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Science and Technology (Germany)

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During the war years contemporaries already coined phrases like "machine warfare", "mechanised battlefield", "war of engineers" or "war of the chemists" to describe the kind of warfare they were experiencing. In collective memory innovations or adaptations for use in conflict such as planes, ships, submarines, tanks, poison gas and, less apparent but more effective, guns and explosives stand out. But the truly revolutionary transformations occurred on the level of organisation resulting in a new cooperation of scientists and engineers, industrialists and military leaders, the "academic-military-industrial complex". Much of it came about due to the commitment of experts.

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Introduction

The 19th century brought an unprecedented expansion of science and technology: knowledge, knowledge production, its organizations and practitioners multiplied and grew ever more diverse. Throughout the period, scholars presented science as an activity beneficial to all humankind, supranational in its codes and values and thus international by nature. They continued to do so even towards the end of the century when scientists and their work more often came to be connected to national prestige. With the outbreak of war in August 1914 scientists and engineers found themselves in the position to take sides on this fundamental issue of the national or international character of science.

As it turned out, the overwhelming majority of German scientists and engineers, from young practitioners to well settled professors at universities, quickly followed the "call to arms" to assist their country in war, just as many of their counterparts elsewhere in the industrialized world did. Some joined the forces to fight at the front, a larger and more influential share, as far as the nation's capacity to continue fighting is concerned, quickly abandoned the concept of an internationalism of science and willingly offered their expertise to bolster Germany's ability to wage war and to do so over a long time span. The Reich's war effort was to profit from their expertise in research, research organization, management and applied science, especially their contacts and cooperation with industry through which they closely integrated science and the military. As a result, a new type and dimension of network emerged, to be stabilized and made a permanent feature of modern warfare in the conflict of 1914-1918. The term of the military-industrial complex was coined later in the 20th century to describe it. In fact, already at its inception it was a tripartite structure: a "triple helix between science, industry and government or academic-military-industrial complex".[1]

What lies at the heart of this article is the evolution of this structure, the actions and motives of the experts in Germany who most prominently contributed to its shape and transformation, the way their work and research organization was in turn affected. It thus highlights the fundamental transformation initiated by the war: the increasingly military character of science and the increasingly scientific character of the military. New technologies as they emerged as a result of this integration, most notably poison gas/chemical warfare, new weaponry and more effective ammunition, technologies like planes, dirigibles and submarines are considered second to this quantum leap in academic-military-industrial entanglement in industrialized societies that World War I brought about.

Historiography so far has largely concentrated on weapons technology as a symbol of modern industrialized warfare, on individual scientists, engineers, institutions or disciplines, namely those whose impact was particularly relevant in providing the equipment for a "*guerre de materiél*". Systematic studies encompassing all the sciences on the one hand and all feats and activities in engineering on the other are still scarce,[2] those combining both fields in which experts left their mark virtually non-existent. Only a few studies compare the changes internationally or go even a step further to include a transnational approach. If they do, they tend to single out one segment of research or armament only.[3]

Scientists and engineers going to war

Mobilising the way of thinking

When hostilities started the majority of scientists in the industrialized countries involved did not take long to answer the question of where they would position themselves. Despite early attempts to keep it alive, they either condoned or ensured that the idea of an internationality of science became one of the early victims of war. One of the attempts to keep it alive took the form of a statement published in the London *Times* on 1 August 1914. In it, nine British professors, chemist William Ramsay (1852-1916) and physicist and Nobel Prize winner Joseph John Thomson (1856-1940) among them, emphasized the leading role of German arts and sciences and the degree to which their country and others had learnt from German scholars. A war "with a nation so near akin to our own" would be "a sin".[4] Nonetheless affirmations of the kind did not survive long, the spirit behind them died soon after the early days of August or in the wake of the German invasion of neutral Belgium at the latest.

However, it was in Germany and with a German appeal that this "debate" turned into a war of intellectuals, a "*Krieg der Geister*" as contemporaries came to call it. And although scientists and engineers only produced a small percentage of the overall torrent of declarations and pamphlets - according to Lothar Burchardt a mere 0.6 percent of the total[5] -, their involvement in the most far-reaching and momentous proclamations issued in September and October 1914 engendered the notion of a united front of German scholars.

The most famous declaration was entitled "To the Civilized World!" ("*Aufruf an die Kulturwelt*"), signed by ninety-three members of the German intellectual elite. Among the fifteen signatories from natural science disciplines ranged a number of the most internationally reputed scholars, physicists such as Max Planck (1858-1947),[6] Wilhelm Röntgen (1845-1923) and Wilhelm Ostwald (1853-1925), chemists such as Emil Fischer (1852-1919), Fritz Haber (1868-1934) and Walther Nernst (1864-1941), biologist Ernst Haeckel (1834-1919) and the meteorologist Gustav Hellmann (1854-1939). Published on 4 October, translated into ten languages, the text contained six refutations of what was considered unsustainable allegations against Germany and her military, all of them starting with the simple and simplifying "it is not true that".[7] What followed was an unprecedented propaganda war of replies and counter-replies led by scholars. The second manifesto of the kind, the "Declaration of the Faculty Members of the German universities" ("*Erklärung der Hochschullehrer des Deutschen Reiches*", issued in five languages only twelve days after the "*Aufruf*", rejected the idea of two different Germanys[8] as well. It seemed even more impressive as it held the names of some 4,000 academics, nearly all of the academic personnel of the German universities at the time - with only a few exceptions, most notably Albert Einstein (1879-1955). Nonetheless, the scope of the German declarations and the hastiness of their issuing were unusual even in the heated atmosphere of the first weeks of war.

Mobilising research, research organisation and industry

Just like their counterparts abroad, German scientists and engineers did not stop short at declarations. World War I was a conflict in which all the leading industrial nations opposed each other for the first time, rendering the industrial, scientific and technological potential into an elementary factor in sustaining a nation's fighting capacity. In Germany, however, individual scientists assumed a special role as they often took the initiative rather than military or political leaders. They did this on the level of organisational structures and scientific innovations and individual technologies, most importantly in the crucial first phase of the war in 1914 and 1915. Their motives and the long-term meaning of their commitment have been the focus of several studies. Many scientists and engineers believed that the war offered a wide range of opportunities not only for individual ambitions, but more generally for a new status of the expert in society and a new kind of relationship between scientists, engineers, industry and the state. In consequence, they welcomed this chance and performed what might be called an unprecedented act of self-mobilization.[9]

Wilhelmine Germany already knew tendencies towards larger research projects and institutions, a more tightly-knit organisation of science in cooperation with industry. For one, the "Mechanical and Technical Research Institute" ("*Mechanisch-technische Versuchsanstalt*"), institutionalizing links between science and the military had been established in 1871. By the end of the century it had progressed into a pioneer institution of "big science" with a staff of eighty-three.[10] Nonetheless, compared to the developments produced by the war this was little more than a tentative first step. The changes after a few weeks of fighting brought with them new demands and thus the pivotal moment for scholars after the initial demonstrations of patriotism. The military was not prepared to face the challenges of trench warfare quickly and efficiently. It was here that scientists stepped in. Walther Rathenau (1867-1922), Emil Fischer and Fritz Haber were among those most authoritative in this phase in helping Germany to overcome the initial shortcomings and shortages.

The early days of war proved many of the military and political leaders wrong. Even before those in charge realized that the conception of a short war not needing interventions into economic and social structures was an illusion, the problems providing the necessary supply for the troops had become evident. This reality of Germany being cut off from access to goods from trading partners abroad was brought home. In August 1914 the War Ministry established the War Raw Materials Department ("*Kriegsrohstoffabteilung*"). After a few weeks of struggling over responsibilities it became the one institution to control resources and their distribution to individual companies as well as the initiatives to synthesize replacements for the products no longer available ("*Ersatzstoffe*"). Its personnel were raised from a mere five to more than 2,500 employees in 1918.[11] From August 1914 to March 1915 the Department was directed by Walther Rathenau, who had studied physics, chemistry and engineering with a PhD in physics before becoming a leading industrialist. In order to considerably increase the production of the goods needed to continue fighting - something in which within fourteen months the Department's coordinating work facilitated an increase of 1,300 percent in ammunition alone[12] - the cooperation with industry and science had to be intensified considerably. This was achieved by installing a "mixed" system of war corporations, boards, and war resource commissions with members from private industry, the military, and academic science.

The internationally reputed chemist Emil Fischer, winner of the Nobel Prize in Chemistry in 1902, became one of the most effective academic scientists in the new system. His field of chemical work favoured close cooperation with medical research and the pharmaceutical industry, so that he was in close contact with several companies even before the turn of the century, first and foremost the *Badische Anilin- and Sodafabriken* (BASF). He was active in many fields of science management, including the founding of the *Kaiser Wilhelm Gesellschaft* in 1911, the most important research institution on a national level in Wilhelmine Germany. Believing in the inevitability of war, he decided to give up science and to become a "chemist of war" ("*Kriegschemiker*"),[13] as he put it in a letter to a colleague on 14 October 1914. He enlisted himself to mobilise German industry for war and to counsel the military as well as the public authorities. As counsellor, organizer, go-between he was active in a great number of boards, many of them with mixed memberships of scientists, industrialists, military experts and bureaucrats. To name but one, he was chairman of a board to provide the resources for the production of benzene, toluene, ammonia ("*Kommission zur Beschaffung von Kokereiprodukten*"), thus of goods indispensable for the production of ammunition among other things necessary for warfare. In positions like these Fischer participated in or even initiated developments which produced new weapons technologies and what is more, helped Germany compensate for the loss of foreign resources without which, for Germany, fighting would have come to an early end.

It is in this degree of enlisting oneself and in taking the initiative that German scientists like Fischer, Walther Nernst, engineer and industrialist Friedrich Uhde (1880-1966), engineer Ferdinand Schneider (1866-1955) and others, appear to have excelled their counterparts abroad. Probably no single German expert did so with such immediate as well as long-term consequences as did the chemist Fritz Haber. His particular impact unfolded on three levels: (1) that of the cooperation of science, industry and the military, (2) that of the invention of new processes and chemical substances for warfare, and (3) that of the development of technologies of mass destruction. At the outbreak of war Haber was director of the Kaiser Wilhelm Institute for physical chemistry, a position he retained during the war years. From the second week of August 1914 onwards he acted as a volunteer for the war ministry, soon joining Walther Rathenau's Raw Materials Department and other government boards, all in an informal function. In this way he was able to move freely between academic, industrial and administrative circles, promoting his own interests as well as those of his partners. Thus he and Fischer managed to force through the Haber-Bosch process to synthesize the much needed ammonia against the competition of other processes, a milestone not only for the production of explosives but for fertilizers synthesized on the same basis as well - though military demand for explosives left hardly any ammonia for the production of fertilizers in wartime. As early as 1915 Haber's initiative resulted in large-scale production and thus independence of the German munitions industry from imported sodium nitrate. His motives were manifold: out of a nationalism typical at the time, of a Prussian stance of "right or wrong, my country", out of an urge to improve the status of scientists over that of military commanders, out of a very personal impetus to achieve acknowledgment in a degree impossible to a Jewish German in peace times.

During the reorganization of the German war effort associated with the Hindenburg Programme in late 1916, a new agency to institutionalize the diverse and scattered activities of individual scientists and engineers for the development of technologies relevant to the country's war effort was established. This was an endowment called the "*Kaiser Wilhelm Stiftung für kriegstechnische Wissenschaft*" (The Kaiser Wilhelm Foundation for Military Science and Technology), through which the tendencies towards big science initiated by Fischer, Haber, Walther Nernst and others saw yet another boost. Haber's own Institute for Physical Chemistry eventually expanded to a staff of some 1,500 employees,[14] a kind of governmental-scientific armaments business according to Gerhard Ritter, anticipating the structures, ambitions and dimensions of World War II's Manhattan Project.[15] Military and political leaders had not only accepted, but fully embraced the fact of a new and potent actor in the field of warfare.

Equipment of Modern Warfare

The transformation of a personnel-intensive to a material-intensive type of warfare expedited the technical development in line with the advance of science and technology into all spheres of life, in short the "artifact revolution"[16] in armaments technologies. Again the initiative and commitment of scientists and engineers was crucial. Motives for those involved were heterogeneous, even more so since many innovations were dual-use technologies: ships, planes and dirigibles, meteorological and optical instruments could be used for civilian as well as military purposes, sodium nitrate and other chemicals could increase agricultural output as well as generate explosives.

In many instances the technology did already exist, just not yet adjusted to military needs such as planes and dirigibles. War boosted the research and development of materials for instance, those used in constructing the first all-metal plane hull, Junkers' J1 of 1915, and of new motors to propel the machines of military aircraft. Initially deployed mainly for reconnaissance missions, they were capable of supporting artillery after their firing power had been enhanced. Aircraft motors were improved to raise average speed from 100 to 200 km/h and maximum flying altitude from 1,200 to 9,000 metres.[17] Submarines were not new technology either when fighting started in 1914. However, in the face of the Allied naval blockade and the chance to prevent supply of Allied troops in various theatres of war, engineers worked hard to provide the German navy with many more than the thirteen classes or types of U-boats available in August 1914. In contrast to the British army, tanks did not succeed with the German military until very late in the war. Only a single type was developed, only a few built up to 1918.

If the innovations in war machinery are reduced to planes, submarines and tanks it is debatable if machine warfare truly produced "technowarriors".[18] Military commanders, many of whom still envisioned war in terms of the traditional combat of men and mobility, took time in being convinced of the value of new machines, not least because of the need to devise new strategies around them. Inventors and engineers had to do a lot of persuading, which was even more true the greater the novelty of their constructions were.

This applies to yet another of the new weapons technologies which, in collective memory, epitomizes the multifaceted aspects of the new kind of industrialized warfare: poison gas. Even before the frontline in the West came to a standstill in autumn 1914, the decision was made to systematically search for new chemical weapons. According to the industrialist Carl Duisberg (1861-1935), whose chemical plants played an important role in producing the poison gas employed by German troops, the original idea to use it came from military circles.[19] This did not go uncontested. After shells containing non-lethal irritants produced by Duisberg's firm failed on the battlefield in October 1914, the high command of the army approved experiments with lethal chemicals. By the end of 1914 Fritz Haber had taken over the initiative, even before the widespread reserve within the military against this kind of "unchivalrous" weapon had been overcome and the decision been made to employ poison gas on a grand scale at Ypres in April 1915. Haber worked out the idea to employ chlorine gas spread by the wind so that the enemy forces would be chased from their trenches. He activated and supervised the process of developing the necessary supplies and equipment and was present on the day at Ypres when the gas was emitted. He became the first scientist to be committed to the development of a weapon of mass destruction. According to biographer Margit Szöllösi-Janze, no sources exist to show that Haber had any moral qualms in the process. In fact, he believed that chemical weapons would make war more humane. He was not only looking for a new weapon, but for a means to make the military accept the scientists' contribution to the war effort as an essential one once and for all.[20] The "success" of this first utilisation of poison gas helped him achieve this goal, the more so since an arms race in the field of chemical agents followed, necessitating more research, a more tightly-knit cooperation between science, industry and the military, leading to a more institutionalised basis of research.[21]

However, poison gas failed to fulfil hopes of a "miracle weapon" or one to bring back the traditional war of movement.[22] In fact, none of the technologies symbolizing the modern character of the war managed to turn the tide for one of the combatants. Since even this modern type of conflict remained in essence a war of infantry and artillery, it was in these fields that the impact of science and technology was felt immediately and most strongly. In an arms race of unprecedented scale German scientists worked on producing an ever-increasing amount of explosives and of continually augmenting their destructive potential;[23] engineers worked on raising the calibre and accuracy of canons, weapons like the machine gun invented in the U.S. by Hiram Maxim (1840-1916) or other smaller weapons. The firing power of small arms used by German troops in World War I excelled that of the Franco-Prussian War of 1871 by more than 300 percent. The newly introduced grenade machine gun, like the German MP18 or the British Vickers machine gun, all these innovations and further developments imposed new requirements on strategy and the formation of detachments, once more bringing home to military commanders the extent to which science and technology had changed warfare. Without the novelties invented by experts, without an industry organised more efficiently in cooperation with scientists and engineers, adequate supplies would not have been available. Without individuals whose initiative was decisive in solving the crises in munitions World War I might have been the short conflict many people envisioned at its outbreak.

Conclusions

The war years marked a watershed in many fields, those of science and technology included. It went along with new methods and structures of developing weapons technologies, new forms and dimensions of research organisation went hand in hand with the organisation of industrial production in wartime. The ensuing network of scientists and engineers, industrialists and military leaders created a density of entanglement unknown as yet, which led to a new stage in "the history of the 'warfare state'".[24] Moreover, it foreshadowed future dimensions of an academic-military-industrial complex, the single most important characteristic of research in armaments and of warfare throughout the 20th and 21st century. All of this resulted from a self-mobilisation of experts which, in Germany, went way beyond patriotism or a mere seizing the moment.

Scientists and engineers often rushed in before military authorities had realized a problem or a need existed. They did so with the impending munitions shortage in September 1914, the necessity of state intervention in armaments production or the development of new weapon systems like tanks or poison gas. Defining whether a problem existed and what it was, put them into a powerful position - particularly so in the first two years of the war -, thus transforming the expert's status in matters of armaments and warfare as well as society at large lastingly and irrevocably. In Germany they did so mostly out of their own accord and with an exceptional fervour.[25]

In the person of Fritz Haber a great number of the transformations in science coalesced: he was a counsellor, a manager, an administrator, an organiser and a brilliant scientist. Like many others active in the front-line of war-science he was a technocrat in the sense that moral implications were disregarded. They did not count in the activities to procure chemical agents for use in the production of food as well as ammunition and explosives, nor did they arise during the development of a gas weapon to be employed for mass destruction. In many instances the war accelerated a loss of moral inhibitions to a degree approaching that usually attributed to scientists and engineers in Nazi Germany.[26]

Since the war, the involvement of science and technology in their characteristic manifestation has been the object of much debate. Was it "catastrophe" or "culture", as Jay Winter has put it?[27] Those offering interpretations in favour of a commitment emphasize the achievements of science for the war effort. In Britain and the U.S. science was appreciated as a kind of additional military unit, an image carefully created and upheld by many of those involved at the time. In contrast, historians talking of catastrophic consequences the actions of experts produced highlight the death of internationalism and the concept of science as a promoter of human progress. A focus on national prestige may have motivated practitioners in the field and public conceptions of science and technology long before the war, but the optimistic idea of science as the producer of benefits to all humankind still existed in 1914. It was lost long before armistice came in 1918.

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Notes

1. ↑ MacLeod, Roy and Johnson, Jeffrey Allan: Introduction, in: MacLeod and Johnson (eds): Frontline and Factory: Comparative Perspectives on the Chemical Industry at War, 1914-1924, Dordrecht 2006, p. xv.
2. ↑ A notable exception that covers a longer period and thus long-ranging tendencies within the 20th century is Reichherzer, Frank: "Alles ist Front! Wehrwissenschaften in Deutschland und die Bellifizierung der Gesellschaft vom Ersten Weltkrieg bis in den Kalten Krieg" in: Krieg und Geschichte, 68 (2012).
3. ↑ Good examples are Eckart, Wolfgang U. and Gradmann, Christoph (eds): Die Medizin und der Erste Weltkrieg, Herbolzheim 2003; MacLeod and Johnson, Frontline and Factory 2006.
4. ↑ Scholars' Protest against War With Germany, in: The Times, 1 August 1914, p. 6.
5. ↑ Burchardt, Lothar: Naturwissenschaftliche Universitätslehrer im Kaiserreich, in: Schwabe, Klaus (ed): Deutsche Hochschullehrer als Elite 1815-1945 (Deutsche Führungsschichten in der Neuzeit, Vol. 17), Boppard 1988, p. 212.
6. ↑ For Planck's position in this situation cf. Heilbron, John L.: Dilemma of an Upright Man: Max Planck as Spokesman for German science, Berkeley/London 1986, pp. 66-71.
7. ↑ For the full text and list of signatories cf. von Ungern-Sternberg, Jürgen/von Ungern-Sternberg, Wolfgang: Der Aufruf 'An die Kulturwelt'. Das Manifest der 93 und die Anfänge der Kriegspropaganda im Ersten Weltkrieg (Historische Mitteilungen Beiheft 18), Stuttgart 1996, pp. 144-147; for an online version see [1] (retrieved: 8 September 2014).
8. ↑ It concluded that Germany's enemies, with Britain the most decided, tended to suspect a "Gegensatz ... zwischen dem Geiste der deutschen Wissenschaft und dem, was sie den preußischen Militarismus nennen". Cf. vom Brocke, Bernhard: Wissenschaft und Militarismus. Der Aufruf der 93 "An die Kulturwelt!" und der Zusammenbruch der internationalen Gelehrtenrepublik im Ersten Weltkrieg, in: Calder, William M., Flashar, Hellmut/Lindken, Theodor (eds): Wilamowitz nach 50 Jahren, Darmstadt 1985, p. 651.
9. ↑ Cf. Flachowsky, Sören: "So viel ich kann, bemühe ich mich, der Heeresverwaltung nützlich zu sein." Wissenschaftler als Krisenmanager zwischen 1914 und 1945. Emil Fischer - Rudolf Schenk - Adolf Fry, in: Berg, Matthias/Thiel, Jens/Walther, Peter Th. (eds): Mit Feder und Schwert. Militär und Wissenschaft - Wissenschaftler und Krieg (Wissenschaft, Politik und Gesellschaft, Vol. 7), Stuttgart 2009, pp. 116-117, Szöllösi-Janze, Margit: Fritz Haber 1868-1934. Eine Biographie, Munich 1998, pp. 262-263.
10. ↑ Cf. Hachtmann, Rüdiger: "Rauher Krieg" und "friedliche Forschung"? Zur Militarisierung der Wissenschaften und zur Verwissenschaftlichung des Krieges im 19. und 20. Jahrhundert, in: Berg/Thiel/Walther: Mit Feder und Schwert 2009, pp. 32-33.
11. ↑ Cf. Szöllösi-Janze, Fritz Haber 1998, p. 266.
12. ↑ Cf. Showalter, Dennis E.: Mass Warfare and the Impact of Technology, in: Chickering, Roger and Förster, Stig (eds): Great War, Total War. Combat and Mobilization on the Western Front, 1914-1918, Cambridge 2000, p. 79.
13. ↑ Fischer, quoted in Flachowsky, Krisenmanager 2009, p. 110.

14. ↑ In 1913/14 the number had been a mere fifteen, five scientists and ten employees - with another thirteen scientists mostly from abroad working without payment. Cf. Szöllösi-Janze, Fritz Haber 1998, p. 263.
15. ↑ Ritter, Gerhard A.: Großforschung und Staat in Deutschland. Ein historischer Überblick, München 1992, p. 33.
16. ↑ Showalter, Mass Warfare 2000, p. 74.
17. ↑ Braun, Hans-Joachim/Kaiser, Walter: Energiewirtschaft, Automatisierung, Information (Propyläen Technikgeschichte, Vol. 5: Seit 1914), Berlin 1997, pp. 176-178, 202.
18. ↑ Showalter, Mass Warfare 2000, p. 74.
19. ↑ Cf. Szöllösi-Janze, Fritz Haber 1998, pp. 321-322.
20. ↑ Cf. ibid., p. 326, for an assessment of Haber's involvement Szöllösi-Janze, Margit: Berater, Agent, Interessent? Fritz Haber, die BASF und die staatliche Stickstoffpolitik im Ersten Weltkrieg, in: Berichte zur Wissenschaftsgeschichte 19/2-3 (1996), pp. 105-117.
21. ↑ Haber's informal status changed into one of a scientist firmly established in a bureaucratic apparatus in November 1915 and November 1916. Cf. Szöllösi-Janze, Fritz Haber 1998, p. 270.
22. ↑ Cf. Müller, Rolf-Dietrich: Total War as a Result of New Weapons? The Use of Chemical Agents in WWI, in: Chickering and Förster: Great War Total War 2000, pp. 99, 103.
23. ↑ "... it was shrapnel and high explosive that were responsible for 80% of the casualties on the Western Front." MacLeod and Johnson, Introduction, p. xiv. MacLeod and Johnson refer to the dual use-aspect of explosives whose basic substances could be used in agriculture to help feed more people too. Ibid.
24. ↑ Ibid., p. xiii.
25. ↑ Cf. Szöllösi-Janze, Fritz Haber 1998, pp. 264-265.
26. ↑ Cf. Flachowsky, Krisenmanager 2009, pp. 116-117, 134.
27. ↑ Cf. Winter, Jay M.: Catastrophe and culture: recent trends in the historiography of the First World War, in: Journal of Modern History 64 (1992), pp. 525-532; MacLeod, Roy: 'Kriegsgeologen and practical men': military geology and modern memory, 1914-18, in: British Journal for the History of Science 28 (1995), pp. 427-428.

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