Military Metabolisms in the American War of Independence: An Environmental History

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When you think about the American Revolution, surely the first things that come to mind are not dirt and trees. But I am an environmental historian, and scholars like me look at the ever-changing relationships between humans and nature to see how they shape the course of history. People take actions in the natural world—by cutting down trees for firewood and to build shelter, for example—and that leads to environmental change such as deforestation. That changed environment then shapes the ideas people have about nature and the actions they take next. Such a deforested environment, for example, might lead some people to move to new forests while others might plant seedlings in order to reforest the spot. These actions then lead, in an ongoing, back-and-forth dynamic, to new relationships between humans and nature.

How did such relationships shape the course of the American Revolution generally and the War of Independence more specifically? That was the focus of the research I did during my sabbatical this past academic year. I am particularly interested in energy because all living organisms need it to survive and to function day after day, and all of that energy comes from the environment, starting with the sun. You and I use energy to maintain our metabolisms so that our hearts pump and our eyes blink. We can then expand the concept of metabolism beyond us individually in order to consider human communities. How is energy in the form of electricity and natural gas created and transported to those living in a city? How do the inhabitants use that energy and then eliminate the waste that they produce?

Now, let's go back in time to the American Revolution and consider one particular type of human community: the armed forces. Military units need energy to fuel their metabolisms so that soldiers can stay alive and carry out their tasks. The book I am working on examines how the Continental Army, the British Army, and the British Navy acquired and used different sources of energy such as food, fuel (typically in the form of firewood), work animals, and the animals' food. By paying attention to such interactions between humans and the natural environment, we can better understand not just the War of Independence—the strategies planned, tactics used, and situations faced—but also war's short- and long-term effects on nature.

I have been trying to answer four types of questions about military metabolisms that functioned during the war. First, how did a metabolism get started? Rebellious colonists mobilized energy sources and went from having scattered small militia companies in April 1775 to having, two months later, the Continental Army. How did they do that? Second, how did metabolisms function leading up to and during a battle? Third, how did the conditions of a siege—a particular type of battle—lead armed forces to use energy differently? Fourth, how did relationships between humans and the environment change during winter encampments, when military forces remained largely in one place for up to six months? I will start by showing you what I have found out about the most famous of those encampments, Valley Forge. Then we will shift to Virginia and briefly look at the siege of Yorktown, the battle that basically ended the war. Finally, we will consider the aftermath of the Battles of Saratoga, which took place in upstate New York, and what they might mean for us today.

Why take this approach to examine the War of Independence? For nearly 250 years, historians have sought to understand the American Revolution, and they have most often focused on developments in the political, social, cultural, and economic spheres. I would like to add one little brick to this towering edifice of scholarship by bringing the environment into those spheres and by paying special attention to what the sciences such as biology, chemistry, ecology, and geology can add to the story.

DEFORESTING VALLEY FORGE

September 1777 was a good month for British and Hessian forces. On September 11, they defeated George Washington and the Continental Army at the Battle of Brandywine Creek, about thirty miles west of Philadelphia, and one week later forced the Continental Congress to flee the capitol. On September 26, British and Hessian forces occupied Philadelphia and concluded their campaign for the year.[1] When Washington and the political leaders agreed there would be no winter campaign, he decided to quarter the army nearby, staying close enough to keep an eye on the enemy but far enough away to remain safe from attacks. Washington and his staff chose Valley Forge, located about twenty miles northwest of Philadelphia.[2]

When the Continental Army moved into Valley Forge on December 19, 1777, its 16,000 soldiers turned an area that had contained about twenty farms into the third-most-populated city in British North America.[3] It was late December, so you can imagine what Washington made his first order of business. The soldiers needed proper quarters, so he ordered them to build huts that measured eighteen feet long, sixteen feet wide, and six feet high at the eaves (see Figure 1 below). Each hut housed twelve enlisted men, or a fewer number of officers, or one general. Washington did not stay in one of these huts but in a stone house that also served as his headquarters. Thomas Paine, the author of *Common Sense*, saw the men hard at work building these huts. He wrote to Benjamin Franklin, “They appeared to me like a family of beavers, everyone busy; some carry logs, others mud, and the rest plastering them together.”[4]

Figure 1: A reproduction of a hut at Valley Forge National Historical Park. Photo credit: Tim Emerich.

How much wood did these busy beavers need? The soldiers built approximately 1500 huts during their six-month encampment, and Marc A. Brier, a former ranger at Valley Forge National Historical Park, calculated that this required over 127,000 trees that measured from three to twelve inches in diameter. Of course, this was not the end of the wood the soldiers needed. Brier further calculated that to heat one hut for the duration of the encampment would require about ten cords of wood.[5] Therefore, to heat all of the huts at Valley Forge required something on the order of 15,000 cords of wood. In other words, the Continental Army needed a pile of split logs stacked to chest height that covered more than eight football fields.[6]

This voracious appetite for wood deforested the local landscape. The soldiers probably chopped down every sizeable tree within a three-mile radius of the encampment. Think about your home or some other place you know well. If we cut down every tree in a three-mile radius of the Juniata College campus, that would mean, going west on Route 22, every tree from here to Lincoln Caverns and, going east, every tree past the Ford dealership. Going south on Fairgrounds Road, you would see no trees to the point where the road curves and hits Route 26. Heading north on Route 26, there would be no trees up to the golf course. An eye-popping number of trees were cut down at Valley Forge, and that led to a lot of erosion, a great deal of flooding, and, perhaps counterintuitively, more frequent drought.[7]

Over time, trees did grow back at Valley Forge, but they were different species than the ones that had existed in 1777. The soldiers cut down white oaks, which are terrific for firewood because they have a high fuel value. What grew back were black oaks and chestnuts, which are not nearly as good a source of fuel.[8] Therefore, Valley Forge residents had to chop down more chestnuts and black oaks to stay as warm as they had been before 1777. The clearcutting that took place during the winter of 1777 and 1778 led to the continuing deforestation of the area in the decades that followed.

THE DANGERS OF ACQUIRING ENERGY

To be effective, armies had to be able to move. Such movement required energy, which came most often in the form of work animals. The Continental Army had thousands of these beasts—horses and oxen—and maintaining their metabolisms required the soldiers to procure a lot of forage: hay, oats, and corn. Washington sent parties of soldiers far afield, fifty to seventy-five miles in every direction, to bring forage back to Valley Forge.[9] These men faced considerable dangers during these excursions, not just from British and Hessian forage parties seeking the same resources. Some of the gravest dangers arose from their own actions.

Washington ordered his men to make a clean sweep of nature's bounty but to do so responsibly. For one major operation, he authorized them to "take, Carry off & secure all such Horses as are suitable for Cavalry or for Draft and all Cattle & Sheep fit for Slaughter together with every kind of Forage that may be found in possession of any of the Inhabitants." When they did this, however, the men had to issue certificates (receipts) for everything taken.[10] Washington wanted to motivate his men to acquire as much energy as they could, but he also wanted to discourage misbehavior. As he instructed Captain Stephen Chambers, "To induce your men to be more active and zealous in the execution of their duty; every thing that may be *actually* taken going into, or coming out of the city [Philadelphia], shall be the property of the captors."[11] Any horses or cattle the soldiers seized had to be turned over to the Quartermaster General or Commissary General "for the Public service," but the men would receive generous compensation. This sort of material incentive, however, could lead the men astray. "But to prevent any abuse of this privilege by making it a cover for plundering the inhabitants," Washington continued, "it must always be managed under the eye of a commissioned Officer, and no forfeiture must be made, but where the fact is clearly ascertained."[12]

The Continental Army always had to be careful to maintain good relations with the civilian population. The soldiers could take forage and give a receipt, but the people were often unhappy about losing their property and being mistreated in the process. General George Weedon of Virginia declared that "Frequent Complaints [had] been made by the Inhabitants of their Forrage being taken without leaving them a reasonable share for the subsistence of their families, and that they are often insulted and abused."[13]

Nobody worried about military-civilian relationships more than George Washington. Year in and year out, he raged against plundering. First of all, it threatened the army itself. Soldiers who were intent on plundering didn't pay attention to the enemy and, therefore, got killed or captured. More importantly, plundering endangered the larger purposes of the Revolution itself. Washington asked his men, "Why did we assemble in arms? Was it not, in one capital point, to protect the property of our countrymen? And shall we to our eternal reproach, be the first to pillage and destroy?"[14] So much rode on acquiring metabolic energy and figuring out the logistical steps foraging parties needed to take—as well as avoid taking—that the survival of American independence depended on it. Washington linked the Continental Army to the American Republic, and the ethical collapse of one would have led to the downfall of the other.

MOVING EARTH

Let me now turn to a different type of metabolism, that of a siege. General Charles Cornwallis (see Figure 2) brought his British and Hessian forces to Yorktown, located on a peninsula between the

Figure 2: Thomas Gainsborough, "Charles Cornwallis, 1st Marquess Cornwallis," 1783. National Portrait Gallery, London.

York and the James Rivers in the southeastern corner of Virginia, on August 2, 1781, and immediately started to establish their defenses. They built large and extensive fortifications; these were earthworks, not stone or log forts like you might see in other times or locations. On September 29, the Continental Army and their French allies began a siege by building trenches, setting up earthworks, positioning cannon and artillery on top of the earthworks, and gradually moving closer and closer to the British fortifications (see Figure 4 below). A relentless artillery bombardment pounded the British for three weeks and showed no signs of abating, so Cornwallis surrendered on October 19, 1781. That ended major military operations on the North American continent.[15]

A siege makes special demands on an armed force's metabolism. Let's consider the British defenses at Yorktown, which included redoubts and batteries. A redoubt is just an enclosed earthwork that defends a key spot on the ground, and a battery is a redoubt with artillery positioned on top of it. In total, Cornwallis ordered three sets of defenses built. In the inner line of defense, a fortification extended for about two thousand feet and contained eight redoubts and ten batteries. All of these strong points in the fortification were connected with thick dirt walls. There was another outer line of defense that included seven more redoubts and several smaller fortifications unconnected by a thick wall. And then across the river at Gloucester Point the British and Hessians built four redoubts and three batteries.[16]

How large were these defenses? For half of that inner line, the fortifications included a parapet, which was a wall about four feet high, eleven feet thick at the top, and fourteen feet thick at the bottom. Think about that: a wall that is as thick as a Volkswagen Beetle is long. For the rest of the interior line, the parapet was roughly triangular in shape with a base of twenty-nine feet (that's the length of a UPS truck) sloping up to a height of eight and one-half feet on the interior side of the defenses. The largest of the outer defenses had a wall seven and one-half feet high, eight feet thick at the top, and 150 yards long. Others were smaller, and, for a few of them, I don't know the exact size. I also don't have the exact dimensions for the defenses at Gloucester Point across the river, so I had to make some estimates.[17] Here are my armchair calculations for the total amount of earth the British-led forces moved:

Inner line of defenses	497,775 cubic feet
Outer defenses	80,884 cubic feet
Gloucester Point	39,599 cubic feet
TOTAL	618,258 cubic feet

Figure 3: Estimate of the amount of dirt in the British fortifications at Yorktown, 1781.

To put this into one context, 618,000 cubic feet of dirt would cover an entire football field to a height of over ten and one-half feet, well above the regulation height of a basketball rim.

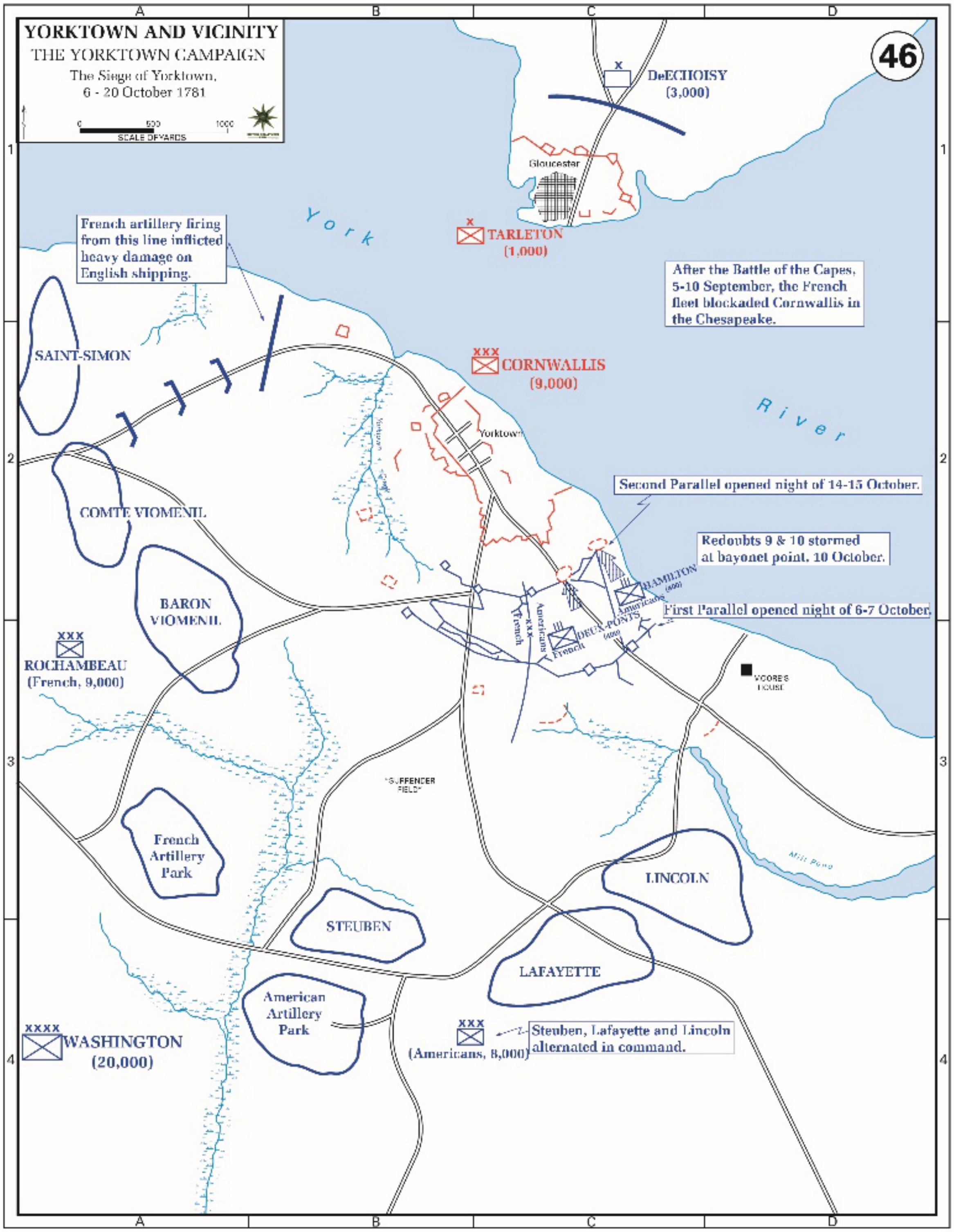

Figure 4: The Siege of Yorktown. Source: United States Military Academy, West Point.

The historian Vaclav Smil estimates that a pre-industrial worker constructing a road handled about thirty-five cubic feet of building materials a day.[18] Using that as our point of reference, digging and moving the dirt for the Yorktown defenses therefore required about 17,600 person-days of work. But, as you gardeners or landscapers know, moving dirt is only the start of the job. In mid-September 1781, General Cornwallis had 9,725 soldiers and 1,500 to 2,000 slaves. If all of these men had worked on the fortifications, they would have finished the job before teatime on the second day. But, of course, men tallied on paper did not automatically become diggers and haulers of dirt. Many were occupied with protecting troops and supplies while others gathered forage (as Continental soldiers had at Valley Forge).[19] Even greater numbers were incapacitated by the sultry climate of southern Virginia and a wide range of diseases.[20] Cornwallis may have commanded over 9,700 men at Yorktown and Gloucester, but his effective strength was 5,316 men at the start of September, and only 4,987 at the beginning of October. That harsh reality contributed to his estimation that the construction of the defenses would not finish before the end of September.[21]

The need for workers led Cornwallis to seek the types of bodies that could work the best in the environment of Virginia's oppressive heat. Black slaves, commonly assumed to be able to withstand the sun's rays and sweltering conditions, would suit the task.[22] Cornwallis urged Brigadier General Charles O'Hara, who was based near the coast at Portsmouth, Virginia, to send slaves up to Yorktown. "I am not easy about my post at Gloucester and am in great want of Negroes to work, as the heat is too great to admit of the soldiers doing it." White soldiers could not do the work, but Black slaves could. O'Hara, however, could only offer a meager supply, and he wrote back, "We have been able to send you 50 Negroes only." Even if he had had additional slaves to send to Yorktown, they would not have helped Cornwallis: "What will you have done," O'Hara asked, "with the hundreds of wretched Negroes that are dying by scores every day?"[23]

Cornwallis agreed with O'Hara and replied, "It is shocking to think of the state of the Negroes, but we cannot bring a number of sick and useless ones to this place." He defined "useless" in terms of labor, the energy those individuals could not provide. Referring to other officers stationed at Portsmouth, Cornwallis continued, "[Captain Ebenezer] Brown and Frazer must draw only for those that can work and that will be usefull to us here."[24] The human labor required to build the defenses brought to the forefront the need to feed those workers. And if workers were too sick to work, it made little sense to have them on site and consuming precious provisions. Cornwallis informed O'Hara that they would need to create a plan regarding those slaves in order to "prevent an evil which not only destroys a great quantity of provisions but will certainly produce some fatal distemper in the army."[25] The British officers were caught on the horns of an energy dilemma: they needed the slaves' labor to help build the defenses, but acquiring it endangered the prospect of keeping the soldiers fed and healthy.

The British military could not feed those who could not work. That reality regarding the importance of energy led to one in a long string of the war's many cruelties. O'Hara knew that diseased slaves at Portsmouth "would inevitably perish if our support was withdrawn from them." On the eve of the British departure from Portsmouth, O'Hara informed Cornwallis that he had to leave behind "*400* wretched Negroes." He continued

> I have passed them all over to the Norfolk side, which is the most friendly quarter in our neighbourhood, and have begg'd of the people of Princess Ann and Norfolk Countys to take them. We have left with them *fifteen days' provisions*, which time will either kill or cure the greatest number of them. Such as recover will by that time be free from the small pox, which is the invincible objection the people here have to these miserable beings.[26]

Perhaps this letter carries a special meaning to us today, as we live through the current pandemic and wrestle with this country's struggles regarding racial equality.

THE WASTES THAT MILITARY METABOLISMS PRODUCE

I would like to finish with the metabolism of a battle and one particular byproduct of it. Military metabolisms acquire fuel and convert it into energy, and, in the process, they create waste. When most people consider war and waste, they might consider lives lost, the radioactive fallout from atomic bombs, or the pernicious effects of chemicals such as Agent Orange.[27] Today, we readily think about hazardous wastes, but we typically don't associate them with the War of Independence.

Yet in every battle, soldiers shot at each other with lead musket balls. The balls that did not hit their targets typically went into the ground, and no one went around afterwards and picked up those musket balls in order to remediate the battlefield. We all know that lead in the environment is bad for people, causing birth defects, nerve damage, and much more.[28] For a case study, let's consider the Battles of Saratoga, which took place in the same general area of John Freeman's farm on September 19 and October 7, 1777, in upstate New York, just a little bit north of Albany. How much lead was deposited during these battles? I made some armchair calculations. When combining the two battles, a total of 10,274 American soldiers and 5,936 British and German soldiers engaged in the fighting.[29] Both armies carried muskets that fired a .75 caliber lead ball that weighed one ounce. Americans also packed in three or four buckshot with each ball.[30] The Americans' cartridge boxes held thirty rounds, while British soldiers carried twice that number.[31] If I assume that every soldier fired his full supply of ammunition—numerous accounts described the fighting on both days as intense and continuous—then in total they fired about 726,000 ounces of lead, or over 45,000 pounds, nearly 23 tons.[32] "Heavy" fighting indeed.

Because modern medical and scientific studies examine lead in terms of concentrations—parts per million or milligrams/kilogram—I have to place these musket balls within the area of the battlefield and in a quantity of soil. I estimated the battlefield covered slightly more than 250 acres. A four-inch-thick slice of the battlefield, like an enormous sheet cake, would contain the musket balls and buckshot. That layer, comprised of Hudson silt loam and Rhinebeck silt loam soils, would weigh over 380 million pounds.[33] After converting everything to metric and running the numbers through the calculator, I got a total concentration of lead on the battlefield of 119 milligrams per kilogram.[34] Given that lead occurs naturally in all soils at concentrations that range from fifteen to forty mg/kg, this three-to-eight-fold increase in concentration at the Saratoga battlefield might cause us some concern.[35] But perhaps I should make a more conservative calculation. Maybe not every soldier fired his weapon or used up all of his ammunition. Maybe souvenir hunters filled their pockets with musket balls over the years following the battle. Some of those balls also went not into the ground but into human and animal bodies. Even if we subtract, say, 25% from the total amount of lead, that would still produce a concentration of 89.3 mg/kg, a two-to-six-fold increase over its natural concentration.

Even a two-to-six-fold increase is bad, right? It's bad if you absorb tiny particles of lead through your skin, inhale it into your lungs, or drink contaminated groundwater. My original analysis stopped there, but then the environmental side of environmental history got me thinking further. How did those lead particles get formed? This is where we have to understand chemistry and geology.

Lead musket balls in the ground slowly mineralize and turn into compounds such as cerussite [$PbCO_3$], hydrocerussite [$Pb_3(CO_3)_2(OH)_2$], and lead sulfate [$PbSO_4$]. In acidic soils, these compounds dissolve fairly rapidly and release their lead into the environment, where it can then get into our bodies. Saratoga has Hudson and Rhinebeck silt loam soils, however, and they are only slightly acidic (pH values between 6.1 and 6.5).[36] Given these conditions, the cerussite, hydrocerussite, and lead sulfate would have been fairly stable and would not have dissolved. Lead certainly damages human health, but not this lead, sitting in this soil at this time.

Furthermore, even if the lead were released at these concentrations, either at the maximum of 119 mg/kg or at the more conservative 89.3 mg/kg, it would not have posed a danger to humans. The US Environmental Protection Agency considers it a hazard when the concentration hits 400 mg/kg of lead in bare soil in children's play areas.[37] The levels at Saratoga fall far below the EPA's threshold, so why go to all the trouble of figuring out these concentrations of lead?

When students doing research projects run into a hurdle like this, I urge them to step back, ask themselves again "Why am I doing this?", and think about different ways to approach that hurdle. In my case regarding the concentration of lead, remembering a basic definition of history—change over time—provided a way forward. How have conditions at Saratoga changed since 1777? As it turns out, they have changed in several important ways.

First, over the past century, the soils at Saratoga have turned more acidic. Primarily due to the burning of fossil fuels, compounds such as sulfur dioxide and nitrogen oxides have entered the atmosphere, turned into sulfuric acid and nitric acid, and have fallen back to the earth in the form of acid rain. This has pushed the acidity of rainfall in upstate New York to an average of 4.0-4.5 on the pH scale, about ten times more acidic than background conditions.[38] The Hudson and Rhinebeck soils don't have the limestone deposits that would buffer this increased acidity, so maybe now, two centuries after the battles of Saratoga, cerussites and hydrocerussites might be starting to dissolve and release their lead.

Second, conditions have also changed because more lead has been deposited on these lands. Americans first pumped leaded gasoline in 1923, and its usage quickly shot up. By 1985, when the US government phased out leaded gasoline, vehicles had released into the atmosphere about seven million tons of lead.[39] How much of this lead fell on the battlefield of Saratoga? I don't have a figure, but perhaps lead that was deposited from the sky and that was combined with the lead liberated in the soil by acid rain might now be reaching critical concentrations. Musket balls fired in 1777 could, nearly 250 years later, be endangering the health of humans and other organisms, targets those soldiers never intended to hit. The costs of the War of Independence may, unexpectedly, continue to rise.

What I have done here with Saratoga, as well as with Yorktown and Valley Forge, could be replicated at dozens of other sites that saw military action during the War of Independence. Such an approach would yield great benefits because, as the historian Micah S. Muscolino argues, "the metabolism of militaries and societies shapes the choices of commanders, the fates of communities, and the course of environmental change."[40] Environmental history reminds us that the details matter; the particular soil in one location and the specific species of trees in another shape both short-and long-term environmental consequences. We must also pay the same attention to distinctions when analyzing commanders and communities; it makes quite a difference, for example, if the commander is George Washington or some other officer. If we examined those dozens of sites from a metabolic perspective, we would see a dizzying array of human choices and environmental changes. That rich mosaic would give us a new and complex picture of the American Revolution.

NOTES

1. John Ferling, *Almost a Miracle: The American Victory in the War of Independence* (New York: Oxford University Press, 2007), pp. 242-252.

2. Wayne Bodle, *The Valley Forge Winter: Civilians and Soldiers in War* (University Park, PA: Penn State University Press, 2002), chapter 3.

3. Charles H. Lesser, ed., *The Sinews of Independence: Monthly Strength Reports of the Continental Army* (Chicago: University of Chicago Press, 1976), pp. 54-56; Nancy K. Loane, *Following the Drum: Women at the Valley Forge Encampment* (Washington, D.C.: Potomac Books, 2009), p. 2; Benjamin L. Carp, *Rebels Rising: Cities and the American Revolution* (New York: Oxford University Press, 2007), p. 225.

4. Thomas Ewing, ed., *The Military Journal of George Ewing (1754-1824), a Soldier of Valley Forge* (Yonkers, NY: Thomas Ewing, 1928), p. 25; Jacqueline Thibaut, "In the True Rustic Order: Material Aspects of the Valley Forge Encampment, 1777-1778," *The Valley Forge Report*, vol. III (Valley Forge National Historical Park, 1979), p. 6.

5. A cord of wood is a pile of split logs four feet high, four feet deep, and eight feet in length. The bed of a large pickup truck could hold this amount of wood.

6. Marc A. Brier, "Tolerably Comfortable: A Field Trial of a Recreated Soldier Cabin at Valley Forge," National Park Service, U.S. Department of the Interior, Valley Forge National Historical Park, 1 August 2004, pp. 6, 21 endnote 33, 17; Thibaut, "In the True Rustic Order," pp. 38, 41, 42, 8.

7. Lysle S. Sherwin, Kristen Brubaker, Peter Sharpe, Justin Kozak, Melissa May, Aubrey Lashaway, Kevin Jensen, and Katherine L. Gordon, "Valley Forge National Historical Park Natural Resource Condition Assessment," Natural Resource Report NPS/VAFO/NRR—2013/737 (Fort Collins, Colorado: National Park Service, 2013), p. 6; William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983), pp. 123-124.

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9. George Washington to Peter Colt, 7 Feb. 1778, *Founders Online,* National Archives, https://founders.archives.gov/documents/Washington/03-13-02-0386.

10. George Washington to Major General Nathanael Greene, 12 February 1778, *Founders Online,* National Archives, https://founders.archives.gov/documents/Washington/03-13-02-0430.

11. George Washington to Captain Stephen Chambers, 27 February 1778, *Founders Online,* National Archives, https://founders.archives.gov/documents/Washington/03-13-02-0578.

12. Ibid.

13. General Orders for 31 Dec. 1777, *Valley Forge Orderly Book of General George Weedon* (New York: New York Times & Arno Press, 1971), p. 174. In the late-eighteenth century, there was no consistent and standardized spelling of words. Therefore, in this and other direct quotations, I have not inserted [*sic*] after words that strike our twenty-first-century eyes as misspelled.

14. General Orders, 4 September 1777, *Founders Online,* National Archives, https://founders.archives.gov/documents/Washington/03-11-02-0141.

15. Jerome A. Greene, *The Guns of Independence: The Siege of Yorktown, 1781* (El Dorado Hills, CA: Savas Beatie, 2013).

16. Greene, *Guns of Independence*, pp. 37-40, 42, 45, 49, 51, 54, 57, 61.

17. Ibid., pp. 43-44, 46, 49, 51, 54, 57, 61.

18. Vaclav Smil, *Energy and Civilization: A History* (Cambridge, MA: MIT Press, 2017), p. 183.

19. Cornwallis to Charles O'Hara, 6 Aug. 1781, *The Cornwallis Papers: The Campaigns of 1780 and 1781 in the Southern Theatre of the American Revolutionary War*, ed. Ian Saberton, vol. VI (East Sussex, England: Naval & Military Press, 2010), p. 45; Johann Ewald, *Diary of the American War: A Hessian Journal*, trans. and ed. Joseph P. Tustin (New Haven: Yale University Press, 1979), pp. 323-324.

20. Ewald, *Diary of the American War*, p. 328.

21. Greene, *Guns of Independence*, p. 33; Cornwallis to Henry Clinton, 22 Aug. 1781, *The Cornwallis Papers*, p. 28.

22. Alan Derickson, "'A Widespread Superstition': The Purported Invulnerability of Workers of Color to Occupational Heat Stress," *American Journal of Public Health*, 109 (2019): 1329-1335.

23. Cornwallis to O'Hara, 4 Aug. 1781, and O'Hara to Cornwallis, 5 Aug. 1781, *The Cornwallis Papers*, pp. 44-45.

24. Cornwallis to O'Hara, 7 Aug. 1781, *The Cornwallis Papers*, p. 46.

25. Cornwallis to O'Hara, 10 Aug. 1781, *The Cornwallis Papers*, p. 48.

26. O'Hara to Cornwallis, 17 Aug. 1781, *The Cornwallis Papers*, p. 52.

27. John Ferling conservatively estimates that 30,000 Americans and 50,000 men supporting Great Britain died bearing arms in the war. Ferling, *Almost a Miracle*, pp. 558-559.

28. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Workplace Safety and Health Topics: Lead, "Worker Information: Health Problems Caused by Lead," http://www.cdc.gov/niosh/topics/lead/health.html.

29. John F. Luzader, *Saratoga: A Military History of the Decisive Campaign of the American Revolution* (New York: Savas Beatie, 2010), pp. 230, 235-236, 240, 242, 245, 278, 289-290, 295, and Appendices B, C, D, and E.

30. Harold L. Peterson, *Arms and Armor in Colonial America, 1526-1783* (Harrisburg, PA: The Stackpole Company, 1956), pp. 183-185, 227; Erik Goldstein and Stuart Mowbray, *The Brown Bess: An Identification Guide and Illustrated Study of Britain's Most Famous Musket* (Woonsocket, RI: Mowbray Publishing, 2010), pp. 9, 62.

31. Peterson, *Arms and Armor*, pp. 237, 239; James Phinney Baxter, *The British Invasion from the North: The Campaigns of Generals Carleton and Burgoyne from Canada, 1776-1777, with the Journal of Lieut. William Digby, of the 53rd, or Shropshire Regiment of Foot* (Albany: Joel Munsell's Sons, 1887; reprinted New York: Da Capo, 1970), pp. 271-272.

32. Thomas Anburey, *Travels through the Interior Parts of America* (New York: Arno Press, 1969), pp. 414-15, 442; Alexander Scammel to Jonathan C. Shadbourn, from Camp Now or Never, 26 Sept. 1777, Schoff Revolutionary War Collection, Box 2, William L. Clements Library, University of Michigan; Luzader, *Saratoga*, p. 296.

33. United States Department of Agriculture [USDA], *Soil Survey of Saratoga County, New York*, "Saratoga Springs, New York, Quaker Springs Quadrangle, Sheet Number 18"; D.L. Miles and I. Broner, "Irrigation: Estimating Soil Moisture," Fact Sheet no. 4.700, Colorado State University Extension, Sept. 1998, reviewed Feb. 2006, http://irrigationtoolbox.com/ReferenceDocuments/Extension/Colorado/04700.pdf. I chose a four-inch slice of soil because a modern study of a shotgun range with untilled soils showed "no significant downward lead movement beyond 10 cm," or about 4 inches. Caleb Scheetz, "Dissolution, Transport, and Fate of Lead on Shooting Ranges," (MA, Virginia Polytechnic Institute and State University, 2004), p. 26.

34. The size of the battlefield multiplied by the four-inch layer: (11,000,000 ft^2) x (.33 ft) = 3,630,000 ft^3. This amount of soil multiplied by the weight of the soil: (3,630,000 ft^3) x (105 lbs/ft^3) = 381,150,000 lbs., or 172,886,732 kg. The total amount of lead converted into milligrams = 20,582,417,388 mg. That amount divided by the weight of the soil produces a lead concentration of 119 mg/kg.

35. "Soil Lead: Testing, Interpretation, & Recommendations," The Center for Agriculture, Food, and the Environment, University of Massachusetts-Amherst, last updated 17 July 2017, http://ag.umass.edu/home-lawn-garden/fact-sheets/soil-lead-testing-interpretation-recommendations.

36. Zhixun Lin, Blaise Comet, Ulf Qvarfort, and Roger Herbert, "The Chemical and Mineralogical Behaviour of Pb in Shooting Range Soils from Central Sweden," *Environmental Pollution*, 89 (1995): 303-309; Scheetz, "Dissolution," pp. 17, 22, 25; USDA, *Soil Survey of Saratoga County,* pp. 197, 209, 235.

37. US Environmental Protection Agency, "Hazard Standards for Lead in Paint, Dust, and Soil (TSCA Section 403)," last updated 9 July 2019, https://www.epa.gov/lead/hazard-standards-lead-paint-dust-and-soil-tsca-section-403.

38. Charles T. Driscoll, Kimberley M. Driscoll, Myron J. Mitchell, and Dudley J. Raynal, "Effects of Acidic Deposition on Forest and Aquatic Ecosystems in New York State," *Environmental Pollution*, 123 (2003): 327; Richard A. F. Warby, Chris E. Johnson, and Charles T. Driscoll, "Continuing Acidification of Organic Soils across the Northeastern USA: 1984-2001," *Soil Sciences Society of America Journal*, 73 (2009): 275.

39. Jerome O. Nriagu, "The Rise and Fall of Leaded Gasoline," *Science of the Total Environment*, 92 (1990): 16.

40. Micah S. Muscolino, *The Ecology of War in China: Henan Province, the Yellow River, and Beyond, 1938-1950* (New York: Cambridge University Press, 2015), 5.