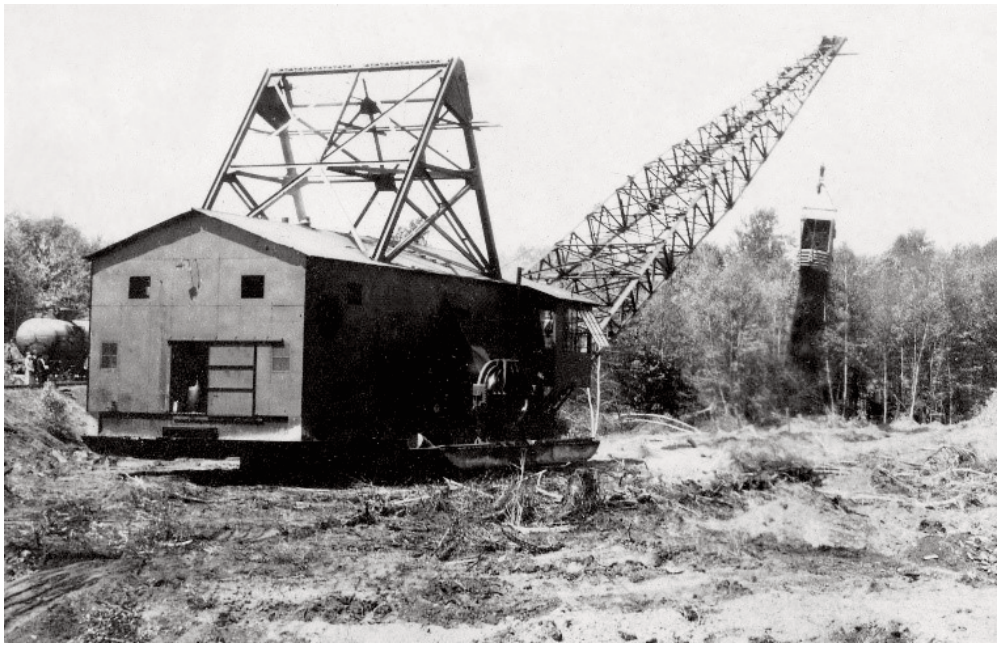
Fax Machine Becomes Extinct!

The Pennsylvania Geological Survey announces that another extinction has occurred. Our fax (facsimile) machine, with its ability to seemingly send paper through wires, has been replaced by machines that can seemingly turn paper into electrons.



Our fax machine, once an indispensable contribution to the function of our Bureau, has become extinct, just like the dinosaurs. Drawing by John A. Harper, retired, Pennsylvania Geological Survey.

A Look Back in Time



Photograph taken in 1931 by former State Geologist (from 1919 to 1946) George Ashley.

The item featured is a Monighan "walking" dragline excavator in coal stripping in the Anthracite region between Carbondale and Forest City. The Monighan Machine Company produced the first walking dragline in 1913. The Monighan Machine Company was later taken over by the Bucyrus-Erie Company in 1932.

To see more photographs from the Bureau's archives, please visit the library's Historical Photographs Collection page.

Calling All Authors

Articles pertaining to the geology of Pennsylvania are enthusiastically invited.

Pennsylvania Geology is a journal intended for a wide audience, primarily within Pennsylvania, but including many out-of-state readers interested in Pennsylvania's geology, topography, and associated earth science topics. Authors should keep this type of audience in mind when preparing articles.

Feature Articles: All feature articles should be timely, lively, interesting, and well illustrated. The length of a feature article is ideally 5 to 7 pages, including illustrations. Line drawings should be submitted as CorelDraw (v. 9 or above) or Adobe Illustrator (v. 8 or above) files.

Earth Science Teachers' Corner: Articles pertaining to available educational materials, classroom exercises, book reviews, and other geologic topics of interest to earth science educators should be 1 to 2 pages in length and should include illustrations where possible.

Announcements: Announcements of major meetings and conferences pertaining to the geology of Pennsylvania, significant awards received by Pennsylvania geologists, and other pertinent news items may be published in each issue. These announcements should be as brief as possible.

Photographs: Photographs should be submitted as separate files and not embedded in the text of the article.

Submittal: Authors may send their article and illustrations as email attachments to RA-pageology@state.pa.us if the file sizes are less than 6 MB. For larger sizes, please submit the files on CD–ROM to the address given below. All submittals should include the author's name, mailing address, telephone number, email address, and the date of submittal.

Director
Bureau of Topographic and Geologic Survey
3240 Schoolhouse Road
Middletown, PA 17057
Telephone: 717–702–2017

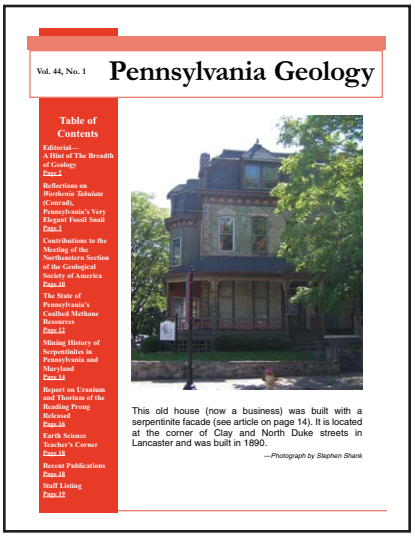

Vol. 44, No. 1 Pennsylvania Geology

Table of Contents

Editorial—A Hint of The Breadth of Geology Page 2

Reflections on *Northenia Tabulata* (Conrad), Pennsylvania's Very Elegant Fossil Snail Page 3

Contributions to the Meeting of the Northeastern Section of the Geological Society of America Page 10

The State of Pennsylvania's Coalbed Methane Resources Page 12

Mining History of Serpentinites in Pennsylvania and Maryland Page 14

Report on Uranium and Thorium of the Reading Prong Released Page 16

Earth Science Teacher's Corner Page 18

Recent Publications Page 18

Staff Listing Page 19

This old house (now a business) was built with a serpentinite facade (see article on page 14). It is located at the corner of Clay and North Duke streets in Lancaster and was built in 1890.

—Photograph by Stephen Shank

Department of Conservation and Natural Resources
Bureau of Topographic and Geologic Survey

Main Headquarters
3240 Schoolhouse Road
Middletown, PA 17057–3534
Phone: 717–702–2017

Pittsburgh Office
400 Waterfront Drive
Pittsburgh, PA 15222–4745
Phone: 412–442–4235

DIRECTOR'S OFFICE

Director and State Geologist
Gale C. Blackmer 717–702–2017

Administrative Services
Connie F. Cross 717–702–2054
Elizabeth C. Lyon 717–702–2063
Jody R. Zipperer 717–702–2073

GEOLOGIC AND GEOGRAPHIC INFORMATION SERVICES

Michael E. Moore, 717–702–2024

GIS Services
Caron E. O'Neil 717–702–2042

Core-Library Services
John C. Neubaum 717–702–2039

IT and Database Services
Sandipkumar P. Patel 717–702–4277
Mark A. Dornes 717–702–4278
David F. Fletcher 412–442–5826

Library Services
Jody L. Smale 717–702–2020

GEOLOGIC MAPPING

Stuart O. Reese, 717–702–2028

Stratigraphic Studies
Rose-Anna Behr 717–702–2035
Aaron D. Bierly 717–702–2034
Clifford H. Dodge 717–702–2036
James R. Shaulis 717–702–2037

Groundwater and Environmental Geology
Simeon B. Suter 717–702–2047
Kristen L. Hand 717–702–2046
William E. Kochanov 717–702–2033
Victoria V. Neboga 717–702–2026

PAMAP and Public Outreach
Helen L. Delano 717–702–2031

ECONOMIC GEOLOGY

Kristin M. Carter, 412–442–4234

Mineral Resource Analysis
Stephen G. Shank 717–702–2021
Leonard J. Lentz 717–702–2040
Antonette K. Markowski 717–702–2038

Petroleum and Subsurface Geology
Brian J. Dunst 412–442–4230
Robin V. Anthony 412–442–4295
Lynn J. Levino 412–442–4299
Katherine W. Schmid 412–442–4232
Renee H. Speicher 412–442–4236

PENNSYLVANIA GEOLOGY is published quarterly by the
Bureau of Topographic and Geologic Survey
Department of Conservation and Natural Resources
3240 Schoolhouse Road, Middletown, PA 17057–3534.

This edition's editor: Anne Lutz.

Links to websites were valid as of the date of release of this issue.

Contributed articles are welcome.

To subscribe, send an email to RA-pageology@state.pa.us.

Bureau website: www.dcnr.pa.gov/Geology/Pages/default.aspx
Bureau Facebook page: www.facebook.com/PennsylvaniaGeology
DCNR website: www.dcnr.pa.gov/Pages/default.aspx
Pennsylvania home page: www.pa.gov