Artillery Survey in the First World War

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by

SIR LAWRENCE BRAGG, C.H., O.B.E., M.C., F.R.S
MAJOR-GENERAL A. H. DOWSON, C.B., C.B.E.
LIEUT.-COLONEL H. H. HEMMING, O.B.E., M.C.

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PREFACE

By LIEUT.-COLONEL H. H. HEMMING, O.B.E., M.C.

ACCORDING to my interpretation of British history, there have been only a very few times, since William the Conqueror invaded and conquered the country in 1066, when the people of these Islands felt that they were in danger of an imminent attack from the Continent: first when we were threatened by the Spanish Armada; next when, before the battle of Trafalgar, Napoleon had his "Grande Armée" waiting at Boulogne; next, in 1914, after the retreat from Mons; and finally in 1940 after the French had capitulated to Hitler.

I think the shock was greatest in 1914. At that time we had complete faith in the ability of our French allies to hold and possibly defeat the Germans. We had a tiny regular army of five divisions, superbly trained, but naturally relying on the Boer War experience. Behind it was the medium-sized Territorial Army which was very social, half-trained and regarded rather light-heartedly by the professional "regulars".

When, in 1914, we woke up to the fact that we were in imminent peril, Kitchener appealed for volunteers, and in a matter of days they flocked in by the hundreds of thousands. There were available no uniforms, no weapons, no barracks, no camps, no officers, and, worst of all, no N.C.O.s, but one had to take the men immediately they volunteered. During 1914 and 1915 it was all mess, confusion, enthusiasm and truly wonderful results. There is no doubt that when the British are really up against it they are magnificent.

Our old regulars were apt to accept very slowly the ideas of the new, enormous army which they were busy creating. We had taken into the Army a cross-section of the whole nation, and these new soldiers had decided opinions of their own. So we went through our awkward period when the old Boer War regulars accepted very reluctantly any new thinking on warfare in general, and particularly on the role that Survey was able to play. These new ideas were advanced by the enthusiastic amateurs.

I remember a Brigadier-General, Royal Artillery, saying to me in 1916 "You damned surveyors with your co-ordinates and angles and all the rest, are taking all the fun out of war; in my day we galloped into action and got the first round off in thirty seconds". To which I could quite well have replied, "Yes, sir, and you hit nothing with it except possibly the backs of your own infantry".

The bright young scientists in Kitchener's Army, of course, resented the rigid army point of view . . . "Why do you do things in that silly way and why not in this way?" However, we were all learning fast in the world's best but most terrible school, real war itself.

By 1918 I suppose we had the finest army in the whole history of the British race. Do not let us make any mistake about it: it was the British Army that won the war in 1918, not the French or the Belgians or even the Americans, although they all contributed enormously. We took the brunt of the attack in March, 1918, after the Russians had quit and the Germans brought their entire eastern army into the Western Front. It was probably the worst attack any army had ever sustained up to that time, and in the 100 days following the turning of the tide at the battle of Amiens in August, 1918, the British captured more guns, took more prisoners, and I expect inflicted more casualties than all our allies put together.

This little booklet tries to give a detailed history of how in one small (but vitally important) sector of the Army, namely Survey, these major developments took place. By the word "survey" I include map-making, battery fixing, counter-battery work, flash-spotting and sound-ranging, and particularly co-operation with the artillery intelligence of the Royal Flying Corps.

But most important of all was the major co-operation between the Gunners and the Sappers. Fortunately for us we had a group of excellent Sapper Colonels commanding the five Field Survey Battalions. To them were seconded many Gunners in the Flash Spotting Groups; there was an outstanding team of young scientists gathered together in the Sound Ranging section from all branches of the Army by that superb leader Willie Bragg (now Sir Lawrence Bragg, C.H.).

There was also a fine hard-core of well-trained practical surveyors who were mostly in the Royal Engineers, and who had had real experience in the field, making and correcting maps, and doing all forms of survey in all sorts of places throughout the British Empire during the years immediately before the war.

Looking back over these years, I am impressed by the skilful way in which this difficult and varied collection of enthusiastic amateurs was led by the six or seven R.E. senior officers. They were anything but hidebound in their attitudes and thinking, and eventually they and the units under their command achieved quite astounding results.

I think the Survey Battalions of the First World War have never been given the credit they deserve for the part that they contributed to our eventual and overwhelming victory.

INTRODUCTION

THE President of the Field Survey Association (Sir Lawrence Bragg), in his speech from the Chair at the Annual Dinner in 1966, proposed that the history of artillery survey in the First World War should be recorded before the still remaining participants became too old to do so. He thought it should be fairly informal, though it should bring out clearly the special contributions made by surveyors, flash spotters and sound rangers to the successful conclusion of the war.

Accordingly, the Chairman of the day (Major-General A. H. Dowson) undertook to get the project moving, which he did by promptly inviting the President to undertake the task . . . an unfair suggestion to make to a busy man, and one which the President countered by agreeing to write the Chapter on sound ranging, on which he was the acknowledged expert. An obvious choice for the Chapter on flash spotting was Colonel H. H. Hemming, who also agreed to do his bit. For the survey chapter, again there was an obvious choice in Major-General M. N. MacLeod, and the Chairman accordingly invited him to write it, drawing upon his wide experience and much thought and writing on the subject since the war. Unfortunately, General MacLeod did not feel equal to the task, much as he would have liked to accept it, but he did generously offer all his material on the subject to anyone who cared to take on the job. The Chairman thought it would be unreasonable to saddle anyone else with the task, so he took it upon himself. It follows, unfortunately, that his contribution must lack the human touch and air of authenticity which can only come from personal experience; though General MacLeod has been good enough to read and approve it.

Some may wonder at the title of this little history, considering that there were other important survey activities besides artillery survey. That is true enough, and the membership of the present day Field Survey Association is witness to the fact that it includes in equal importance all the professions concerned in "survey, air survey photography,

sound ranging, flash spotting, radar location and other scientific methods employed in the production of maps, location of targets and direction of fire thereon". But what makes this particular aspect so outstandingly worth recording is that artillery survey was an entirely new conception and was developed in the First World War for the first time. Moreover, it brought together a number of highly original, versatile and enterprising people of character and determination, and it was some of these who were largely responsible for bringing the Field Survey Association into being.

The author of Chapter 1 wishes to acknowledge not only the material kindly lent by General MacLeod, but also reference to two publications now out of print:

Report on Survey on the Western Front, 1914–1918, by the War Office, 1920, published by H.M.S.O.

Flash Spotters and Sound Rangers, by John R. Innes, 1935.

CHAPTER ONE

SURVEY

BY MAJOR-GENERAL A. H. DOWSON, C.B., C.B.E.

The B.E.F. went to war in 1914 with no more than two officers, two clerks and one Printing Company, R.E., divided between G.H.Q. and the L. of C., to keep the Force supplied with maps mainly prepared and printed in England. No other topographical service was thought necessary. Though the Ordnance Survey had maintained in peace three Survey Sections on call for war, thus repeating provisions made for the South African war, it was decided that they were not required; consequently many valuable skilled men were dispersed to other Arms and Services and were only partially recovered later when they were much needed.

By the end of the war there were five Field Survey Battalions, one to each Army, each 800–1,000 strong, and "Maps G.H.Q." was headed by a Colonel, with eight other officers in charge of staff sections or as technical advisers. Their names and those of the Battalion Commanders are given in the Appendix.

Clearly there was a steady increase in the demands made upon, and consequently the size, of the Survey Service. By the end of 1914 the 1st Ranging Section R.E. had been formed, with a view to fixing an aircraft in flight while over a hostile target. Early in 1915 this was augmented by topographers from Ordnance Survey and became the 1st Ranging and Survey Section. Later that year this Section was further strengthened and divided into three Topo Sections, one to each Army of that time. Each Section included mapping and printing. In 1916 there was yet more expansion into three Field Survey Companies, including sections for survey, map compilation and drawing, printing, "observation" (flash spotting) and sound ranging. Later two more such Companies were added, making five in all, and in 1917 Corps Topo Sections were added as well. At the same time a Depot Field Survey Company was formed under G.H.Q. for training, research and experiment. By mid-1918 the Companies had been transformed into Battalions (shoulder

flash "F.S.B."). Besides a much expanded Maps G.H.Q., there were enlarged establishments on the L. of C. and at Base. The Printing Company remained at G.H.Q., and was eventually absorbed into a Depot Field Survey Battalion.

The entire survey effort was thus entrusted to one technical control and carried out by units of the Royal Engineers. Though mature reflection after the war led very sensibly to handing over the operations of target fixation and also local battery survey to the Royal Artillery, it was in the R.E. that the new techniques of visual observation by flash spotting and of sound ranging were developed. Special sections were formed and launched into their tasks, amid a certain amount of scepticism at first (there had evidently been all too many enthusiastic but abortive pet theories for locating enemy guns) but with tremendous success as they were refined by research, experiment and experience. These topics are dealt with in Chapters 3 and 4, so no more will be said about them here, except to mention that, although Sound Ranging Sections continued to be so named throughout, the units or sub-units practising the techniques of flash spotting suffered many changes in title: first Artillery Survey Sections, quickly dropped in favour of Artillery Survey Detachments (the Army's habit of abbreviation leading to a preference for "A.S.D." over the first), then Observation Sections and Observation Groups.

The remainder of this Chapter will examine the special contribution made by surveying to the final success of our Arms. It will readily be understood that the number and magnitude of survey tasks grew all the time, especially as early ideas about a fast moving, open war were disappointed and static trench warfare became the rule. The original maps were inaccurate, out of date and on too small a scale. Revision and new mapping were more and more wanted, the sheer demand for maps grew enormously and ever more special maps were called for. It followed that field surveyors, map makers and printers were at full stretch, as also those engaged in the less glamorous but essential task of map distribution. But if there is one element of warfare which in the end had a devastating effect upon the enemy, it was the artillery, used not as at first mainly to destroy trenches and wire, but to engage and destroy enemy guns, whether static or frequently moved from one position to another . . . guns which, unless silenced, made a havoc of an infantry advance and halted an advance by tanks. It was survey that enabled our guns to achieve their biggest surprise and shock, so much so that a German Commander ordered his artillery to refrain from registering on its targets. It is arguable that this combination of survey and gunnery did as much as anything else, including tanks, to defeat the enemy. The survey part has been described by General MacLeod, a former F.S.B. Commander, as a Sapper "Secret Weapon". Its potency is acknowledged in the Official History of the battle of Cambrai.

Let us examine in more detail what survey did for the artillery, apart from the services common to all Arms. Survey's greatest contribution was in helping to find targets and accurately positioning them on the

theatre grid, and even more in devising a means of laying the guns on these targets (determining range and bearing) without previous registration, thus achieving possibly the greatest of all advantages, surprise. Predicted shooting had indeed been tried before, without much success. It was Major B. F. E. Keeling, O.C. 3rd Field Survey Company, who devised the means, now well known, of enabling the gunner to lay his gun accurately by survey.

The artillery began the war with an addiction to firing over "open sights", but as any gunner will know, this soon had to be abandoned by both sides. Concealment and indirect fire became the rule. Thus the observation post (O.P.) was born and the necessary techniques associated with it, including the practice of registration on the target, firing a few shots to see where they fell, so giving the game away. But even in early 1915 heavy batteries were surveyed in by the Ranging and Survey Section, which gave them aiming points and ranges and bearings to known targets. For batteries which reached their positions late, only just in time for an offensive, the survey was done in advance, and this led to the bearing picket (B.P.) and the artillery board. The latter was a map or plain grid mounted on a non-distorting board, with the B.P., aiming points and targets plotted. Originally a French idea, it was adopted by us in 1915. Large numbers were made, some 11,000 by the Ordnance Survey alone. The practice was extended to Field Artillery, surveyors being detached to H.Q. Corps Artillery for the purpose. In 1915 a very large number of B.P.s were fixed in active and reserve positions (including forward positions). They were marked by iron stakes and numbered and listed, with data about aiming points. In mobile operations, the triangulation framework was pushed rapidly forward in the difficult task of keeping up with the artillery. The value of the B.P. and its associated aiming points was that they gave the gunner a ready means of accurately aligning his gun in terms of the theatre grid which, especially for long ranges, is a much more critical factor than the gun position. The latter was often taken from the map, though usually by trig interpolation. Line was given by trig or astro, occasionally by compass. It was understandably difficult to wean the gunner from the apparently greater certainty of registration, though this was done with dramatic effect at the battle of Cambrai in 1917, as we shall see later.

Meanwhile, what about fixing targets for the guns to engage? Here we meet various methods of which flash spotting and sound ranging have already been mentioned; also intelligence reports, Royal Artillery and Royal Flying Corps observation reports and air photos; a mass of data, usually conflicting. It was obvious that some means of collating and weighing up all this evidence was essential, and through the efforts of Major Winterbotham an R.E. "Compilation Section" was set up under Lieut. Goldsmith in 3rd Army to do this. Their work included interpreting air photos and fixing targets found upon them, and generally putting all verified targets on the map, or rather the grid. Target identifications were frequently published on "Hostile Battery" maps. Similar arrangements

were made in all the other Armies. Naturally, the instruments used by the flash spotters and sound rangers had also to be fixed on the grid and given line in the same terms, and this again was a task for the surveyors. For the Somme in 1916 a Counter Battery officer was appointed and the Compilation Section was attached to him under the Maj.-Gen. Royal Artillery. This worked so well that it was decided that all means of target location should be under R.A. control.

The battle of Cambrai in 1917 is well known as the first occasion when tanks were used with stupendous effect, after having been on the whole disappointing on previous attempts. What is much less well known is the part played by survey which, by enabling the gunners to silence a large proportion of the enemy artillery, gave the tanks ideal conditions for their part in bursting through the enemy lines. General Byng, commanding 3rd Army, vetoed all previous registration, and Keeling, commanding the Survey troops, undertook to provide all the data necessary for accurate predicted shooting. A Survey officer visited every battery to make sure that they were well versed in the way to engage their targets by predicted fire. So when battle commenced, it was a double surprise for the enemy: a withering and unexpected fire on his guns; and the tanks against his infantry and machine guns. The result was tremendous; but only until the advance got beyond our own artillery support. Then the enemy counter-attacked, and much of the gains were lost. It was clear that the strategy as well as the tactics needed some improvement, and this was gradually evolved, reaching its consummation at Amiens in 1918. Here the same tactics were employed, a surprise artillery bombardment and a tank attack, but when the advance ran to the limit of immediate artillery support, the battle was temporarily broken off and the gains consolidated. Meanwhile, another part of the front had already been surveyed and thoroughly prepared, and an attack was launched there. At the same time, the new gun positions were prepared and surveyed in, and targets located on the original front for the battle to be resumed there, with success. On the first day of this battle there were 1,000 casualties, at the Somme they were 60,000. No one will deny the noble parts played by the tanks and all other Arms; but it was the sound rangers who discovered that the enemy were pulling out their guns and moving back, and it was they who located them in their new positions; it was the artillery who silenced the enemy guns once more; and it was the surveyors who had made it possible for the gunners to fire accurately without registration.

A precisely similar set of survey events occurred on the Italian front in 1918, when 6th Field Survey Company earned their due credit in a dispatch by the Earl of Cavan: "At 11.30 p.m. . . . bombardment . . . opened . . . no single British gun had opened previously . . . arty was registered by 6th Field Survey Company . . . bombardment and subsequent barrage were excellent . . . greatest credit to all ranks of 6th Field Survey Company".

One may therefore heartily agree with the summing up of the War

Office in "Survey on the Western Front" in setting out the survey lessons of the war: the paramount importance of accurate survey; the necessity for adequate, well-trained survey troops; the need for one technical control of these (less the R.A. survey functions mentioned before); that the effect of survey on operations is out of all proportion to the relatively small numbers so engaged; and that it is false economy to starve the Survey Service.

Members of the Field Survey Association may well agree that these lessons had been absorbed and were acted upon in World War II.

CHAPTER TWO

COUNTER BATTERY

BY LIEUT.-COLONEL H. H. HEMMING, O.B.E., M.C.

Historical Background

In order to understand the counter battery problems that arose in the First World War, I suggest that we should first take a very brief look at the history of the employment of artillery.

During the Middle Ages, the normal procedure for making war was for an army to cross the frontier and besiege a fortified place. It would then sit waiting for its "siege train" to arrive. When it eventually did so, the "siege train" would make a breach in the walls through which the attacking infantry could enter.

I am not sure when artillery first started to fire at troops. Certainly by the time of Cromwell and Marlborough infantry en masse was sometimes fired at, though the effectiveness of this fire must have been pretty low because of the short range of the guns, the inaccuracy of their fire and the long time required to reload. It was rather extraordinary how little advance was made in the design of artillery during the 17th and 18th centuries, and particularly that Napoleon, who was one of the outstanding military geniuses of all time and was a trained artillery officer, could have fought twenty years of war without making any serious technical advance whatsoever in the design of the French artillery.

Early Counter Battery Activities

At the Battle of Waterloo the British guns were absolutely in the front line and fired at the masses of the French infantry, in the valley in front of them. When they were attacked by the French cavalry, our gunners abandoned their pieces at the last possible moment and ran back for safety inside the infantry squares. The cavalry were then supposed to do-in the guns by spiking them, that is to say, driving a small metal spike into the touch hole. Fortunately for the British, the French cavalry who charged the British squares so heroically at Waterloo had no spikes with them so we were able to use our guns once more. Charging and

then spiking the guns was, as far as I can make out, the standard method of counter battery action right up to the Crimean War:

"Forward, the Light Brigade,
Charge for the guns!" he said.

I do not think this celebrated charge achieved anything except to have Tennyson write a superb poem and for a French General to make a much quoted cliche, "C'est magnifique mais ce n'est pas la Guerre". In the Boer War I think the artillery played a pretty minor part. It was essentially a cavalry and guerrilla war. I do not know if there was any counter battery activity at all. One never hears of it.

When the First World War started, the British Army was still looking back to its Boer War experiences, which after all was only twelve years earlier. As a result, most of our top generals were cavalrymen, but unfortunately for them conditions soon proved that the cavalry was almost useless in France and Belgium. So the war rapidly became a gunner and infantry war

During the retreat from Mons, Sergeant Nelson won one of the first V.C.s with "L" Battery, Royal Horse Artillery, when two batteries shelled each other, using open sights. Both had camped for the night and when morning broke, the countryside was covered in mist. As the mist lifted a German battery and a British battery both saw that they had camped in full view of each other and only about a mile or so apart. The Germans woke up to this situation first and managed to knock out three or four of our guns, killing most of the men. Sgt. Nelson then worked his gun alone, all of his gun-crew having been either killed or wounded by the German fire. Loading, laying and firing with great deliberateness and skill, Nelson succeeded in silencing all the four German guns. I suppose it was the first and last time that guns fired at guns over open sights. But again, one could quote the Crimean War Frenchman, "C'est magnifique mais ce n'est pas la Guerre. . . ."

Trench Warfare – 1914–15 Artillery Methods

Following the battle of the Marne, both armies dug themselves in and extended their flanks until the trenches reached the North Sea on one flank and the Swiss frontier on the other. Then an entirely new type of trench warfare was evolved. This was one of those horrible periods when for a few years defence was infinitely stronger than offence and whichever side attacked, lost. The British Artillery had gone to war armed chiefly with shrapnel. In my 18-pounder battery we had no High Explosives (H.E.) at all during our first six months in France, only shrapnel. This shell, which had been invented by a Col. Henry Shrapnell at the time of the Peninsular War, was very effective against troops advancing across the open, but was practically useless against trenches or guns in gun-pits. When it burst in the air it sent a shower of shrapnel bullets which did no harm at all to the men in the trenches. If the shells hit the ground before bursting, their effect was so small that the British infantry soon gave them the derisive name of "pipsqueak".

I arrived in France early in 1915, being second in command of an 18-pounder battery (B/84) in the 18th Division. Our division was given a sector six or seven days after we had landed at Le Havre. The training I had received in England was almost useless. I had been to a course at Shoeburyness where the chief thing I had to learn was how to do some trick mental arithmetic sums in order to get the approximate range and line to a target which was presumably in full view from my observation post (O.P.). These unscientific methods assumed that you did not know the map position of the target, of the observation post, or of the battery.

I believe it was only in the 1890's that our artillery had started to fire from concealed positions behind the crest. Even in 1900 the method of laying out the lines of fire was very primitive. The method may have worked well in the treeless open veldt in the Transvaal, but was completely useless in Flanders and particularly in trench warfare.

The only survey instruments which we artillery officers were equipped with in 1914 and which, incidentally, we had to buy at our expense, were a pair of field glasses with graticules, a prismatic compass, a celluloid protractor with a piece of black thread in it, a boxwood scale, and a map case. In theory one knew and had plotted on one's map the approximate position of one's battery. If one was observing from a church tower one would know the precise position of the O.P., for the church towers were always accurately positioned on the French maps. Unfortunately, most church towers near the front line soon got knocked down and were not very healthy. Usually the O.P. was dug into the side of a communication trench and was often even more inaccurately located on the map than was the battery. The position of the target was anyone's guess. Northern France was covered with little woods and copses and they were all marked on the maps, but, of course, wrongly marked, for if the map had not been revised for ten or fifteen years, the farmers had probably cut down most of the little copses and grown a new batch in the interval.

Everything began to change very rapidly towards the end of 1915. Soon the German whizbang . . . their 77 millimetre field gun . . . began to be reinforced with 5.9 howitzers (or "krumps"). We on our side had the 4.5 howitzers which, for firing on trenches and enemy batteries, was a little but not much better than the 18 pounder. But now we started to get a lot of 6 inch howitzers and after a while we got 8 inch howitzers and eventually 9.2 howitzers, all of which had a sufficient range to be able to reach most of the enemy artillery. Also, as they used H.E. shells, they could do a lot of harm even to pretty solidly built gunpits. So the problem now arose of getting adequate information about where the enemy artillery was located.

Early Flash-spotting Ideas

Shortly after I had arrived in France, I was doing a period as Forward Observing Officer with the West Kents, near Albert on the Somme Front. The enemy artillery was very inactive—though occasionally they fired a few rounds knocking some sandbags off our parapet. One evening

the Infantry Colonel arrived in the little H.Q. mess in a vile temper. "The Huns have knocked the parapet all to Hell in H Sector and the Brigadier is visiting us tomorrow. Why don't you blasted gunners silence the enemy battery?" I quite truthfully replied: "For three reasons, sir. I don't know where he is; he is probably out of range; and I have only shrapnel which won't hurt him". This infuriated the colonel. "Well, I can tell you exactly where he is. He is just over the first crest – one can see the sky-flash when he fires at night and one hears the bang almost immediately".

Of course, neither he nor I realised that the bang we heard was the shell wave and not the sound of the gun firing. I expect this sort of dialogue was taking place everywhere in 1915 between infantry units and their supporting artillery. However, this is why I started to be interested in flash-spotting in 1915.

Counter Battery Intelligence

The location of enemy batteries can be discovered mainly in three ways. First, there was flash-spotting, which meant surveying the flash. If the country was really flat, as it was round Ypres, one could at times see the muzzle flashes of the guns in daylight and then, of course, one could fix the gun's position with great accuracy, say with an error of less than ten yards. However, in more rolling country where the guns were deployed well behind the crest, one saw only the sky reflection at night, but one could get a rough bearing to it, accurate to say about one or two degrees. If three observation posts all took bearings on to the same sky flash, the rays when plotted would form a triangle of error. Also there was the difficulty of making sure that different observation posts, located a mile or so apart, were observing the same gun. This could be pretty difficult if a lot of enemy guns were firing at the same time.

The next method was to locate the guns by sound. Here, of course, one is surveying the sound and is measuring the differences in time of the arrival of the sound of the gun's discharge. This sound was carried through the air and this air had different layers of temperature and also different wind velocities. Also, one had the problem of making sure that one could spot on the film when the same sound reached each of the different microphones. As with flash-spotting, sound ranging could be defeated if too many guns were firing at once.

The third method was observation from the air, either from a captive observation balloon or from an aeroplane belonging to one of our artillery reconnaissance squadrons. Again, this information could vary enormously in accuracy, depending on the ability of the pilot or observer in the aeroplane to locate on his map the point at which he saw the gun flashes. On a battlefield which had been more or less converted into a featureless sea of mud, it was often extremely difficult to be sure just where the enemy battery was located. The captive balloons were too far back to be of much use. Our reconnaissance airplanes frequently crossed the line into the air above the enemy territory and at times gave extremely valu-

able information, but unfortunately most of it was pretty inaccurate.

All these sources of information, however, dovetailed into each other and one submitted all of them to the test of the air photograph. It is impossible to have guns deployed at the same point and in action for weeks or months without the position being given away on the air photograph by tracks and gun pits, no matter how one tried to camouflage it. As the war continued, our supply of air photographs got better and better, and was amazingly good by 1917 and 1918.

During 1915 the need for counter battery fire to silence the enemy guns made itself evident to all our senior commanders. In 1915 and 1916 flash-spotting and sound range methods were developed. The Field Survey Companies R.E. were formed and the Flash-Spotting Groups and Sound Range Sections which were in many cases manned by artillery officers, were put into these Companies. There was one such Company for each Army.

Counter Battery Operations

During 1916 the output of flash-spotting and sound-ranging intelligence increased enormously. The next problem that arose was how to make sure that the counter battery intelligence was correctly used by the artillery command. I fear that at first they knew very little about its accuracy or its limitations. Colonel Winterbotham was then commanding the 3rd Field Survey Company. He was my C.O., was a brilliant man and a great "wangler". He had the ear of his Army Commander, who at first was General Allenby. After Allenby had gone off to Egypt and Palestine, the Army Commander was General Byng. Colonel Winterbotham persuaded the Army Commander to take the three flash-spotting Commanders who, it happened, were all artillery officers, and have them posted to the staffs of the G.O.sC., R.A. (General Officers Commanding, Royal Artillery) in each of the three Corps in our Army, on the theory that they would be able to advise the General about the accuracy and reliability of the counter battery intelligence. They were given the title of Reconnaissance Officers. I am sorry to say this was not a successful idea. However, I was made a Staff Captain and posted to the Headquarters of the 6th Corps which at that time covered the front just south of Arras, and was preparing for the Arras battle which took place on Easter Sunday, 1917. It was during this battle that the Canadians just north of us captured the Vimy Ridge.

General Rotton, on whose staff I served, had under him one Brigadier-General in command of the artillery of each infantry division in the line and also a Brigadier-General Commanding all the heavy artillery in the Corps. It was the latter who, of course, was chiefly interested in and responsible for all counter battery fire. So at the same time as the Sapper Surveyor Winterbotham and the Cavalry Army Commander Allenby were aiming to solve the Artillery Counter Battery Staff problem by originating the Reconnaissance Officers, the top Artillery Commands were setting up a rival and more sensible organisation by attaching to

each corps Heavy Artillery Command the so-called Counter Battery Colonel and with him an artillery intelligence officer. So at one fell swoop we created two competing and duplicate staffs to deal with the same counter battery intelligence.

I had no power to order any artillery fire. That was entirely the responsibility of the Counter Battery Colonel. This happened in the 6th Corps to be Colonel Fawcett, the explorer who was lost in Brazil a few years after the war. I am sorry to say we did not see eye to eye on a single subject. I was twenty-four years old and Fawcett was about forty-five. I thought that Fawcett had a most unscientific and "unsurvey" approach to all counter battery intelligence. I still shudder to think how many rounds he ordered to be fired at points where there could not possibly have been an enemy battery because he did not understand the limitations of our Counter Battery information.

My Experiences as a Reconnaissance Officer.

I spent fifteen months as the so-called "reconnaissance officer" of the 6th Corps. During that time we fought the Arras battle and advanced our line about five miles to the east in front of Arras. That, of course, gave me a fine opportunity of checking the exact position of all the enemy batteries which we had over-run. In many cases the guns were still in the gunpits and were surrounded by dead German gunners who had been killed either by our counter battery fire or later by our infantry. However, there were also a lot of other positions where we had assumed that there were guns but where there were none nor had there ever been any. All there was to be seen would be the shell-holes from Fawcett's ridiculous shelling.

Some months after the Arras battle, the Germans decided to shorten their line and retreat to the so-called Hindenburg line. This retreat hinged on a point just east of Arras. During the night the enemy retreated in some cases twenty or thirty miles, and we advanced into a vast and completely empty wilderness. The army to our south moved right across the horrible Somme battlefield. The Germans had cut down all the trees and destroyed most of the villages in the area which they now vacated. This was to prove a mixed blessing to them in the Spring of 1918.

During my year with the 6th Corps I kept very close to the sound-rangers and flash-spotters but I also devoted a lot of time to air photographs and air reconnaissance intelligence. I used to go to the Corps squadron in the evening after every flying day and personally interview every pilot who had reported seeing enemy artillery activity. I would be armed with a portfolio of air photographs and would ask the pilot to show me on the air photograph exactly where he had seen the flash. This, I am sorry to say, revealed to me that at least half of our air intelligence was useless. The pilots just didn't know where it was that they had seen the flashes. They could not pinpoint the spot on the air photo and they frequently gave co-ordinates of places which were in full view of our lines and from which no battery could possibly have been firing. Also,

of course, every week or so one of the best pilots who had supplied the most accurate and useful information would fail to return. These pilots were so keen that they had flown over too low and had been hit by anti-aircraft fire or had been shot down in an aerial combat by enemy fighters swooping down on them from above.

I used to prepare a report on artillery intelligence every evening and this was sent to all the units, sound ranging, flash spotting and air, who were engaged in counter battery intelligence, and also to the intelligence officer on the R.A. Army staff. I presume he then combined the 3rd or 4th Corps reports into his own report to G.H.Q.

The March 1918 Blitz

The Germans launched a terrific attack in March, 1918. By that time the Russians had made a separate peace and the Germans had brought over to the West the whole of the army they had had in Russia. They quite wisely decided to launch it against the British and French at the point where our two armies met and which was therefore the point of maximum weakness. We knew for some time where we were going to be attacked. Not merely did we have the evidence of prisoners and spies, but we also used to fix the path of every German aircraft which flew over our lines taking air photos. By plotting these paths, superimposed on each other for a month, one saw very clearly what areas they were photographing and what areas they were not interested in. And the front of our 6th Corps was definitely an area of major interest.

I remember one morning at the beginning of March, 1918, which was to be my little day of glory. Field Marshall Sir Douglas Haig, the Commander of the British Forces, paid a visit to our Corps and after talking to the Corps Commander and the "G" Staff, he came around to the artillery office. It was the only time in my life that I met him and I was very impressed by him. General Rotton, my general, had said to him that he was confident that the enemy would not break through. Haig turned on him like lightning. "Of course he will break through. Any army with sufficient artillery and tanks can break through if it is ready to pay the price and the Germans are ready. The point is, at what point can you stop them. You will be lucky if they don't get to your Corps H.Q." – which was a very prophetic remark because that was exactly where the German advance did get to on our Corps front. He then said to General Rotton, "Where is your Reconnaissance Officer?" And when I was introduced he said, "Will you please take me to your desk? I want to ask you some questions". I, of course, was the junior member of the staff, so this did not exactly please the General or the Staff Major. When he got to my desk he said to me, "Could the Germans attack tomorrow?" I said, "I don't think they could." He said, "Why not?" and I said, "Because I understand that we had one gun per three yards of front (or whatever the figure was) during our Ypres offensive last year and he will therefore go one better and have one gun for, say, every 2½ yards. That means I should find on the 6th Corps front 'x' enemy

batteries and we have only found one-third of 'x' so far, though we have now spotted some which have apparently just moved in. Here is my map of the enemy batteries we have located so far." He said, "Will you spot the rest when they come in?" I said, "Given good flying weather, I think we will, because there are very few trees in this area; so all new batteries will show up on the air photographs. Here, everything shows up on the air photographs." "All right," he said, "as soon as you have found half of the missing batteries please send me a telegram to G.H.Q. marked for my personal attention." I actually sent that telegram off on the 18th of March and the offensive occurred on the 21st of March.

We had had two or three superb air photograph flying days on our particular front, and I was able to spot a great number of new enemy batteries which up to that time had never fired. I suppose they had learnt the lesson we had taught them at Cambrai and were not letting the new batteries disclose their presence by firing before the attack was launched. On the 19th and 20th we put down very heavy artillery fire all through the valleys where these new batteries were located and which were very close to their front line trenches. Our reconnaissance aircraft reported seeing numerous explosions and fires.

G.H.Q.

Two weeks after the March offensive had been launched I was suddenly transferred to G.H.Q. Colonel Winterbotham had by this time left the 3rd Army H.Q. and was on the staff of Colonel Jack who commanded "Maps G.H.Q." Winterbotham and Jack had arranged to have two staff officers appointed to Jack's staff to co-ordinate the work of all the sound ranging and flash-spotting units in our army and also to liaise with our French and American allies. So Bragg and I were sent to G.H.Q. in April, 1918.

I had a very interesting time during 1918. I was able to visit all our flash-spotting units in action and to make sure that any brilliant results or methods which had been achieved by one Field Survey Battalion would be known to the others. Up to that time each army had worked in a sort of vacuum.

Thus I was able during the war both to work as a "supplier" of counter battery intelligence and also as a "user". One of the reasons why the British army so successfully defeated the enemy in the last 100 days was because by that time our counter battery intelligence was really working superbly well. Flash-spotting was still most productive, for flashless propellants had not yet come into use. The sound rangers were now thoroughly trained and very skilful, and the supply of air photographs and air intelligence has probably never since been surpassed, both in quantity and quality. Planes were still relatively slow and they flew much lower than in the Second World War. So our photographs were large scale and really first-class, and our pilots were trained in the best possible school, which is real war.

CHAPTER THREE

FLASH-SPOTTING AND THE WORK OF THE OBSERVATION GROUPS

BY LIEUT.-COLONEL H. H. HEMMING, O.B.E., M.C.

The Start of Flash-Spotting

As far as I know, the accurate observation of enemy targets in general, and of enemy gun flashes in particular, from carefully-surveyed observation posts and by trained observers, was commenced in the British Third Army in the autumn of 1915. I also believe that the British ante-dated by some months, similar activities by either our French or Belgian allies or our German enemies.

When a gun fires it makes a muzzle flash, at any rate it did in those days when flashless propellant was still a thing of the future. In flat country like Flanders one could see the muzzle-flash in daylight, a small red flame of very short duration. But further south where the country was more rolling and the batteries were deployed well down behind the crest, one could see nothing by day, but at night every time a gun fired the sky reflection would light up the whole sky for an instant. Of course everyone on both sides conceived the idea of taking bearings from different points on to these flashes or sky-reflections, and of plotting them on the map. If two or more of these plotted rays met at a point one assumed that near that intersection would be the location of the enemy battery.

The fact that we started it in the 3rd Army before anyone else was largely to the credit of Major Winterbotham R.E., who was commanding the Topo Section R.E. that was attached to that Army. He was an officer of quite exceptional ability and determination and had the ear of General Allenby, the 3rd Army Commander.

Unlike sound-ranging there is no technical mystery about flash-spotting, which was relatively simple in conception and where success depended on having suitable observing instruments. The only real problem was to devise methods to ensure that two, or if possible three, observation posts located a mile or so apart, were all observing at any one time the flashes from the same battery. Imagine that ten enemy batteries are firing at the same time and that four flash-spotting posts are

all taking bearings on to their flashes. Then there will be forty different bearings reported to the plotting centre and the number of false intersections will be very large if one plotted all these rays on the board.

Because of the relative simplicity of the task and of the way in which each army worked out its own system for flash-spotting, the methods in use at first differed considerably. There was no "high-priest" as there was with sound ranging, where everyone turned to Willy Bragg (now Sir Lawrence Bragg), either to report developments or to ask for help and advice.

I can only report on what happened in those early days in the 3rd Army and to me personally. It is true that towards the end of the war when I was sent to Maps G.H.Q. to be the staff officer in charge of flash-spotting, I was able to visit all the twenty-five to thirty Flash-Spotting Groups in the five British Armies, and the Flash-Spotting School near G.H.Q. at Montreuil that was run by the Depot Battalion. I also went to see the French and American flash-spotters in action. After the Armistice I had the good fortune to spend a few months at Wahn, near Cologne, at the German flash-spotting school, where I learnt a bit about the German army flash-spotting methods, equipment and results.

Early deployments

In the autumn of 1915 Major Winterbotham obtained permission from General Allenby to form an experimental unit, the purpose of which was the accurate location of enemy targets, using careful surveying methods. This unit was to be called the Artillery Survey Detachment. Winterbotham was a professional surveyor with some years experience in map making, both in the field (mostly South Africa) and at the Ordnance Survey. He decided to give a week's course of instruction for twelve officers and from these students to pick the six most suitable ones. So each Division in the army was asked to send two or more officers to this course. In my Division my Brigadier General R.A. knew that I had been experimenting for some time, in a pretty amateurish way, with the problem of getting bearings to night flashes. So I was asked if I would like to volunteer. The course was held at St. Pol and was pretty feeble, for Winterbothom knew very little more than his pupils about the difficulties we were going to encounter. After the course we returned to our units while Winterbotham selected and had constructed the O.P.'s we were to man. Next came the problem of getting our men. I was particularly fortunate for my General said that I could take as my sixteen N.C.O.s and men any of those who volunteered from my own battery. To my pleasant surprise a lot more than sixteen volunteered, so I was able to select a fine team.

Winterbotham's original idea was to have one long line of O.P.s along the whole Army front, each O.P. being about two miles from its neighbour. There was to be one officer in each post. But strange to relate there was to be no headquarters. This was a very unmilitary arrangement

and it rapidly broke down. It soon became pretty evident that the O.P. could not observe or fix the position of many worthwhile targets, other than hostile batteries in action. We reported a few observation balloons and transport in the rear areas, well out of range; also now and then a few trains, but that was all. We also discovered eventually that we would get really worthwhile counter-battery information only if we were split up into smaller units, where most of the O.P.s in one group overlooked the same hostile sector. Further, we learnt that it was better to get one certain and accurate location on one enemy battery in action than it was to get a lot of single rays on to various gun-flashes. Because of the danger of getting a false intersection by reporting the point where two rays, which were actually on to different batteries, happened to meet, we soon decided to report only if a minimum of three rays were obtained on to a gun-flash, with a small triangle of error. When four rays were obtained all going through the same position, we were pretty certain that the location was a really accurate one. At first most Flash-Spotting Groups had five posts in action, but by the end of 1916 we had in all armies come around to the idea that it was better to have more groups with smaller sectors. In the end they all had only four posts each and a Group H.Q. where the observations were plotted and from where the Group was administered.

I first went into action in October or November, 1915, with only two O.P.s, one on each side of the Somme River at the extreme south of the British sector where we joined the French army. My results were almost negligible. From there Winterbotham took me to be in charge of the first plotting centre, which was near Albert and was supposed to receive the bearings from all the O.P.s on the whole army front. I was given an old R.E. sergeant major to compute the location of the intersecting rays. This was quite silly in view of the inaccuracies of the bearings observed. A line drawn on a map would have been quite accurate enough.

Early in 1916 the British Army took over the intervening section of the front that was occupied by General Foch's French Army. The 3rd British Army side-stepped north and our new 4th Army came into section on the Somme front, south of the 3rd Army. Partly because I spoke good French, Winterbotham detailed me to take over from the French so I took the remnants of my old volunteers and moved north and deployed five posts between Arras on the south and our 1st Army on the north near Lens. This front was bang opposite the Vimy Ridge. It had one glorious O.P. on the top of the Notre Dame de Lorette spur of land, and also one high up in the ruined towers of the old abbey at Mont St. Eloi. I stayed there a year and it was there that I devised the Flash Buzzer Board, which both revolutionised flash-spotting methods and also made all methods more or less alike in all the Groups of the British armies, and also in the American Army which eventually adopted our methods. I am sorry to say that both in sound ranging and flash-spotting the French were always too proud to adopt any British equipment or methods, even where these were manifestly superior to the French ones.

Ranging and Calibration

Quite early in 1916 it was realised that there was another use of real military importance which could be carried out by the Groups. They had been formed originally to fix all sorts of military targets with accuracy, but unfortunately there were very few such targets that were not already accurately located on the excellent maps which we were provided with, and which were also observable from two or more O.P.s. In the flat Flanders country up north or in certain specially favourable locations, like the Vimy Ridge after we had captured it, the posts were kept busy during daylight observing daylight flashes. But in rolling country, with the enemy guns well down behind the crest, gun-flashes were only visible as sky reflections at night. So naturally when another worthwhile activity arrived it was grabbed with enthusiasm by all Groups. In 1916, 1917 and 1918 ranging our own guns and also calibrating them were both done with considerable success.

Now and then especially heavy guns or howitzers would be moved up to deal with certain important targets. The flash-spotters were permanently deployed on the particular front and had well constructed and well surveyed posts, so they were often instructed to aid in the observation of the fire of such special shelling. I remember once in 1916 when my post on Notre Dame de Lorette observed for a heavy naval gun that was to fire on a target away in the rear of the Lens area.

A more usual use of cross observation from the flash-spotting posts was for calibration shoots. When a gun starts to wear out it is very useful to ascertain its muzzle velocity. To do that one fires say ten rounds at a certain point specially chosen because all the rounds will be visible. The flash-spotters fix them with considerable precision by cross observation from three or more posts. The Groups did so much of this at one period in 1917 that special Ranging Sections R.A. were formed in the 3rd Army and put under the command of the Flash-Spotting Group. They had either their own O.P.s or the normal flash-spotting O.P. was enlarged so that two instruments could observe through the slit simultaneously. In order to plot the results quickly and accurately Capt. Coburn of the 2nd Field Survey Company invented the so-called Coburn Graphs, which were in use all through the Second World War and may, as far as I know, still be used.

From ground ranging by cross observation the next step was air burst ranging. The range and line to a target is worked out, preferably a hostile battery behind the crest but at a known point. The gun is then laid on that point. Then a false angle of sight is added and a group of rounds are fired with time fuses. The position of these bursts is then fixed, both horizontally and vertically. This enables the battery commander to make the correction for the day which, of course, arises from the temperature, wind, etc. He then drops his angle of sight to the correct one to hit the target and does not forget the correction for the non-rigidity of the trajectory. He then fires sufficient rounds to destroy the hostile battery.

Technical Equipment

The chief instrument used in an Observation Post was the telescope with which to view the enemy country and also, of course, to obtain the bearing to anything of interest. At first Winterbotham proposed equipping us with theodolites but this impractical idea was very rapidly abandoned. They were much too delicate, were far more accurate than was needed, were in relatively short supply and, worst of all, the image was seen upside down. About that time we discovered that there was quite an adequate supply of an artillery instrument called a Mark five Director at the Woolwich Arsenal. They had been designed to be used by the Siege Artillery but never issued as the Siege Batteries considered that they were too heavy and cumbersome for use in the field. However, they were not at all bad for use in a more or less stationary O.P. They were by no means perfect, as their optical properties were not very good, nor did they have big enough magnification. The object lense was too small; also it was not very easy to read the bearing on the Director.

When I took over from the French on the Vimy Ridge area I had a pretty hard look at their equipment and was more than delighted with their telescope which they called a Longue Vue. It had a very large objective lens, a rotating eye-piece with three magnifications, and was not too difficult to mount on a base so as to read the bearings. I told Winterbotham about my find and he at once got in touch with the Service Geographique in Paris, where he was very popular and had a lot of influence. They investigated the subject and discovered that the French had a large supply of the Longue Vues; so a deal was done and we very soon received one per post in addition to our Mark five Directors. Our supply services in England had a quantity of bases on which it was possible to mount the Longue Vue after a fashion. Actually the base was not nearly heavy enough to hold such a large telescope and it soon developed a good deal of unpleasant wobble and backlash, but that did not matter much for once something was spotted through the Longue Vue telescope it was quite easy to get an accurate bearing on to it with the Mark five Director.

When I went to G.H.Q. at the end of the war I discovered that an N.C.O. called Sergeant Coles, in one of the Field Survey Battalions, was busy designing an entirely new type of instrument especially suitable for Flash-spotting. I was soon able to get him sent home to England to work in one of our large optical instrument firms. The first prototype arrived at the front just as the war ended. His instrument embodied a truly beautiful idea which is now practically universally used in all types of surveying instrument. That is to have the bearing read by the same human eye that is looking through the telescope. In other words, the bearing appears and is read right in the telescope itself, without having to take one's eye from the eyepiece. For flash-spotting this facility would enormously speed up the process of obtaining the bearing on to the enemy gun-flash. I do not know what happened to Sgt. Coles. I hope he was adequately rewarded for his brilliant idea, though I am not very

sure about it. I included his name on the report to the War Inventions Board which gave out cash sums to outstanding inventors.

However, the main advance in flash-spotting equipment was the Flash and Buzzer Board which I feel should discuss with a certain amount of detail, even though I was its author. As I have said, the main problem confronting the flash-spotters was how to make sure that all the posts were observing the same flash. Roughly the same problem had to be solved by the sound rangers who had to identify the breaks on their film made by the same bang. They solved it by locating their microphones at regular intervals along an arc-shaped base. That was not possible in flash-spotting for our O.P.s had to be sited wherever we could get a good location on top of a hill, up a factory chimney or church tower, etc. Further, we had to consider ease of concealed access and the safety of our telephone lines, for once they were cut and the post was out of communication with its headquarters it was useless.

The main idea of the Flash and Buzzer Board was to have a telegraphic key in each post so that when the observer saw a flash he would press this key and that would cause a small lamp to light momentarily on the telephone switchboard at headquarters. I soon discovered that when he pressed his key there was not enough current arriving from the post to light the lamp at H.Q. I wrote my idea to Winterbotham and this marvellous chap at once sent it to Willie Bragg at the experimental sound ranging at Mt. Kemmel. I had never met or even heard of Bragg or sound ranging before. Bragg replied immediately and suggested I should try a sensitive relay which would turn the lamp on and off. I was due for fourteen days leave about that time so I applied and was granted it immediately. As soon as I got to London I went to a shop that sold electrical second-hand junk in High Holborn and bought six very large but very sensitive relays and also six telegraphic keys and a bunch of buzzers. I returned at once to the Front, thereby establishing a precedent by going back to France after only four days of a fourteen days leave. Half my brother officers considered me to be insane, and the other half thought I was not merely insane but definitely a cad or criminal for I was undermining an unbreakable principle.

Back at the Front I worked night and day and in a week had mocked up a real Heath Robinson affair which however *worked.* Beside the lamps and relays I had incorporated another idea which was equally important and that was the buzzer. Its use can best be explained by describing how the Board operated. Imagine a small "straff" at night with five German batteries firing on our trenches. One post, say "Bea", gets on to a flash and as soon as the observer has seen it through his Director he presses his key. That causes his lamp to light on the H.Q. switchboard and his buzzer to give quite a buzz, which is heard not merely by the H.Q. telephonist but also in the earphone of the observers in the three other observations posts. The plotting board N.C.O. at H.Q. then tells "Bea" to *lead* and the telephonist switches off the buzzers from the other three posts. He also asks "Bea" for its bearing. The N.C.O. plots that bearing

on the plotting board and is able to get a pretty shrewd idea of roughly where the battery in question is located. He gives the other three posts approximate bearings at which to look. Two minutes later the same battery may fire another round and this time not merely does "Bea" observe it but also another post, say "Ack". That observer had pressed his key and his lamp had lit up. When three or four posts are all observing the same flash on which "Bea" is "leading" and all the lamps are lighting together, the Plotting N.C.O. turns off "Bea's" buzzer. If all the lamps still light simultaneously he knows that it is a completely genuine fix and that one of the posts is not confusing the flash of the German shells bursting on their target with the real gun-flash.

I was sent back to England once more for a quick visit and went to the G.P.O. Chief Engineer to explain my design. A few months later the first Flash and Buzzer Boards arrived at the Front. They were an immediate success. Not merely did they enormously increase the number of gun locations that we obtained but they use to enthrall and amuse countless Generals and other V.I.P.s. I am slightly ashamed when I think back to the phoney drill that we devised to impress our visitors. When the war was over the War Inventions Board gave me £100, which was very welcome I can tell you, at that time.

Conclusion

What were the results obtained by the Observation Groups and did they justify the employment of 1,000 to 1,500 soldiers, particularly in 1917 and 1918 when we were beginning to run out of man-power? It is a most interesting question but extremely hard to answer, particularly fifty years after the event, when one has only one's memory on which to rely for data to assess the situation.

Let us, in turn, examine the various activities of the Groups. First, as regards daylight observation over the enemy territory, using the Longue Vue or other telescope. The answer is certainly that this activity was not a success, and I doubt very much if it contributed anything to the final defeat of the enemy. There was very little to see during the calm periods; for the enemy was careful not to expose himself when within range of our artillery. Even if the flash-spotters did see something that made a worthwhile target, it was difficult to get any military action taken to deal with it before it was too late. During the major attacks by the enemy in 1918 there was undoubtedly a great deal to be seen; but there was too much confusion at the time and the artillery were too busy with their own targets for them to take much notice of reports emanating from the Observation Groups. So I think we can write off the military value of this activity almost completely.

Next for flash-spotting and the fixation of enemy batteries. Here the results were tremendously influenced by the nature of the terrain. In rolling country there would be practically no worthwhile results in daylight. The night results would depend on how much night firing was going on. At first, when ammunition was short on both sides, the shells

were generally reserved for observed shoots during daylight. Later, when ammunition was more plentiful, the infantry would call for and get artillery support all through the night. Both sides had infantry patrols crawling all over No-Man's-Land all night with frequent little hand grenade scraps. Also both sides tried to winkle out a prisoner or two from the other side's front line trenches in order to identify the enemy division that had been deployed there. So the infantry on both sides were pretty nervous and would call for a mild barrage on No-Man's-Land at the slightest provocation. All this meant fine chances for the flash-spotters and it was quite common to make as many as five or six battery locations per night.

Where the ground was completely flat, as in Flanders or on the vast plane stretching east from the Vimy Ridge, there was almost no cover behind which to site the field and medium batteries and almost every time they opened fire in daytime the flash-spotters would bag a few of them.

In his excellent book, "Flashspotters and Soundrangers", published in 1935, and now unfortunately out of print, John Innes, who had been a flash-spotting officer in the 1st Field Survey Battalion, gives some interesting figures (see page 119). He had obviously had access to official data, probably issued by his old battalion. He says that between December, 1917, and September, 1918, under "average conditions" (whatever that may mean) six groups obtained 7,540 locations or about five to six per twenty-four hours. During the same period and presumably on the same section of the front, the Soundrangers got 11,315 locations. I think the territory in question was from Armentières, south of Ypres, to Notre Dame de Lorette, just north of the Vimy Ridge, and was pretty good territory for flash-spotting. If similar figures applied to the whole front then flash-spotting was very much worth while.

The fine counter-battery picture that emerged from the flash-spotters and sound-rangers, plus the complete air photo cover, was one of the main reasons why our Army was able to stop the terrible German onslaught in 1918. We re-assumed the offensive in the Amiens attack in August, 1918, and were able to smash the enemy into complete surrender in the next 100 days. Don't forget that this was largely a British victory, for instead of being beaten to our knees by the Germans, as they had hoped, it was the British Army that opposed more than half of all the enemy divisions in existence. We captured more prisoners during those 100 days than all our allies put together. If prisoners are a measure of the total enemy casualties, then we probably also killed and wounded more of the enemy than did all our allies.

I have also no hesitation in stating categorically that our counter-battery intelligence and the measures taken to deal with enemy batteries under our system of Corps counter-battery officers was infinitely superior to what was happening either on the French or American sectors. I had the good fortune to visit both fronts in 1918, and was able to watch them in action and compare them with ourselves.

Lastly, what was the value of "calibration" and "ranging"? Calibration was first class. It enabled the guns to be calibrated in situ without having to withdraw them from the line. A calibrated gun enables its battery commander to put his rounds where he wants them to burst, with enormously greater precision than before the gun was calibrated. Towards the end of the war the sound-rangers were used to calibrate guns. They measured the time taken for a shell to pass through two screens located a short distance apart. This was excellent and was quicker and more accurate than the results from the flash-spotters. The trouble was the gun had to be pulled out of action and sent down to the calibration range where rounds were fired out to sea.

Ranging by observation from flash-spotting posts was not very useful, for most targets that we wished to engage were not visible from our lines. However, air burst ranging was just coming in, thanks in no small way to the activities of Major-General Andy McNaughton of the Canadian Corps, who had been the Canadian Counter-battery officer and who was later to become the G.O.C.R.A. of the Canadian Corps. Unfortunately there were not many gunner officers as able technically as he was, and it is difficult to teach an old dog new tricks. So though flash-spotters were deployed and all ready to do air burst ranging, their facilities were not used as much as one would have hoped.

The last question before I close is to what extent the Groups were able to operate and supply counter-battery information either during the temporary retreats following the German attacks early in 1919, or when we had them on the run at the end of the war. I fear that again a truthful answer must be rather disappointing. They were pretty immobile. They had too many technical stores and not enough transport. Also they lacked cable. Once they had used their cable they had to reel it all up or, at any rate, attempt to do so before they were ready to advance and deploy a new base. But there was no reason why they should not have been able to deploy quickly if they had been more ready for and trained to cope with semi-mobile warfare. Of course, it is then that counter-battery intelligence is worth its weight in gold, for the enemy guns are out in the open and not in concrete gun emplacements. Also our forces are more vulnerable to hostile fire. So silencing even a few batteries might make all the difference between our infantry being held up, or for them to go crashing through and achieve a quick local victory.

I think that taken as a whole the Observation Groups were well worthwhile and justified their existence; though there were undoubtedly times and sectors where they were almost useless, through no fault of theirs but because the terrain was too unsuitable for their employment.

CHAPTER FOUR

SOUND-RANGING

BY SIR LAWRENCE BRAGG, C.H., O.B.E., M.C., F.R.S.

It is very tempting to reminisce about people and incidents in such an account as this, because memories of them are so vivid and interesting to those of us who served in the First World War; but I think this temptation must be sternly resisted, because they cannot have the same interest for a later generation. I shall instead concentrate on the technical development of Sound-Ranging. It must be hard for those who only knew World War II to realise how little science of any kind was involved in World War I. The thermionic valve had been invented, and its use for radio communication was just starting; in addition it was used in trench listening sets to pick up enemy messages sent over a circuit with an earth return. Meteorological conditions were forecast. Survey and mapping had already established their expert position. But apart from this I cannot recall any organisation in the Army which specifically enlisted scientists in its service. When I was seeking recruits for sound-ranging, I had only to ask for a parade at the Depot and say "Bachelors of science, one step forward" to get a generous response of eager aspirants to some job in which their knowledge could be used. There was an almost impassable barrier between the military and the scientific minds. The military thought us scientists far too visionary and gadgety to be of any help in the field; the scientists could not understand why their brain waves, which seemed to them such war-winners, made no appeal to the military mind.

It was into this rather unfriendly world that British Sound-Ranging was born. It had been started in both the French and the German Armies. The principle is simple. A series of listening posts or microphones are situated in known positions along a base behind the front line. The time differences between the arrival of the report at the posts are measured. Suppose the sound to reach post 1 first at time T_1, post 2 at time T_2 and so forth. Then if one draws a circle on the map around post T^2 with radius V (T_2-T_1), where V is the velocity

of sound, and similar circles for the other posts, a great circle which passes through T_1 and touches the other circles represents the form of the report wave, with the gun at its centre.

The French experiments were viewed with great interest by some of our Sappers, Colonel Winterbotham in particular, and he pressed for a similar organisation in the British Army. The gunners would have nothing to do with it, but Winterbotham was a persistent man. I saw the files after the war, when I was writing a sound-ranging manual, and one letter said in so many words that the R.A. could see no possible advantage in sound-ranging, but that if an officer were detailed to experiment with it who was of no use for anything else, they supposed there was no harm in giving it a try. As a result, 2nd Lt. W. L. Bragg was summoned to the presence of Colonel Hedley in M.I.5, and told that he was to proceed to France, collect a sound-ranging outfit in Paris, and experiment with it at the Front. I was at that time in a territorial Horse Artillery Battery, very much out of my element as my knowledge of horses was not at all extensive, and my fellow officers and men were Leicestershire hunting enthusiasts. Returning from my interview down Whitehall, I realised what is meant by "walking on air", having a scientific job in the war thrilled me so greatly.

The French had tried several systems. In the simplest, the arrival of the sound was registered by observers who pressed keys. There is always, of course, a small lag of about one-fifth to one-tenth second in the response to the sound. An attempt was made to assess the typical delay for each observer, so as to allow for it. This system had the advantages of great simplicity and also that of discrimination by the observer who only pressed his key for the gun report and ignored other sounds. It was a possible though approximate method when guns were very close to the observer. It broke down completely for guns at longer ranges because the determination of position was meaningless with such large errors in timing.

In the method which was finally adopted as standard by the French Army, currents from the microphones at the posts actuated "pens' whose movements were recorded on smoked paper at the headquarters behind the base to which the microphones were connected.

Yet a third system employed a recorder which had been designed by Lucien Bull, of the Institut Marey in Paris. This was the most elegant and accurate of the recorders, but it was complex and required photographic development. Bull employed a six-string Einthoven galvanometer, in which the currents were recorded by the displacement of fine wires in a strong magnetic field. The wires were strongly illuminated and their shadows were thrown, by six small totally reflecting prisms, into juxtaposition across a slit. A cine film ran behind the slit and a toothed time wheel governed by a tuning fork interrupted the light 100 times a second, so ruling time markings across the film. The apparatus was switched on and off by one or more forward observers in front of the base, who heard the sound before it reached the microphones. When

the apparatus ceased running, the operator at headquarters cut off the portion of film which had run, developed and fixed it, and passed it to the reader who measured the time intervals and deduced the position of the gun.

Lucien Bull has kindly given me an account of the way in which he and Charles Nordmann, of the Paris Observatory, started their experiments on sound-ranging together. It is so interesting that I must quote in full:

"In the middle of October, 1914, I was working at the Marey Institute, on Electro-cardiography and recording heart-sounds, when a knock came at the door of my laboratory. 'Come in,' and appeared a non-commissioned officer (brigadier) in full uniform. Introduced himself as Charles Nordmann, astronomer at the Paris Observatory, called up for military service in the artillery. Asked me, with a more or less air of mystery, if I could give him some information concerning the registration of 'faint sounds of low frequency'? Replied I thought I could, guessing without the slighest difficulty the Sounds he meant. On my saying so, he abandoned his mysterious airs and exposed his whole object.

He had conceived, as a mathematician, the idea that it should be possible to locate on the Front the position of the enemy's guns, by measuring the time-interval between the arrival of the sound at different points of a measured base. He was lucky enough to have had his immediate superiors sufficiently intelligent to allow him to make some experiments!

These were made with three human observers with well-regulated stop-watches who noted the time they heard the sound of the detonation. His crude experiments, in spite of lack of precision, showed the possibility of doing better, and Nordmann obtained permission to return to Paris and work out his idea.

Having no personal knowledge of how this could be done, he went to the Sorbonne to inquire and met Professor Dastre, professor of physiology, who knew me well and my work on registering heart beats, and who directed him to the Marey Institute. That is how, by mere chance, Nordmann and I met and commenced work together.

I proposed at once the use of the Einthoven string galvanometer and our first experiments were carried out with our big physiological instrument weighing over 150 lb. Thanks to our clever mechanic, G. Kelsen, without whose remarkable skill I don't know if we could have ever completed so well, and certainly never so rapidly, our instrumentation, we managed to lodge in the narrow magnetic field of our huge instrument, three strings instead of one. This enabled us to record the signals from three microphones placed a kilometre apart on our experimental base. With these we succeeded in the middle of November, in demonstrating the excellence of the method before a jury of French generals, by locating the position of a gun fired in the woods of St. Cloud, 4 or 5 kilometres away, with an error of only 5 metres

in azimuth and 25 metres 'en portée' (I don't know the English term for this). This convinced the military authorities and we received the order to construct three sets of apparatus for use on the front.

And this set me working for a portable set, constructing a small galvanometer for five (later six) strings, a device for bringing the enlarged and consequently widely separated images (a prism bench) on to a 35 mm. film, a timing device (phonic wheel). All this was completed towards the middle of December, and in the beginning of February, 1915, the first set came into service on the French front.

There is one date that I don't remember; that is when Capt. Leroy was sent over to France by the War Office to investigate on the Front the different methods of sound-ranging used by the French; as you know, there were at least three; the T.M. (Telegraphic militaire) system with mechanical recording pens, the Cotton-Weiss method, photographic like ours."

I am also not sure of the precise time when Leroy investigated the methods, but it probably was in the summer of 1915. It was in October of that year that I went to Paris to take over the Bull equipment, which has been housed in a specially built lorry by our transport Depot.

The Bull system was chosen for the British experiments, and it was very fortunate that this choice was made, though I am not sure that its potential advantages were all appreciated at the time. As the war went on, and the ranges at which guns fired became increasingly great, the timing had to be very accurate indeed if the results were to be significant. The arrival of the report had to be recorded with an error less than 1/100 second. The Bull recorder amply met this demand. Indeed, at a later stage of the war, it was used to record the time interval between the passage of a shell through two screens about 100 feet apart, and so to calibrate guns, by speeding up the film. The simpler fool-proof systems, of some service in the first stages of the war, were incapable of an improvement which would meet this demand for accuracy. A prejudice against the Bull system, because it involved photographic equipment, showed a false sense of values. The importance of locating an enemy battery infinitely outweighed the bother of a darkroom and its equipment.

So in the autumn of 1915 I was ordered to report to Colonel Jack, head of "Maps G.H.Q." which was then at St. Omer, with a view to my starting soung-ranging at the Front with the Bull equipment. I was to find a fellow-officer in England who had a scientific training to accompany me, and the choice fell on H. Robinson, afterwards Professor of Physics in London University and its Vice-Chancellor. He was also serving in a battery in England.

We went first to the Vosges, where a Bull section was installed in a ski-lodge, under a Captain Schultz. He was to instruct us in running the apparatus. It was so quiet a sector of the Front that, if I remember rightly, not a single enemy battery fired during our fortnight's training. A French battery near us, with whose officers we messed, used to spread its washing on the gun emplacements, hastily taking it in if there was a

rumour of an enemy plane. Then, when we returned to G.H.Q., Robinson remained at St. Omer to arrange about the siting of the experimental section, while I went to Paris to collect the set. We set up our gear with a headquarters at a village called La Clytte just south of Ypres (it was moved later to Kemmel Hill). The section consisted of Robinson and myself, the driver and mate of the lorry who also operated the set, the two drivers of two small Singer cars for our personal use, one linesman, and one N.C.O. It was a very small show compared to the establishment of fifty or so which sections were subsequently allotted. Neither Robinson nor I had any experience at the Front, and our only official contact was Colonel Jack at G.H.Q. We were two "innocents abroad" with a vengeance.

All the first sound-ranging systems suffered from a defect which made them useless for placing guns, though they could under ideal conditions place howitzers. The microphones were sensitive to high-frequency noises, and quite insensitive to low-frequency noises, which is just wrong for gun-recording. The Bull system used carbon granule microphones of the "Paris-Rome" type. They were excellent at recording traffic noises, rifle fire, people talking near them, dogs barking and, in fact, everything but the muffled low "boom" of a gun going off. In particular, they were very sensitive to the "shell-wave" made by a gun with a muzzle velocity greater than the velocity of sound. When a high-velocity gun is firing towards an observer, he hears a very loud crack coming from a point in mid-trajectory, followed by a far fainter boom which is the true gun report. It is, of course, the latter which must be recorded in order to calculate the position of the gun. The microphones were so disturbed by the shell wave that they failed to give any record of the gun report.

The French tried to get round this difficulty in a typically ingenious way. They constructed curves of the forms assumed by the shell wave for each type of gun, such as the 88 mm. field gun, firing at a series of ranges. One tried to find a shell-wave which fitted the observation. But this did not really work. Not only did every type of gun require a different set of curves, but also they varied with range and direction of fire. It was all too complicated. For the first year, from October, 1915, onwards, sound-ranging was really a wash-out though we tried to pretend it was not. Clearly we had to find a selective microphone which responded to the right kind of noise if sound ranging were to be any good.

The solution came in stages. First, it was clear in a number of ways that although the gun report produced very little impression on the ear it was associated with large pressure changes. It rattled windows. In our billet at La Clytte, of the usual Belgian farmhouse type, the privy was in an annexe opening out of the kitchen with no outer door or window and as all windows of the farm-house were hermetically closed one sat on the only aperture between interior and the outer air. The deafening shell wave of a six inch gun which fired over us left one's posture undisturbed, whereas the faint gun report had a marked lifting effect. A phenomenon which led nearer to the solution was our noting in winter, in the tarred-

paper hut in which we were quartered, the jet of bitterly cold air which came through each of the many rents in the wall when a gun report arrived.

The final touch was added by Tucker. Corporal Tucker came to our section on Kemmel Hill from a post in the Physics Department of Imperial College. He had been making experiments on the cooling of very fine hot platinum wires, known as Wollaston wires, by air currents. Somehow we arrived at the brilliant idea of using the jet of air coming through an aperture in the wall of an enclosure to cool a Wollaston wire, heated by an electrical current, and so to alter its resistance. What we hoped was that high frequency sounds, with their very rapid oscillations, would not drag away the film of warm air round the wire, but that the slow but large air movement due to low frequency sounds would do so. We got some fine wire from England, placed it across a hole we drilled in an ammunition box, and made it one arm of a Wheatstone Bridge, which we balanced, with our galvanometer in the usual circuit. I remember vividly the night we rigged it up. A German field battery obligingly fired towards us, and when the film was developed there was a small sharp "break" for the shell wave, followed by a quite characteristic and definite large break made by the gun report, which could be read with accuracy. It was a wonderful moment, the answer to prayer. It converted sound-ranging from a very doubtful proposition to a powerful practical method.

The passage of air into or out of the container cooled the wire. Hence the displacement of the galvanometer string was always in the one direction, as if the lower sections of a sine wave had been reversed upwards. The characteristic frequency of a field gun report was about 25, that of a large piece about 10, though this was only a rough guide to calibre. The great advantage of sound ranging was that it recorded shell-bursts as well, so that one could determine the type of gun or howitzer from the time of flight or by recovering fuses from the shell holes. A typical report gave the calibre, number of guns, and target on which the battery had registered.

The Tucker microphone satisfied another condition which was important, in that the record it gave was a faithful transcript of the actual pressure variations. This faithfulness enabled the reader to become expert in recognising sounds of various kinds. We were fortunate in choosing an ammunition box as a vessel, because it was heavily damped and so did not impose its own characteristics. Later, when the microphones were made in England, a tidy-minded instrument designer supplied metal containers, but these were far inferior because they were resonant and imposed their own character on all the sounds.

It was a tricky business keeping the Wheatstone bridges in balance. The current was fed to the microphones from the headquarters battery, and any variations of resistance of the lines disturbed the balance. They had to be of good quality and hence batteries and infantry found it hard to resist the temptation of pinching sections of attractive cable which apparently led nowhere. Lines on posts were obvious loot. Buried

lines were run over by transport and tanks and developed leaks to earth. Line maintenance was a great problem.

A special difficulty which had to be overcome with the Tucker microphone was interference by wind. It is not the noise of the wind, but the fluctuations in pressure due to turbulence, which cause the trouble. Putting a solid wall around the microphone to shelter it from the wind current only makes matters worse, because the wall increases the turbulence. We found that anything in the nature of a thick hedge, or of multiple sheets of camouflage netting, was the answer. The gusty wind stress is converted into a steady flow, an effect like that of holding a piece of gauze across a tap. After the war Hemming and I had an opportunity to study the German reports on British apparatus which had been captured. It was interesting to see that they could not understand how we avoided the wind trouble, which seems to have defeated them completely when they tried out our method. In the Second World War, this same device was useful to the Observer Corps. They listened for enemy aeroplanes from the tops of towers, and found the buffeting by turbulent wind very baffling. A horizontal shelf projecting about 6 feet round the top of the tower, made of something like hop-netting, much reduced the disturbance.

Two inventions greatly increased the efficiency of sound-ranging. The first was originally proposed, I think, by Lloyd Owen at Armentières. I confess I thought it an over-elaboration at first and quite failed to see its usefulness. He proposed putting the microphones at exactly equal distances in a straight line. The consequence is that the six 'breaks' on the film due to any one sound fall on a smooth curve, and with experience it is easy to spot a set of breaks which belong together, even when there are many noises. One can also see at a glance roughly where the gun is, and neglect the sets of breaks due to our own batteries or to anti-aircraft fire. It enabled location to be made when quite a strafe was going on. The straight base was later abandoned for an arc of a circle, with its centre roughly in the most interesting area behind the enemy lines. Plotting boards were printed for a few standard-sets of radii and distances between microphones, and it was always possible to shuffle a standard layout so that the six microphones fell in convenient places. The surveyors fixed three places correct to a metre. The next great scheme was the "wind-section". In this J. A. Gray made a main contribution. Wind and temperature corrections were always troublesome if one tried to deduce them from meteor data, because both varied so much with height and local contours. On the other hand, upper winds and temperatures were much the same along the whole front. The "wind-section" was a sound-ranging section behind the lines which recorded reports from a known position. A pound or so of explosive was set off at intervals of a few hours, and the sound was recorded by a series of microphones in two or three areas, at about the same range as enemy guns. Since the position of the explosion was known one could measure the extent to which the wind and temperature had affected the

readings, and so circulate to the sound-ranging sections the required corrections.

All those schemes were developed at the Front, and I think this was the main reason why sound-ranging got going so quickly, after the first wasted year when we lacked an effective microphone. Each section (there were, if I remember rightly, about forty in all) had a mechanic with a kit of tools, a watchmaker's lathe, and a chest of assorted bits and pieces of wood and metal, so each could try out its own schemes. At intervals of two months or so, we had a meeting at some central point such as Doullens, to which each section sent an expert. They swopped stories, schemes, and boasts of their achievements and I am sure emulation made everything go much faster. The meeting generally ended with a binge of heroic magnitude. If the experiments had been done in England with (*a*) the inevitable lessening of a sense of urgency, (*b*) less touch with the actual problems, and (*c*) delay in communicating and testing ideas, sound-ranging would have taken two or three times as long to develop. An experimental section was later established on Salisbury Plain and did very good work, but by this time the problems were well defined.

An interesting side issue of the Bull recorder was its use for calibrating our field guns, a tribute to its extreme accuracy. Bob Chapman was responsible for setting it up. The film was speeded up till it ran at about a metre a second. It was thus possible to record with sufficient accuracy the time between breaking wires on screens through which the shell was fired. Chapman had a special section on the coast near Dunkirk when the field guns fired out to sea.

Towards the end of the war we had an apparatus (horribly messy) which developed and fixed the film as it issued from the camera. I doubt if it was really worthwhile as it easily went wrong and one lost precious records. By using strong solutions the developing and fixing were done in a matter of seconds. It is true that the photographic recording was a complex process, but if one bears in mind the great value of a locating (something for which an aeroplane was commonly risked) this fuss about the photography is seen to be utterly meaningless.

The Germans had a great respect for our sound-ranging. It was a great day when a captured German order was circulated to the sound-ranging sections which read:

All Field Survey Companies.

The following extract from a German Order is forwarded for your information:–

Group Order. "In consequence of the excellent sound-ranging of the English, I forbid any battery to fire alone when the whole section is quiet, especially in east wind. Should there be occasion to fire, the adjoining battery must always be called on, either directly or through the Group, to fire a few rounds."

Maps, G.H.Q. E. M. J. Lieutenant-Colonel
23 June 1917 General Staff

We were particularly pleased because with our Tucker microphones and regular bases we could record almost any number of guns firing at once, the more the merrier. It is interesting that the scientific Germans never developed a refined method. Right towards the end of the war they had a system which depended on the binaural effect. An observer had two horns at the end of a rod, each connected to an ear, and by estimating the direction of the sound with references to direction posts he deduced its bearing. Intersections from three or more stations gave a location. I cannot believe they were of any value. I think they were committed too early to a simpler but crude system, and it was too late to change it when ranges increased and greater accuracy was essential. We were extremely fortunate in having started with the Bull recorder, which had ample accuracy.

The one thing which was never developed was the "radio link". It would hardly have been possible to develop it in World War I when radio was so very crude. I find it extraordinary, however, that it was never established in the years between the two World Wars, when it was such an obvious goal. In fact, when World War II threatened and I was asked to give my views on the sound-ranging apparatus as it had been developed in the interim, I was appalled. It was like the World War I set which had grown the most complex whiskers. I much doubted the usefulness of most of the gadgets possibly because I was so keen on the "stripped down" unit we were using at the end of World War I. I regret greatly now that I was tactless in expressing my doubts. I would have made my influence felt far more usefully if I had been wiser, and not put up so many backs. But as the war progressed the frills mostly disappeared and the set came back to very much the one we had been using in World War I. It was fascinating to see that sound-ranging was once more of great use. Much doubt had been expressed on this point because it was thought it would take too long to survey and instal a base, and so sound-ranging would never get into action in a war of movement. This, however, was a wrong assessment. When there is a hold up of any kind guns must be got into position and surveyed, and sound-ranging can be installed as quickly as can the batteries. We had reports that sound-ranging was often the only way, particularly in country where maps were inadequate, of getting information about enemy batteries.

The great drawback of sound-ranging is that it fails when the wind is blowing away from our lines towards the enemy lines. In these conditions, not only is the sound faint but also it has an irregular beginning. One does not know what point to read on the film. The wind gradient is responsible for this effect. Since the wind velocity is less nearer the ground, the sound is refracted upwards. On the other hand, with a wind blowing towards the base the sound is crisp and its time of travel can be read to 1/100 second Unfortunately on the Western front the prevailing wind was westerly, and sound-ranging sections were often cursed for their ineffectiveness when it was really as impossible to work as it is to use visual observation in a thick mist. On the other hand, in

easterly winds, and particularly in foggy weather when wind is light and temperature uniform, sound-ranging worked perfectly.

Whether it will ever be used again is hard to guess when so much is uncertain. The story of sound-ranging in World War I is perhaps of special interest, however, as an example of the very rapid development of a scientific technique right in the front line.

EPILOGUE

By Sir Lawrence Bragg, C.H., O.B.E., M.C., F.R.S.

The schemes, the hopes and fears, the disappointments and successes, which are described in this account of Artillery Survey in World War I are now a matter of history. The conditions of warfare change so rapidly and so profoundly that few, if any, of the technical developments in which we were so intimately involved can be directly useful now. The value of an account like this must be, not its detailed record of the tactics of that time, but its story of a pioneer application of scientific and technical knowledge to problems of national defence.

In World War I science played only a small part; probably more examples of its use are to be found in Survey than in any other field. In World War II the resources of science and technology were called upon to a very great extent, yet it was far from being realised at the start how great a need for them would arise. The story with which Major-General Dowson begins his contribution, that although the Ordnance Survey had maintained before World War I three survey sections on call for war, it was decided at the outset that they were not required and the skilled teams were dissipated, illustrates how very difficult it is to foresee needs. It was not very different at the start of World War II. During the year of tension after Munich, the Royal Society prepared a card-index of several hundred researchers in the country, grouping them by their subjects and giving details of their experience and qualifications. I remember well the meeting at which this list was presented to the scientists in charge of research for Navy, Army and Air Force. While expressing their appreciation, they unanimously said the list was unrealistic. I recall our being told that research could only be done in peace-time, that once war started it was too late to develop anything new, that perhaps six or a dozen scientists might be recruited to the existing research establishments but certainly not more. Yet six months after the war started the barrel was being scraped for experienced scientists and technologists to tackle a multitude of new and unforeseen problems.

In vivid contrast, another project of vital importance in the war got away to a magnificent start owing to foresight and imagination. John Crockcroft, who was then a professor in Cambridge, with a party from the Cavendish Laboratory, visited Watson-Watt's pioneer radar station at Bawdsey soon after Munich with a list of some hundred of the brightest young physicists in the country. As a result of this visit, it was arranged that a number of them should man radar stations around the coast during the summer of 1938.

The early rapid advance of our country in the radar field, and the world lead which we never lost, were largely due to this scheme. These young scientists provided the nucleus of the brilliant teams which devised all the new advances in radar, and their experience before the war gave them a year's start; they knew what the practical problems were.

The general problem of collaboration between the services and science remains the same, though actual conditions may alter so vastly. The services naturally value the absolutely reliable, which implies the familiar and often tested; the scientist by his training is interested in the new and untried, that which has yet to be proved. A bridge can only be built by personal relationship and a mutual understanding and trust, so that collaboration can rapidly be established when a new emergency presents new and unforeseeable problems for solution.

APPENDIX

Officers at Maps, G.H.Q.

Officer in Charge:	Colonel E. M. Jack
Technical Assistant:	Lieut.-Col. H. St. J. Winterbotham
Sound-ranging Adviser:	Major W. L. Bragg
Cross Observation Adviser:	Major H. H. Hemming
Map Supply:	Captain E. E. Field and Lieut. Whitby
Personnel:	Captain G. Carlyle
Equipment:	Lieut. G. A. Allingham
Geodesy:	Lieut. G. T. McCaw

Commanding Field Survey Battalions

1st: Lieut.-Col. B. H. Wilbraham (who succeeded Major H. Wood)
2nd: Lieut.-Col. C. S. Reid.
3rd: Lieut.-Col. B. F. E. Keeling (who succeeded Lt.-Col. Winterbotham)
4th: Lieut.-Col. M. N. MacLeod.
5th: Lieut.-Col. F. B. Legh (who succeeded Major Keeling when he was wounded).

(Lieut.-Col. Keeling died shortly after the war from the effects of wounds received while serving with the Survey.)