

Refraction of sound waves influenced the outcome of several Civil War Battles!

Acoustician Charles D. Ross has found that refraction of sound caused by temperature and wind gradients may have had a significant impact on the outcome of several Civil War Battles (Gettysburg, Gaines Mill, Fort Donelson, Seven Pines/Fair Oaks, Iuka, Perryville, Chancellorsville, and Five Forks). A summary of his findings are summarized in **Echoes**, the newsletter of the Acoustical Society of America, and he has a new book **Civil War Acoustic Shadows** which describes his research in detail.

Outdoor Sound Propagation in the U.S. Civil War

by Charles D. Ross

Students of military history know that acoustic refraction and unusual audibility have often played significant roles in the outcome of battles. Before electrical and wireless communications became common on the tactical level, the sound of battle was often the quickest and most efficient method by which a commander could judge the course of a battle. Troop dispositions were often made based on the relative intensity of the sounds from different locations on the battlefield.

Unusual acoustics due to atmospheric conditions or to terrain are sometimes given the catch-all name "acoustic shadows." The first recorded incidence of the phenomenon occurred during the Four-Day Battle in 1666. The naval battle was fought between the coasts of England and Holland, and sounds of the battle were heard clearly at many points throughout England but not at intervening points. Passengers on a yacht positioned between the battle and England heard nothing. A number of other examples have been recorded since that time. Guns fired at the funeral of Queen Victoria in London in 1901 were heard in Scotland, but not across a wide region in between. The German bombardment of Antwerp in World War I was heard clearly for a 30-mile radius, then beyond 60 miles from the Belgian city, but not in between.

In the course of my research for my book on science and technology in the Civil War, I noted examples of similar acoustical phenomena. Some historians were apparently aware of these incidents, but no one had ever investigated their causes. By intensive study of war records, regimental histories, diaries, and period newspapers, I was able to piece together information allowing me to determine the causes of each acoustical shadow. The most famous battles during which these events occurred and affected command decisions were: Seven Pines, Gettysburg, Iuka, Fort Donelson, Chancellorsville, Five Forks, and Perryville. Unusual audibility at great distances was associated with several of these battles and also with the battle of Gaine's Mill.

In each of these seven battles listed above, the inability of commanders to hear and interpret the sounds of battle was directly responsible for the outcome. One might even go so far as to say the acoustical shadows determined the course of the entire war. The unusual acoustics at Seven Pines placed Confederate commander Joseph Johnston in a position of danger when the battle should have been over. Because of Johnston's wound, Robert E. Lee **assumed command of the Confederate forces two days later.**



The Causes of Acoustical Shadows

Acoustical shadows can usually be traced to one or more of three causes: absorption, wind direction and wind shear, or temperature inversions.

Absorption - Sometimes material between a sound source and an observer will render the sound inaudible. The material can be soil (Gettysburg), forest (Five Forks and Chancellorsville), snow (Fort Donelson) or a variety of other substances.

Wind direction and wind shear - In general, sounds are more likely to be heard downwind of a sound source than upwind. Since winds aloft are usually faster than at ground level, the upper part of a sound wave will travel faster than the lower part when traveling with the wind and more slowly when against the wind. This will cause a refraction towards the ground in the former case and away from the ground in the latter case. Such an effect was certainly at work at Fort Donelson and Iuka.

Temperature inversions - Sound waves travel faster in warm air than cool air (the speed (m/s) is approximately $331.36 + 0.6067t$, where t is temperature in Celsius). Under most conditions, the air temperature decreases as altitude increases. This causes sound waves to refract upwards and decreases audibility along the ground at a distance. Sometimes, however, the temperature is higher above the ground than near the ground - a condition called a temperature inversion. The effect is to bend sound waves back towards the ground and increase audibility. Temperature inversions are common on clear, cool nights (and the mornings following them) and during widespread rainstorms (at Gettysburg and Seven Pines, for example, and also at the battle of Perryville, Kentucky in 1862).

Sometimes upwardly refracted waves hit a warmer layer higher up and are refracted back down, creating rings of audibility, as in the battle of Gettysburg as well as in the European examples previously described.

Five Forks

The scene - On April 1, 1865, Confederate forces under Major General George Pickett held the far western flank of General Robert E. Lee's Petersburg defenses. Pickett's forces were at Five Forks, the intersection of five country roads, located about 12 miles from Petersburg. Lee's forces were stretched thin, and protecting this right flank was crucial to maintaining the integrity of the Confederate position and the safety of the capital in Richmond. Holding the position also offered Lee the possibility of slipping away to the southwest and joining up with forces under General Joseph E. Johnston in North Carolina.

Wary of the threat of losing Lee after having had him clamped down around Petersburg for almost a year, Union General Ulysses S. Grant sent cavalry under Major General Philip Sheridan to probe the position at Five Forks. After being repulsed on March 31, Sheridan informed Grant that he could turn the Confederate right if he had support from an infantry

corps. Accordingly, by the morning of April 1, the Union V Corps under G. K. Warren was arriving on the scene.

What happened - The Confederates were entrenched at Five Forks, with cavalry units dug in on the flanks, Pickett's infantry in the center, and reserves under Brigadier Thomas Rosser behind Pickett's men. On the morning of April 1, Rosser invited Pickett and Major General Fitzhugh Lee (in command of the cavalry) to his position (on a stream a mile behind the lines to a "shad bake" or fish roast. Despite the imminent danger from the enemy, both generals inexplicably accepted the offer. When Sheridan and Warren began their attack in mid-afternoon, the Confederate commanders were blissfully unaware, of their impending doom. In between the front lines and Rosser's position was a dense pine forest which completely absorbed the sound of small arms fire. In the crucial opening minutes of the battle, the leaderless Confederates were overwhelmed by Union forces on their left. The battle of Five Forks quickly turned into a rout and signaled the beginning of the end for Lee's army. With his flank turned, Lee was forced to abandon Petersburg and Richmond and flee to the west. Eight days later, Grant and Sheridan caught the Confederates at Appomattox Court House, where Lee surrendered.

Chancellorsville

The scene - Spring of 1863 found the Union Army of the Potomac and the Confederate Army of Northern Virginia in a standoff across the Rappahannock River at Fredericksburg. After the crushing Union defeat there in December 1862, Union morale was low. The new Union commander, Major General Joseph Hooker, unveiled a plan designed to surprise and crush the Confederate forces. Leaving a large force in front of Fredericksburg, in late April he took five infantry corps upriver and crossed fords to the southern bank. Confederate commander Robert E. Lee was not aware of the maneuver until the Federals were already over the river. Lee now had an enemy force in front of him and one on his left flank, each larger than his whole army. It seemed his only choices were either to retreat towards Richmond or be crushed in the Union vise.

What happened - Defying conventional military strategy, Lee separated his forces despite being outnumbered. Leaving a small force on the heights behind Fredericksburg, Lee took the rest of his army to meet Hooker head on. The armies clashed on May 1 near the crossroads of Chancellorsville. Though his troops outnumbered the Confederates, Hooker seemed momentarily stunned by the opposition and halted his men in a defensive position along the Orange Turnpike. The next day Lee gambled again. He sent forces under Lieutenant General Thomas J. "Stonewall" Jackson on one of history's greatest flanking attacks. Using a guide and traveling over little-known farm roads, Jackson managed to get his men on the left flank of the Union position without being detected. Near sundown on May 2, Jackson's forces attacked, rolling up the stunned Union army. Hooker, at Chancellorsville, was shielded from the sounds of battle by the dense forest known locally as "The Wilderness" and first became aware of the rout as panic-stricken Federal soldiers overran his position. There was undoubtedly a refractive effect at work on this day as well: Confederate Major General Cadmus Wilcox, 10 miles to the east near Fredericksburg, noted the sounds of battle clearly. This refraction may have been due to wind shear (high winds kept Union balloonists grounded).

Seven Pines

The scene - After the Union debacle at Bull Run, George C. McClellan was placed in command of the forces around Washington. Rather than move towards Richmond directly overland, McClellan decided to save his infantry some work by shipping them to the peninsula southeast of Richmond to begin his attack from there. Working against the able but cautious Confederate General Joseph E. Johnston, McClellan's men worked their way slowly but steadily up the peninsula until by late May 1862 McClellan could hear the clocks of Richmond striking from his headquarters. Under pressure from the Confederate government to take some action to save the capital, Johnston mapped out a plan. He formulated a three-pronged attack in which Confederate forces would be funneled by three different roads towards a convergence on the Union forces at the intersection called Seven Pines.

What happened - The plan was complex and required perfect timing on the part of Johnston's subordinates. Instead, what Johnston got was bickering and arguments about seniority among the Confederate generals as their troops ran into each other and blocked each other's routes. Still, by early afternoon the Confederates had managed to attack and were holding their own against the Federals. Johnston, at his headquarters near Fair Oaks a few miles from the front lines, did not hear the battle and could not be convinced by others that a fight was raging. He held key reserves back until a desperate note from Major General James Longstreet at 4 o'clock convinced him that a battle was indeed underway. By then it was too late; the Federals had been reinforced by troops under Edwin Sumner, and the battle ended in a draw. Near dusk, Johnston went to observe the closing moments of the conflict and was seriously wounded. Two days later, Robert E. Lee assumed command of the Confederate forces, replacing the wounded Johnston.

The battle, silent to Johnston two miles from the front, was heard clearly by citizens of Richmond ten miles to the west and to Federals as far to the east. The probable cause was a temperature inversion bending the sound back to the ground. On the night before the battle, a violent thunderstorm (many soldiers said it was the worst they had ever seen) raged over the area. The day of the battle dawned with widespread, low cloud cover-ideal conditions for a low- atmosphere temperature inversion.

Gettysburg

The scene - In the summer of 1863, the Confederacy was in dire straits. The vital garrison at Vicksburg, Mississippi was under siege and near collapse. In the east, things looked better, but the situation was still bad. The Army of Northern Virginia had withstood all Union attempts to take the war to Richmond, but General Robert E. Lee knew that he faced an uphill battle. The Union seemed to have a never-ending supply of men ready to volunteer, filling holes in the ranks, while the Confederate rosters dwindled to ever-smaller numbers. And the war-ravaged land north of Richmond could not long support his men and horses.

In the hopes of relieving the pressure on Vicksburg and giving his men access to the fertile bounty of the north, Lee decided to invade Pennsylvania. The Confederates and the Union troops, now under Major General George Meade, met at the town of Gettysburg. The Confederates had the better of it on the first day, but the Federals dug in along a series of hills and ridges behind Gettysburg.

What happened - July 2 dawned hot and sunny, and Lee had a plan for dislodging the Union army from its perch. While forces on the Confederate left under Lieutenant General Richard S. Ewell made a show of force, troops under Lieutenant General James Longstreet on the

Confederate right would attack and take the virtually unoccupied Round Top mountains at the south end of Cemetery Ridge. Confederate artillery would be able to sweep Meade's men from the hills. Ewell's demonstration was to begin when he heard the artillery barrage which would signal the beginning of Longstreet's attack. For a long time after Longstreet had begun his attack, Ewell heard nothing and hence did not move his troops. As a result, Meade was able to shift troops from the right of his line down towards the Round Tops, just in the nick of time to defeat Longstreet's attack. Ewell's inability to hear Longstreet's artillery appears to stem first from the shielding effects of Cemetery Ridge and Culp's Hill between the two Confederate forces. More importantly, the hot temperatures near the ground probably caused a dramatic upward refraction of sound waves. Upon hitting another warm layer higher up, these waves could be refracted back downwards. On the previous day, Meade had been unable to hear the Gettysburg fighting from his position at Taneytown (12 miles away), yet the battle was clearly audible in Pittsburgh, 150 miles from Gettysburg.

Iuka

The scene - In September of 1862, Confederate forces under Major General Sterling Price struck and ran off the small Union garrison at Iuka, Mississippi. After confiscating supplies left behind by the Federals, Price decided to stay put in Iuka until he received orders for his next move. Twenty miles away, someone was making plans for Price, but not of the type he expected. Ulysses S. Grant, headquartered at Corinth, decided that Price's resting period would be a perfect time to strike and annihilate his forces. Though Grant had only 17,000 men on hand (Price had 15,000), he had an idea for a trap that would ensure Price's defeat. While forces under Major General Edward Ord approached Iuka from Corinth in the northwest, the other half of Grant's force under Brigadier General William Rosecrans would swing around and approach Iuka from the south, trapping Price from the rear. On September 17, Grant put the plan in motion.

What happened - Following Grant's plan, Ord stopped his battle lines four miles from Iuka and waited for the sounds of battle between Price and Rosecrans before proceeding (Grant wanted to make sure that the southern escape route was blocked before striking from the north). Late in the afternoon, Ord saw dense clouds of smoke coming from Iuka but assumed that Price was burning his supplies to keep them out of Union hands. In fact, Price and Rosecrans had been engaged for several hours, but Ord was unable to hear the battle. A strong wind blowing from the northwest had carried the sounds of battle away from Ord and Grant. When Grant finally learned the next morning that Rosecrans had been in a fight with Price, he immediately ordered both forces to advance. The Union troops met only each other; Price and his men had slipped out between them during the night.

Fort Donelson

The scene - In early February 1862, Union forces under Brigadier General Ulysses S. Grant had easily taken Confederate Fort Henry on the Tennessee River and reestablished the Stars and Stripes on Tennessee soil. Twelve miles to the east was Fort Donelson (on the Cumberland River), which Grant also vowed to take. If both the forts fell into Union hands, the Federals would have control over both rivers, providing valuable transportation arteries into the heart of the Confederacy. While Grant's men surrounded Donelson on three sides, gunboats under Flag Officer Andrew Foote steamed down the Cumberland to attack the fort from the fourth side. After their easy submission of low-lying Fort Henry, the gunboats were believed by both sides to be nearly invincible. To their surprise, the gunners in Fort Donelson,

elevated much higher above the water than Fort Henry, shot the Union boats to pieces. Elated, the Confederates planned a breakout through the Union lines for the next day, February 14.

What happened - Nursing their wounds, Foote's sailors steamed five miles north of Fort Donelson to regroup. Not suspecting that the Confederates might go on the offensive from their precarious position, Grant rode north at dawn on February 14 to confer with Foote and plan the next move of the siege. At Fort Donelson, Confederate commander John Floyd planned for forces under Brigadier General Gideon Pillow to force a breakthrough towards the south while troops under Simon Bolivar Buckner held the other Union forces in position and then forced their way through the same opening. Attacking in early morning, the battle raged between Pillow and Union forces under John McClernand for over three hours before McClernand's men gave way. Grant was completely unaware of the battle; five miles away he could hear nothing. This due to two factors. On the previous day, a spring snow had blanketed the ground, absorbing sound in all directions. Also, a howling wind blew from north to south, carrying sounds away from Grant and refracting sounds upwards. Only indecision by Pillow and Buckner at the crucial moment prevented the entire Confederate force from escaping. Notified by courier, Grant raced back to the battlefield and reorganized his men to the point where they drove the Confederates back into the fort, forcing their surrender the next day.

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