

# The Underground War: Military Mining Operations in support of the attack on Vimy Ridge, 9 April 1917

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## Introduction

This article aims briefly to describe the significance and evolution of military mining as a battlefield tactic during the Great War, with special reference to the role these underground operations played in the greatest success of Canadian arms - the capture of Vimy Ridge.

No military historian's visit to Vimy Ridge, this country's most symbolic and emotion-laden battlefield, would be complete without a stop at the Grange Tunnel, an infantry subway dug during the winter and spring of 1916-1917 by the soldier-miners of 172 Tunnelling Company, Royal Engineers. They were ably assisted by work parties from all four veteran battalions of 3rd Canadian Infantry Division's 7th Brigade: The Black Watch (42 Battalion), The Royal Canadian Regiment, Princess Patricia's Canadian Light Infantry and the Edmonton Regiment (49 Battalion).

Tunnel guides explain how this cool, humid, subterranean passage, hurriedly burrowed into the compacted flint and chalk of an Artois hill, was part of a 13-tunnel underground labyrinth. It protected the assaulting infantry battalions of the Canadian Corps from the terrible and ever-present dangers of German bombardment as they made their final move from their reserve trenches in the rear, forward to their assembly trenches in the very front of the Canadian line.

## Background

The infantry subways, however, are only a part of the underground story of the Canadian Corps' operations against the enormously powerful German fortress on Vimy Ridge. A stone's throw away from the Grange Tunnel separating the concrete-sandbagged German and Canadian forward outpost lines are the well-manicured remains of the Duffield, Grange and Birkin crater groups.<sup>1</sup> They are but a small fraction of the scores of craters produced by the German, French and British mining operations on the ridge during two years of near constant fighting.

The first battle of the Artois in 1915 saw the French 10th Army begin a slow, stubborn year-long advance up the ridge which ended in February 1916 when, urgently needed to stem the German onslaught at Verdun, it was relieved by the 17th Corps of the British Third Army, commanded by Lieut.-General Sir Julian Byng, a figure soon to be well-known to the Canadian Corps. No sooner had this aggressive formation of the British Expeditionary Force (BEF) settled in to brave the hardships of a cold, wet Artois spring when it faced a hurricane of mine explosions which were carefully, violently and successfully orchestrated by the German defenders to throw the newly arrived force back down the slopes of the ridge. It was during the month of October 1916 that the British troops at the base of the ridge were relieved by the Canadian Corps, or what was

left of it after its bloody journey across the killing fields of the Somme.

Mining operations are a fundamental, but seldom explored element of the French, British and Canadian battles for the ridge. The old craters which remain in that small well-preserved piece of no man's land are silent witnesses to great battles lost and won. These mine craters are more than just deep holes in the ground produced by the detonation of enormous amounts of high explosive; they represent the vestiges of a particular form of warfare, already thousands of years old when war was declared in 1914. During this conflict, mining techniques were resurrected, modernized and vigorously applied by both sides. Aggressive mining characterized trench warfare during the middle two years of World War One, especially in the active sectors of the Western Front.<sup>2</sup> On Vimy Ridge, commanders at all levels employed mines to seize the initiative, to dominate terrain and to inflict casualties, with a view to creating a local tactical advantage.

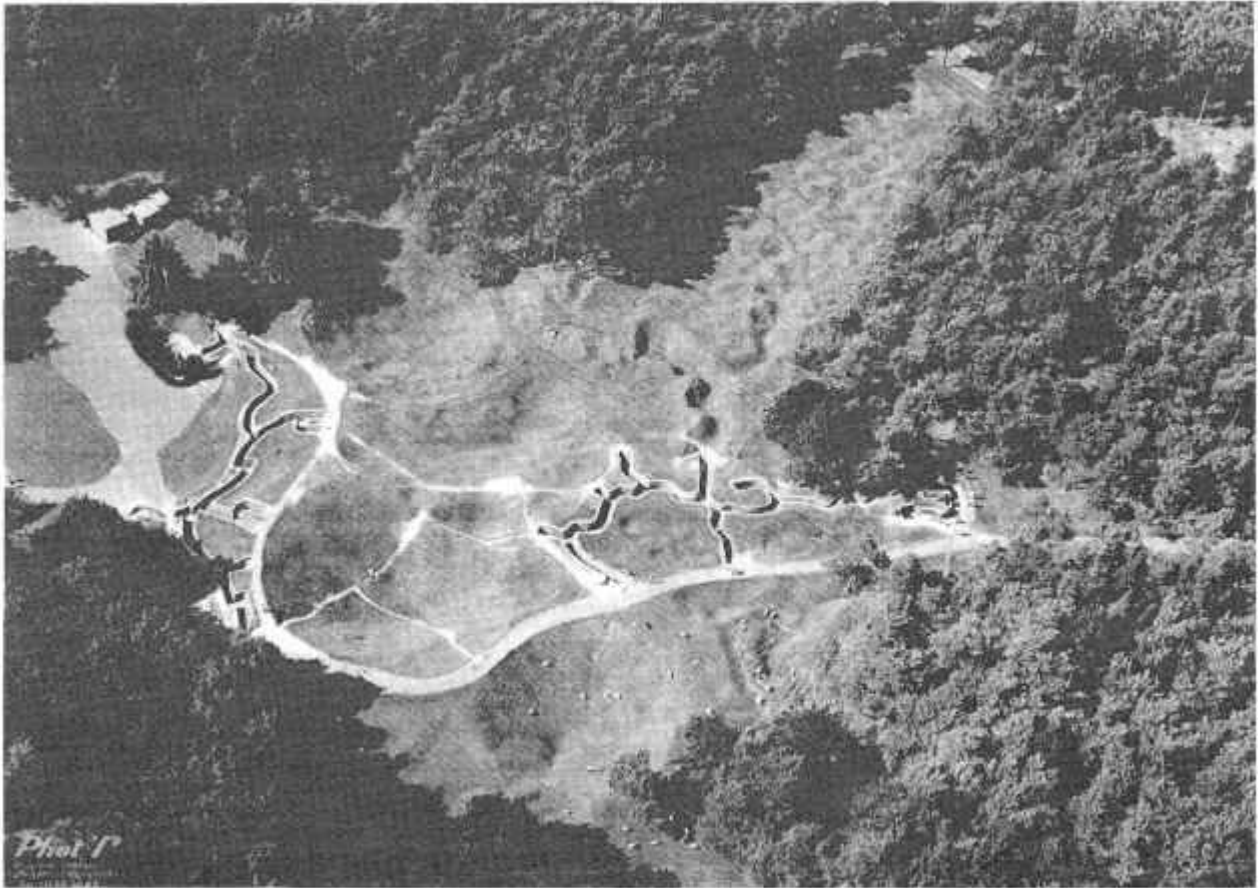
Manoeuvre warfare on the Western Front came to an end in the late autumn of 1914. By the time the race to the sea ended in November, both sides had run out of open flanks to turn, strategic envelopment was now impossible. It became clear to both warring camps that, without the possibility of manoeuvre, the chances of obtaining a clear decisive victory on the Western Front were increasingly remote. The belligerents squared off against each other from positions of increasing strength along a 400-mile corridor from the Franco-Swiss border to the Channel port of Flanders. Technological improvements in the delivery of firepower, the failure of tactical doctrine, very heavy casualties and acute shortages of ammunition left both sides with no option but to consolidate their positions and settle into a positional style of warfare for which their pre-war training had left them totally unprepared. Developing solutions to the problem of tactical stalemate with a view to restoring manoeuvre on the battlefield became urgent priorities for commanders and staffs on both sides of the wire. Reestablishing open warfare was

perceived to be the only way of achieving a clear decision in the field.

In addition to improving the accuracy and lethality of their respective artillery, as well as developing the destructive potential of chemical weapons, both sides resurrected the mining techniques which had proven so effective in breaching fixed defences during the complicated siege operations which characterized so many of the European campaigns of the 18th and 19th centuries. These technical solutions to the tactical problem of stalemate in the trenches evolved unevenly on both sides of no man's land as the conflict wore on.<sup>3</sup>

Demonstrating the talent for innovation which characterized its operations throughout the conflict, the German Army seized the initiative and went underground, scoring its first tactical success against the British at Festubert (20 km north of Vimy), just before Christmas 1914. There, German tunnellers detonated ten mines under forward positions manned by an Indian Brigade and destroyed over a thousand yards of densely occupied trenches. Morale was so shaken by the surprise and violence of the attack that the entire Indian Corps had to be withdrawn into Army reserve to rest and recover. Underground, the Germans kept up the pressure; the relentless attacks continued without pause and the morale of the BEF plummeted.<sup>4</sup>

The psychological impact of German mining was devastating. British soldiers in the front lines could actually hear the German miners coming at them. The noise of their picks and shovels carried for long distances underground, as did the sounds they made while placing their explosives charges under British forward positions. Soldiers felt they had no defence against the terrible, inevitable fate of being buried alive or blown apart by a sudden thundering explosion coming up at them from the bowels of the earth.<sup>5</sup> By the spring of 1915, it had become difficult for the British infantry commanders to keep their soldiers in the front lines of sectors where German miners were known to be active.<sup>6</sup>



*The Duffield, Grange and Birkin Crater Groups, now preserved and manicured. The entrance to the Grange Tunnel is on the left.*

Struggling to regain the initiative, the BEF attempted to stop the German underground offensive but its efforts were ineffective. As senior British commanders soon realized, Royal Engineer units at brigade and division level were short of soldiers trained in mining as well as the necessary officer expertise to direct operations from underground. Time was running short and prompt decisive action was required. The BEF was being blown out of its trenches and could do little to defend itself.

Informed of this deteriorating situation and acting on the advice of several notable personalities within the British mining industry who were concerned by the inertia of senior British military leadership,<sup>7</sup> Lord Kitchener, the Secretary of State for War, approved the immediate recruitment and deployment of specialized tunnelling companies to the Western

Front. The organization, training and tactical employment of these companies were to be the responsibility of the Royal Engineers. Wherever possible they were to be composed entirely of professional miners who could be recruited and organized where they worked.

The formation of these new Royal Engineer tunnelling companies began during the winter of 1914-1915 and was treated as an urgent priority by the War Office. In the coalfields and pit mines of Britain and the Dominions, mining engineers and geologists volunteered to become the company and platoon commanders. Mining foremen with a taste for adventure were found and promoted to senior NCO rank. They would become the shift supervisors underground. Those miners, declared to be surplus to the war effort at home, were encouraged to join

these new, secret "underground" organizations. Sometimes events moved very quickly. One tunnelling company was recruited and formed on a Thursday morning in Yorkshire and was underneath German forward positions in Flanders the following Wednesday afternoon.<sup>8</sup>

Once at the front, the plan was simple. After a very short period of military training these companies would be rushed to the sectors where their expertise was most needed. Initially they would defend the BEF against enemy mines by destroying the Germans underground in their own tunnels, before they could plant their mines beneath friendly positions. This tactic was labelled defensive mining and depended upon tunnellers quickly finding enemy tunnels and then collapsing them with small explosive charges called *camoufiets*. Having neutralized the enemy's efforts underground, British miners would then push their own tunnels forward underneath German positions, thereby regaining the initiative (offensive mining). The Germans had to be stopped underground if the British and French were to remain in the war.

The introduction of Royal Engineer tunnelling companies, composed of well-trained and highly-motivated professional miners, to the Western Front was initially welcomed by commanders in the field, but it was staunchly resisted by the uppermost echelons of the BEF who "were unenthusiastic about taking in some hundreds of miners with no military training at all and [who had] a reputation for fierce independence."<sup>10</sup> Despite these reservations, the underground menace posed such a serious threat to the BEF that the shared perception amongst the senior commanders was that only resolute, effective and coordinated action could defeat it. To ensure economy of effort and concentration of force, tunnelling companies were centralized at Army level and commanded by a Royal Engineer colonel who carried the title, "Controller of Mines". This officer provided technical advice to his army commander and assigned mining priorities in the Army's area of operations in consultation with the commander's staff and

according to the commander's operational plan. Further up the chain of command was the "Inspector of Mines" stationed at HQ BEF. This officer of general rank allocated companies to armies according to operational priorities established by the commander of the British Expeditionary Force.<sup>11</sup>

A total of 33 companies of tunnellers was deployed to the Western Front in the summer of 1916. The Commonwealth was well represented in the British Army Mining Service with one New Zealand, three Canadian and three Australian companies serving alongside their Imperial counterparts. When at full strength, a company could field 500-600 miners and was often reinforced by fatigue parties drawn from infantry battalions in reserve (always a popular job with tired soldiers). With attachments, company strengths were often well into four figures, as was the case with 172 Company while it dug the Grange Tunnel from November 1916 to March 1917.<sup>12</sup>

In 1915, British mining operations on the Western Front were limited in scope and essentially defensive. Digging was restricted to shallow tunnels, seldom surpassing 100 yards long and 20 feet deep. The charges were also small, rarely exceeding 10,000 lbs.<sup>13</sup> Gunpowder and gun cotton, though far too sensitive to enemy fire, were the only explosives available in great quantity. Many miners perished when the explosives bags they were carrying were hit by small arms fire or shrapnel. Throughout 1915 the Germans maintained the momentum they had initiated during the autumn of 1914 though the presence underground of unfriendly miners from the BEF caused them to be much more circumspect, as the tunnellers' war diaries testify.<sup>14</sup>

Without doubt 1916 was the most active year of the underground war. When the last of the tunnelling companies was recruited and deployed in early summer, the 33 companies could field 24,000 miner-soldiers. Digging techniques had improved to the point where miners could push tunnels deep underneath the enemy at a rate of 20 feet a day, soil conditions permitting. Underground listening

devices had been developed which could accurately detect German tunnelling up to 100 yards away.<sup>15</sup>

Ammonal, a new and powerful explosive, could be safely handled and transported, even under fire. It was used in huge quantities and produced impressive results. A new French invention, *le cordeau detonnant* ("det cord" in Canadian field engineer parlance), assured a reliable alternate means of exploding heavy mine charges, which by this time were being measured in tons of explosives.

During that same year the tunnelling companies exploded a total of 750 mines along the front line of the BEF. The Germans answered with 696 devices of their own.<sup>16</sup> In the Arras sector, which included Vimy Ridge, ten Royal Engineer tunnelling companies dug thousands of yards of shafts, exploding well over 100 large mines underneath or close to German positions. The majority of the craters still visible today near the Grange Tunnel were fired during 1916. The tide was turning. On the ridge, as in other sectors of the Western Front, the Germans were losing the initiative, and were not to regain it.

While British companies were busy on Vimy Ridge, No.1 Canadian Tunnelling company began digging underneath Saint Eloi. It was to be the longest mine shaft to date (1,650 feet), at the greatest depth (125 feet) and after 9 months of dangerous work contained the biggest charge of the war (95,600 lbs of Ammonal). It was exploded, along with 18 other large mines (a total of 1,000,000 lbs of Ammonal) as part of the Messines offensive in June 1917.

At the end of 1916, pressures on the German war economy had forced the recall of 125,000 miners from the Army to reinforce the industrial effort at home; 50,000 more men followed in June 1917.<sup>18</sup> As these men were not replaced, enemy underground activity dropped off dramatically. Furthermore, the new German defensive doctrine introduced in December 1916, called for the creation of multiple and mutually supporting defensive belts thickened with numerous strongpoints. Thus the deployment of the German Army in much greater depth pushed many attractive enemy targets well back from no man's land, effectively placing them out of range of BEF tunnellers.<sup>19</sup>



In comparison to the previous year, 1917 was relatively quiet; 117 British mines were detonated, as compared to 106 German charges.<sup>20</sup> The war underground had become, at best, a series of skirmishes. As a result, from November of 1916 onwards, far fewer tunnelling companies were required to face the rapidly decreasing German menace underground. Consequently, more miners could be employed digging infantry subways, which was the case in the Vimy sector.

By the beginning of 1917, the BEF had won the war underground but not without paying a steep price in soldier-miners.

*An aerial view of the reconstructed trenches at Vimy. (NAC PA 183533)*

## Under Vimy Ridge

The staff of the Canadian Corps began planning for the monumental task of seizing Vimy Ridge on 21 November 1916, while the last remnants of the Corps were finishing the long march from the battlefields of the Somme Valley to the hills of the Artois.<sup>21</sup> From the beginning of the preparation process, planners at all levels came to grips with numerous and seemingly insurmountable problems. To their everlasting credit they solved all of them.<sup>22</sup>

To make good the losses of the Somme campaign, where a quarter of its fighting strength<sup>23</sup> had been lost, the Corps' infantry battalions had to absorb and train thousands of newly arrived reinforcements. In preparation to equip, supply and maintain the front line units before and during the battle ahead, the Corps' engineer units began construction on new roads, sewage systems, barracks, ammunition dumps, water reservoirs, artillery gun emplacements, trenches, tunnels and dugouts. An aggressive, effective and technologically sophisticated artillery programme was developed to destroy the hundreds of enemy strongpoints, trench systems and barbed wire obstacles which would put Canadian attackers at great risk. It would not only protect Canadian infantry while they closed with and destroyed the enemy, but would silence enemy artillery during the attack itself.<sup>24</sup>

Given the tactical stalemate, the lack of manoeuvre room left planners with no choice but to prepare an attack which took the form of a determined simultaneous assault<sup>25</sup> by all four of the Corps' infantry divisions advancing abreast from their assembly trenches, across the ridge, to the Douai Plain beyond. But as in any attack, success in the initial stages would be critical. Should the infantry be held up in any way they would lose the protection of the creeping barrage which would simply continue on across the battlefield, at a marching pace, without them.

With this in mind planners looked closely at the enemy's fortified trench systems. Across the 7,000 yards of Corps frontage, many

German strongpoints sheltered their machine gun crews in deep artillery-proof dugouts which would protect them from even the most sustained bombardment by the Corps' heavy artillery. Leaving these powerful positions intact would permit those machine gunners to inflict terrible casualties amongst the attacking infantry battalions. How could these positions be destroyed?

Given the successful conclusion of the underground campaign of 1916, it is understandable that the staff turned first to the soldier-miners whose offensive mining capability had produced much recent success. As German activity underground had decreased dramatically as 1916 drew to a close, it was reasonable to expect there would be little effective resistance to tunnelling operations aimed at these strongpoints.

The brutal lessons of the Somme campaign weighed heavily upon the Corps planners who expressed a strong preference for expending explosives and artillery shells rather than the precious lives of Canadian infantrymen. Consequently, initial attack planning called for 26 German strongpoints, immediately in front of the Corps front line, to be attacked with mines.<sup>26</sup> In all four divisional areas, these offensive mines were to be fired at Z-hour, the very moment the attack was to be launched. There was no intention of exploding any of these charges before the main attack as had been done near Beaumont Hamel on the first morning of the Somme offensive. There the detonation of the Hawthorne mine, though destroying its intended target, had warned the German defenders in adjacent sectors of the line that a British attack was imminent.

At first, the Corps' staff appeared to be mesmerized by what they perceived to be the advantages to be realized from offensive mining. In analyzing the 19 distinct mine crater groups fired by the French, Germans, British and Canadians in the four miles of no man's land separating the combatants in the Vimy sector, it was concluded that not one of these 19 groups constituted an insurmountable obstacle to movement. However, the analysis did advise that four of these crater groups should be avoided as they had been blown in clay and as

such were always full of water.<sup>27</sup> Clearly, offensive operations through these areas would inevitably bog down. However, the remaining 15 groups, most containing several deep craters, were deemed to be "no obstacle" and as such "easily traversable by small parties of men",<sup>28</sup> a euphemism, perhaps, for attacking infantry platoons.

In fairness, this conclusion was well intentioned and based upon extensive and balanced analysis. Officers of the Corps staff had visited the La Boisselle - Fricourt sector of the Somme battlefield, arguably one of the most heavily-mined sectors of the Western Front. There no man's land was filled by some of the largest craters yet fired. Local British commanders told the Canadian visitors that these enormous holes posed no problems. They were routinely navigated and traversed by patrols and raiding parties from both sides. Given the Corps staffs keen desire to use the miners and in light of the favourable testimony they had acquired in the field, the staff minimized the potential obstacles which further mining might cause assaulting Canadian battalions as they launched their assault towards the waiting Germans.

At the sharp end, where the bullets flew and the shells exploded, the officers whose job it was to lead their soldiers in the assault were no longer confident that mining was always worthwhile. Though the tunnellers had turned the tables on the Germans, thereby making their own trenches safer places to live and fight, three years of war had taught that while mines could destroy strongpoints, their craters became enormous obstacles to movement.

From the moment it arrived in the Vimy sector, the Canadian Corps' raiding and patrolling policy had been aggressive.<sup>29</sup> By the month of March 1917 every assaulting battalion had sent out many patrols into and across the wire. Raiding parties had stormed into German defenses to destroy trenches and dugouts as well as to capture prisoners. Most operations had been successful, though losses were sometimes high, especially in 4 Division.<sup>30</sup> Practical experience produced self-confidence. Many junior infantry commanders had been across no man's land and into the enemy's

front lines on more than one occasion. Their frequent forays made them aware of the difficulties caused by the existing crater groups. Though it was a fact that craters could be crossed or bypassed, any mine explosion could cause more damage and create commensurately harder going than had been foreseen. Infantry commanders, as the attack grew near, balked at the possibility of the Corps' mining plan adding new and dangerous obstacles for them to cross.<sup>31</sup>

More to the point, they realized that the infantry's survival depended on its ability to stay close to the creeping barrage. This alone, with its thunderous, destructive curtain of high explosive, gas and shrapnel could keep German heads down and away from their weapons until the infantry could close with and destroy them in their trenches and dugouts. During raid after raid, platoons, companies and sometimes entire battalions had followed a barrage, manoeuvring just behind its deadly effects. What had been done on numerous occasions since the Corps' arrival in December 1916 could be accomplished on a larger scale when it came time to face the Germans at Z-hour. Creating further obstacles to movement, however well-intentioned, was definitely not welcome.

It was this perception, widespread among Canadian infantry commanding officers and solidly supported by their formation commanders, which caused some important last-minute changes to the mining orders contained in the final Canadian Corps Scheme of Operations. Lieut.-General Sir Julian Byng, the much-respected commander of the Canadian Corps, supported his subordinate commanders and heeded their concerns on the question of further mining. As a result, of 26 large mines of various types initially planned to support the assault,<sup>32</sup> four were abandoned due to technical difficulties, two were detonated before 9 April for defensive purposes, five were fired as planned, eight were prepared but not used and seven others, though mentioned in the earliest stages of planning do not appear in subsequent tunnellers' war diaries as having been undertaken.<sup>33</sup>

The development of mining operations in 4th Division's area leading up to the attack appears to vindicate both the Corps' staff view that mining was a useful tool and did have a viable role in support of offensive operations; and the front line infantry perception that mining was an extremely risky tactic whose results were at best unpredictable and at worst most dangerous to those it was designed to support, the infantry.

In this divisional area, four major mining operations had been planned. The most important was abandoned

due purely to technical reasons, a second was carried through to completion and achieved the desired results and two were abandoned without significant effect on the outcome of the battle.<sup>34</sup>

In the initial planning, a German redoubt nicknamed the Pimple was earmarked for destruction at Z-hour by a deep offensive mine.<sup>34</sup> This well-defended enemy position was built into the chalk quarries of Givenchy-en-Gohelle on the northern end of the ridge opposite the British positions. It bristled with dozens of machine guns whose fire dominated the northern, western and eastern slopes of 4th Division's objective, Hill 145. Of all the features making up the ridge, Hill 145 was the highest, tactically the most important and certainly the most heavily fortified. Above and beyond its

own formidable defences, Hill 145 was solidly supported from the north by the guns of the Pimple. Though the division had the shortest

assault, never more than 800 yards deep in any battalion sector, it was uphill all the way. No one doubted the enormity of the task facing 4th Division. Therefore any interference coming from the Pimple would greatly jeopardize the division's chances of success. To ensure its total neutralization before the attack, a second deep mine was planned to destroy an adjacent and mutually supporting enemy



*Remnants of the Canadian Outpost Line, now preserved with concrete sandbags.*

position in le Bois de Givenchy, just north of the Pimple.

Both mines were part of the earliest preparations for the attack. In a very real sense both of these projects were inspired by the 19 great mines which were at that time being carefully laid underneath the German defences on Messines Pudge, as part of the Passchendaele offensive planned for later that year in the Flanders sector. Unfortunately, work on both mines was halted in the early stages due to technical reasons. The Pimple mine tunnel was being driven through a layer of blue clay which, though deep under the target, was dangerously shallow at the tunnel face. During the first days of construction, a barrage of friendly fire from the Corps' heavy artillery, though aimed at German forward



positions on the Pimple, fell far short and landed squarely on top of the tunnel face, collapsing it completely. Given the shallow depth of the tunnel and the ever-increasing weight of shellfire in that sector, work was halted and the operation discontinued. Work on the second Pimple mine was halted when it became apparent that it would not be completed in time. On the morning of the attack, that tunnel was only 100 feet from its target. So near yet so far.<sup>35</sup>

Had these two mines been completed and fired the subsequent battle for Hill 145 might have been far different. It is reasonable to assume that the effect of these two massive explosions on the Pimple would have had the same effect on its defenders as the Messines Ridge mines had on their victims: total annihilation of the defenders and a walk-over for the attackers. With its garrison neutralized, the Pimple could not have offered organized resistance. Hill 145 might have been outflanked from the north by its attackers and would not have wreaked the havoc it did on the battalions of 11 Brigade. It would certainly have saved many lives in 10 Canadian Infantry Brigade, whose job it was to seize the Pimple on 12 April.

Given the impossibility of dealing directly with the Pimple's defences, they were masked by an elaborate smoke and shrapnel barrage during the opening phase of the attack.<sup>36</sup> However, the problem of securing 4th Division's northern flank remained. To ensure that 12 Brigade's battalions were protected as they took on the defenders of Hill 145, three mines were laid and blown in the Kennedy crater group on that formation's northern flank. The mines went up as scheduled, burying and killing many German defenders in the front line and wrecking many yards of German mining galleries underneath.<sup>37</sup> With debris from the explosions still falling, the 73rd Battalion (The Black Watch) dashed forward to seize the farthest lips of the newly formed craters which anchored the Brigade's strong defensive flank guard which protected, in turn, the 72nd and 38th Battalions attacking to the south. Those three mines had achieved the desired tactical result.

Two other series of mines had been included in the original plan but were dropped as the attack drew near. The first, immediately to the south of the Kennedy craters consisted of five large mines which were to be fired under enemy outposts built along the lips of existing older craters in the German front line.<sup>38</sup> They were abandoned in deference to local commanders' misgivings. It was over this piece of ground that the 73rd's sister battalions, the 72nd and 38th, charged forward. The second series, three mines in all, planted underneath the older Broadmarsh crater on the boundary between the 3rd and 4th Divisions was not detonated, again due to local commanders' objections.<sup>39</sup> The 54th and 102nd Battalions, in 4 Division as well as the 42nd Battalion (The Black Watch) in the 3rd Division traversed this sector quickly, giving credence to the infantry's concerns.

From its reappearance in 1914 when it had shown so much promise as a means of restoring mobility to the battlefield, to its great mining offensive under Messines Ridge in 1917, military mining had proven to be a classic double-edged sword, as dangerous to friend as to foe. The trench fighters of the Canadian Corps, inhabiting a terrifying world of violent bombardment, eerie calm and sudden death, understood this reality and employed this old yet adapted technique accordingly.

## Notes

1. BEF mine craters took their name from either nearby trenches, the family names of tunnelling company officers or local infantry commanders.
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4. Barrie, Alexander. *War Underground*. London, 1961; reprinted London: W.H. Allen & Co. Ltd., 1981. pp.10.

5. Ibid, p. 14.
6. Ibid, p. 15.
7. Ibid, p. 21.
8. Ibid, p. 23.
9. Ibid, p. 31.
10. Ibid, p. 33.
11. Nicholson, Colonel G.W.L. *he Corps Expeditionary canadien 1914-1919*. Ottawa: Imprimeur de la Relne, 1963. p.501.
12. Barrle, p.46.
13. Ibid, p.49.
14. Great Britain. Public Record Office. *172 Tunnelling Company Royal Engineers War Diary, 1914-1919*. PRO 95/244.
15. Barrle, p.50.
16. Nicholson, p.502.
17. Ibid, p.302.
18. Ibid, p.502.
19. Lupfer, p. 15.
20. Nicholson, p.502.
21. Ibid, p.245.
22. Great Britain. Public Record Office. "First Army Administrative Report on the Vimy Ridge Operations, Parts I-V." PRO 158/900.
23. Nicholson, p. 198.
24. For an excellent discussion of the work of the artillery planners at Canadian Corps HQ see Nicholson, Colonel G.W.L. *The Gunners of Canada*. Toronto: McClelland and Stewart, 1967.
25. Nicholson, p.247.
26. Great Britain. Public Record Office. *Canadian Corps Scheme of Operations for Assault on Vimy Ridge, Part I Tactical with Corps Commanders Covering Letter G.701/S.156/31/16dated19March1917*. PRO WO 158/244, Annexes F and G.
27. Ibid.
28. Ibid.
29. Nicholson, p.233.
30. Ibid.
31. Barrie, p.56.
32. Robinson, Lt.Col. G.P.G. *The Durand Mine and the First World War Tunnel System in the Grange Area of the Canadian Memorial Park, Vimy*. Chatham: Royal School of Military Engineering, 1989.
33. Ibid.
34. Great Britain. Public Record Office. *Report by the Inspector of Mines on the Work of the Tunnelling Companies in Connection with Operations of 9th April 1917*. PRO WO 158/138 and *First Army Mining Plans 1916-1917*. PRO WO 153/913 and 914, Annex B.
35. Ibid.
36. Nicholson, p.261.
37. Robinson, pp. 10-21.
38. PRO WO 158/138.
39. Robinson, p.22.

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